Electronic Raman spectra and origin of Fano resonance in metallic single wall carbon nanotubes

Riichiro Saito¹, Eddiwi H. Hasdeo¹, Ahamad R. T. Nugraha¹, Kentaro Sato¹, Mildred S. Dresselhaus²

1 Department of Physics, Tohoku University, Sendai 980-8578 Japan (rsaito@flex.phys.tohoku.ac.jp)
2 Massachusetts Institute of Technology, MA 02139-4307 USA

In metallic single wall carbon nanotubes (m-SWNT), G band (in-plane optical phonon modes) Raman spectra becomes soft and broad because of the coupling of the G band phonon with an electron-hole pair (or exciton) excitation in the gapless linear energy sub-band, which is known as the Kohn anomaly effect [1]. However, the asymmetric spectral shape of the G band for m-SWNTs, also known as Breit-Wigner-Fano (BWF) line shape, is still not well explained theoretically. Since BWF line shapes are commonly observed in graphene or graphite intercalation compounds [1], electrons in the linear energy band of m-SWNTs should be expected to exhibit this asymmetry spectral shape. In this presentation, we explained the origin of BWF line shape by interference of phonon G band spectra and electronic Raman spectra (ERS). The ERS is observed in m-SWNTs [2] and the exciton-exciton interaction between a photo-excited exciton and an exciton in the metallic energy sub-band is relevant to the ERS. We calculated ERS spectra as a function of laser excitation energy and the Fermi energy which reproduce the experimental BWF spectral shape well. One surprising message in this calculation is that the direct Coulomb interaction between the two excitons vanishes at $q=0$ because of the symmetry of the two sub-lattices of graphene even though the Coulomb interaction at $q=0$ is generally considered to be a maximum. This surprising effect can be shown analytically, too. As an interference effect between the ERS and G band spectra, BWF spectral shape is calculated in which experimental BWF features can be analyzed [3].