Tecnai on-line help manual -- Alignments

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1 Alignments in the Tecnai microscope

When a user logs into the microscope (by starting the Tecnai user interface), the microscope will recall the necessary alignments. The microscope will follow a fixed procedure in restoring these alignments:

- Look if a particular alignment exists for the user and, if so, load it.
- If no user alignment exists, look if the alignment exists for the supervisor and, if so, load it.
- If no supervisor alignment exists, look if the alignments exists for service and, if so, load it.
- If no service alignment exists, look if the alignments exists for factory and, if so, load it.
- If no factory alignments exists, load default settings.

Alignments will exist for a particular user if the user has ever executed (part) of an alignment procedure. Alignments are as much as possible saved as a single parameter (except in the case of linked parameters like pivot points or x-y values which are always kept together). A complete alignment for a user may thus consist of a mix of user-aligned values and values from other levels (supervisor, ...). A user who has never done a gun alignment thus inherits the alignment from supervisor or higher. If the filament (on LaB6 or W) or FEG tip has been changed and a new alignment done by the higher level, the user will automatically get the new, correct alignment.

When alignments are stored, they are stored completely (thus not only the user's own values). Upon restore the microscope will compare the values being reloaded. If the values are identical to the values in the next higher existing level, the values are not stored in the user's own alignments.

2 Alignment procedures

Below is a list of alignment procedures. Some of the procedure steps may not be visible (dependent on user level 'user' or 'expert'). Some alignments like STEM, EFTEM and Lorentz may also be absent, since they depend on the hardware configuration of the instrument.

General notes:

- In principle some alignments could be combined in single steps, thereby reducing the number of steps. In practice, it is then often forgotten to one of the possible alignments, with the consequence that one alignment is then misaligned. Alignment procedure steps generally therefore perform only a single alignment at a time.
- In an alignment procedure some steps may be skipped when using Next and Previous. This is done to skip those alignments that are not sensitive to changes in operating conditions (like pivot points), so that the procedure only follows the more often-used alignments. The visual indication which alignments are skipped and which are executed, takes the form of two different icons in front of the subprocedure step. Where the icon is a blue arrow on a white background, pointing to the right (into the subprocedure) the subprocedure is not skipped. Where the arrow points down on a yellow background, the subprocedure is skipped.
- Some alignment procedures start with a preparation step. This step can be necessary because otherwise the entry point for the whole procedure would be in a 'skipped' subprocedure (see previous point).

The following alignment procedures exist:

Gun

- Gun tilt
- Gun tilt pivot point
- Gun shift
- Spot-size dependent gun shift

Beam HM-TEM

- Preparation
- Minicondenser lens
- Beam shift pivot point
- Beam tilt pivot point
- Dynamic conical dark field pivot point HM (STEM systems only)
- Rotation center
- Align beam shift
- Beam shift calibration
- Beam tilt calibration
- Dynamic conical dark field beam tilt calibration HM (STEM systems only)
- Spot size-intensity calibration
- Coma-free amplitude
- Coma-free pivot points
- Coma-free alignment

Image HM-TEM
- Preparation
- Image shift pivot point HM
- Diffraction shift pivot point SA
- SA objective lens preset
- Diffraction shift pivot point Mh
- Mh preset and alignment
- SA magnifications alignment
- Diffraction shift pivot point Mi
- Mi preset and alignment
- Align diffraction pattern
- Align camera lengths
- Image shift calibration
- Diffraction shift calibration
- Beam shift - image shift calibration
- Off-axis TV HM image alignment (only if off-axis TV installed)
- Off-axis TV diffraction alignment (only if off-axis TV installed)

Beam LM
- Preparation
- Beam shift pivot poin t
- Beam tilt pivot point
- Rotation center
- Align beam shift
- Beam shift calibration
- Beam tilt calibration
- Spot size -intensity calibration

Image LM
- Preparation
- Image shift pivot point
- Diffraction shift pivot point
- LM magnifications alignment
- Align LAD pattern
- Image shift calibration
- Diffraction shift calibration
- Beam shift - image shift calibration
- Off-axis TV LM image alignment (only if off-axis TV installed)

Beam Nanoprobe
- Preparation
- Beam shift pivot point
- Beam tilt pivot point
- Dynamic conical dark field pivot point Nanoprobe (STEM systems only)
- Dynamic conical dark field distortion Nanoprobe (STEM systems only)
- Rotation center
- Align beam shift
- Beam shift calibration
- Beam tilt calibration
- Dynamic conical dark field beam tilt calibration Nanoprobe (STEM systems only)
- Spot size -intensity calibration

Image Nanoprobe
- SA objective lens preset
- Mh objective lens preset
- Mi objective lens preset
- Align diffraction pattern
- Beam shift - image shift calibration

Stigmators
- Condenser
- Condenser stigmator shunt
- Objective
- Diffraction

HM-STEM
- Preparation
- Objective / Intensity preset
- Beam tilt pivot points
- Rotation center
- Beam shift pivot points
- Align diffraction pattern
- Detector alignment
- Scan distortion adjustment
- Default scan rotation

LM-STEM
- Preparation
- Intensity preset
- Beam shift pivot points
- Align diffraction pattern
- Detector alignment
- Scan distortion adjustment
- Default scan rotation

EFTEM HM
- Preparation
- HM Image-shift pivot points
- SA Diffraction-shift pivot points
- Mh Diffraction-shift pivot points
- Mi Diffraction-shift pivot points
- Mh Pre-alignment
- SA Image-shift pre-alignment
- SA Cross-over correction pre-alignment
- Mi Image shift pre-alignment
- Mi Cross-over correction pre-alignment
- Mh Image-shift alignment
- SA Image-shift alignment
- SA Cross-over correction alignment
- Mi Image-shift alignment
- Mi Cross-over correction alignment
- Camera length pre-alignment
- Camera length alignment

EFTEM LM
- Preparation
- Image-shift pivot points
- Diffraction-shift pivot points
- Image-shift pre-alignment
- Image-shift alignment

Lorentz beam
- Preparation
- Beam shift pivot points
- Beam tilt pivot points
- Rotation center
- Align beam shift
- Beam shift calibration
- Beam tilt calibration
- Spotsize-intensity calibration

Lorentz image

- Preparation
- Image shift pivot points
- Diffraction shift pivot points SA
- Lorentz lens preset
- Image alignment
- Diffraction shift pivot points Mh
- Mh image alignment
- Diffraction shift pivot points Mi
- Mi image alignment
- Align diffraction pattern
- Camera lengths
- Image shift calibration
- Diffraction shift calibration
- Beam shift - image shift calibration

Lorentz EFTEM

- Preparation
- HM Image-shift pivot points
- SA Diffraction-shift pivot points
- Mh Diffraction-shift pivot points
- Mi Diffraction-shift pivot points
- Mh Pre-alignment
- SA Image-shift pre-alignment
- SA Cross-over correction pre-alignment
- Mi Image shift pre-alignment
- Mi Cross-over correction pre-alignment
- Mh Image-shift alignment
- SA Image-shift alignment
- SA Cross-over correction alignment
- Mi Image-shift alignment
- Mi Cross-over correction alignment
- Camera length pre-alignment
- Camera length alignment

3 Introduction to electron optics

The microscope consists essentially of three parts:

1. The electron gun where the beam is generated.
2. The lenses, deflection coils and stigmators that make the image and project it on the screen.
3. The projection chamber with one or more types of electron detectors to record images, diffraction patterns, ... (plate camera, TV, ...).

The first two topics will be covered in this section.

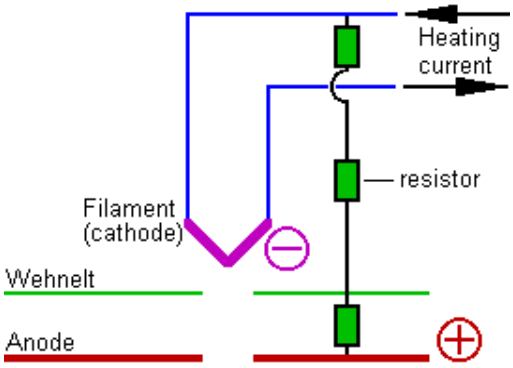
3.1 Electron gun

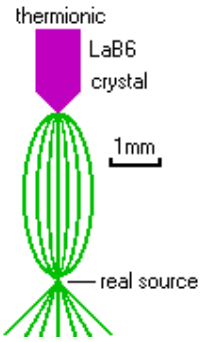
The electron beam is generated in the electron gun. Two basic types of gun can be distinguished: the thermionic gun and the field emission gun (FEG).

- Thermionic guns are based on two types of filaments: tungsten (W) and lanthanum-hexaboride (LaB6) (cerium-hexaboride, CeB6, can also be used instead of LaB6; its performance is roughly the same as that of LaB6). On modern instruments the different types of thermionic filaments can be used interchangeably.
- The FEG emp loys either a (thermally-assisted) cold field emitter - as on the Philips EM 400-FEG - or a Schottky emitter - as on the more recent generations of FEG microscopes (CM20/CM200 FEG, CM30/CM300 FEG, Tecnai F20 and F30).

3.1.1 Thermionic gun

The thermionic gun (so-called triode or self-biassing gun) consists of three elements: the filament (cathode), the Wehnelt and the anode. The Wehnelt has a potential that is more negative - the bias voltage - than the cathode itself. The bias voltage is variable (controlled by the Emission parameter) and is used for controlling the emission from the filament. A high bias voltage restricts the emission to a small area, thereby reducing the total emitted current, while lowering the bias voltage increases the size of the emitting area and thus the total emission current.



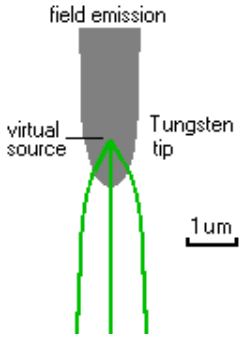


The emitted electrons that pass through the Wehnelt aperture are focused into a cross-over between the cathode and anode. This cross-over acts as the electron source for the optics of the microscope.

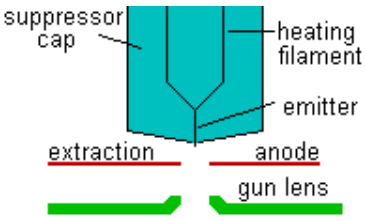
The size of the cross-over is determined by the type of filament, the electric field between cathode and anode and by the exit angles of the electrons from the filament. At low bias voltages, electrons are emitted from a larger area of the curved tip of the filament, causing a higher divergence of emission angles and thus a larger source size. Higher emission therefore not necessarily improves the brightness (a performance parameter of the emitter, measured in A/cm²srad). In addition, higher emission increases the Coulomb interaction between electrons - the so-called Boersch effect - (some get accelerated, others decelerated) which increases the energy spread.

3.1.2 Field Emission Gun

In the case of a Field Emission Gun (abbreviated FEG), electron emission is achieved in a different way than with thermionic guns. Because a FEG requires a different gun design as well as much better vacuum in the gun area (~10e-8 Pa instead of the ~10e-5 Pa necessary for thermionic guns), it is found only on dedicated microscopes (Tecnai F20, F30). The FEG consists of a small single-crystal tungsten needle that is put in a strong extraction voltage (2-5 kV). In the case of a cold FEG or thermally-assisted cold FEG, the needle is so sharp that electrons are extracted directly from the tip. For the Schottky FEG (as used on the Tecnai microscopes) a broader tip is used which has a surface layer of zirconia (ZrO_2). The zirconia lowers the work function of the tungsten (that is, it enhances electron emission) and thereby makes it possible to use the broader tip. Unlike the thermionic gun, the FEG does not produce a small cross-over directly below the emitter, but the electron trajectories seemingly originate inside the tip itself, forming a virtual source of electrons for the microscope.



The FEG emitter is placed in a cap (suppressor) which prevents electron emission from the shaft of the emitter and the heating filament (very similar to the Wehnelt of the thermionic gun). Electron emission is regulated by the voltage on the extraction anode. Underneath the extraction anode of the FEG is a small electrostatic lens, the gun lens. This lens is used to position the first cross-over after the gun in relation to the beam-defining aperture (usually the C2 aperture). If the gun lens is strong, the cross-over lies high above the aperture while a weak gun lens positions the cross-over close to the aperture, giving a high current but at the expense of aberrations on the beam. A strong gun lens is therefore used where small, intense and low-aberration electron probes are needed (diffraction, analysis and scanning), while a weak gun lens is used when high currents are important (TEM imaging). In the latter case, the beam is spread and the aberrations do not affect the area within the field of view.

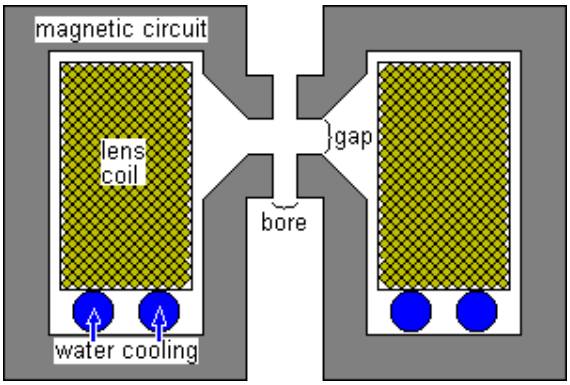


The high brightness of FEGs comes about because of two reasons:

1. The small size of the tip ensures that large numbers of electrons are emitted from a small area (high A/cm²).
2. The electrons come out of the tungsten crystal with a very restricted range of emission angles (high A/srad). FEGs also have a low energy spread due to their low working temperature and emission geometry (small virtual source size, but much larger actual size of the emitting area).

3.2 Lenses

The lenses in electron microscopes are electromagnetic lenses (the only exception being the gun lens in the FEG instruments, which is an electrostatic lens). These lenses all consist of a coil, through which an electrical current flows, and a magnetic circuit, which is a piece of magnetic alloy with a specific shape. The current flowing through the coil generates a magnetic field in the magnetic circuit. Where the circuit is interrupted (the gap), the magnetic field goes out into the vacuum and creates the lens field that is used for focusing the electron beam. How the lens works is determined by the shape of the pole piece (the part of the magnetic circuit where the bore and gap are). Water flows through pipes to remove the heat generated by the electron current in the lens coil.



Changing the current through the lens coil changes the magnetic field and thus the strength of the lens. Although electromagnetic lenses and electrons behave quite differently from light lenses and light, the general principles of light optics can be applied and the electromagnetic lenses can be described for convenience like the lenses of light optics.

The TEM usually contains two condenser lenses:

- The first condenser lens, or C1, determines the demagnification (size reduction) of the electron source onto the specimen and thus the spot size. Its control is found under the spot size control, which has 11 steps.
- The second condenser lens, or C2, determines how strongly the beam is focused onto the specimen. As a consequence it varies the intensity of the beam on the viewing screen. The C2 lens is controlled through the Intensity knob. Inside or close to the second condenser lens there is an aperture (the second-condenser or C2 aperture), which is used as the beam-defining aperture (it limits the amount of the beam convergence for a fully focused beam).

The magnification system of the microscope consists of a set of five lenses: the objective, diffraction, intermediate, projector 1 and projector 2 lenses. Except in low-magnification (LM) mode, the objective lens is always the strongest lens in the microscope, magnifying between about 20 and 50x, depending on the type of objective lens.
The individual lenses of the magnification (or projector) system are not controlled directly by the operator, but instead the microscope contains a number of magnifications for image and diffraction mode, each with its own settings of the magnifying lenses. The only lenses that are controlled directly by the operator are the objective lens (for focusing the image) and the diffraction lens (for focusing the diffraction pattern).

In LM mode the objective lens is switched (nearly) off in order to achieve the smallest magnifications. With the objective lens off, the diffraction lens is used for focusing the image. The electron-optical configuration in LM is reversed with respect to the high-magnification range: the functions of the

objective and diffraction lenses and stigmators switch as do the functions of the objective and selected-area apertures.

Lens and aperture functions in HM (objective lens on) and LM (objective lens off)

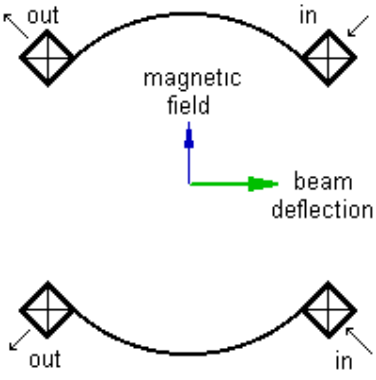
	High Magn	Low Magn
Obj. lens	Image focus	Diffraction (LAD) focus
Diff. lens	Diffraction focus	Image focus
Obj. aperture	Contrast forming	Area selection
SA aperture	Area selection	Contrast forming
Obj. stigmator	Image stigmation	Diffraction stigmation
Diff. stigmator	Diffraction stigmation	Image stigmation

TWIN-type objective lenses
Most Tecnai microscopes are equipped with a TWIN-type objective lens (the variants BioTWIN, TWIN, S-TWIN and U-TWIN). The lens design and the two resulting basic optical modes, the microprobe and nanoprobe modes, are discussed separately in more detail.

3.3 Deflection coils

Throughout the microscope, the path followed by the electron beam is affected by a number of deflection coils, mounted in different locations. Deflection coils play an essential role in the alignment of the microscope and are used for aligning the gun, beam, objective lens, magnification system (image and diffraction shifts to the screen center) and detector alignments (image or diffraction shifts to a detector that is situated off the optical axis). Most of the steps in the alignment procedures either align the deflection coils themselves or use the deflection coils to align another electron-optical element.

In principle a single deflection coil is sufficient for a particular action, provided that it is mounted at the level where its action is needed. In practice, such arrangements are not feasible due to space limitations or other constraints. All deflections are done therefore through double deflection coils that are situated at another level in the microscope.



A deflection coil is a set of coils on either side of the electron beam. If one is given a positive magnetic field and the other one a negative one, the electrons in the beam will be attracted by the positive field and repelled by the other, leading to a deflection towards the positive coil. The actual coils are extended over arcs of 120°. The arcs are used to generate a homogeneous magnetic field.

By arranging the coils in sets of two, mounted perpendicular to each other (X and Y directions), the beam can be deflected into any direction by a suitable combination of x and y. The deflection coils are always mounted in sets of two above another (so-called double deflection coils). Use of double deflection coils involves the important concept of pivot points as explained below.

Each microscope has three sets of double deflection coils: the gun coils just underneath the electron gun (or underneath the high-tension accelerator in case of 200 or 300 kV instruments); the beam deflection coils above the objective lens; and the image deflection coils below the objective lens. An additional, more simple, one-directional coil forms the microscope shutter that is used for exposure of the negatives.

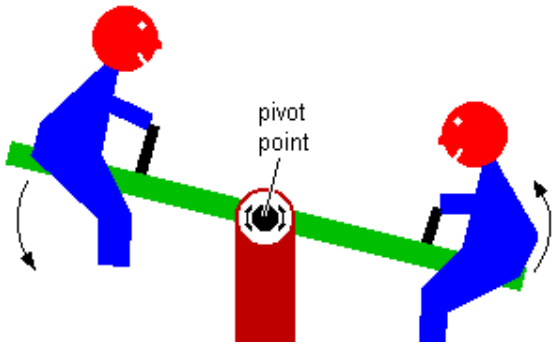
3.3.1 Pivot points

Double deflection coils are capable of two completely independent actions, a tilt and a shift. These two actions should be decoupled, that is, when a shift is intended only a shift and no tilt should occur (a pure shift) and vice versa (pure tilt).

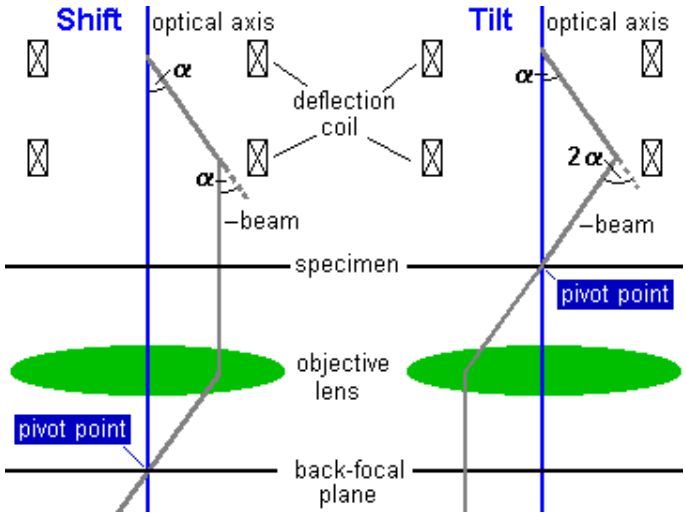
Examples of the importance of pure shift are:

- high-resolution imaging, where a beam tilt would undo all the effort spent in correctly aligning the objective lens;
- scanning, where a tilt in addition to the beam shift will change the magnification;
- TEM dark-field imaging, where a beam shift with an additional beam tilt would change the incident-beam direction and thus the nature of the diffracting condition.

