Optical phonons in GaN/AlN quantum dots: leaky modes and electron energy relaxation

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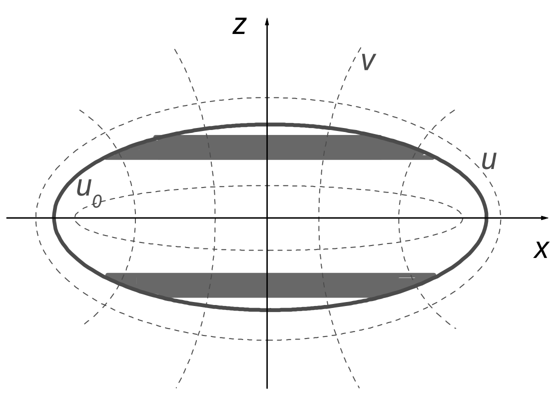
We consider surface polar vibrations of a GaN quantum dot in AlN matrix, employing the macroscopic dielectric continuum model [1], which neglects spatial dispersion of the bulk optical phonons and characterizes them by singular longitudinal and transverse frequencies. Due to wurtzite crystal symmetry, the dielectric permittivity tensors of both nitride compounds are anisotropic and defined by four characteristic frequencies each. We model the quantum dot as oblate spheroid with its short semiaxis aligned with the *c*-axis of the crystal structure.



$z = a \sinh u \cos v$
$y = a \cosh u \sin v \sin \phi$
$x = a \cosh u \sin v \cos \phi$

In the oblate spheroidal coordinates associated with the dot (see Fig.), the dielectric permittivity tensor is no longer diagonal, so that the boundary conditions for the electric potential on the dot surface involve both *u* and *v* coordinates. To determine the allowed windows for the surface phonon states in the (v, ω) plane and to obtain wavefunctions and eigenfrequencies of these states, we use adiabatic approximation for the *u* direction and semiclassical approximation for the *v* direction.

The surface modes fall into three categories:

i) truly localized modes, in the form of circular strips between certain values of *v* on the dot surface (shaded areas), surrounded by barrier regions;

ii) quasistationary, or leaky, modes; for which the barrier regions are followed by regions of the surface state nonexistence;

iii) runaway modes, for which the regions of suface state nonexistence directly neighbor the allowed windows.

In the given geometry, the escape routes for quasistationary modes and for runaway modes lie in the equatorial region of the dot. The frequencies of the allowed surface modes and the lifetimes of quasistationary modes depend essentially on the aspect ration of the dot spheroid.

The runaway modes and, especially, the quasistationary modes can effectively facilitate the energy relaxation of electrons confined in the dot. We calculate interaction of the electrons with these phonon states and estimate the rate of the energy flow away from the dot.

[1] B.C.Lee, K.W.Kim, M.Dutta, and M.Stroscio, Phys. Rev B, 56, 997 (1997).