Narrow-band thermal exciton radiation in individual suspended single-walled carbon nanotubes

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A number of intriguing phenomena arising from many-body quantum correlations have been discovered in single-walled carbon nanotubes (hereafter referred to as nanotubes); their understanding and control are intensively studied from the viewpoint of the fundamental physics and device applications. Majority of these experimental works have been conducted below room temperature, and it has been revealed that their optical properties are dominated by excitons and/or exciton complexes. In contrast to these properties, thermal radiation, which is one of the fundamental optical properties, remains unclear because of technical difficulties. Although some pioneering studies reported light emission spectra consisting of broad peaks from nanotubes under Joule-heating conditions [1,2], the carrier doping and current injection required to heat the nanotubes may considerably modify their one-dimensional quantum correlation effects [3], and the origin of the peak features (whether they are band-to-band or excitonic transitions) remains debatable [1,2]. In addition, the possibility of competing electroluminescence mechanisms, including ambipolar carrier injection and impact excitation, further complicates the interpretation of light emission phenomena during current injection.

In this work, we show the fundamental thermal radiation properties of intrinsic semiconducting and metallic nanotubes suspended in a vacuum [4]. We employed continuous-wave (cw) laser irradiation for heating nanotubes, which provided non-contact local heating while retaining the neutral charge balance of the nanotubes throughout the measurements. In addition, it enabled temperature measurement using Raman spectroscopy of the in-plane carbon stretching mode (*G*-mode) [5]. At 1,000–2,000 K, an intrinsic semiconducting nanotube emitted linearly polarized, narrow-band near-infrared radiation, in contrast to its broadband metallic counterpart. We unambiguously confirmed that this narrow-band radiation was enabled by the thermal generation of excitons using the distinctive spectral difference between semiconducting and metallic nanotubes, the temperature dependence of the radiation intensities, and simultaneous observation of the radiation spectra and the optical susceptibilities. In the presentation, universal features of thermal radiation of one-dimensional structures will be discussed.

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