Because of the importance of pure shift and pure tilt, considerable effort is spent in correctly aligning the deflection coils. No two electron microscope columns are exactly identical and slight differences that exist between deflection coils make it necessary to align the coils by means of setting pivot points. A pivot point is simply a point around which the beam will pivot (like the analogue of the seesaw in the children's' playground). The alignment of the pivot point determines the relation between the two coils used, making sure that the beam pivots around the correct point.



The concept of the pivot point is probably easiest to understand for beam deflection coils in a simplified microscope consisting of a double deflection coil followed by a lens with equal distances between the deflection coils and between the lower coil and the image plane above the lens.



A beam shift comes about by deflecting the beam through an angle a by the upper coil and then doing the reverse (-a) with the lower coil. In a perfect system the beam would come out parallel to its initial direction but displaced sideways. Since all beams that are parallel at the image plane must go through a single point in the back-focal plane, shifting the beam should have no effect on the location of the beam in the back-focal plane.
A beam tilt comes about by deflecting the beam through an angle a with the upper deflection coil and then deflecting by -2a by the lower coil. A beam tilt will result in a beam shift in the back-focal plane but should cause no shift in the image plane.

If a combination of beam shift and beam tilt is needed, then the settings for these are simply added. In the example above, setting beam tilt plus beam shift would involve setting an angle 2a on the upper coils and -3a on the lower coil.

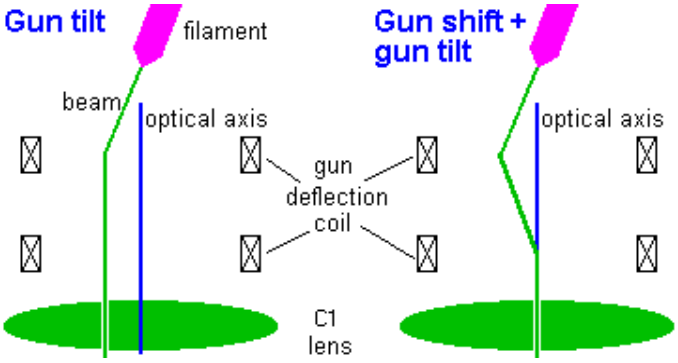
Setting the pivot points is done by deflecting the beam with a wobbler and minimising any movement - of the beam in the diffraction plane in the case of beam shift (no tilt should occur) and of the beam in the image in the case of beam tilt (no shift should occur). A wobbler is a mechanism for rapidly switching a microscope element or function from a negative value to an identical but positive value; it can thus be on beam shift or beam tilt, image shift, a stigmator, objective-lens current, high tension, etc., even though the traditional meaning is the beam-tilt aid for focusing the TEM image.

Since a beam tilt is visible in diffraction as a diffraction shift, beam shift pivot points are set in diffraction mode, while beam tilt pivot points are set in image mode - where a beam shift will be visible.

Where it is important, pivot point alignment has two adjustable directions - a main one and the perpendicular correction. If the coils were perfect, the latter would not be necessary. In practice a small correction may be needed, because the lower coils is rotated slightly relative to the upper one. If the perpendicular correction is unnecessary (e.g. for the gun tilt pivot points), then only the main direction is adjustable (only the Multifunction X knob works).

3.3.2 Gun coils

The gun deflection coils are situated directly underneath the anode in the case of a Tecnai 10 or 12 and below the high-tension accelerator in the case of Tecnai 20, F20, 30 and F30. These coils perform two functions. They make sure that the electron beam enters the microscope (that is, the C1 lens) parallel to the optical axis by means of the gun tilt and that the beam goes through the center of the C1 lens by means of the gun shift.



3.3.3 Beam coils

The beam deflection coils, situated above the objective lens, serve many purposes. They shift and tilt the beam, both static and dynamic (the latter in most of the scanning modes), are used for aligning the objective lens, and correct beam movement caused by the condenser stigmator. They play a role therefore in many alignment steps. In addition, the beam deflection coils can be used coupled to the image deflection coils in a number of instances, for example for image shift or descanning.

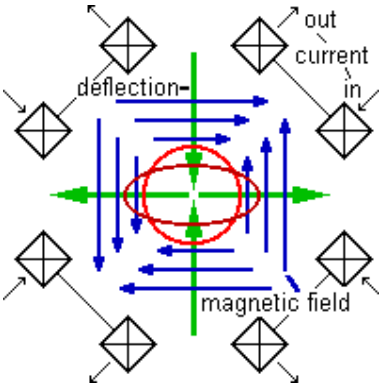
3.3.4 Image coils

The image deflection coils, situated below the objective lens, have many uses. They shift the image and the diffraction pattern, to align various magnifications, camera lengths and modes (such as TEM and STEM), they correct image or diffraction-pattern movement caused by the objective and diffraction stigmators, respectively, and set the Detector alignments that move the image or diffraction pattern to a detector that is situated off the microscope axis (STEM BF/DF, TV). In addition, the image deflection coils can be used coupled to the beam deflection coils in a number of instances, for example for image shift or descanning.

3.4 Stigmators

Even though considerable effort is spent in order to ensure high lens quality, none of the lenses in a microscope is 100 percent perfect. Small inhomogeneities remain or can come about later, for instance by dust adhering to a pole piece or by magnetism or charging of the specimen itself. These imperfections cause a loss of rotational symmetry of the lens. In one direction the lens will therefore focus more strongly than in the perpendicular direction, causing an asymmetry called astigmatism. This image defect is corrected by the stigmator.

The stigmator consists of a quadrupole, which basically is a lens whose astigmatism can be varied continuously. The quadrupole has four elements, arranged at 90 degrees around the beam. These elements are used together in two sets, with each set lying on opposite sides of the beam. If one set is given a positive value and the other a negative, then the positive elements will attract the electrons and have a defocusing effect, while the negative elements repel the electrons and focus (green arrows). The resulting astigmatism (dark red ellipse) cancels the astigmatism in the electron lens (making the beam round: red circle). The actual design of the stigmators inside the microscope is - as with the deflection coils - more complicated and based on a magnetic field (field direction and strength shown by blue arrows). Each stigmator consists of two of the elements, one mounted above the other and rotated by 45° with respect to each other. Each of these elements is controlled by one of the Multifunction knobs (X and Y directions). The combination of two elements allows correction of the astigmatism in any direction.



Microscopes have three sets of stigmators: the condenser stigmator to make the focused beam circular; the objective stigmator to correct astigmatism in the high-magnification (M, SA) image and the low-angle diffraction (LAD) pattern; and the diffraction stigmator to correct astigmatism in the diffraction pattern and the low-magnification (LM) image.

The quadrupoles used as stigmator can only correct second-order astigmatism. Fortunately (or perhaps logically), this is the strongest astigmatism found. Third-order astigmatism is usually apparent only in the so-called caustic image. This type of image is obtained when a strongly convergent beam is focused into

a small spot, as can be the case for a diffraction pattern or nanoprobe. Occasionally, fourth-order astigmatism is observed when small, dirty objective apertures are used.

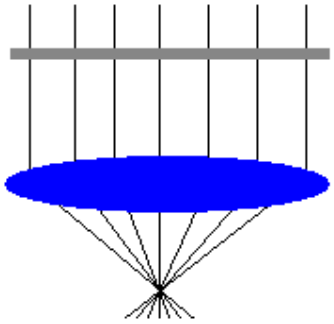
Because the stigmator settings vary from one mode to another and between various spot sizes, a number of independent stigmator values are stored by the microscope.

3.4.1 Three-fold stigmators

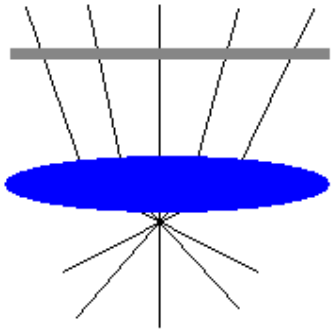
For ultra-high resolution (well below 0.2 nanometers) and very small spots on FEG instruments, it is not sufficient to correct only the two-fold astigmatism (astigmatism has many terms; since the effect of each term decreases exponentially, it is rarely necessary to correct more than two-fold astigmatism), but three-fold astigmatism as well. Microscopes where such corrections are important are therefore often equipped with three-fold stigmation in addition to the normal two-fold stigmation. In these cases the normal (beam and/or objective) stigmators are replaced by a variant where opposite elements are not coupled but can be adjusted individually. By using the opposite elements coupled, two-fold stigmation is done, while the three-fold stigmation uses combinations of several elements, producing a seeming set of six elements. The two stigmation settings are simply added, giving the required combination of two- and three-fold astigmatism correction.

3.5 Focusing the diffraction pattern

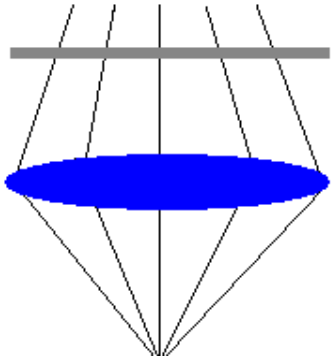
Unlike the image, the diffraction pattern does not have a clear criterion for establishing when it is in focus. Often it is presumed to be 'in focus' when the pattern has spots that are as small as possible. This is not strictly true. The diffraction pattern is in focus when the focus lies at the back-focal plane of the objective lens. Only when the incident beam is parallel does the cross-over lie in the back-focal plane.



With a parallel beam incident on the specimen (grey), the objective lens focuses the electrons into a cross-over whose position coincides with the back-focal plane (and thus the true diffraction focus).



When the beam is convergent (but not wholly focused), there still is a cross-over but it is displaced from the back-focal plane upwards (in the extreme case, a fully focused beam, the cross-over lies at the image plane).



When the beam is divergent, the cross-over is displaced downward from the back-focal plane.

If the diffraction pattern is not focused properly, there are a number of consequences:

- The camera length can be wrong
- The diffraction will be rotated away from its proper orientation
- The pattern may be distorted
- Alignments such as beam shift pivot points can be wrong
- The scanning magnification can be wrong due to misaligned pivot points

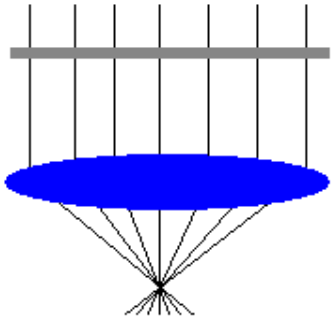
Due to the absence of a clear criterion, we end up with a chicken-and-egg situation (what was first, the chicken or the egg?). For example, if it can be assumed that the shift pivot points are correct, then it is easy to establish the correct diffraction focus by wobbling a beam shift and minimising diffraction-pattern movement. However, the pivot points can only be aligned correctly if the diffraction pattern is focused properly.

In order to resolve this situation, we have determined Intensity settings for the different modes (LM, HM-TEM and Nanoprobe) for a parallel beam. These Intensity settings are preset in the alignment procedures, making it easy to find diffraction focus (the spot-pattern condition). After the alignment have been done (camera length focus), the diffraction focus can also be found by simply pressing the Eucentric focus button (this resets the variable diffraction focus to zero). With this method for establishing diffraction focus, the SA aperture is not (and should not be) used.

3.6 The diffraction shadow image

When the diffraction pattern is focused properly at the back-focal plane, the pattern is either a spot pattern in SAED or a disk pattern in CBED (with a fully focused beam). In either case the diffraction pattern contains no image information at all (the magnification of the image in the diffraction pattern is infinite). It is also possible to defocus the diffraction pattern slightly (see below). When this is done, the (by now expanded) spots or disks do contain image information (the magnification is no longer infinite) and so we have obtained a mixture of diffraction and image information. This is called a shadow image.

The shadow image (in this case from SAED diffraction) can be understood from the diagram below. When a parallel illuminates an area of the specimen, all transmitted (bright-field) beams converge in a single cross-over in the back-focal plane of the objective lens. In this cross-over we cannot distinguish between beams coming from the different parts of the specimens, because all beams go through a single point (ideally). However, above or below the back-focal plane, the beams do not go through a single point but - in three dimensions - they form a disk and each point in the disk corresponds to an area of the specimen.



In SAED the shadow image is obtained by changing the diffraction focus (FOCUS). In CBED the shadow image is obtained by defocusing the beam on the specimen (INTENSITY).

The shadow image is often used when working with crystals:

- During tilting it allows observation of both crystal orientation (from the diffraction pattern) and position (the shadow image), making it easier to correct (with X-Y stage movement) for apparent image shift during tilting (especially with the non-eucentric b tilt).
- It can be used to create multiple dark-field images (the pattern contains the bright-field disk with the bright-field image and several diffraction disks, each with its own dark-field image).
- It can be used to position, focus and stigmate the focused beam accurately while in diffraction (or STEM).

In the shadow image, there are a couple of effects dependent on the direction of defocusing (under- or overfocus). In going from under- to overfocus the shadow image:

- Flips by 180°.
- Inverts the contrast.

Because of these effects, one should work consistently (either always underfocus or always overfocus).

4 Gun procedure

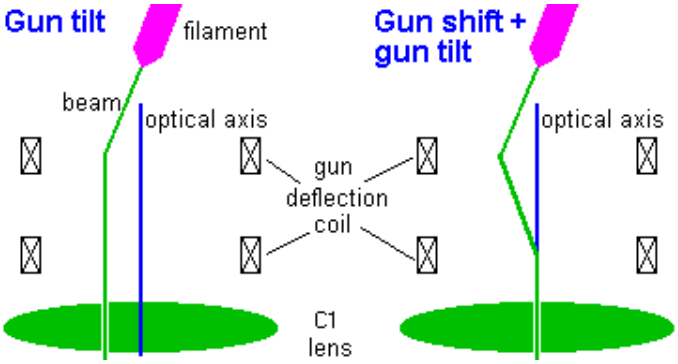
4.1 Gun tilt

Purpose: The gun tilt makes sure that the electron beam from the gun comes down parallel to the optical axis, so that no electrons from the beam are lost before they can be used for imaging, etc.
Importance: ESSENTIAL for having sufficient beam intensity.
Method: Obtain maximum intensity.

Procedure
The gun tilt alignment consists of two steps:

- A step for preparation and finding light.
- A step to set the gun tilt itself.

Description
Gun alignment consists of two parts: gun tilt and gun shift. The gun tilt alignment makes sure that the electron beam enters the microscope (that is, the C1 - spot size - lens) parallel to the optical axis, while gun shift ensures that the beam goes through the center of the C1 lens.



The gun tilt is aligned simply by maximizing the intensity (with a useful guide often being the exposure time measured on the screen). For fine-tuning at high magnifications use the direct alignments and the criteria outlined under FEG alignment.

Since gun tilt alignment implies no gun shift (which would be visible as a beam shift), it should be possible to align the gun tilt without movement of the beam. If this is not the case, the gun tilt pivot points are not aligned properly.

4.2 Gun tilt pivot points

Purpose: Minimize movement of the beam during gun tilt alignment.
Importance: CONVENIENCE for not having to correct beam position while doing the gun tilt alignment.
Method: Minimize beam movement.

Procedure
The gun tilt pivot point alignment consists of four steps:
- A step for preparation.
- Two steps to align the pivot points for the x and y directions.

And a final step to redo the gun tilt itself (because the pivot points affect the gun tilt, the latter step can be necessary).

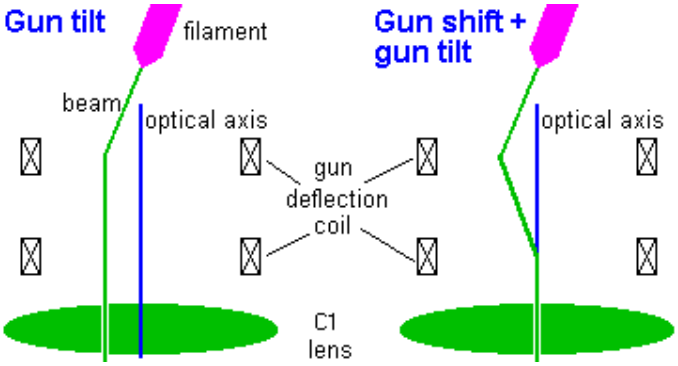
4.3 Gun shift

Purpose: Shift the electron beam sideways so that it comes down along the optical axis.
Importance: ESSENTIAL for minimizing movements between different spot sizes and for having the beam correctly along the optical axis for all spot sizes.
Method: Minimize spot displacement when spot size (that is focal length of C1 lens) is changed.

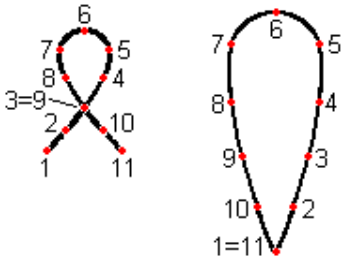
Procedure
The gun shift alignment consists of two steps:
- A first step in which spot 9 is centered with the beam deflection coils.
- A second step in which spot 3 is centered with the gun deflection coils.

The two steps are repeated until the change in gun shift is very small. In the gun shift procedure the spot-size dependent gun shift values for spots 3 and 9 are reset to zero (for proper alignment the spot-size dependent gun shift should therefore be done after the gun shift procedure).

Description
Gun alignment consists of two parts: gun tilt and gun shift. The gun tilt alignment makes sure that the electron beam enters the microscope (that is, the C1 - spot size - lens) parallel to the optical axis, while gun shift ensures that the beam goes through the center of the C1 lens.



When spot size 9 is used (or any spot size above that), the C1 lens is strong. Under these conditions all aberrations of the microscope system above it are demagnified by the lens (C1 works in the opposite way of the magnification system; instead of magnifying the image, it makes the image of the source - the electron gun - smaller). Thus the demagnification of the misalignment of the gun shift is much smaller for spot 9 than for spot 3, so spot 9 gives the reference ('no' gun shift) and spot 3 defines the gun shift itself.



These diagrams show schematically how the beam position would change as a function of spot number when spots 3 and 9 are used for gun shift alignment (left) and spots 1 and 11 (right). For spots 3 and 9 the overall shift is smaller. The remaining deviations are corrected by the spot-size dependent gun shift.

4.4 Spot-size dependent gun shift

Purpose: Set the exact gun shift for all spots individually.
Importance: ESSENTIAL for minimizing movements between different spot sizes and for having the beam correctly along the optical axis for all spot sizes.
Method: Align all spots relative to spot 11.

Procedure
The spot-size dependent gun shift alignment consists of three steps:

- A first step in which spot 5 is centered with the beam deflection coils.
- A second step in which spot 11 is centered with the beam deflection coils (spot 5 is done first because spot 11 may be difficult to find, especially if the beam is defocused).
- A third step in which all spots down from 11 (10 to 1) are centered.

5 Beam HM-TEM procedure

5.1 Preparation Beam HM-TEM alignment

Purpose: Set up microscope for aligning the upper part of the column (the illumination system) in HM-TEM.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center.

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

5.2 Adjust Minicondenser lens

Purpose: Set the focal length of the Minicondenser lens at the front-focal plane of the objective lens.
Importance: ESSENTIAL for proper nanoprobe and scanning operation.
Method: First set up by focusing the diffraction pattern (smallest diffraction spots). Then minimize the size of the diffraction spots with the Minicondenser lens.

Procedure
The alignment procedure consists of three steps:
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- A step in which the minicondenser lens can be adjusted.

Note: The Minicondenser lens can be used to change the optics of the condenser system (e.g. the convergence angles in microprobe and nanoprobe modes depend on the minicondenser lens setting). It should be noted, however, that changing the minicondenser lens has a number of consequences:
- Because the Minicondenser lens is located below the beam deflection coils, changes of the lens affect many beam alignments.
- Strong changes of the Minicondenser lens may result on strong beam drift (the lens doesn't have any water-cooling, since it releases its heat to the objective lens itself).
- Changing the Minicondenser lens affects the field of view that can be illuminated, especially when small objective apertures are used.

5.3 Pivot point beam shift HM

Purpose: Align beam shift pivot point = make sure that the beam does not tilt when it is shifted.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and the alignment of the pivot point can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two central spots in the diffraction pattern should overlap.

