Photoluminescence Quantum Yield and Effective Exciton Radiative Lifetime in Monolayer Transition Metal Dichalcogenides

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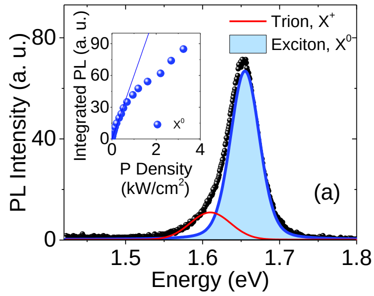
The discovery of graphene and its fascinating properties [1] motivates new research fields in two-dimensional (2D) atomically thin-layered materials. The semiconductor transition metal dichalcogenides (TMDs) with chemical formula of MX_2, (M = Mo, W; X = S, Se, Te) have attracted great research interest due to its intriguing properties [2,3]. It is very crucial to know the photoluminescence (PL) quantum yield and exciton radiative lifetime of this material in both viewpoint of research and opto-electronic device applications [4].

In this study, monolayer tungsten diselenides (1L-WSe_2) from mechanically exfoliation technique was experimentally evaluated its PL quantum yield, Φ_{PL} and effective radiative lifetime, τ_{rad} at room temperature. Figure 1(a) show that PL spectrum of 1L-WSe_2 at power density of 1 kW/cm^2 is mainly dominates by exciton, while the inset figure shows the integrated PL with varying power density in the linear region. In addition, PL quantum yield of 0.2 % was estimated using relative quantum yield method using highly fluorescent standard dye [5] as reference. We also conducted time-resolved PL spectroscopy measurement to measure the PL decay time of 1L-WSe_2 at room temperature. The exciton effective radiative lifetime of 280 ns was determined using the PL quantum yield and PL decay time, τ_{PL} of ~ 560 ps (Figure 1(b)). This experimental result with considerably long exciton effective radiative lifetime compared to 5 ns of theoretical predicted value at room temperature [6], is suggested due to existence of the dark states. Our finding will provide some information for future development of TMDs application.



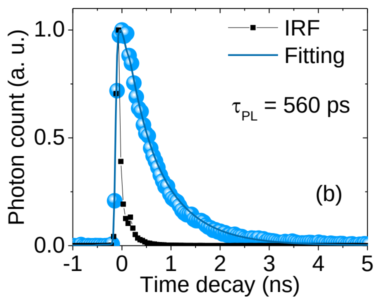


Figure 1: (a) PL spectra at 1kW/cm^2 (inset: Integrated PL vs. P density in 1L-WSe_2); (b) PL decay profile at 532 nm wavelength excitation.

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