# BRILLOUIN LIGHT SCATTERING FROM PHONONS IN NANOSTRUCTURES

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Brillouin light scattering (BLS) provides a means of characterizing elastic moduli and vibrational modes of materials through inelastic interactions of thermal phonons with incident photons. Since it usually is performed with lasers in the visible range, BLS can detect acoustic modes with submicron wavelengths and, correspondingly, frequencies in the low gigahertz range. This capability has led to extensive use of BLS for characterizing elastic properties of thin films from surface waves. In recent years, BLS has begun to be employed for characterizing structures with nanoscale dimensions in more than one direction. In conjunction with this experimental work, theoretical models must be developed for vibrational modes and elastic properties of nanoscale materials.

The wavelength selectivity of BLS provides a particularly powerful means of determining the dispersion curves and corresponding elastic moduli of linear nanostructures, such as nanolines on substrates, nanowires, and nanotubes. The first measurements of this type at the University of Akron and NIST have focused on arrays of imprinted polymeric nanolines with heights on the order of a hundred nanometers and widths of a few tens of nanometers. The determination of elastic moduli of such lines is important for optimizing their mechanical intergrity in future lithographic applications, especially considering that intrinsic size effects are expected to decrease the moduli and introduce elastic anisotropy. BLS spectra from polymethyl methacrylate (PMMA) nanolines show peaks from modes with flexural displacements parallel to the substrate and modes with displacements similar to Rayleigh and Sezawa waves of a uniform film. Elastic moduli of these nanolines were estimated from the measured dispersion curves using an inversion algorithm incorporating a finite-element model.

Several groups also have performed exploratory BLS studies of carbon nanotubes, but no consistent picture has emerged with respect to the origin of spectral peaks. A significant obstacle to progress in this area is the current lack of appropriate arrays of aligned, weakly interacting, single-walled nanotubes. At NIST, spectra from bundles of single-walled carbon nanotubes have shown a broad peak near 5 GHz (with an incident-light angle of $60^\circ$). This peak is similar to one observed in highly oriented pyrolytic graphite (HOPG) that is understood to arise from a superposition of Rayleigh waves and surface-incident shear waves.

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