Procedure
The alignment procedure consists of four steps:
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Notes:
- The shift 'wobble' may have one beam position blocked by the specimen. If no second beam is visible when turning MF -X, then (re)move the specimen.
- Diffraction focus: the Intensity setting is preset to a fixed value that gives a parallel incident beam which in turn should give a spot diffraction pattern. If the pattern is not focused, it should be focused with the diffraction lens (FOCUS), not Intensity.

5.4 Pivot point beam tilt HM

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during rotation-center alignment, focusing with the wobbler and dark-field imaging.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of three steps:
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Note: Unlike the shift pivot point (previous subprocedure), the tilt pivot point is sensitive to objective-lens focus.

5.5 Dynamic conical dark field pivot point HM (STEM systems only)

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during dynamic conical dark-field imaging.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of three steps :
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Notes:
- The AC beam tilt pivot point is sensitive to objective-lens focus.
- The AC beam tilt pivot point is used only for Dynamic Conical Dark Field.
- Because TIA drives the beam in Dynamic Conical Dark Field, TIA must be running during execution of this alignment.

5.6 Dynamic conical dark field distortion HM (STEM systems only)

Purpose: Make sure that the beam tilt describes a circle as seen in diffraction.
Importance: ESSENTIAL for proper dynamic conical dark-field imaging.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of four steps :

- One preparation step for setting up the image.
- One step in which the diffraction pattern is centered.
- One step in which the static beam tilt on the AC coils is adjusted until the beam is at the 4 cm circle.
- A final step in which the beam scans around and the distortion is adjusted until the movement is circular.

5.7 HM-TEM rotation center

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimizing lens aberrations and image movement during focusing.
Method: The microscope 'wobbles' the objective lens current, making the image go through focus. Make the sideways movement of the image as small as possible with the rotation center (= tilting the beam to the optical axis).
The 'focus wobble' can be made smaller or larger with the Focus Step Size knob.

Procedure
The alignment procedure consists of two steps:

- One preparation step for setting up the image.
- A step in which the rotation center is aligned.

Notes:

- The rotation center is an alignment that is based on a beam tilt, hence it appearance in the Beam alignment procedure and not the Image alignment procedure.
- For proper high-resolution alignment of the objective lens on 200 and 300 kV instruments, rotation center is only suitable as a first step. Coma-free alignment should be used as the final objective-lens alignment.

5.8 Align beam shift HM

Purpose: Set the zero position for the beam shift.
Importance: CONVENIENCE for easy resetting of the beam shift to the screen center.
Method: Center the beam using Multifunction X,Y.

Procedure
The alignment procedure consists of two steps:
- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero.
- In the second step, the direction of the beam shift is aligned with respect to the movement by the trackball. When the trackball is moved from left to right, the beam should also move from left to right on the screen. If the beam moves in a different direction, adjust the direction with the Multifunction Y knob.

Description
The beam shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the beam centered on the screen. It then is only necessary to reset the 'user' value to zero to have the beam back at the screen center.

The alignment value for the beam shift is used frequently in alignment (any time the beam must be centered with Multifunction X,Y). In any such step, the 'user' value of the beam shift is always reset to zero. Therefore, on a properly aligned microscope, it is always possible to find the beam again simply by entering this alignment step: the 'user' value is reset to zero, so the beam should now be centered.

5.9 Beam shift calibration HM

Purpose: Calibrate the beam shift to physically meaningful values.
Importance: CONVENIENCE.
Method: Move the focused beam to the edge of the viewing screen with Multifunction X and adjust the displayed value of the image shift using Multifunction Y.

Procedure
The alignment procedure consists of four steps:
- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the beam shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the beam shift.

5.10 Beam tilt (dark field) calibration HM

Purpose: Calibrate the beam tilt (dark field) to physically meaningful values.
Importance: ESSENTIAL for meaningful beam tilt values in dark field.
Method: Tilt the beam and adjust the displayed value of the beam tilt using Multifunction X,Y.

Procedure
The alignment procedure consists of five steps:
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the beam is tilted (this is, the diffraction pattern is shifted) with Multifunction X to bring a ring to the center and the beam tilt value is adjusted with Multifunction Y to the correct value.
- The fourth and fifth steps repeat the procedure of the second and third steps for the Y diffraction shift.

Description
The beam tilt is converted through the calibration procedure into to physically meaningful units. The beam tilt can be read off in the flap-out of the Alignment Control Panel and is used in the Dark Field Control Panel.

5.11 Dynamic conical dark field beam tilt calibration HM (STEM systems only)

Purpose: Calibrate the AC beam tilt (dynamic conical dark field) to physically meaningful values.
Importance: ESSENTIAL for meaningful beam tilt values in dynamic conical dark field and for ensuring a match between static and dynamic conical dark field.
Method: Tilt the beam and adjust the displayed value of the beam tilt using Multifunction X,Y.

Procedure
The alignment procedure consists of three steps :
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the beam is tilted (this is, the diffraction pattern is shifted) with Multifunction X to bring a ring to the center and the beam tilt value is adjusted with Multifunction Y to the correct value.

Description
The beam tilt is converted through the calibration procedure into to physically meaningful units. The beam tilt can be read off in the flap-out of the Alignment Control Panel and is used in the Dark Field Control Panel.

5.12 Spot size-intensity calibration

Purpose: Make sure that a focused beam remains focused when spot size is changed.
Importance: CONVENIENCE for keeping spot focus the same for all spot sizes, ESSENTIAL for proper operation of Intensity Zoom and Intensity Limit.
Method: After focusing spot 3, all spots are focused in turn. The deviations in intensity setting from spot focus are stored for all spots.

Procedure
The alignment procedure consists of two steps:
- One preparation step in which the beam is focused for spot size 3.
- A step in which all spot sizes are focused.

Note: The condenser system (C1 and C2 lenses) is normalized when the spot size is changed to make the spot setting better reproducible.

Description
The Intensity (C2 lens) and spot size (C1 lens) settings are not independent. In order to give the same effect for all spot sizes, the Intensity is changed whenever spot size is changed. In addition to the preprogrammed changes, individual instruments differ slightly in their relation between C1 and C2. The spot size-intensity calibration allows adjustment for this individual behavior. For the Intensity Zoom and Intensity Limit functions this procedure defines the Intensity settings at which the beam is focused, which is essential for proper operation of these functions.

5.13 Coma-free amplitude

Purpose: Adjust the tilt angle used during coma-free alignment.
Importance: ESSENTIAL for obtaining reliable and accurate high-resolution data.
Method: The microscope will slowly wobble the beam in the X direction with a set amount of beam tilt. Adjust the coma-free amplitude until the tilt has the desired angle. Typically the angle should be not too small (in that case the accuracy is reduced) nor too large (the astigmatic appearance of the image makes it very hard to judge the defocus). A good compromise is the beam tilt angle corresponding to a diffraction spacing of about 0.3 nm.

Procedure
The alignment procedure consists of three steps:
- The first step is a preparation step to center the beam and focus the image.
- In the second step the diffraction pattern is centered.
- In the third step the beam is wobbled slowly back and forth. The beam tilt angle (seen as a diffraction shift) can be adjusted with the Multifunction X knob (there is only one coma-free amplitude set, used for both X and Y directions).

5.14 Coma-free pivot points

Purpose: Make sure that the beam stays well-centered while wobbling.
Importance: ESSENTIAL for obtaining reliable and accurate coma-free alignment.
Method: Minimize the movement of the beam under coma-free alignment conditions.

Procedure
The alignment procedure consists of three steps:
- The first step is a preparation step to center the beam and focus the image.
- In the two following steps, the beam is wobbled (first step in the x, second step the y direction), and the coma-free pivot point is adjusted until the two wobbling beams overlap.

Description
See coma-free alignment for a detailed description of this alignment. The difference between the coma-free pivot point alignment and the beam-tilt pivot point alignment is the amplitude used for the wobbling of the beam. In the former case, the amplitude is much larger than for the coma-free pivot points (where the amplitude used is the same as for the actual alignment. This is important because the pivot point adjustment is very critical at the high magnifications used for coma-free alignment.

Note: The actual pivot point values are in the same setting for both methods. The beam-tilt and coma-free pivot points thus differ only in their method of aligning.

5.15 Coma-free alignment

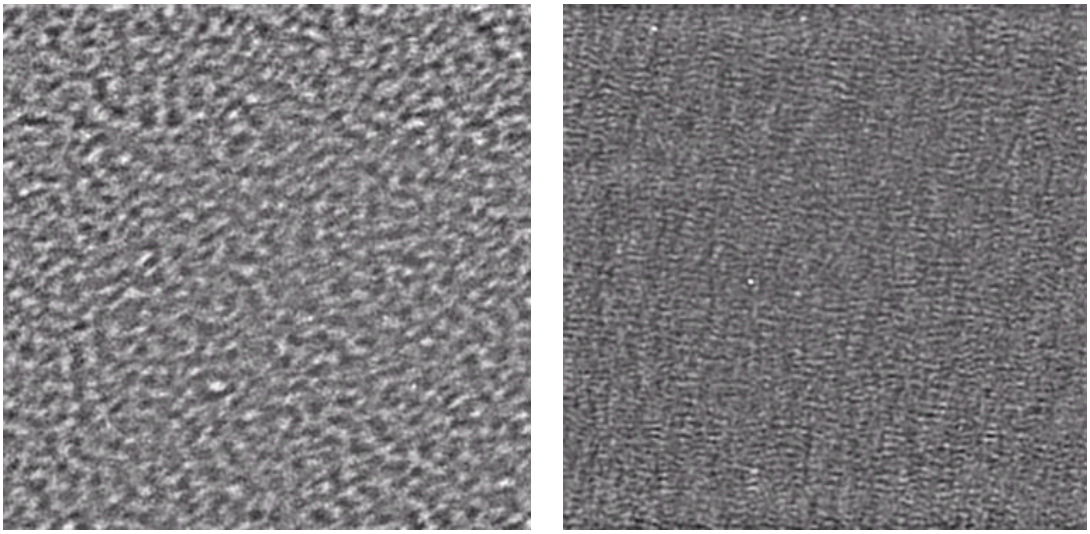
Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for obtaining reliable and accurate high-resolution data.
Method: The microscope will slowly wobble the beam in the x or y direction with a set amount of beam tilt (determined by the coma-free amplitude alignment). Adjust the coma-free center until the images for both tilts have the same apparent defocus.

Procedure
The alignment procedure consists of three steps:
- The first step is a preparation step to center the beam and focus the image.
- In the two following steps, is wobbled (first step in the x, second step the y direction), and the coma-free center is adjusted until the two 'wobble' images have the same defocus.

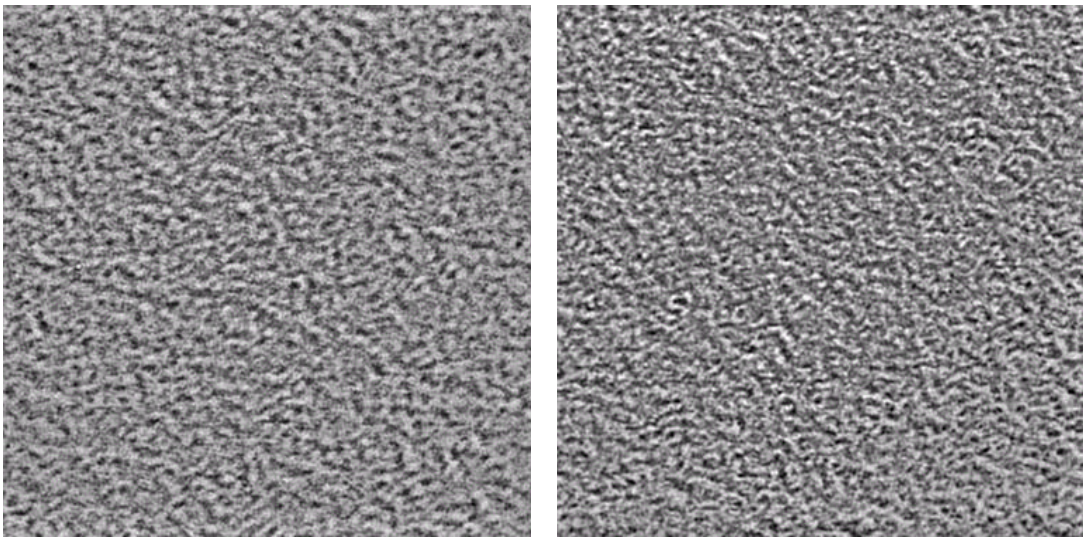
Description
There are several possible methods for aligning the objective lens (but all affect the same parameter - the tilt of the electron beam):
- Current center - by wobbling the objective lens and minimizing image displacements.
- Voltage center - by wobbling the high tension and minimizing image displacements (not implemented on Tecnai).
- Coma-free alignment - by wobbling the incident beam and minimizing focus difference.

The former two methods came about in an age when it was important to minimize the effects of objective-lens (current center) and high-tension (voltage center) instabilities in order to achieve high resolution. Nowadays these instabilities are so small that they are no longer of major concern. Meanwhile it had been found by Zemlin et al. (1978; Ultramicroscopy 3, 49) and later Smith et al. (1983; Ultramicroscopy 11, 263) that neither current nor voltage center is sufficient alignment for high-resolution imaging. One difficulty is often the precision (reproducibility) with which the current or voltage center can be aligned. The main problem is, however, that for most instruments neither center lies along the true objective-lens optical axis. A misaligned objective lens will lead to different phase shifts (the Contrast Transfer Function) for the equivalent hkl and -h-k-l diffracted beams, which has a major effect on apparent symmetry in high-resolution images.

Only coma-free alignment is sufficiently accurate for centering of the objective lens for high-resolution imaging. In coma-free alignment, the beam is wobbled slowly between a -x and +x tilt. Because of the presence of spherical aberration, these beam tilts lead to an apparent defocus (overfocus). This defocus is relative to the true optical axis and not to the 'unwobbled' case. In order to align the objective lens, the beam tilt is then adjusted to make the defocus of the two wobble directions identical. The adjustment is done for the x and y tilt directions.



Carbon foil images (above) obtained at two different angles of the incident beam, before coma-free alignment. Note the difference in defocus between the two images.



Carbon foil images (above) obtained at two different angles of the incident beam, after coma-free alignment. The difference in defocus between the two images is small and the coma-free alignment has been done correctly.

Note 1: It is important to remember that it is the apparent defocus that must be the same for the two images. This doesn't mean that the images become identical. After all, the beam still goes through the specimen (best an amorphous carbon foil or amorphous edge of a hole in the specimen) in two different directions and the difference in the line-up of atoms in the amorphous material can still lead to differences in the images themselves.

Note 2: Because coma-free alignment and the rotation center affect the same parameter (the tilt of the incident beam), there is no point in iterating rotation center, then coma-free alignment and then rotation center again (with the last alignment the coma-free alignment is undone). These alignments differ in the method, not in their result.

Note 3: The effect of coma (the lens error introduced by beam tilt) looks very similar to that of astigmatism. The final astigmatism correction should be done after coma-free alignment, but it may be necessary to do an initial astigmatism correction before.

6 Image HM-TEM Procedure

6.1 Preparation Image HM-TEM alignment

Purpose: Set up microscope for aligning the lower part of the column (the imaging system) in HM-TEM.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center.

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

6.2 Pivot point image shift HM

Purpose: Align image shift pivot point = make sure that the diffraction pattern does not shift when the image shift is changed.
Importance: ESSENTIAL for the proper functioning of image shifts.
Method: Minimize the movement of the diffraction pattern. The microscope 'wobbles' the image shift which should cause no diffraction shift.

Procedure
The alignment procedure consists of four steps:
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Note: Diffraction focus. The Intensity setting is preset to a fixed value that gives a parallel incident beam which in turn should give a spot diffraction pattern. If the pattern is not focused, it should be focused with the diffraction lens (FOCUS), not Intensity.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

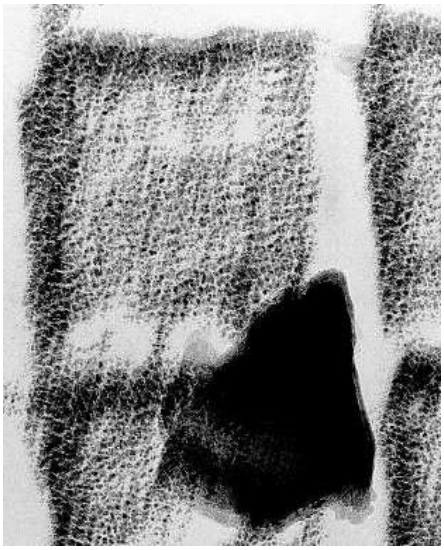
6.3 Pivot point diffraction shift SA

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

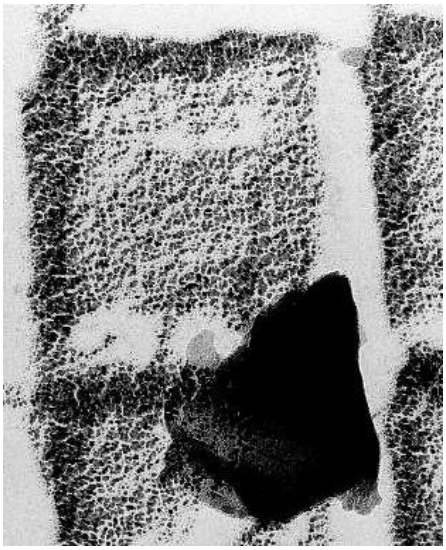
A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture.

Procedure
The alignment procedure consists of three steps:
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).



Misaligned diffraction shift pivot point.



Aligned diffraction shift pivot point.

6.4 Objective Lens preset SA

Purpose: Setting the eucentric focus preset at the eucentric height.
Importance: CONVENIENCE for having the eucentric focus at the eucentric height.
Method: Focus the image for the highest SA magnification.

Procedure
The alignment procedure consists of two steps:
- A preparation step in which the SA image is focused at an intermediate magnification.
- A step in which the highest SA magnification must be focused.

6.5 Pivot point diffraction shift Mh

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture.

Procedure
The alignment procedure consists of three steps:
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

In the preparation step the P1 lens is maximized (with MF-X) to reduce the effective magnification. Still, the beam (when wobbling in the next two steps) may be difficult to find.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images, see section 6.3.

6.6 Mh objective-lens preset and image shift

Purpose: Aligning the Mh-magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image. Repeat for all Mh magnifications.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification.
- A step in which the lowest Mh magnification is focused and aligned relative to the highest SA magnification.
- A step in which all other Mh magnifications are focused and aligned.

Notes:
- The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.
- The instruction 'center illumination' with MF-X,Y is correct ! When the magnification is changed from the highest SA to the lowermost Mh, the beam will remain in the same position but the whole image may be shifted. Bringing the beam to the center first by shifting the image - not the beam - allows one to see the image feature and then center it.

Using the P1 lens
Because of the high magnifications used (and the resulting small field of view), it can be difficult to align the Mh magnifications (no light visible). The alignment procedure therefore provides a trick. It is possible to change the P1 lens (increase its current) by toggling the MF-X control to it (press the R2 button). When the P1 lens is made stronger, it reduces the effective magnification but has very little effect on image position and focus. This makes it possible to spread the beam (and actually see it more easily because of the lower magnification) and center it.

Use the following procedure if the beam is not visible at the normal Mh magnification:
- Toggle the MF-X control to the P1 lens (press R2).
- Turn the MF-X knob a bit clock-wise.
- Change the Intensity setting and see if the beam can be found.
- Repeat the previous two steps until the beam is seen. Note that at very much changed P1 setting, the image is partly blocked by an aperture (the differential pumping aperture between the column and the projection chamber) so not the whole screen can be illuminated.
- If the image is out of focus, focus it.
- Toggle back to MF-X,Y control to the image shift and center the beam (and image).
- Turn the magnification once up and down (this resets the P1 lens to its proper value).
- Focus and center the image.

6.7 Image shifts SA

Purpose: Aligning all SA images with each other.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of two or four steps, dependent on the presence of absence of Parfocal Magnification Series (last two steps):
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification.
- A step in which all SA magnifications are aligned relative to the highest SA magnification.
- A preparation step in which the highest SA magnification is focused accurately.
- A step in which all other SA magnifications are focused accurately.

Parfocal magnification series
The parfocal magnification series applies an automatic correction to each SA magnification so as to make the focus difference between the SA magnification steps as small as possible. This correction factor is independent of focus settings and applies only to the SA magnifications. Similar correction factors for the M (Mi, and Mh) magnifications as well as diffraction (D) are already present as standard in the Tecnai software.

