Phonon Trigonal Warping Effect in Isolated Single Wall Carbon Nanotubes and Graphite

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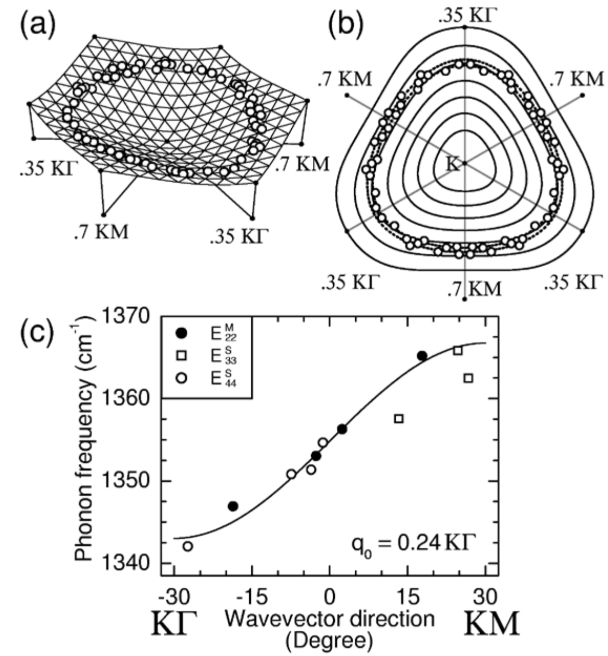

- By making resonance Raman measurements at the single nanotube level, it is possible to determine the phonon frequency as a function of both the magnitude and direction of the phonon wave vector, the first such determination in any solid.

- From measurements on many individual nanotubes, the anisotropy of the phonon equi-frequency contours can be determined.

- From the relation between the electron and phonon wave vectors under resonance conditions, electron equi-energy contours can be constructed.

- From the relation between nanotubes and 2D graphite, the anisotropy of the in-plane phonon dispersion relations for graphite can be inferred.

(a) Phonon dispersion relations $\omega_{ph}(\mathbf{q})$ for nanotubes around the K point of the 2D graphite BZ fitted to the (open circles) experimental points. (b) Phonon equi-frequency contours (solid lines) fit to experimental points (circles), and the corresponding electronic equi-energy contours (dotted lines). (c) Dependence of $\omega_{ph}(\mathbf{q})$ on the *q*-vector direction for a given *q* magnitude q_0=0.24KΓ. The phonon anisotropy is shown by the frequency difference $\Delta\omega_{ph}$=24 cm^{-1} between the *q*-vector directions KM and KΓ.

Ge.G. Samsonidze *et al.* Phys.Rev.Lett. **90**, 027403 (2003).

Dispersive and Non Dispersive Modes in the Raman Spectra of Single Wall Carbon Nanotubes

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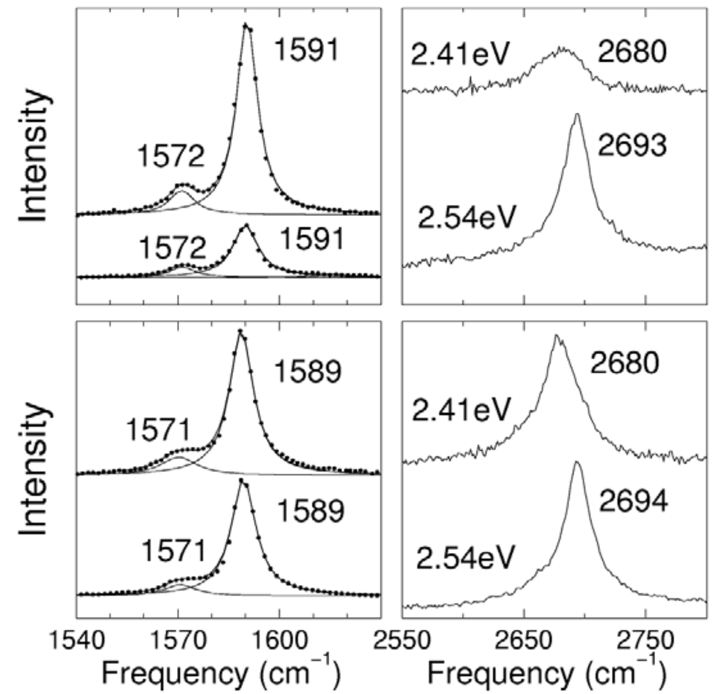
• By measuring Raman spectra at the single nanotube level it is possible to measure the same Raman feature on the same physical nanotube with two different laser excitation energies to determine whether or not the feature is dispersive, and if dispersive to measure the dispersion with laser excitation energy.

• Figures on the left show that the G-band feature, derived from the fundamental lattice vibration in graphite, is non-dispersive.

• The Raman spectra for the G′ band on the right, associated with a double resonance process, are dispersive, and the dispersion with laser excitation energy can be measured for individual tubes of different diameters and chiralities. Strong chirality dependent behavior is found. When the results are summed over many individual tubes, the dispersion of the G′ feature for 2D graphite is obtained.



Raman spectra from two isolated semiconducting SWNTs using E_{laser}=2.41 eV (top trace) and E_{laser}=2.54 eV (bottom trace). For each SWNT, ω_{G-} and ω_{G+} (left) and $\omega_{G'}$ (right) are in cm^{-1}.

A. Jorio *et al.*, *Phys. Rev. Lett.* **90**, 107403 (2003)

Mentoring

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• Young students (K-6) are very interested in state-of-the-art science topics like carbon nanotubes and can understand many things about their structure and properties.

•High school students presentations on carbon nanotubes and other nanostructures provide an effective method for teaching scientific principles while conveying the excitement of scientific discovery.

•With each endowed lecture series given this year by the principal investigator, one public lecture accessible to a general audience was given on frontiers of nanoscience, including carbon nanotubes and single molecule spectroscopy.

The principal investigator teaching and conveying the excitement of discovery in the context of carbon nanotubes and fullerenes to elementary school children at Coal Creek Elementary School in Louisville, Colorado.