Simultaneous enhancement in phonon-assisted photoluminescence and Raman scattering of an air-suspended carbon nanotube

○H. Sumikura[1,2], H. Takaki[3], H. Maki[3,4], and M. Notomi[1,2]

[1]NTT Nanophotonics Center, [2]NTT Basic Research Laboratories, [3]Keio University, [4]JST PRESTO

E-mail: sumikura.hisashi@lab.ntt.co.jp

1. Introduction: In carbon nanotubes (CNTs), the excitons and phonons confined in the one-dimensional structure are strongly interacted each other, which has been observed as an intense resonant Raman scattering and phonon-assisted photoluminescence (PL) of the excitons [1]. Recently, we focus on the combination of photonic nanostructures and CNTs to enhance the Raman scattering and photon emission from the CNTs by a modified density of optical states [2,3]. In this study, first we have studied fundamental optical properties of our CNTs before device fabrication and observed a strong exciton-phonon interaction.

2. Experimental: The CNTs were grown by alcohol CVD method and suspended between the line-patterned Co catalysts. The microscopic photoluminescence excitation (PLE) spectroscopy was performed with a tunable cw Ti:sapphire laser. The sample was set in a vacuum chamber at room temperature. The PL and Raman scattering of single CNT were filtered with a high-performance optical filter, and then guided to the single-stage spectrometer attached with a cooled InGaAs detector array.

3. Results and discussion: Figure 1(a) shows the PLE map of single CNT. The chirality of this CNT is assigned to be (11,3) by another PLE result in higher excitation energy. In Fig. 1(a), it is found that the exciton PL at 1176.3 nm is enhanced when the Stokes Raman line of *G* band is across the PL line at an excitation wavelength of 990.4 nm (1.254 eV). The intensities of the PL and Raman line of *G* band are peaked at 990.4 nm as seen in Figs. 1(b) and (c). These results show the simultaneous enhancement of both the PL and Raman scattering of single CNT. If the excitation energy is adjusted to the sum of the exciton emission energy (1.056 eV) and phonon energy of *G* band (0.198 eV) as shown in the inset of Fig. 1(c), the Raman scattering is resonantly enhanced by the large density of excitonic states at the Γ point. At the same time, the exciton PL intensity is also increased by phonon emissions assisting exciton creation. This work was supported by JSPS KAKENHI 15H05735.

Reference: [1] H. Sumikura et. al., APL **102**, 231110 (2013). [2] T. Endo et. al., APL **106**, 113106 (2015). [3] S. G. Chou et. al., PRL **94**, 127402 (2005), H. Htoon et. al., PRL **94**, 127403 (2005).

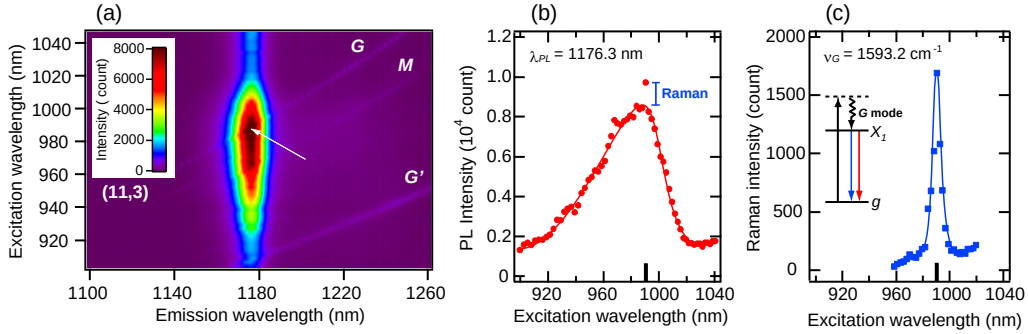

Figure 1 (a) PLE map of single CNT with a chirality of (11,3). The PL and Raman lines are found. (b) PL intensity at an emission wavelength of 1176.3 nm. The spike at an excitation wavelength of 990.4 nm is an overlaid Raman scattering line of *G* band. (c) Raman intensity of *G* band at 1593.2 cm^{-1}.