Notes:
- The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.
- The highest SA magnification is the reference image for the whole microscope, with regard to focus (eucentric focus preset) and image shift.

6.8 Pivot point diffraction shift Mi

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture.

Procedure
The alignment procedure consists of three steps:
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images, see section 6.3.

6.9 Mi objective lens preset and image shift

Purpose: Aligning the Mi-magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE for finding the same image feature centered and the image in focus when going from SA to Mi and vice versa.
Method: Move the required feature in the specimen to the center with the image shift and focus the image.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which an image feature is centered (with the specimen-stage) in the lowest SA magnification.
- A step in which the highest Mi magnification is focused and aligned relative to the lowest SA magnification.
- A step in which all Mi magnifications are aligned relative to the highest Mi magnification.

Note: The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.

6.10 Align diffraction pattern

Purpose: Set the zero position for the diffraction shift.
Importance: CONVENIENCE for easy resetting of the diffraction shift to the screen center.
Method: Center the diffraction pattern using Multifunction X,Y.

Procedure
The alignment procedure consists of a single step.

Description
The diffraction shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the diffraction pattern centered on the screen. It then is only necessary to reset the 'user' value to zero to have the pattern back at the screen center.

6.11 Align camera lengths

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the center when the camera length is changed.
Importance: CONVENIENCE for having the diffraction patterns centered when the camera length is changed.
Method: Center the diffraction pattern for the reference camera length (~500 mm), then align all camera lengths to the reference camera length. Focus all camera lengths.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which the image is focused.
- A step in which the reference camera length (~500 mm) is focused and centered.
- A step in which all other camera lengths are focused and centered.

Notes:
- The magnification system (projector lenses) is normalized when the magnification is changed to make the diffraction pattern position better reproducible.
- For each camera length the focus setting is stored during this alignment.

6.12 Image shift calibration HM

Purpose: Calibrate the image shift to physically meaningful values.
Importance: ESSENTIAL for meaningful image measurement results.
Method: Move the focused beam to the edge of the viewing screen (the microscope uses the image shift to do this) and adjust the displayed value of the image shift using Multifunction Y. The focused beam is thus used as a reference marker.

Procedure
The alignment procedure consists of four steps:
- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the image shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the image shift.

Description
The image shift calibration provides the conversion factor for the image shift used in measuring and for the beam shift - image shift.

6.13 Diffraction shift calibration HM

Purpose: Calibrate the diffraction shift to physically meaningful values.
Importance: ESSENTIAL for meaningful diffraction measurement results.
Method: Move the diffraction pattern and adjust the displayed value of the diffraction shift using Multifunction Y.

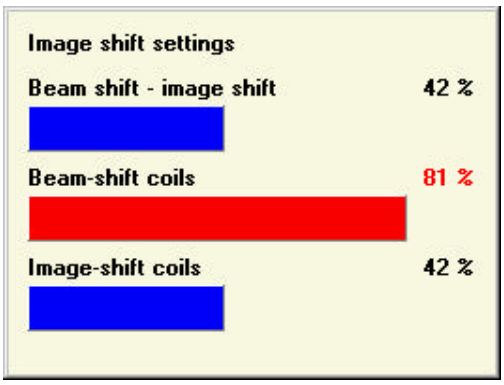
Procedure
The alignment procedure consists of five steps:
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the diffraction pattern is shifted with Multifunction X to bring a ring to the center and the diffraction shift (nm value or angle) is adjusted with Multifunction Y to the correct value.
- The fourth step repeats the procedure of the third step for the Y diffraction shift.

Description
The diffraction shift is converted through the calibration procedure into to physically meaningful units such as Bragg angles and d spacings (in the latter case the Bragg Law formula is used). The diffraction shift can be read off in the flap-out of the Alignment Control Panel and is used in the Measuring Control Panel.

6.14 Beam shift - image shift calibration HM

Purpose: Define the beam shift compensation for the image shift.
Importance: CONVENIENCE for keeping the beam on the screen when the image is shifted. The beam shift - image shift is used in the Image shift Control Panel and in Low Dose.
Method: Move the image off-axis and recenter the beam using Multifunction X,Y.

Note: This procedure is complicated by the fact that it is not easy to tell how far the beam-shift/image-shift should be changed. The on-line help file therefore contains a control that indicates the status of the beam-shift/image-shift, beam coils and image coils.



Using this you change the beam shift-image shift until either:

- the beam is at the screen edge.
- the beam shift-image shift is more than 50% (bar becomes green) OR one of the coils is more than 80% (bar becomes red).

The microscope will sound a beep when the beam shift-image shift is at its limit but also when one of the coils is at its limit. In the former case you can continue with the calibration, but when a coil is limited very likely you cannot. The control in the help file which is directly linked to the microscope displays the situation.

Procedure

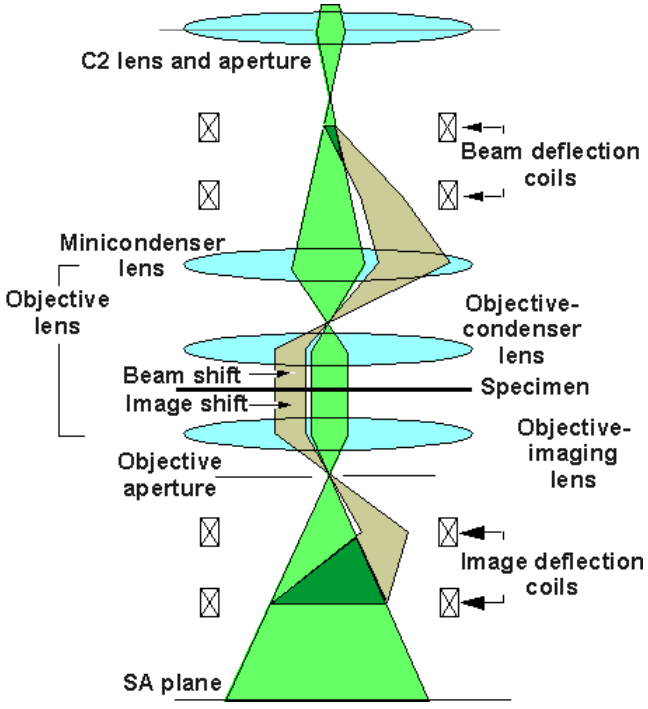
The calibration procedure consists of six steps:

- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero. At the same time the image shift is set to zero.
- In the second step, the image shift X is changed, either until the microscope beeps (at the limit of the image shift) or until the beam moves off the screen (the latter typically happens when the calibration has not been done yet).
- In the third step the beam is recentered using the Multifunction X,Y. If the microscope beeped during the second step, continue, otherwise step back and repeat the second and third steps (so the final calibration is done with the image shift at its limit).
- The fourth and fifth steps repeat the same procedure as the second and third steps, but this time for the Y image shift.
- The final step just ensures that the image-beam shift is reset to zero after the procedure is finished.

Description

The Tecnai microscope has a function for image shift where the beam position is automatically compensated to keep the beam on the area of interest (what is currently seen on the viewing screen). The beam shift compensation must be calibrated before it will work properly.

When the user shifts the image (from the central green ray path to the off-axis, tan ray path), the microscope automatically applies a compensating beam shift.



6.15 Off-axis TV HM image alignment (only if off-axis TV installed)

Purpose: Aligning all Mh and SA (as far as attainable) magnifications on the off-axis TV.
Importance: CONVENIENCE so that the image is shifted automatically from the center of the viewing screen to the off-axis TV camera .
Method: Center a recognizable image on the viewing screen with the specimen stage. Center the image with the Multifunction X,Y knobs on the off-axis TV camera. Repeat for all attainable magnifications.

Note 1: The off-axis TV camera is located about 7 cm from the center of the viewing screen between W and WNW (where N is defined as the direction furthest away from the operator). The image can be shifted to the TV camera by selecting manual mode and the Off-axis TV in the Detector Configuration Control Panel.

Note 2: The shift of the image to the off-axis TV uses the image shift coils below the objective lens. The effect of these coils is magnified by the magnification system. The highest magnifications therefore give no problems but some of the lowermost magnifications may be out of reach of the range of these coils. In addition, any other use of these coils (e.g. for the Image-Beam shift) will also affect the range of attainable magnifications.

Procedure
The alignment procedure consists of four steps :

- A preparation step in which an image feature is centered on the viewing screen (with the specimen stage) in the highest SA magnification.
- A step in which the highest SA magnification is centered on the off-axis TV.
- A step in which the Mh magnifications are centered on the off-axis TV.
- A step in which all other SA magnifications are centered on the off-axis TV (as far as attainable, see Note 2 above).

6.16 Off-axis TV diffraction alignment (only if off-axis TV installed)

Purpose: Aligning all (as far as attainable) camera lengths on the off-axis TV.
Importance: CONVENIENCE so that the diffraction pattern is shifted automatically from the center of the viewing screen to the off-axis TV camera .
Method: Center the diffraction pattern on the viewing screen. Then center the diffraction pattern with the Multifunction X,Y knobs on the off-axis TV camera. Repeat for all attainable camera lengths.

Note 1: The off-axis TV camera is located about 7 cm from the center of the viewing screen between W and WNW (where N is defined as the direction furthest away from the operator). The diffraction pattern can be shifted to the TV camera by selecting manual mode and the Off-axis TV in the Detector Configuration Control Panel.

Note 2: The shift of the diffraction pattern to the off-axis TV uses the image shift coils below the objective lens. The effect of these coils is magnified by the magnification system. The highest camera lengths therefore give no problems but some of the lowermost camera lengths may be out of reach of the range of these coils. In addition, any other use of these coils (e.g. for the Image-Beam shift) will also affect the range of attainable camera lengths.

Procedure
The alignment procedure consists of four steps :

- A preparation step in which the image is focused in the SA magnification range.
- A preparation step in which the diffraction pattern is centered on the viewing screen.
- A step in which the diffraction pattern is centered on the off-axis TV.
- A step in which all other camera lengths are centered on the off-axis TV (as far as attainable, see Note 2 above).

7 Beam LM Procedure

7.1 Preparation Beam LM alignment

Purpose: Set up microscope for aligning the upper part of the column (illumination system) in LM.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

7.2 Pivot point beam shift LM

Purpose: Align beam shift pivot point = make sure that the beam does not tilt when it is shifted.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the diffraction lens (the 'objective' lens in LM). This plane is conjugate to the back-focal (LAD diffraction) plane and the alignment of the pivot point can thus be seen in LAD diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two central spots in the diffraction pattern should overlap.

Procedure
The alignment procedure consists of four steps:
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Notes:
- The shift 'wobble' may have one beam position blocked by the specimen. If no second beam is visible when turning MF -X, then (re)move the specimen.
- Diffraction focus: in LAD the objective lens (which is here the focusing lens) is switched to fixed setting. To focus the diffraction pattern to a spot pattern the Intensity should be used, not the Focus. Only if the pattern cannot be focused with the Intensity should the Focus knob (objective lens) be used.

7.3 Pivot point beam tilt LM

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during rotation-center alignment and focusing using the wobbler.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of three steps:
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

7.4 LM rotation center

Purpose: Make sure that the beam is along the optical axis of the diffraction lens (= the 'objective lens' in LM).
Importance: ESSENTIAL for minimizing lens aberrations and image movement during focusing.
Method: The microscope 'wobbles' the diffraction lens current, making the image go through focus. Make the sideways movement of the image as small as possible with the rotation center (= tilting the beam to the optical axis). The 'focus wobble' can be made smaller or larger with the Focus Step Size knob.

Procedure
The alignment procedure consists of two steps:
- One preparation step for setting up the image.
- A step in which the rotation center is aligned.

Note: The rotation center is an alignment that is based on a beam tilt, hence it appearance in the Beam alignment procedure and not the Image alignment procedure.

7.5 Align beam shift LM

Purpose: Set the zero position for the beam shift.
Importance: CONVENIENCE for easy resetting of the beam shift to the screen center.
Method: Center the beam using Multifunction X,Y.

Procedure
The alignment procedure consists of two steps:
- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero.
- In the second step, the direction of the beam shift is aligned with respect to the movement by the trackball. When the trackball is moved from left to right, the beam should also move from left to right on the screen. If the beam moves in a different direction, adjust the direction with the Multifunction Y knob.

Description
The beam shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the beam centered on the screen. It then is only necessary to reset the 'user' value to zero to have the beam back at the screen center.

The alignment value for the beam shift is used frequently in alignment (any time the beam must be centered with Multifunction X,Y). In any such step, the 'user' value of the beam shift is always reset to zero. Therefore, on a properly aligned microscope, it is always possible to find the beam again simply by entering this alignment step: the 'user' value is reset to zero, so the beam should now be centered.

7.6 Beam shift calibration LM

Purpose: Calibrate the beam shift to physically meaningful values.
Importance: CONVENIENCE.
Method: Move the focused beam to the edge of the viewing screen and adjust the displayed value of the image shift using Multifunction Y.

Procedure
The alignment procedure consists of four steps:

- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the beam shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the beam shift.

7.7 Beam tilt (dark field) calibration LM

Purpose: Calibrate the beam tilt (dark field) to physically meaningful values.
Importance: ESSENTIAL for meaningful beam tilt values in dark field.
Method: Tilt the beam and adjust the displayed value of the beam tilt using Multifunction X,Y. Because few specimens provide the (large) d spacings appropriate for the small beam tilts obtained in LAD, it may not be possible to use a d spacing as calibration. The software therefore suggests to use the camera length value as a reference and simply calculate the angle corresponding to the shift to the 4 cm circle of the viewing screen.

Procedure
The alignment procedure consists of five steps:

- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the beam is tilted (this is, the diffraction pattern is shifted) with Multifunction X to bring a ring to the center and the beam tilt value is adjusted with Multifunction Y to the correct value.
- The fourth and fifth steps repeat the procedure of the second and third steps for the Y diffraction shift.

Description
The beam tilt is converted through the calibration procedure into to physically meaningful units. The beam tilt can be read off in the flap-out of the Alignment Control Panel and is used in the Dark Field Control Panel.

7.8 Spot size-intensity calibration LM

Purpose: Make sure that a focused beam remains focused when spot size is changed.
Importance: CONVENIENCE for keeping spot focus the same for all spot sizes, ESSENTIAL for proper operation of Intensity Zoom and Intensity Limit.
Method: After focusing spot 3, all spots are focused in turn. The deviations in intensity setting from spot focus are stored for all spots.

Procedure
The alignment procedure consists of two steps:
- One preparation step in which the beam is focused for spot size 3.
- A step in which all spot sizes are focused.

Note: The condenser system (C1 and C2 lenses) is normalized when the spot size is changed to make the spot setting better reproducible.

Description
The Intensity (C2 lens) and spot size (C1 lens) settings are not independent. In order to give the same effect for all spot sizes, the Intensity is changed whenever spot size is changed. In addition to the preprogrammed changes, individual instruments differ slightly in their relation between C1 and C2. The spot size-intensity calibration allows adjustment for this individual behavior. For the Intensity Zoom and Intensity Limit functions this procedure defines the Intensity settings at which the beam is focused, which is essential for proper operation of these functions.

8 Image LM Procedure

8.1 Preparation Image LM alignment

Purpose: Set up microscope for aligning the lower part of the column (imaging system) in LM.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

8.2 Pivot point image shift LM

Purpose: Align image shift pivot point = make sure that the LAD diffraction pattern does not shift when the image shift is changed.
Importance: ESSENTIAL for the proper functioning of image shifts.
Method: Minimize the movement of the diffraction pattern. The microscope 'wobbles' the image shift which should cause no diffraction shift.

Procedure
The alignment procedure consists of four steps:
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Note: Diffraction focus: in LAD the objective lens (which is here the focusing lens) is switched to fixed setting. To focus the diffraction pattern to a spot pattern the Intensity should be used, not the Focus. Only if the pattern cannot be focused with the Intensity should the Focus knob (objective lens) be used.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

8.3 Pivot point diffraction shift LM

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the LAD diffraction shift which should cause no image shift.

Procedure
The alignment procedure consists of three steps:
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images, see section 6.3.

8.4 LM images

Purpose: Aligning the LM-magnification image with the M image and all LM image magnifications with each other.
Importance: CONVENIENCE for finding the same image feature centered when crossing from M to LM (or vice versa) and within the LM range.
Method: Focus the image (LM magnification) and center the recognizable image feature with MF-X,Y.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which an image feature is centered (with the specimen stage) in the lowest Mi magnification.
- A step in which the whole LM range is aligned with the Mi magnification.
- A step in which all LM magnifications are aligned relative to the highest LM magnification.

Note: The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.

Description
The alignment uses two different values:
- One value determines the shift of the whole LM range relative to the lowermost Mi magnification (and is thus a shift of the whole LM range)
- The other values determine the shifts between individual LM magnifications (defined as the shift between a particular magnification and the highest LM magnification).

8.5 Align LAD diffraction pattern

Purpose: Set the zero position for the LAD diffraction shift.
Importance: CONVENIENCE for easy resetting of the diffraction shift to the screen center.
Method: Center the diffraction pattern using Multifunction X,Y.

Procedure
The alignment procedure consists of a single step.

Description
The diffraction shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the diffraction pattern centered on the screen. It then is only necessary to reset the 'user' value to zero to have the pattern back at the screen center.

8.6 Image shift calibration LM

Purpose: Calibrate the image shift to physically meaningful values.
Importance: ESSENTIAL for meaningful image measurement results.
Method: Move the focused beam to the edge of the viewing screen - with the image shift - and adjust the displayed value of the image shift using Multifunction Y. The focused beam is thus used as a reference marker.

Procedure
The alignment procedure consists of four steps:
- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the image shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the image shift.

Description
The image shift calibration provides the conversion factor for the image shift used in measuring and for the beam shift - image shift.

8.7 Diffraction shift calibration LAD

Purpose: Calibrate the diffraction shift to physically meaningful values.
Importance: ESSENTIAL for meaningful diffraction measurement results.
Method: Move the diffraction pattern and adjust the displayed value of the diffraction shift using Multifunction Y. Because few specimens provide the (large) d spacings appropriate for the small diffraction shifts obtained in LAD, it may not be possible to use a d spacing as calibration. The software therefore suggests to use the camera length value as a reference and simply calculate the angle corresponding to the shift to the 4 cm circle of the viewing screen.

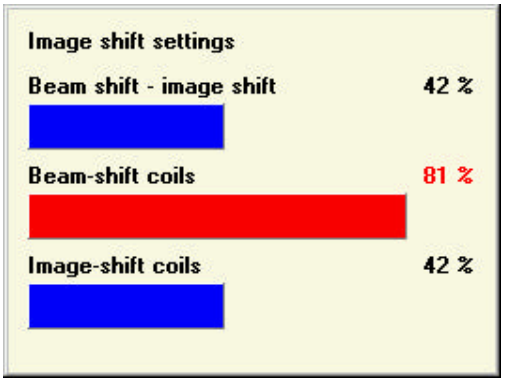
Procedure
The alignment procedure consists of five steps:
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the diffraction pattern is shifted with Multifunction X to bring a ring to the center and the diffraction shift (nm value or angle) is adjusted with Multifunction Y to the correct value.
- The fourth step repeats the procedure of the third step for the Y diffraction shift.

Description
The diffraction shift is converted through the calibration procedure into to physically meaningful units such as Bragg angles and d spacings (in the latter case the Bragg Law formula is used). The diffraction shift can be read off in the flap-out of the Alignment Control Panel and is used in the Measuring Control Panel.

8.8 Beam shift - image shift calibration LM

Purpose: Define the beam shift compensation for the image shift.
Importance: CONVENIENCE for keeping the beam on the screen when the image is shifted. The beam shift - image shift is used in the Image shift Control Panel and in Low Dose.
Method: Move the image off-axis and recenter the beam using Multifunction X,Y.

Note: This procedure is complicated by the fact that it is not easy to tell how far the beam-shift/image-shift should be changed. The on-line help file therefore contains a control that indicates the status of the beam-shift/image-shift, beam coils and image coils.



Using this you change the beam shift-image shift until either:
- the beam is at the screen edge.
- the beam shift-image shift is more than 50% (bar becomes green) OR one of the coils is more than 80% (bar becomes red).

The microscope will sound a beep when the beam shift-image shift is at its limit but also when one of the coils is at its limit. In the former case you can continue with the calibration, but when a coil is limited very likely you cannot. The control in the help file which is directly linked to the microscope displays the situation.

