

Anisotropic phonon systems in liquid ^4He

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Liquid ^4He is an excellent material in which to study phonons as it is extremely pure, isotropic and only supports longitudinal phonons. This means that phonon-phonon interactions can be studied in a very clear way and a considerable understanding has been developed over many years. Recently we have discovered that phonon beams in cold helium, where there are no thermal excitations, behave quite differently to phonons in isotropic distributions. This arises because the phonon-phonon interactions are strongly angular dependent and in a narrow-angle beam, interactions are severely curtailed and sometimes forbidden. The three phonon process (3pp) is very strong and the phonons with energy $<10\text{K}$ very strongly interact. However phonons with energy $>10\text{K}$ cannot interact by 3pp as it is kinematically forbidden. They can only interact by the much weaker four phonon process (4pp).

Phonons injected into cold liquid helium, with a narrow cone of momenta, rapidly thermalise by 3pp to a temperature $\sim 1\text{K}$ and cone angle $\sim 10^\circ$. These phonons also interact by 4pp and create high energy phonons with energy above 10K . For short injected phonon pulses this process is remarkably efficient and more than half the injected energy can be transformed to high energy phonons. These high energy phonons are completely stable as they are spatially isolated from the low energy phonons. They are seen experimentally as a separate pulse which follows the low energy phonon pulse. Their high energy is measured by quantum evaporation.

For long injected pulses, the high energy phonons are spatially mixed with the low energy phonons and come into dynamic equilibrium with them. However the narrow cone-angle causes their density to be suprathreshold; that is their density is orders of magnitude greater than that of similar energy phonons in an isotropic distribution at the same temperature as the low energy phonons.

We will review the properties of phonons in liquid ^4He and then discuss the experiments and theory of anisotropic phonon beams.