Procedure
The calibration procedure consists of six steps:
- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero. At the same time the image shift is set to zero.
- In the second step, the image shift X is changed, either until the microscope beeps (at the limit of the image shift) or until the beam moves off the screen (the latter typically happens when the calibration has not been done yet).
- In the third step the beam is recentered using the Multifunction X,Y. If the microscope beeped during the second step, continue, otherwise step back and repeat the second and third steps (so the final calibration is done with the image shift at its limit).
- The fourth and fifth steps repeat the same procedure as the second and third steps, but this time for the Y image shift.
- The final step just ensures that the image-beam shift is reset to zero after the procedure is finished.

Description
The Tecnai microscope has a function for image shift where the beam position is automatically compensated to keep the beam on the area of interest (what is currently seen on the viewing screen). The beam shift compensation must be calibrated before it will work properly.

For a schematic diagram of the beam shift-image shift, see section 6.14.

8.9 Off-axis TV LM image alignment (only if off-axis TV installed)

Purpose: Aligning all LM (as far as attainable) magnifications on the off-axis TV.
Importance: **CONVENIENCE** so that the image is shifted automatically from the center of the viewing screen to the off-axis TV camera .
Method: Center a recognizable image on the viewing screen with the specimen stage. Center the image with the Multifunction X,Y knobs on the off-axis TV camera. Repeat for all attainable magnifications.

Note 1: The off-axis TV camera is located about 7 cm from the center of the viewing screen between W and WNW (where N is defined as the direction furthest away from the operator). The image can be shifted to the TV camera by selecting manual mode and the Off-axis TV in the Detector Configuration Control Panel.

Note 2: The shift of the image to the off-axis TV uses the image shift coils below the objective lens. The effect of these coils is magnified by the magnification system. The highest magnifications therefore give no problems but some of the lowermost magnifications may be out of reach of the range of these coils. In addition, any other use of these coils (e.g. for the Image-Beam shift) will also affect the range of attainable magnifications.

Procedure
The alignment procedure consists of three steps :

- A preparation step in which an image feature is centered on the viewing screen (with the specimen stage) in the highest LM magnification.
- A step in which the highest LM magnification is centered on the off-axis TV.
- A step in which all other LM magnifications are centered on the off-axis TV (as far as attainable, see Note 2 above).

9 Beam Nanoprobe procedure

9.1 Preparation Beam Nanoprobe alignment

Purpose: Set up microscope for aligning the upper part of the column (condenser system) in Nanoprobe.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

9.2 Pivot point beam shift Nanoprobe

Purpose: Align beam shift pivot point = make sure that the beam does not tilt when it is shifted.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and the alignment of the pivot point can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two central spots in the diffraction pattern should overlap.

Procedure
The alignment procedure consists of four steps:
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Notes:
- The shift 'wobble' may have one beam position blocked by the specimen. If no second beam is visible when turning MF -X, then (re)move the specimen.
- Diffraction focus: the Intensity setting is preset to a fixed value that should give a (nearly) parallel incident beam which in turn should give a spot diffraction pattern. In order to keep the diffraction focus the same as in the microprobe mode (where it can be set more reliably), the pattern should be focused (after it has been focused properly in microprobe) with the Intensity, not Focus.

9.3 Pivot point beam tilt Nanoprobe

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during rotation center alignment, focusing with the wobbler and dark-field operation.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of three steps:
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Note: Unlike the shift pivot point (previous steps), the tilt pivot point is sensitive to objective-lens focus.

9.4 Dynamic conical dark field pivot point Nanoprobe (STEM systems only)

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during dynamic conical dark-field imaging.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of three steps :
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Notes:
- The AC beam tilt pivot point is sensitive to objective-lens focus.
- The AC beam tilt pivot point is used only for Dynamic Conical Dark Field.

Because TIA drives the beam in Dynamic Conical Dark Field, TIA must be running during execution of this alignment.

9.5 Dynamic conical dark field distortion Nanoprobe (STEM systems only)

Purpose: Make sure that the beam tilt describes a circle as seen in diffraction.
Importance: ESSENTIAL for proper dynamic conical dark-field imaging.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

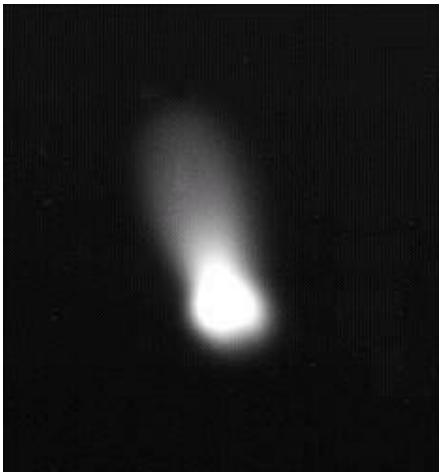
Procedure
The alignment procedure consists of four steps :
- One preparation step for setting up the image.
- One step in which the diffraction pattern is centered.
- One step in which the static beam tilt on the AC coils is adjusted until the beam is at the 4 cm circle.
- A final step in which the beam scans around and the distortion is adjusted until the movement is circular.

9.6 Nanoprobe rotation center

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimizing the effects of aberrations on the small spot.
Method: The microscope 'wobbles' the objective lens current, making the image and beam go through focus. The 'focus wobble' can be made smaller or larger with the Focus Step Size knob. Because the spot and not the image is important in nanoprobe, optimize the spot by first setting the 'wobble' to the

smallest step (focus step 1), focus the beam (Intensity) and increase the wobble (focus step). Adjust the rotation center until the beam expands and contracts concentrically.

Procedure
The alignment procedure consists of two steps:
- One preparation step for setting up the image.
- A step in which the rotation center is aligned.



A misaligned nanoprobe is recognizable from its diffuse tail that is pointing in one direction. In the case of a properly aligned beam, any tail (produced by a too large condenser aperture) should be arranged concentrically around the beam.

Note: The rotation center is an alignment that is based on a beam tilt, hence it appearance in the Beam alignment procedure and not the Image alignment procedure.

9.7 Align beam shift Nanoprobe

Purpose: Set the zero position for the beam shift.
Importance: CONVENIENCE for easy resetting of the beam shift to the screen center.
Method: Center the beam using Multifunction X,Y.

Procedure
The alignment procedure consists of two steps:
- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero.
- In the second step, the direction of the beam shift is aligned with respect to the movement by the trackball. When the trackball is moved from left to right, the beam should also move from left to right on the screen. If the beam moves in a different direction, adjust the direction with the Multifunction Y knob.

Description
The beam shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the beam centered on the screen. It then is only necessary to reset the 'user' value to zero to have the beam back at the screen center.

The alignment value for the beam shift is used frequently in alignment (any time the beam must be centered with Multifunction X,Y). In any such step, the 'user' value of the beam shift is always reset to zero. Therefore, on a properly aligned microscope, it is always possible to find the beam again simply by entering this alignment step: the 'user' value is reset to zero, so the beam should now be centered.

9.8 Beam shift calibration Nanoprobe

Purpose: Calibrate the beam shift to physically meaningful values.
Importance: CONVENIENCE.
Method: Move the focused beam to the edge of the viewing screen and adjust the displayed value of the image shift using Multifunction Y.

Procedure
The alignment procedure consists of four steps:
- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the beam shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the beam shift.

9.9 Beam tilt (dark field) calibration Nanoprobe

Purpose: Calibrate the beam tilt (dark field) to physically meaningful values.
Importance: ESSENTIAL for meaningful beam tilt values in dark field.
Method: Tilt the beam and adjust the displayed value of the beam tilt using Multifunction X,Y.

Procedure
The alignment procedure consists of five steps:
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the beam is tilted (this is, the diffraction pattern is shifted) with Multifunction X to bring a ring to the center and the beam tilt value is adjusted with Multifunction Y to the correct value.
- The fourth and fifth steps repeat the procedure of the second and third steps for the Y diffraction shift.

Description
The beam tilt is converted through the calibration procedure into to physically meaningful units. The beam tilt can be read off in the flap-out of the Alignment Control Panel and is used in the Dark Field Control Panel.

9.10 Dynamic conical dark field beam tilt calibration Nanoprobe (STEM systems only)

Purpose: Calibrate the AC beam tilt (dynamic conical dark field) to physically meaningful values.
Importance: ESSENTIAL for meaningful beam tilt values in dynamic conical dark field and for ensuring a match between static and dynamic conical dark field.
Method: Tilt the beam and adjust the displayed value of the beam tilt using Multifunction X,Y.

Procedure
The alignment procedure consists of three steps :
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the beam is tilted (this is, the diffraction pattern is shifted) with Multifunction X to bring a ring to the center and the beam tilt value is adjusted with Multifunction Y to the correct value.

Description
The beam tilt is converted through the calibration procedure into to physically meaningful units. The beam tilt can be read off in the flap-out of the Alignment Control Panel and is used in the Dark Field Control Panel.

9.11 Spot size-intensity calibration Nanoprobe

Purpose: Make sure that a focused beam remains focused when spot size is changed.
Importance: CONVENIENCE for keeping spot focus the same for all spot sizes, ESSENTIAL for proper operation of Intensity Zoom and Intensity Limit.
Method: After focusing spot 3, all spots are focused in turn. The deviations in intensity setting from spot focus are stored for all spots.

Procedure
The alignment procedure consists of two steps:
- One preparation step in which the beam is focused for spot size 3.
- A step in which all spot sizes are focused.

Note: The condenser system (C1 and C2 lenses) is normalized when the spot size is changed to make the spot setting better reproducible.

Description
The Intensity (C2 lens) and spot size (C1 lens) settings are not independent. In order to give the same effect for all spot sizes, the Intensity is changed whenever spot size is changed. In addition to the preprogrammed changes, individual instruments differ slightly in their relation between C1 and C2. The spot size-intensity calibration allows adjustment for this individual behaviour. For the Intensity Zoom and Intensity Limit functions this procedure defines the Intensity settings at which the beam is focused, which is essential for proper operation of these functions.

10 Image Nanoprobe Procedure

10.1 SA objective lens preset Nanoprobe

Purpose: Setting the eucentric focus preset at the eucentric height.
Importance: CONVENIENCE for having the eucentric focus at the eucentric height.
Method: Focus the image for the highest SA magnification.

Procedure
The alignment procedure consists of two steps:
- A preparation step in which the SA image is focused at an intermediate magnification.
- A step in which the highest SA magnification must be focused.

Note: Although the objective lens is at a different setting for a focused nanoprobe image relative to the focus setting for a microprobe image, this does not imply that the microscope imaging system is altered in some way. The difference between the objective-lens settings is caused by the minicondenser lens whose setting has an effect on the magnetic field of the objective lens, so that in nanoprobe a slightly higher current is needed to obtain the same electron-optical effect as in microprobe.

10.2 Mh objective lens preset Nanoprobe

Purpose: Finding the difference in focus between the Mh-magnification and SA.
Importance: CONVENIENCE for being able to have the image in focus when switching between SA and Mh and vice versa.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which the image is focused for the highest SA magnification.
- A step in which the lowermost Mh magnification is focused.
- A step in which all other Mh magnifications are focused.

10.3 Mi objective lens preset Nanoprobe

Purpose: Finding the difference in focus between Mi and SA.
Importance: CONVENIENCE for having the image in focus when going from SA to Mi and vice versa.
Method: Focus the image.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which the lowermost SA magnification is focused.
- A step in which the highest Mi magnification is focused.
- A step in which all Mi magnifications are focused.

10.4 Align diffraction pattern (Nanoprobe)

Purpose: Set the zero position for the diffraction shift.
Importance: CONVENIENCE for easy resetting of the diffraction shift to the screen center.
Method: Center the diffraction pattern using Multifunction X,Y.

Procedure
The alignment procedure consists of a single step.

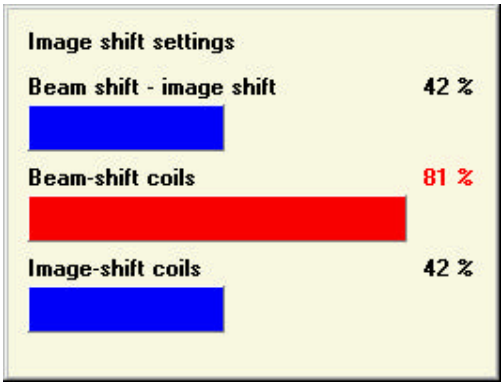
Description
The diffraction shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the diffraction pattern centered on the screen. It then is only necessary to reset the 'user' value to zero to have the pattern back at the screen center.

The diffraction pattern alignment setting is the only setting that is separate for microprobe and nanoprobe modes. The user diffraction shift as well as the diffraction alignments between the different camera lengths are common for the two modes.

10.5 Beam shift - image shift calibration Nanoprobe

Purpose: Define the beam shift compensation for the image shift.
Importance: CONVENIENCE for keeping the beam on the screen when the image is shifted. The beam shift - image shift is used in the Image shift Control Panel and in Low Dose.
Method: Move the image off-axis and recenter the beam using Multifunction X,Y.

Note: This procedure is complicated by the fact that it is not easy to tell how far the beam-shift/image-shift should be changed. The on-line help file therefore contains a control that indicates the status of the beam-shift/image-shift, beam coils and image coils.



Using this you change the beam shift-image shift until either:
- the beam is at the screen edge.
- the beam shift-image shift is more than 50% (bar becomes green) OR one of the coils is more than 80% (bar becomes red).

The microscope will sound a beep when the beam shift-image shift is at its limit but also when one of the coils is at its limit. In the former case you can continue with the calibration, but when a coil is limited very likely you cannot. The control in the help file which is directly linked to the microscope displays the situation.

Procedure
The calibration procedure consists of six steps:
- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero. At the same time the image shift is set to zero.
- In the second step, the image shift X is changed, either until the microscope beeps (at the limit of the image shift) or until the beam moves off the screen (the latter typically happens when the calibration has not been done yet).
- In the third step the beam is recentered using the Multifunction X,Y. If the microscope beeped during the second step, continue, otherwise step back and repeat the second and third steps (so the final calibration is done with the image shift at its limit).
- The fourth and fifth steps repeat the same procedure as the second and third steps, but this time for the Y image shift.
- The final step just ensures that the image-beam shift is reset to zero after the procedure is finished.

Description
The Tecnai microscope has a function for image shift where the beam position is automatically compensated to keep the beam on the area of interest (what is currently seen on the viewing screen). The beam shift compensation must be calibrated before it will work properly.

For a schematic diagram of the beam shift-image shift, see section 6.14.

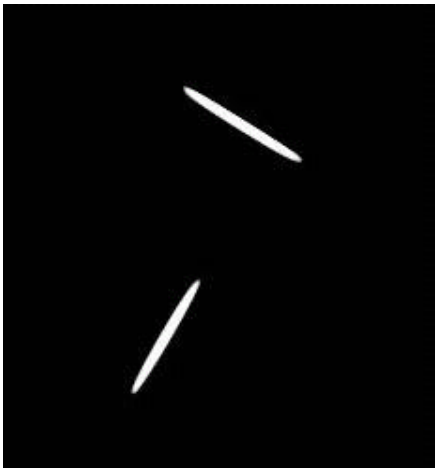
11 Stigmator Procedure

11.1 Condenser stigmator calibration

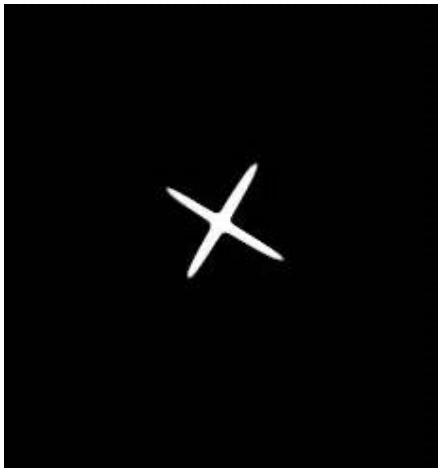
The microscope contains a condenser stigmator to correct for beam astigmatism. When this stigmator is misaligned, adjustment of the stigmator setting will lead to an apparent beam shift. When the stigmator is aligned correctly, these shifts are compensated by an identical but opposite beam shift - this time using the beam deflection coils. In order to align the stigmator, it is necessary to determine the relation between a change in stigmator setting and the beam shift. This relation is determined in the procedure for aligning the stigmator.

The procedure follows these steps:

- A preparation step in which the beam is nearly (not completely) focused.
- The current through the stigmator is wobbled in the X direction and the operator minimizes beam movement.
- The same is done for the Y direction.
- Two highly astigmatic beams (almost lines) should become visible. If the beams do not look like that, change the INTENSITY until they do. With the condenser stigmator misaligned the two lines will not cross each other in the middle. Adjust the Multifunction knobs until they do.



Condenser stigmator misaligned.



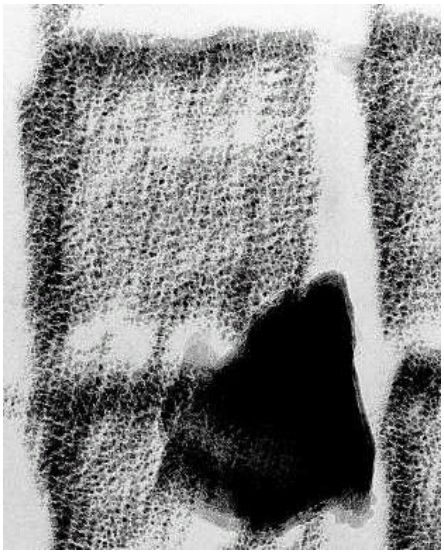
Condenser stigmator aligned.

11.2 Objective stigmator calibration

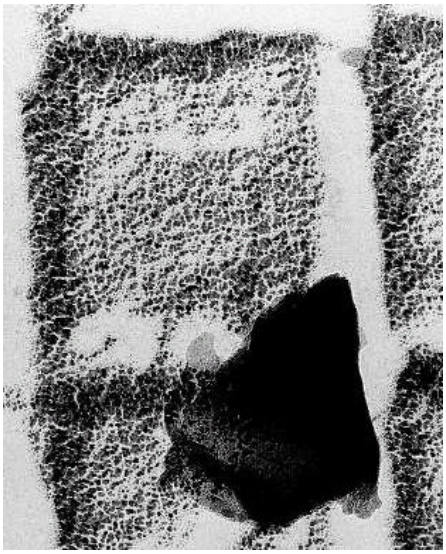
The microscope contains an objective stigmator to correct for astigmatism in HM image and LM diffraction. When this stigmator is misaligned, adjustment of the stigmator setting will lead to an apparent HM image (or LM diffraction shift). When the stigmator is aligned correctly, these shifts are compensated by an identical but opposite shift - this time using the image deflection coils. In order to align the stigmator, it is necessary to determine the relation between a change in stigmator setting and the HM image shift. This relation is determined in the procedure for aligning the stigmator.

The procedure follows these steps:
- A preparation step in which the HM image is focused.
- The current through the stigmator is wobbled in the X direction and the operator minimizes image movement.
- The same is done for the Y direction.

The stigmator current wobble will result in two images, which will overlap when the stigmators are aligned correctly. It is advisable to use a specimen with relatively large, easily recognized image detail.



Misaligned objective stigmator.



Aligned objective stigmator.

11.3 Diffraction stigmator calibration

The microscope contains a diffraction stigmator to correct for astigmatism in HM diffraction and LM image. When this stigmator is misaligned, adjustment of the stigmator setting will lead to an apparent HM diffraction shift / LM image shift. When the stigmator is aligned correctly, these shifts are compensated by an identical but opposite shift - this time using the image deflection coils. In order to align the stigmator, it is necessary to determine the relation between a change in stigmator setting and the LM image shift. This relation is determined in the procedure for aligning the stigmator.

The procedure follows these steps:
- A preparation step in which the microscope is switched to LM and the image is focused.
- The current through the stigmator is wobbled in the X direction and the operator minimizes image movement.
- The same is done for the Y direction.

The stigmator current wobble will result in two images, which will overlap when the stigmators are aligned correctly. It is advisable to use a specimen with relatively large, easily recognized image detail.

12 HM-STEM Procedure

12.1 HM-STEM Preparation

Purpose: Set up microscope for aligning the column in HM-STEM.
Importance: CONVENIENCE as a reminder to set up the proper conditions before starting the actual alignment.

For STEM alignment a number of pre-conditions must be met, otherwise no proper alignment can be done:

First, the specimen must be at the **eucentric height**. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)

Second, HM-STEM relies on a proper setting of **several optical parameters**:

- The proper focusing of the diffraction pattern will be essential for the alignment of the beam shift pivot points, which in turn is very important for reproducible STEM settings (magnification). The diffraction focusing can only be done properly in the HM Image alignment procedure.
- Since HM-STEM is derived from the Nanoprobe mode, it is essential that the Nanoprobe alignment has been done properly (especially the setting of the SA image focus preset). To avoid problems between Nanoprobe and HM-STEM this setting (which is very important for HM-STEM) can not be set in the HM-STEM alignment procedure.
- Finally, a proper gun alignment (including the spot-size dependent gun shifts) should be present before attempting to align the HM-STEM mode.

Third, **Tecnai Imaging & Analysis (TIA) must be running** when for STEM alignment.

Fourth, the **settings for the Preview view mode must be set** so as to give an image size of 512x512 pixels and a frame time of approximately 6 seconds.

Finally, the **Bright-Field (BF) detector must be selected** (and all other detectors deselected) in the STEM Detector Control Panel.

12.2 HM-STEM Objective / Intensity preset

Purpose: Set up Objective-lens and Intensity settings for focused beam in HM-STEM.
Importance: ESSENTIAL for proper settings for HM-STEM (Objective lens and Intensity settings).
Method: First focus the image at the eucentric height, then focus the beam.

Important:

- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of four steps :

- A first step (using the Nanoprobe mode settings) in which the specimen is brought to focus (the eucentric height, which should have been aligned in the Nanoprobe image alignment previously) by adjusting the Z height.
- A second step in which the image is focused (setting the objective-lens preset for HM-STEM) and next the beam is focused (setting the intensity preset). If necessary stigmate the image (if the image is astigmatic, the beam will also appear astigmatic but this is due to the image, not to the shape of the beam itself, and if you "stigmate" the beam with an astigmatic image, you will actually make the beam (and thus the STEM image) astigmatic. Note: Since we want to have the same objective-lens setting in Nanoprobe and HM-STEM, the alternative to setting it by looking at the image is to make sure you can observe the objective-lens excitation (%; e.g. by dragging it into a status display panel or popping up the System status) and making the value in step two the same as in step one.
- A third step in which the microscope is switched to diffraction and the diffraction pattern is centered.
- A fourth step similar to step three but now for all spot sizes (except 3 which has been done already).

Description
In principle there is no a priori requirement in scanning to define the objective-lens setting as the same as that in TEM imaging. The only requirement for STEM imaging is that the beam can be focused on the specimen, which can be done through a range of objective-lens/intensity setting combinations. In practice it is, however, not very convenient to use an objective-lens setting that differs appreciably from that in TEM imaging for various reasons:

- Some of the settings of Nanoprobe and STEM imaging are shared (they use the same setting; change one in Nanoprobe and the change will work through in STEM, and the other way around). Examples are beam tilt pivot points and the alignment of the diffraction pattern. Some of these settings are quite sensitive to objective-lens current so it would be necessary to re-align the Nanoprobe and STEM upon switching from one to the other. It would be possible to decouple these settings (make them different for Nanoprobe and STEM) but that would increase the complexity of the alignments.
- If Nanoprobe and STEM have the same objective-lens setting, one can inspect the beam (e.g. for stigmation) in STEM by stopping the scan, moving the beam to the center, and switching to (TEM) imaging (out of diffraction). The beam is now visible while the TEM image is also in focus. If the objective-lens setting was different, the beam would look defocused in TEM imaging (but it is focused on the specimen if the STEM image is in focus). Changing the focus (objective-lens setting) to obtain a focused beam is possible, but this leads to an objective-lens setting different from that actually used in STEM which in turn leads to changes in astigmatism, rotation center, etc., so it is never possible to be sure that the beam is properly set when changing back to STEM imaging.

12.3 HM-STEM Beam tilt pivot points

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during rotation center alignment.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Important:
- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of three steps:
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Note: The tilt pivot point set in this subprocedure is the same as the Nanoprobe beam-tilt pivot point. The alignment is repeated here to ensure that the rotation center alignment in STEM can be done properly.

12.4 HM-STEM Rotation center

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimizing lens aberrations and image movement during focusing.
Method: The microscope 'wobbles' the objective lens current, making the image go through focus. Make the sideways movement of the image as small as possible with the rotation center (= tilting the beam to the optical axis).
The 'focus wobble' can be made smaller or larger with the FOCUS STEP SIZE knob.

Important:
- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of five steps:
- A preparation step in which the beam is focused. The image must be focused by setting the specimen to the proper eucentric height (by now the eucentric focus for STEM should have been defined).
- A second step in which the beam is (temporarily - for this alignment procedure) defocused.
- A third step in which the image movement is minimized.
- A fourth step in which the beam is centered and focused.
- A fifth step in which the condenser aperture is aligned properly.

Note: If the aperture required considerable re-alignment, one should step back through the procedure and repeat from step 2 onwards.

12.5 HM-STEM Beam-shift pivot points

Purpose: Align beam shift pivot point = make sure that the beam does not tilt when it is shifted in HM-STEM.
Importance: ESSENTIAL for for keeping the beam parallel to the optical axis when sh ifting so that:

- The STEM magnification calibration remains accurate.
- The STEM image is not distorted.
- The diffraction pattern does not move off the detector during scanning.
- The image is in focus from one edge to the other.

Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and the alignment of the pivot point can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two central disks in the diffraction pattern should overlap.

Important:

- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucen tric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of five steps:

- A preparation step in normal SA (Microprobe mode) in which the image is focused.
- A second step in SA diffraction (Microprobe mode) which the diffraction pattern is focused and centered. Here the pattern is the TEM pattern which is a spot pattern.
- A third step in which the diffraction focus in STEM (Nanoprobe mode) is centered (NOT focused!). Now it is the STEM (convergent-beam) pattern which has disks, not spots. The correct focus for the pattern is defined in the previous step.
- Two steps in which the X and Y pivot points are aligned (the Multifunction X knob sets the pivot points, the Multifunction Y the perpendicular correction).

Perform this alignment carefully. Pivot-point misalignment can have considerable effect on the STEM magnification calibration, and perpendicular correction misalignment can lead to distortion in the STEM image.

12.6 HM-STEM Align diffraction pattern

Purpose: Make sure the diffraction pattern is centered properly on the viewing screen and all camera lengths are properly focused.
Importance: CONVENIENT for making sure the detector alignment is correct.
Method: Center the diffraction pattern on the screen. Since the position of the pattern is affected by a number of factors such as condenser-aperture position and rotation center, while the shift to the detector is reproducible (not affected by hysteresis), the only requirement later is to make sure the diffraction pattern is centered at the screen center (with the off-axis shift not active) and then switch the off-axis shift on in order to have the pattern properly centered on the BF-DF detector.

Important:
- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of four steps:
- In the first step the normal TEM is focused and the beam is centered.
- In the second step the normal TEM diffraction pattern is focused properly (focus the diffraction pattern to a spot pattern on the basis of a preset intensity setting).
- In the third step, the microscope is switched to STEM and the STEM diffraction pattern (now a disk pattern) is centered.
- In the fourth step, each camera length is centered on the screen and focused.

Notes:
- This alignment affects the same diffraction alignment parameter as the diffraction alignment for nanoprobe. The focusing of the individual camera lengths is the same as in the HM Image camera lengths procedure. These alignments are repeated in this HM-STEM alignment subprocedure for convenience.
- The focusing of the camera lengths is repeated here because it can be done more accurately in STEM. Once we know that the beam-shift pivot points are correct, we know that any movement of the diffraction pattern must be due to a diffraction focus that is away from the back-focal plane. Focusing can thus be done by minimizing movement.
- For the movement of the diffraction pattern in STEM, it is important to make a distinction between any movement seen during the 'normal' scan and during the flyback (the rapid beam movement back to the beginning of the next scan line). During the flyback the beam often cannot keep up due to the inertia in the optics and the diffraction pattern may make an irregular swing. During the flyback the diffraction pattern typically has much less intensity than during the normal scan, producing an irregular line of lower intensity. The flyback should be ignored when it comes to minimizing movement.

12.7 HM-STEM Detector alignment

Purpose: Make sure the diffraction pattern is centered properly on the STEM Bright-Field/Dark-Field detector.
Importance: ESSENTIAL for obtaining correct STEM Bright-Field and Dark-Field images.
Method: First center the diffraction pattern on the screen, then define the off-axis shift necessary to have the pattern centered on the bright-field/dark-field detectors. Since the latter shift is reproducible (not affected by hysteresis), the only requirement later is to make sure the diffraction pattern is centered in the screen center (with the off-axis shift not active) and then switch the off-axis shift on in order to have the pattern properly centered again.

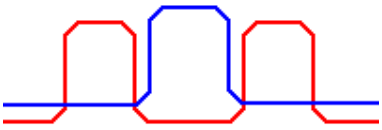
Important:
- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of three steps:

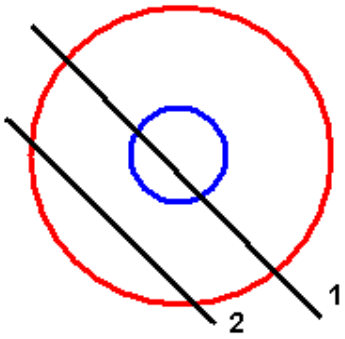
- In the first step the diffraction pattern (for a camera length of ~500mm) is centered on the viewing screen with the screen down.
- In the second step the off-axis shift is activated and the same camera length is centered on the STEM detectors, first by moving the pattern to the approximate position with the screen down, then with the screen up by looking at the detector signal.
- In the final step, a number of camera lengths is centered on the detector. Which camera lengths are to be aligned is somewhat instrument-dependent (see below).

Centering on the detector
Use a specimen that is thin (or remove the specimen altogether by retracting the specimen holder a bit), because in thick specimens the dark-field signal is too close in intensity to the bright-field signal. Move the diffraction pattern roughly to the place where the detectors are located. When the diffraction pattern is shifted across the detectors, the following behavior is seen:

- On the Bright-Field (BF) detector, the signal follows a simple top-hat function(see picture below): low (when the central disk is not on the BF detector) - high (on the BF detector) - low (off again). To align, first go for maximum intensity in the BF signal. The reduce the X shift until the signal drops off. Then increase the X shift again while 'counting' knob turns until the signal has gone through its maximum and drops off again. Turn back by half of the number of turns counted. Repeat for Y.
- On the Dark-Field (DF) detector, the signal follows a double top-hat function: low - high - low - high - low (initially off the detector, the on one side of the ring-shaped detector, then on the BF detector and thus off the DF, on the other side of the ring, and finally off the detector again). It is also possible for the pattern to follow a simple top-hat. as for the BF. In the latter case the diffraction pattern does not move across the central part of the detector (as in path 2 in the lowermost picture below) but away from the center so the central beam never hits the BF detector properly.



Schematic diagram of the change in detector signals for the BF (blue) and DF (red) detectors observed when the diffraction pattern is moved along a path similar to 1 below.



Schematic diagram of possible paths of the diffraction pattern across the BF (blue) and DF (red) detectors (seen from the top). Along path 1, the detector-signal changes are as sketched in the picture above. Along path 2 the BF signal never gets to be a true BF, and the pattern must be moved first in the perpendicular direction to get the proper alignment.

Always check that the pattern is centered properly for the whole image (if part of it is dark, the alignment is not correct).

Notes:

- It is useful to activate the Scope function on the STEM Imaging Control Panel. This function displays the detector signal levels on a fixed scale and thereby makes it easier to judge the alignment (the STEM image has its contrast and brightness re-adjusted after an image has been collected, which makes it difficult to judge the signal levels from the detector).
- The near-axis position (where the STEM Bright-Field/Dark-Field detector assembly is located) is at ~30 mm from the screen center to the WNW (slightly away from the screen center to the top right). This physical position is of course the same for all camera lengths but the actual diffraction shifts required to get there depend on the camera length (which magnifies the diffraction shift), so the settings are dependent on the camera length.
- Because hysteresis can have considerable effect on the diffraction-pattern position, you should use the normalization facility whenever the optical conditions have changed (the automatic normalizations take care of this, so it is advised to keep them enabled).
- Some of the lowermost camera lengths are too small to reach the near-axis detector (typically the camera length must be at least 90 mm). There is no point in trying to align these. Simply go on to the next camera length.
- Some of the large camera lengths will overlap the bright-field disk onto the dark-field detector and are therefore of little use. You can skip these camera lengths as well.
- When the camera length changes, the signal on the detectors will change, so it will be necessary to adjust contrast and brightness. For this purpose, the alignment procedure makes it easy to switch to detector control by pressing R2 (toggle between detector alignment and BF detector control).
- Since the size of the Condenser aperture determines the beam convergence angle, it also determines the size of the diffraction disks and thereby what the effective camera lengths are for BF/DF imaging (if the central beam is too large, it will fall on the DF detector). To determine if the beam doesn't have long tails due to the combined effects of spherical aberration and large convergence angles (and thus poorly defined spots), you can observe the focused beam in nanoprobe mode (for the particular condenser aperture). Normally the two smallest condenser apertures are the ones that are suitable for STEM.
- Some camera lengths are difficult to use at low STEM magnifications because the spherical aberration of the diffraction lens makes it impossible to have the diffraction remain sufficient stationary to keep it on the detectors (the pattern described by the central-beam disk looks like a bird flying, with its wings flapping up and down). Either use higher magnifications or other camera lengths in those cases.

12.8 HM-STEM Distortion adjustment

Purpose: Adjust the AC deflection coils settings so that the resulting STEM image has no distortions.
Importance: ESSENTIAL for proper STEM imaging.
Method: Collect an image of a cross-grating and adjust the relative strength of X and Y coils, and their perpendicularity.

Important:

- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of five steps:
- The first step is a preparation step to center and focus the beam.
- In the second step a STEM image must be made of a cross-grating specimen.
- In the third step the scan rotation is set so the horizontal lines of the cross-grating are horizontal in the STEM image. The rotation required should be less than ~15° (see note below).
- In the fourth step the distortions are adjusted. Multifunction X controls the trapezoid distortion (the vertical lines of the grating are not perpendicular to the horizontal lines), while the Multifunction Y adjusts the relative strengths of the horizontal and vertical scans (rectangular distortion).
- A check on the previous alignment with the image rotated by 90°.

If necessary, iterate steps three and four (see also notes below).

Notes:
- It is essential that the pivot point alignment has been done properly before the distortion adjustment is done.
- The cross-grating used must be inserted into the microscope in such a way that the horizontal and vertical lines in the grating are roughly parallel to the horizontal and vertical in the image when the scan rotation (and the default scan rotation) is close to 0° (within ~15°), otherwise the alignment is very difficult (requires many iterations). Judge whether the orientation of the cross-grating is suitable in the second or third step of the procedure. If the orientation is further away from 0°, remove the specimen holder from the microscope and rotate the specimen until its orientation is suitable for this alignment.
- The distortions of the image may be judged more easily by drawing a square in the image. Click on the Image Selection Tool toolbar button in TIA , click in the top left quadrant of the image and drag the cursor to bottom right while keeping the Shift key on the keyboard pressed down (the latter forces the image selection drawn to remain square). It is then easy to count the number of cross-grating squares in the horizontal and vertical dimensions and making sure that the numbers are the same.
- Description
- The deflection coils used in the microscope are not all equal and exactly the same from one microscope to another. There are therefore alignment procedures that will result in adjustments that compensate for the variation in the coils. For the deflection coils used in TEM operation, the two adjustable parameters are the pivot points and the perpendicular correction. The pivot adjusts for the difference in strength between upper and lower coil (e.g the X coil). The perpendicular correction adjusts for a rotation between the upper and lower coils (e.g. the upper and lower X coils) by adding a small deflection to the other lower coil (in that case the lower Y coil). For use in TEM this is sufficient.
- In STEM, however, additional adjustments are necessary, otherwise image distortions (stretch of one direction relative to the other and angular distortion) appear. These adjustments correct for the difference in strength between the X and Y coils and for any deviation from 90° between the X and Y coils. In principle this can be done both for the upper and lower coils separately but in practice this is too difficult to align and a single adjustment is sufficient.

12.9 HM-STEM Default rotation

Purpose: Define the rotation correction for STEM imaging.
Importance: CONVENIENCE for having the STEM image (at 0° scan rotation) in the same orientation as the TEM image (on the viewing screen).
Method: Observe the scan frame on the viewing screen and rotate it until it runs as described below.

Procedure
The alignment procedure consists of two steps:
- The first step is a preparation step to center and focus the beam on the viewing screen.
- In the second step the beam is scanned so the scan frame is visible on the viewing screen. Change the rotation correction setting until the scan line (the fast scan direction) goes from left to right (W to E) on the screen and the scan frame (the slow scan direction) goes from top to bottom.

Note: The movement of the beam during scanning can be described as follows:
- Move the beam to the starting position of the scan image (top left).
- Move the beam along a line (the horizontal direction in the scan image).
- At the end of the line, jump back to the beginning of the line (the flyback) and change the beam position one line down.
- Repeat this until you reach the bottom of the scan image at the end of the last line.
- Go back to the first step.

The horizontal direction in scanning is referred to as the 'line', while the vertical direction is called the 'frame'. Since the frame is built up line by line, the scan in the direction of the frame is much slower than that along the lines.

13 LM-STEM procedure

13.1 LM-STEM Preparation

Purpose: Set up microscope for aligning the column in LM-STEM.
Importance: CONVENIENCE as a reminder to set up the proper conditions before starting the actual alignment.

For STEM alignment a number of pre-conditions must be met, otherwise no proper alignment can be done:

- First of all, LM-STEM relies on a proper setting of **several optical parameters** for which the Gun, LM Beam and LM Image as well as HM-TEM Image alignment must have been done.
- Second, **Tecnai Imaging & Analysis (TIA) must be running** when for STEM alignment.
- Third, the settings for the **Preview view mode** must be set so as to give an image size of 512x512 pixels and a frame time of approximately 6 seconds and the **Search view mode** to an image size of 256x256 and a frame time of approximately 3 seconds.
- Finally, the **Bright-Field (BF) detector** must be selected (and all other detectors deselected) in the STEM Detector Control Panel.

Note: The diffraction focus (LAD) is LM-STEM is kept as set in LAD (proceed to LM, then to diffraction). In most cases this should be kept at the default setting. Unless there is a reason to deviate from this, it is important to make sure the setting is properly done. Go to LM, then LAD and press the Eucentric focus button to reset the LAD focus to the default value.

13.2 LM-STEM Intensity preset

Purpose: Set up Intensity setting for focused beam in LM-STEM.
Importance: ESSENTIAL for proper setting for LM-STEM (Intensity settings).
Method: First focus the image, then focus the beam.

Important : During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of three steps :

- A first step in which the image is focused and the beam is centered.
- A second step in which the beam is focused accurately (sets the Intensity setting).
- A third step in which the focusing of the beam is repeated for all spots (except 3 which has already been done in the previous step).

13.3 LM-STEM Beam-shift pivot points

Purpose: Align beam shift pivot point = make sure that the beam does not tilt when it is shifted in LM-STEM.
Importance: ESSENTIAL for for keeping the beam parallel to the optical axis when shifting so that :

- The STEM magnification calibration remains accurate.
- The STEM image is not distorted.
- The diffraction pattern does not move off the detector during scanning.
- The image is in focus from one edge to the other.

Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point). This plane is conjugate to the back-focal (diffraction) plane and the alignment of the pivot point can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two central disks in the diffraction pattern should overlap.

Note: The diffraction focus (LAD) is LM-STEM is kept as set in LAD (proceed to LM, then to diffraction). In most cases this should be kept at the default setting. Unless there is a reason to deviate from this, it is important to make sure the setting is properly done. Go to LM, then LAD and press the Eucentric focus button to reset the LAD focus to the default value.

Important: During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of three steps :

- A first step in LAD diffraction which the diffraction pattern is centered.
- Two steps in which the X and Y pivot points are aligned (the Multifunction X knob sets the pivot points, the Multifunction Y the perpendicular correction).

Perform this alignment carefully. Pivot-point misalignment can have considerable effect on the STEM magnification calibration, and perpendicular correction misalignment can lead to distortion in the STEM image.

Note: Because of the large shifts of the beam (in LM-STEM) it is possible that one of the wobble directions (or even both) is blocked by the specimen (grid). If this is the case, either move the specimen around a bit or retract the holder slightly (about 1 cm).

13.4 LM-STEM Align diffraction pattern

Purpose: Make sure the diffraction pattern is centered properly on the viewing screen.
Importance: CONVENIENT for making sure the detector alignment is correct.
Method: Center the diffraction pattern on the screen. Since the position of the pattern is affected by a number of factors such as condenser-aperture position and rotation center, while the shift to the detector is reproducible (not affected by hysteresis), the only requirement later is to make sure the diffraction pattern is centered at the screen center (with the off-axis shift not active) and then switch the off-axis shift on in order to have the pattern properly centered on the BF-DF detector.

Important: During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of one step in which the LAD diffraction pattern is centered on the screen.

Note: In LM-STEM only one camera length is used.

13.5 LM-STEM Detector alignment

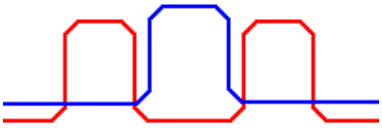
Purpose: Make sure the diffraction pattern is centered properly on the STEM Bright-Field/Dark-Field detector.
Importance: ESSENTIAL for obtaining correct STEM Bright-Field and Dark-Field images.
Method: First center the diffraction pattern on the screen, then define the off-axis shift necessary to have the pattern centered on the bright-field/dark-field detectors. Since the latter shift is reproducible (not affected by hysteresis), the only requirement later is to make sure the diffraction pattern is centered in the screen center (with the off-axis shift not active) and then switch the off-axis shift on in order to have the pattern properly centered again.

Important: During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

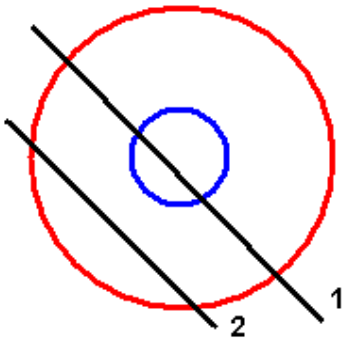
Procedure
The alignment procedure consists of two steps :

- In the first step the diffraction pattern is centered on the viewing screen with the screen down.
- In the second step the off-axis shift is activated and the same camera length is centered on the STEM detectors, first by moving the pattern to the approximate position with the screen down, then with the screen up by looking at the detector signal.

Centering on the detector
Use a specimen that is thin (or remove the specimen altogether by retracting the specimen holder a bit), because in thick specimens the dark-field signal is too close in intensity to the bright-field signal. Move the diffraction pattern roughly to the place where the detectors are located. When the diffraction pattern is shifted across the detectors, the following behavior is seen:
On the Bright-Field (BF) detector, the signal follows a simple top-hat function(see picture below): low (when the central disk is not on the BF detector) - high (on the BF detector) - low (off again). To align, first go for maximum intensity in the BF signal. The reduce the X shift until the signal drops off. Then increase the X shift again while 'counting' knob turns until the signal has gone through its maximum and drops off again. Turn back by half of the number of turns counted. Repeat for Y.
On the Dark-Field (DF) detector, the signal follows a double top-hat function : low - high - low - high -low (initially off the detector, the on one side of the ring-shaped detector, then on the BF detector and thus off the DF, on the other side of the ring, and finally off the detector again). It is also possible for the pattern to follow a simple top-hat. as for the BF. In the latter case the diffraction pattern does not move across the central part of the detector (as in path 2 in the lowermost picture below) but away from the center so the central beam never hits the BF detector properly.



Schematic diagram of the change in detector signals for the BF (blue) and DF (red) detectors observed when the diffraction pattern is moved along a path similar to 1 below.



Schematic diagram of possible paths of the diffraction pattern across the BF (blue) and DF (red) detectors (seen from the top). Along path 1, the detector-signal changes are as sketched in the picture above. Along path 2 the BF signal never gets to be a true BF, and the pattern must be moved first in the perpendicular direction to get the proper alignment.

Always check that the pattern is centered properly for the whole image (if part of it is dark, the alignment is not correct).

Notes:
- It is useful to activate the Scope function on the STEM Imaging Control Panel. This function displays the detector signal levels on a fixed scale and thereby makes it easier to judge the alignment (the STEM image has its contrast and brightness re-adjusted after an image has been collected, which makes it difficult to judge the signal levels from the detector).
- The near-axis position (where the STEM Bright-Field/Dark-Field detector assembly is located) is at ~30 mm from the screen center to the WNW (slightly away from the screen center to the top right). This physical position is of course the same for all camera lengths but the actual diffraction shifts required to get there depend on the camera length (which magnifies the diffraction shift), so the settings are dependent on the camera length.
- Because hysteresis can have considerable effect on the diffraction-pattern position, you should use the normalization facility whenever the optical conditions have changed (the automatic normalizations take care of this, so it is advised to keep them enabled).

13.6 LM-STEM Distortion adjustment

Purpose: Adjust the AC deflection coils settings so that the resulting STEM image has no distortions.
Importance: ESSENTIAL for proper STEM imaging.
Method: Collect an image of a cross-grating and adjust the relative strength of X and Y coils, and their perpendicularity.

Important:
- The specimen must be at the eucentric height. To do this properly, go to the Nanoprobe mode and press the Eucentric Focus button. The objective lens current is now set to the proper value for Nanoprobe (provided the SA objective preset has been aligned properly). Then bring the specimen into focus with the Z height of the specimen stage. (By doing it this way you will attain a more reproducible setting than by using the alpha wobbler.)
- During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of five steps:
- The first step is a preparation step to center and focus the beam.
- In the second step a ST EM image must be made of a cross-grating specimen.
- In the third step the scan rotation is set so the horizontal lines of the cross-grating are horizontal in the STEM image. The rotation required should be less than ~15° (see note below).
- In the fourth step the distortions are adjusted. Multifunction X controls the trapezoid distortion (the vertical lines of the grating are not perpendicular to the horizontal lines), while the Multifunction Y adjusts the relative strengths of the horizontal and vertical scans (rectangular distortion).
- A check on the previous alignment with the image rotated by 90°.

If necessary, iterate steps three and four (see also notes below).

Notes:
- It is essential that the pivot point alignment has been done properly before the distortion adjustment is done.
- The cross-grating used must be inserted into the microscope in such a way that the horizontal and vertical lines in the grating are roughly parallel to the horizontal and vertical in the image when the scan rotation (and the default scan rotation) is close to 0° (within ~15°), otherwise the alignment is very difficult (requires many iterations). Judge whether the orientation of the cross-grating is suitable in the second or third step of the procedure. If the orientation is further away from 0°, remove the specimen holder from the microscope and rotate the specimen until its orientation is suitable for this alignment.
- The distortions of the image may be judged more easily by drawing a square in the image. Click on the Image Selection Tool toolbar button in TIA , click in the top left quadrant of the image and drag the cursor to bottom right while keeping the Shift key on the keyboard pressed down (the latter forces the image selection drawn to remain square). It is then easy to count the number of cross-grating squares in the horizontal and vertical dimensions and making sure that the numbers are the same.
- Description
- The deflection coils used in the microscope are not all equal and exactly the same from one microscope to another. There are therefore alignment procedures that will result in adjustments that compensate for the variation in the coils. For the deflection coils used in TEM operation, the two adjustable parameters are the pivot points and the perpendicular correction. The pivot adjusts for the difference in strength between upper and lower coil (e.g the X coil). The perpendicular correction adjusts for a rotation between the upper and lower coils (e.g. the upper and lower X coils) by adding a small deflection to the other lower coil (in that case the lower Y coil). For use in TEM this is sufficient.
- In STEM, however, additional adjustments are necessary, otherwise image distortions (stretch of one direction relative to the other and angular distortion) appear. These adjustments correct for the difference in strength between the X and Y coils and for any deviation from 90° between the X and Y coils. In principle this can be done both for the upper and lower coils separately but in practice this is too difficult to align and a single adjustment is sufficient.

13.7 LM-STEM Default rotation

Purpose: Define the rotation correction for LM-STEM imaging so that the LM-STEM image is displayed with the same orientation as the HM-STEM image.
Importance: CONVENIENCE for making it easier to switch from LM-STEM imaging or HM-STEM imaging and vice versa.
Method: Observe the movement in the scan image when the stage is moved from left to right and adjust the rotation correction until the image also moves from left to right.

Important: During STEM alignment TIA (Tecnai Imaging & Analysis) must be running.

Procedure
The alignment procedure consists of three steps :
- The first step is a preparation step to center the diffraction pattern.
- In the second step an LM-STEM image is made.
- In the third step the specimen is moved from left to right with the stage and the rotation correction adjusted until the features in the image also move from left to right.

14 HM-EFTEM procedure

14.1 HM-EFTEM Preparation

Purpose: Set up microscope for aligning the colu mn for EFTEM.
Importance: ESSENTIAL to make sure the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus. Also find a recognizable image feature for later alignment steps.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- The EFTEM alignments are in many cases (lower magnifications and camera lengths) sensitive to hysteresis. It is therefore important to use the normalization facility of the microscope to make image and diffraction-pattern positions reproducible.

14.2 HM-EFTEM Image-shift pivot points

Purpose: Align image shift pivot point = make sure that the diffraction pattern does not shift when the image shift is changed.
Importance: ESSENTIAL for the proper functioning of image shifts and cross-over correction.
Method: Minimize the movement of the diffraction pattern. The microscope 'wobbles' the image shift which should cause no diffraction shift.

Procedure
The alignment procedure consists of six steps :
- Two preparation steps for setting up the image in normal and EFTEM modes.
- Two steps for setting up the diffraction pattern in normal and EFTEM modes.
- Two steps in which the X and Y pivot points are aligned.

In EFTEM a misaligned image shift will lead to an apparent diffraction shift when the cross-over correction is changed.

Note: Diffraction focus. The Intensity setting is preset to a fixed value that gives a parallel incident beam which in turn should give a spot diffraction pattern. If the pattern is not focused, it should be focused with the diffraction lens (FOCUS), not Intensity.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (imag e shift, diffraction shift/diffraction alignment).

14.3 HM-EFTEM SA Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of four steps :
- Two preparation step for setting up the image in normal and EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

14.4 HM-EFTEM Mh Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image in EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

The preparation here does not contain a step for the normal mode, because it is assumed that that has already been done for the SA pivot points.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to a ligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

14.5 HM-EFTEM Mi Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image in EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

The preparation here does not contain a step for the normal mode, because it is assumed that that has already been done for the SA pivot points.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

14.6 HM-EFTEM Mh Pre-alignment

Purpose: Aligning the Mh-magnification images for EFTEM (as seen on the Filter) with the Mh images for the normal mode, and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image.

Procedure
The alignment procedure consists of four steps :

- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which the highest EFTEM-SA magnification is focused and centered relative to the normal mode.
- A step in which the lowest EFTEM-Mh magnification is focused and aligned relative to the highest EFTEM-SA magnification.
- A step in which all other EFTEM-Mh magnifications are focused and aligned.

Note: Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.

14.7 HM-EFTEM SA Image-shift pre-alignment

Purpose: Aligning all EFTEM-SA images with each other.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of two steps :

- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which all EFTEM-SA magnifications are aligned relative to the highest normal SA magnification.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

14.8 HM-EFTEM SA Cross-over pre-alignment

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
A preparation step in the highest SA magnification for the normal mode.
A step in which the cross-over corrections are set for all EFTEM-SA magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

14.9 HM-EFTEM Mi Image-shift pre-alignment

Purpose: Aligning the EFTEM Mi magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the lowest EFTEM-SA magnification.
- A step in which the highest EFTEM-Mi magnification is aligned relative to the lowest EFTEM-SA magnification.
- A step in which all EFTEM-Mi magnifications are aligned to lowest EFTEM-SA magnification.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

14.10 HM-EFTEM Mi Cross-over pre-alignment

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
- A preparation step in the lowest EFTEM-SA magnification.
- A step in which the cross-over corrections are set for all EFTEM-Mi magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

14.11 HM-EFTEM Mh Image shift

Purpose: Aligning the Mh-magnification images for EFTEM (as seen on the Filter) with the Mh images for the normal mode, and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image.

Procedure
The alignment procedure consists of four steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which the highest EFTEM-SA magnification is focused and centered relative to the normal mode.
- A step in which the lowest EFTEM-Mh magnification is focused and aligned relative to the highest EFTEM-SA magnification.
- A step in which all other EFTEM-Mh magnifications are focused and aligned.

Note: Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.

14.12 HM-EFTEM SA Image shift

Purpose: Aligning all EFTEM-SA images with each other.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which the highest EFTEM-SA magnification is aligned on the Imaging Filter and focused.
- A step in which all EFTEM-SA magnifications are aligned relative to the highest normal SA magnification.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

14.13 HM-EFTEM SA Cross-over correction

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
- A preparation step in the highest SA magnification for the normal mode.
- A step in which the cross-over corrections are set for all EFTEM-SA magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

14.14 HM-EFTEM Mi Image shift

Purpose: Aligning the EFTEM Mi magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps :

- A preparation step in which an image feature is centered (with the specimen stage) at the lowermost EFTEM-SA magnification.
- A step in which the highest EFTEM-Mi magnification is aligned relative to the lowermost EFTEM-SA magnification.
- A step in which all EFTEM-Mi magnifications are aligned to the lowermost EFTEM-SA magnification.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

14.15 HM-EFTEM Mi Cross-over correction

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :

- A preparation step in the lowest EFTEM-SA magnification.
- A step in which the cross-over corrections are set for all EFTEM-Mi magnifications.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

14.16 HM-EFTEM Camera-length pre-alignment

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the center when the camera length is changed.
Importance: CONVENIENCE for having the diffraction patterns centered when the camera length is changed.
Method: Center the diffraction pattern for the reference camera length, then align all camera lengths to the reference camera length.

Procedure
The alignment procedure consists of five steps :

- A preparation step in which the image for the normal mode is focused.
- A step in which the reference camera length for the normal mode (~500mm) is focused and centered.
- A step in which the equivalent EFTEM camera length is focused and centered.
- A step in which all other camera lengths are focused and centered.
- A step in which for each camera length the cross-over correction is set.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.
- Although the camera length series for EFTEM typically will contain low camera lengths, this does not imply that such camera lengths are usable on all instruments (very much dependent on a number of factors such as the mechanical alignment of the projector lenses). Typical lowermost usable camera lengths are as follows:

BioTWIN lens	700mm
TWIN lens	320mm
S-TWIN lens	200mm
U-TWIN lens	260mm

14.17 HM-EFTEM Camera-length alignment

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the center when the camera length is changed.
Importance: CONVENIENCE for having the diffraction patterns centered when the camera length is changed.
Method: Center the diffraction pattern for the reference camera length, then align all camera lengths to the reference camera length.

Procedure
The alignment procedure consists of five steps :

- A preparation step in which the image for the normal mode is focused.
- A step in which the reference camera length for the normal mode (~500mm) is focused and centered.
- A step in which the equivalent EFTEM camera length is focused and centered.
- A step in which all other camera lengths are focused and centered.
- A step in which for each camera length the cross-over correction is set.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.
- Although the camera length series for EFTEM typically will contain low camera lengths, this does not imply that such camera lengths are usable on all instruments (very much dependent on a number of factors such as the mechanical alignment of the projector lenses). Typical lowermost usable camera lengths are as follows:

BioTWIN lens	700mm
TWIN lens	320mm
S-TWIN lens	200mm
U-TWIN lens	260mm

15 LM-EFTEM Procedure

15.1 LM-EFTEM Preparation

Purpose: Set up microscope for aligning the column for EFTEM.
Importance: ESSENTIAL to make sure the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus. Also find a recognizable image feature for later alignment steps.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- The EFTEM alignments are in many cases (lower magnifications and camera lengths) sensitive to hysteresis. It is therefore important to use the normalization facility of the microscope to make image and diffraction-pattern positions reproducible.

15.2 LM-EFTEM Image-shift pivot points

Purpose: Align image shift pivot point = make sure that the diffraction pattern does not shift when the image shift is changed.
Importance: ESSENTIAL for the proper functioning of image shifts and cross-over correction.
Method: Minimize the movement of the diffraction pattern. The microscope 'wobbles' the image shift which should cause no diffraction shift.

Procedure
The alignment procedure consists of six steps :
- Two preparation steps for setting up the image in normal and EFTEM modes.
- Two steps for setting up the diffraction pattern in normal and EFTEM modes.
- Two steps in which the X and Y pivot points are aligned.

In EFTEM a misaligned image shift will lead to an apparent diffraction shift when the cross-over correction is changed.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

15.3 LM-EFTEM Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.

Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of four steps :
- Two preparation step for setting up the image in normal and EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

15.4 LM-EFTEM Image-shift pre-alignment

Purpose: Aligning all EFTEM-LM images with each other and with the LM images of the normal mode.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of four steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest LM magnification for the normal mode.
- A step in which the same feature is centered with the MF-X,Y for the highest EFTEM-LM magnification.
- A step in which all EFTEM-LM magnifications are aligned relative to the highest EFTEM-LM magnification.
- A step in which the cross-over correction is set for each EFTEM-LM magnification.

Notes:
- The lowermost EFTEM-LM magnifications may not be usable. Simply skip the alignment for these magnifications.
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

15.5 LM-EFTEM Image-shift alignment

Purpose: Aligning all EFTEM-LM images with each other and with the LM images of the normal mode.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of four steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest LM magnification for the normal mode.
- A step in which the same feature is centered with the MF-X,Y for the highest EFTEM-LM magnification.
- A step in which all EFTEM-LM magnifications are aligned relative to the highest EFTEM-LM magnification.
- A step in which the cross-over correction is set for each EFTEM-LM magnification.

Notes:
- The lowermost EFTEM-LM magnifications may not be usable. Simply skip the alignment for these magnifications.
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

16 Lorentz Beam procedure

This procedure is present only on instruments equiped with the Lorentz lens.

16.1 Preparation Lorentz beam

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Set up microscope for aligning the upper part of the column (the illumination system) in Lorentz mode.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center.

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

16.2 Lorentz beam shift pivot points

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Align beam shift pivot point = make sure that the beam does not tilt when it is shifted.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and the alignment of the pivot point can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two central spots in the diffraction pattern should overlap.

Procedure
The alignment procedure consists of four steps :
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Notes:
- The shift 'wobble' may have one beam position blocked by the specimen. If no second beam is visible when turning MF -X, then (re)move the specimen.
- Diffraction focus: the Intensity setting is preset to a fixed value that gives a parallel incident beam which in turn should give a spot diffraction pattern. If the pattern is not focused, it should be focused with the diffraction lens (FOCUS), not Intensity.

16.3 Lorentz beam tilt pivot points

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Align beam tilt pivot point = make sure that the beam does not shift when it is tilted.
Importance: ESSENTIAL for keeping the beam centered during rotation-center alignment, focusing with the wobbler and dark-field imaging.
Method: A tilting beam must remain centered on the specimen (so the tilt pivot point coincides with the specimen). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Procedure
The alignment procedure consists of three steps :
- One preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Note: Unlike the shift pivot point (previous subprocedure), the tilt pivot point is sensitive to Lorentz-lens focus.

16.4 Lorentz rotation center

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimizing lens aberrations and image movement during focusing.
Method: The microscope 'wobbles' the objective lens current, making the image go through focus. Make the sideways movement of the image as small as possible with the rotation center (= tilting the beam to the optical axis).
The 'focus wobble' can be made smaller or larger with the Focus Step Size knob.

Procedure
The alignment procedure consists of two steps :
- One preparation step for setting up the image.
- A step in which the rotation center is aligned.

Note: The rotation center is an alignment that is based on a beam tilt, hence it appearance in the Beam alignment procedure and not the Image alignment procedure.

16.5 Lorentz align beam shift

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Set the zero position for the beam shift.
Importance: CONVENIENCE for easy resetting of the beam shift to the screen center.

Method: Center the beam using Multifunction X,Y.

Procedure
The alignment procedure consists of two steps :
- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero.
- In the second step, the direction of the beam shift is aligned with respect to the movement by the trackball. When the trackball is moved from left to right, the beam should also move from left to right on the screen. If the beam moves in a different direction, adjust the direction with the Multifunction Y knob.

Description
The beam shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the beam centered on the screen. It then is only necessary to reset the 'user' value to zero to have the beam back at the screen center.

The alignment value for the beam shift is used frequently in alignment (any time the beam must be centered with Multifunction X,Y). In any such step, the 'user' value of the beam shift is always reset to zero. Therefore, on a properly aligned microscope, it is always possible to find the beam again simply by entering this alignment step: the 'user' value is reset to zero, so the beam should now be centered.

16.6 Lorentz beam shift calibration

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Calibrate the beam shift to physically meaningful values.
Importance: CONVENIENCE.
Method: Move the focused beam to the edge of the viewing screen and adjust the displayed value of the image shift using Multifunction Y.

Procedure
The alignment procedure consists of four steps :
- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the beam shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the beam shift.

16.7 Lorentz beam tilt calibration

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Calibrate the beam tilt (dark field) to physically meaningful values.
Importance: ESSENTIAL for meaningful beam tilt values in dark field.
Method: Tilt the beam and adjust the displayed value of the diffraction shift using Multifunction X,Y.

Procedure
The alignment procedure consists of five steps :

- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the beam is tilted (this is, the diffraction pattern is shifted) with Multifunction X to bring a ring to the center and the beam tilt value is adjusted with Multifunction Y to the correct value.
- The fourth and fifth steps repeat the procedure of the second and third steps for the Y diffraction shift.

Description
The beam tilt is converted through the calibration procedure into to physically meaningful units. The beam tilt can be read off in the flap-out of the Alignment Control Panel and is used in the Dark Field Control Panel.

16.8 Lorentz spotsize-intensity calibration

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Make sure that a focused beam remains focused when spot size is changed.
Importance: CONVENIENCE for keeping spot focus the same for all spot sizes, ESSENTIAL for proper operation of Intensity Zoom and Intensity Limit.
Method: After focusing spot 3, all spots are focused in turn. The deviations in intensity setting from spot focus are stored for all spots.

Procedure
The alignment procedure consists of two steps :

- One preparation step in which the beam is focused for spot size 3.
- A step in which all spot sizes are focused.

Note: The condenser system (C1 and C2 lenses) is normalized when the spot size is changed to make the spot setting better reproducible.

Description
The Intensity (C2 lens) and spot size (C1 lens) settings are not independent. In order to give the same effect for all spot sizes, the Intensity is changed whenever spot size is changed. In addition to the preprogrammed changes, individual instruments differ slightly in their relation between C1 and C2. The spot size-intensity calibration allows adjustment for this individual behavior. For the Intensity Zoom and Intensity Limit functions this procedure defines the Intensity settings at which the beam is focused, which is essential for proper operation of these functions.

17 Lorentz Image Procedure

This procedure is present only on instruments equiped with the Lorentz lens.

17.1 Preparation Lorentz image

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Set up microscope for aligning the lower part of the column (the imaging system) in Lorentz mode.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus.

Method:
C2 aperture centering:
- Focus spot and center it on the screen
- Turn INTENSITY overfocus (clockwise)
- Center aperture until illuminated area is symmetrical around the screen center.

Eucentric height: with the CompuStage switch on the Alpha wobbler and minimize image movement by changing the Z height.

17.2 Lorentz image shift pivot points

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Align image shift pivot point = make sure that the diffraction pattern does not shift when the image shift is changed.
Importance: ESSENTIAL for the proper functioning of image shifts.
Method: Minimize the movement of the diffraction pattern. The microscope 'wobbles' the image shift which should cause no diffraction shift.

Procedure
The alignment procedure consists of four steps :
- Two preparation steps for setting up the image and diffraction pattern, respectively.
- Two steps in which the X and Y pivot points are aligned.

Note: Diffraction focus. The Intensity setting is preset to a fixed value that gives a parallel incident beam which in turn should give a spot diffraction pattern. If the pattern is not focused, it should be focused with the diffraction lens (FOCUS), not Intensity.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.

The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

17.3 Lorentz diffraction shift pivot points SA

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignme nts may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

17.4 Lorentz lens preset

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Setting the eucentric focus preset at the eucentric height.
Importance: CONVENIENCE for having the eucentric focus at the eucentric height.
Method: Focus the image for the highest SA magnification.

Procedure
The alignment procedure consists of two steps :
- A preparation step in which the SA image is focused at an intermediate magnification.
- A step in which the highest SA magnification must be focused.

17.5 Lorentz image alignment SA

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Aligning all images with each other.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest normal SA magnification.
- A step in which the highest SA Lorentz magnification is aligned relative to the highest normal SA magnification.
- A step in which all other Lorentz magnifications (Mi, SA,

Notes:
- The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.
- The highest SA magnification is the reference image for the whole microscope, with regard to focus (eucentric focus preset) and image shift.

17.6 Lorentz diffraction shift pivot points Mh

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

17.7 Lorentz Mh preset and image shift

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Aligning the Mh-magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image. Repeat for all Mh magnifications.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification.
- A step in which the lowest Mh magnification is focused and aligned relative to the highest SA magnification.
- A step in which all other Mh magnifications are focused and aligned.

17.8 Lorentz diffraction shift pivot points Mi

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

Notes:
- The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.
- The instruction 'center illumination' with MF-X,Y is correct ! When the magnification is changed from the highest SA to the lowermost Mh, the beam will remain in the same position but the whole image may be shifted. Bringing the beam to the center first by shifting the image - not the beam - allows one to see the image feature and then center it.

17.9 Lorentz Mi preset and image shift

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Aligning the Mi-magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE for finding the same image feature centered and the image in focus when going from SA to Mi and vice versa.
Method: Move the required feature in the specimen to the center with the image shift and focus the image.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen-stage) in the lowest SA magnification.
- A step in which the highest Mi magnification is focused and aligned relative to the lowest SA magnification.
- A step in which all Mi magnifications are aligned relative to the highest Mi magnification.

Note: The magnification system (projector lenses) is normalized when the magnification is changed to make the image position better reproducible.

17.10 Lorentz align diffraction pattern

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Set the zero position for the diffraction shift.
Importance: CONVENIENCE for easy resetting of the diffraction shift to the screen center.
Method: Center the diffraction pattern using Multifunction X,Y.

Procedure
The alignment procedure consists of a single step.

Description
The diffraction shift has two components, an alignment value and a variable 'user' value. If properly aligned, the alignment value will have the diffraction pattern centered on the screen. It then is only necessary to reset the 'user' value to zero to have the pattern back at the screen center.

17.11 Align camera lengths Lorentz

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the center when the camera length is changed.
Importance: CONVENIENCE for having the diffraction patterns centered when the camera length is changed.
Method: Center the diffraction pattern for the reference camera length (~7 m), then align all camera lengths to the reference camera length.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which the image is focused.
- A step in which the reference camera length (~7 m) is focused and centered.
- A step in which all other camera lengths are focused and centered.

Note: The magnification system (projector lenses) is normalized when the magnification is changed to make the diffraction pattern position better reproducible.

17.12 Lorentz image shift calibration

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Calibrate the image shift to physically meaningful values.
Importance: ESSENTIAL for meaningful image measurement results.
Method: Move the focused beam to the edge of the viewing screen - with the image shift - and adjust the displayed value of the image shift using Multifunction Y. The focused beam is thus used as a reference marker.

Procedure
The alignment procedure consists of four steps :
- In the first step the beam is accurately centered on the screen.
- In the second step, the beam is shifted with Multifunction X to the edge of the viewing screen (the area where the fluorescent material - yellow/green - stops and the aluminium substrate is visible). Then the displayed value for the image shift is adjusted to the correct value with the Multifunction Y.
- The third and fourth steps repeat the first and second steps but now for the Y direction of the image shift.

17.13 Lorentz diffraction shift calibration

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Purpose: Calibrate the diffraction shift to physically meaningful values.
Importance: ESSENTIAL for meaningful diffraction measurement results.
Method: Move the diffraction pattern and adjust the displayed value of the diffraction shift using Multifunction Y.

Procedure
The alignment procedure consists of five steps :

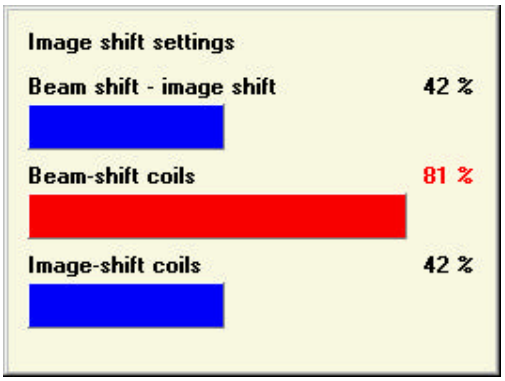
- The first step is a preparation step for the diffraction mode.
- In the second step the diffraction pattern must be centered accurately (on the center of the viewing screen or the tip of the beam stop).
- In the third step, the diffraction pattern is shifted with Multifunction X to bring a ring to the center and the diffraction shift (nm value or angle) is adjusted with Multifunction Y to the correct value.
- The fourth and fifth steps repeat the procedure of the second and third steps for the Y diffraction shift.

Description
The diffraction shift is converted through the calibration procedure into to physically meaningful units such as Bragg angles and d spacings (in the latter case the Bragg Law formula is used). The diffraction shift can be read off in the flap-out of the Alignment Control Panel and is used in the Measuring Control Panel.

17.14 Beam shift - image shift calibration Lorentz

Warning: Never execute this procedure with a sensitive magnetic specimen inside the microscope. During and after the procedure the objective lens will be turned on and the specimen may be destroyed by the magnetism of the objective lens. Always use a normal specimen for alignment. Use direct alignments for aligning with a magnetic specimen in the microscope.

Note: This procedure is complicated by the fact that it is not easy to tell how far the beam-shift/image-shift should be changed. The on-line help file therefore contains a control that indicates the status of the beam-shift/image-shift, beam coils and image coils.



Using this you change the beam shift-image shift until either:

- the beam is at the screen edge.
- the beam shift-image shift is more than 50% (bar becomes green) OR one of the coils is more than 80% (bar becomes red).

The microscope will sound a beep when the beam shift-image shift is at its limit but also when one of the coils is at its limit. In the former case you can continue with the calibration, but when a coil is limited very likely you cannot. The control in the help file which is directly linked to the microscope displays the situation.

Purpose: Define the beam shift compensation for the image shift.
Importance: CONVENIENCE for keeping the beam on the screen when the image is shifted. The beam shift - image shift is used in the Image shift Control Panel and in Low Dose.
Method: Move the image off-axis and recenter the beam using Multifunction X,Y.

Procedure
The calibration procedure consists of six steps :

- In the first step the beam is shifted to the center of the screen. For this purpose the alignment value is used while the user value is reset to zero. At the same time the image shift is set to zero.
- In the second step, the image shift X is changed, either until the microscope beeps (at the limit of the image shift) or until the beam moves off the screen (the latter typically happens when the calibration has not been done yet).
- In the third step the beam is recentered using the Multifunction X,Y. If the microscope beeped during the second step, continue, otherwise step back and repeat the second and third steps (so the final calibration is done with the image shift at its limit).
- The fourth and fifth steps repeat the same procedure as the second and third steps, but this time for the Y image shift.
- The final step just ensures that the image-beam shift is reset to zero after the procedure is finished.

Description
The Tecnai microscope has a function for image shift where the beam position is automatically compensated to keep the beam on the area of interest (what is currently seen on the viewing screen). The beam shift compensation must be calibrated before it will work properly.

18 Lorentz-EFTEM procedure

This procedure is present only on instruments equiped with the Lorentz lens.

18.1 Lorentz-EFTEM Preparation

Purpose: Set up microscope for aligning the column for EFTEM.
Importance: ESSENTIAL to make sure the alignment is done for the correct conditions: centered C2 aperture, eucentric height and specimen in focus. Also find a recognizable image feature for later alignment steps.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- The EFTEM alignments are in many cases (lower magnifications and camera lengths) sensitive to hysteresis. It is therefore important to use the normalization facility of the microscope to make image and diffraction-pattern positions reproducible.

18.2 Lorentz-EFTEM Image-shift pivot points

Purpose: Align image shift pivot point = make sure that the diffraction pattern does not shift when the image shift is changed.
Importance: ESSENTIAL for the proper functioning of image shifts and cross-over correction.
Method: Minimize the movement of the diffraction pattern. The microscope 'wobbles' the image shift which should cause no diffraction shift.

Procedure
The alignment procedure consists of six steps :
- Two preparation steps for setting up the image in normal and EFTEM modes.
- Two steps for setting up the diffraction pattern in normal and EFTEM modes.
- Two steps in which the X and Y pivot points are aligned.

In EFTEM a misaligned image shift will lead to an apparent diffraction shift when the cross-over correction is changed.

Note: Diffraction focus. The Intensity setting is preset to a fixed value that gives a parallel incident beam which in turn should give a spot diffraction pattern. If the pattern is not focused, it should be focused with the diffraction lens (FOCUS), not Intensity.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

18.3 Lorentz-EFTEM SA Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of four steps :

- Two preparation step for setting up the image in normal and EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

18.4 Lorentz-EFTEM Mh Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image in EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

The preparation here does not contain a step for the normal mode, because it is assumed that that has already been done for the SA pivot points.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

18.5 Lorentz-EFTEM Mi Diffraction-shift pivot points

Purpose: Align the diffraction shift pivot point = make sure the image does not move when the diffraction shift is changed.
Importance: ESSENTIAL for the proper functioning of image and diffraction shifts and the cross-over correction.
Method: Minimize the movement of the image. The microscope 'wobbles' the diffraction shift which should cause no image shift.

A common consequence of a diffraction shift that has not been aligned is a mismatch between the image detail selected with the selected area aperture and the area actually contributing to the diffraction pattern. When the image coils have not been aligned properly, image and diffraction shift are not uncoupled and the diffraction shift will also cause an image shift, thereby moving the image detail out of the selected area aperture. In EFTEM a misaligned diffraction shift will lead to an apparent image shift when the cross-over correction is changed.

Procedure
The alignment procedure consists of three steps :
- A preparation step for setting up the image in EFTEM mode.
- Two steps in which the X and Y pivot points are aligned.

The preparation here does not contain a step for the normal mode, because it is assumed that that has already been done for the SA pivot points.

Description
The alignment of the pivot points of the image deflection coils is essential to the proper functioning of many other alignments and calibrations: image shifts, diffraction shifts, detector alignments and measurement functions.
The image coils pivot points (image shift and diffraction shift) alignment is reasonably insensitive to the operating conditions and normally needs to be done only once. It is important that the image coils pivot points are aligned prior to aligning other parts of the microscope where the image coils are used, otherwise the latter alignments may have to be redone. Alignments where the image coils are used are those where images or diffraction patterns are moved (image shift, diffraction shift/diffraction alignment).

For images displaying the effect of the alignment, see section 6.3.

18.6 Lorentz-EFTEM Mh Pre-alignment

Purpose: Aligning the Mh-magnification images for EFTEM (as seen on the Filter) with the Mh images for the normal mode, and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image.

Procedure
The alignment procedure consists of four steps :

- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which the highest EFTEM-SA magnification is focused and centered relative to the normal mode.
- A step in which the lowest EFTEM-Mh magnification is focused and aligned relative to the highest EFTEM-SA magnification.
- A step in which all other EFTEM-Mh magnifications are focused and aligned.

Note: Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.

18.7 Lorentz-EFTEM SA Image-shift pre-alignment

Purpose: Aligning all EFTEM-SA images with each other.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of two steps :

- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which all EFTEM-SA magnifications are aligned relative to the highest normal SA magnification.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

18.8 Lorentz-EFTEM SA Cross-over pre-alignment

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
A preparation step in the highest SA magnification for the normal mode.
A step in which the cross-over corrections are set for all EFTEM-SA magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

18.9 Lorentz-EFTEM Mi Image-shift pre-alignment

Purpose: Aligning the EFTEM Mi magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps:
- A preparation step in which an image feature is centered (with the specimen stage) in the lowest EFTEM-SA magnification.
- A step in which the highest EFTEM-Mi magnification is aligned relative to the lowest EFTEM-SA magnification.
- A step in which all EFTEM-Mi magnifications are aligned to lowest EFTEM-SA magnification.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

18.10 Lorentz-EFTEM Mi Cross-over pre-alignment

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
- A preparation step in the lowest EFTEM-SA magnification.
- A step in which the cross-over corrections are set for all EFTEM-Mi magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

18.11 Lorentz-EFTEM Mh Image shift

Purpose: Aligning the Mh-magnification images for EFTEM (as seen on the Filter) with the Mh images for the normal mode, and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Focus the image for the lowermost Mh magnification and center the image relative to the highest SA image.

Procedure
The alignment procedure consists of four steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which the highest EFTEM-SA magnification is focused and centered relative to the normal mode.
- A step in which the lowest EFTEM-Mh magnification is focused and aligned relative to the highest EFTEM-SA magnification.
- A step in which all other EFTEM-Mh magnifications are focused and aligned.

Note: Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.

18.12 Lorentz-EFTEM SA Image shift

Purpose: Aligning all EFTEM-SA images with each other.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen stage) in the highest SA magnification for the normal mode.
- A step in which the highest EFTEM-SA magnification is aligned on the Imaging Filter and focused.
- A step in which all EFTEM-SA magnifications are aligned relative to the highest normal SA magnification.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

18.13 Lorentz-EFTEM SA Cross-over correction

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
- A preparation step in the highest SA magnification for the normal mode.
- A step in which the cross-over corrections are set for all EFTEM-SA magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

18.14 Lorentz-EFTEM Mi Image shift

Purpose: Aligning the EFTEM Mi magnification images with SA and finding the difference in focus.
Importance: CONVENIENCE so that the image remains centered when the magnification is changed.
Method: Center a recognizable image with the specimen stage. Lower the magnification one step, center the image with the Multifunction X,Y knobs. Repeat for all magnifications.

Procedure
The alignment procedure consists of three steps :
- A preparation step in which an image feature is centered (with the specimen stage) at the lowermost EFTEM-SA magnification.
- A step in which the highest EFTEM-Mi magnification is aligned relative to the lowermost EFTEM-SA magnification.
- A step in which all EFTEM-Mi magnifications are aligned to the lowermost EFTEM-SA magnification.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.

18.15 Lorentz-EFTEM Mi Cross-over correction

Purpose: Make sure the cross-over correction is set correctly, so the beam passes unhindered through the differential pumping aperture.
Importance: ESSENTIAL for having the image visible on the Imaging Filter, especially at the lower magnifications.
Method: Change the cross-over correction until there is no shadowing by the differential pumping aperture. For best results, change the cross-over correction first on Multifunction-X in one direction until a shadow appears. Turn the other way while 'counting' turns until the shadow on the other side appears. Turn back halfway. Repeat for Multifunction Y.

Procedure
The alignment procedure consists of two steps :
- A preparation step in the lowest EFTEM-SA magnification.
- A step in which the cross-over corrections are set for all EFTEM-Mi magnifications.

Notes:
- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the image shift is strongly misaligned, it is possible to switch to the image shift adjustment and back by pressing the R2 button.

18.16 Lorentz-EFTEM Camera-length pre-alignment

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the center when the camera length is changed.
Importance: CONVENIENCE for having the diffraction patterns centered when the camera length is changed.
Method: Center the diffraction pattern for the reference camera length, then align all camera lengths to the reference camera length.

Procedure
The alignment procedure consists of five steps :

- A preparation step in which the image for the normal mode is focused.
- A step in which the reference camera length for the normal mode (~500mm) is focused and centered.
- A step in which the equivalent EFTEM camera length is focused and centered.
- A step in which all other camera lengths are focused and centered.
- A step in which for each camera length the cross-over correction is set.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.
- Although the camera length series for EFTEM typically will contain low camera lengths, this does not imply that such camera lengths are usable on all instruments (very much dependent on a number of factors such as the mechanical alignment of the projector lenses).

18.17 Lorentz-EFTEM Camera-length alignment

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the center when the camera length is changed.
Importance: CONVENIENCE for having the diffraction patterns centered when the camera length is changed.
Method: Center the diffraction pattern for the reference camera length, then align all camera lengths to the reference camera length.

Procedure
The alignment procedure consists of five steps :

- A preparation step in which the image for the normal mode is focused.
- A step in which the reference camera length for the normal mode (~500mm) is focused and centered.
- A step in which the equivalent EFTEM camera length is focused and centered.
- A step in which all other camera lengths are focused and centered.
- A step in which for each camera length the cross-over correction is set.

Notes:

- Because of the difficulty of aligning the microscope for EFTEM (image/diffraction shift and cross-over correction are often quite critical, otherwise there is no image or diffraction pattern visible on the Imaging Filter), the EFTEM alignment procedure contains two parts, one a pre-alignment, where all alignments are done with the screen down, the other the final alignment where all is aligned on the Filter itself. Once the microscope has been aligned properly, the pre-alignment should not be necessary anymore and the final alignment can be used for fine-tuning.
- In case the cross-over correction is strongly misaligned, it is possible to switch to the cross-over correction adjustment and back by pressing the R2 button.
- Although the camera length series for EFTEM typically will contain low camera lengths, this does not imply that such camera lengths are usable on all instruments (very much dependent on a number of factors such as the mechanical alignment of the projector lenses).