Photoluminescence spectroscopy of single-photon emitters in a WSe_2 monolayer

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Application Note

Introduction

Monolayers of transition metal dichalcogenides (TMDCs), such as MoS_2, $MoSe_2$, WSe_2, and WSe_2 are promising for conceptually new opto-electronic devices. These TMDCs are direct band gap semiconductors and exhibit valleytronic effects. Recently, transistors, photodetectors, and light emitting devices have been demonstrated using these materials. Here, we present single-photon emission of localized excitons in monolayer WSe_2 [1], which renders TMDCs also promising for quantum optics.

Setup

WSe_2 monolayers are obtained by mechanical exfoliation of a bulk single crystal [2]. The photon emission from the atomically thin layers is investigated in a homebuilt laser scanning confocal microscope with a deep depletion CCD (Andor iDus DU420A-BR-DD) attached to spectrograph (Andor Shamrock SR-750-D1-SIL). For excitation either a 532 nm diode-pumped solid state laser or a tunable Ti:Sapphire laser are used.

Results

Fig. 1 shows a photoluminescence map of the WSe_2 monolayer at a temperature of 10 K. The laser is scanned over the sample and at each point the spectrum is recorded. In Fig. 1a) the broad energy range of 1.55 – 1.77 eV is shown. The monolayer is clearly visible with some bright emission centers at the edges of the flake. Photoluminescence spectra recorded from different positions (i-v) are depicted in Fig. 1b. The typical photoluminescence emission of the WSe_2 monolayer (position v) exhibits two maxima due to the neutral exciton (X^0 at 1.747 eV) and charged exciton ($X^{\pm}$ at 1.718 eV), together with a broad emission band at lower energies. At the bright center positions at the flake edges sharp emission lines are found (i-iv). The second-order correlation function measured with a Hanbury-Brown and Twiss setup proves that the localized emitters are excellent single-photon sources [1].

Photoluminescence in the narrow energy window around 1.694 eV containing some of these centers is shown in Fig. 1c, whereas the photon emission at energy of the free neutral exciton (1.745 eV) is plotted in Fig. 1d. It is clearly visible that at positions of the bright emission centers the intensity of the free neutral exciton X^0 is strongly decreased. This observation together with evidence from photoluminescence excitation spectroscopy suggest that the single-photon emitters are originating from localized excitons.

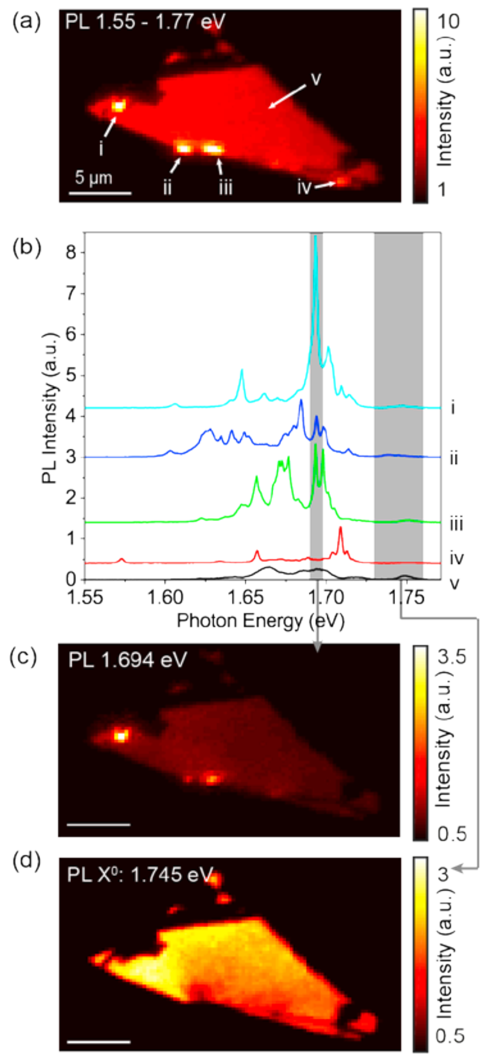

Figure 1. Photoluminescence mapping of a WSe_2 monolayer with localized emission centers. a) Broad spectral range from 1.55 to 1.77 eV. b) Spectra for positions i-v. c), d) Narrow spectral range. The grey rectangles indicate the spectral window used in (c) and (d).

The spectrum in Fig. 2 obtained with a high resolution grating (1800 lines/mm) reveals that the spectral width of the emission lines of centers in freestanding WSe_2 monolayers is less than 120 µeV, which is the spectral resolution of the system. Due to the high detection efficiency of the iDus CCD the spectral wandering of the two emission lines can be measured with 0.1 s time resolution (Fig. 2b). We find a spectral diffusion of 500 µeV over 8 minutes.

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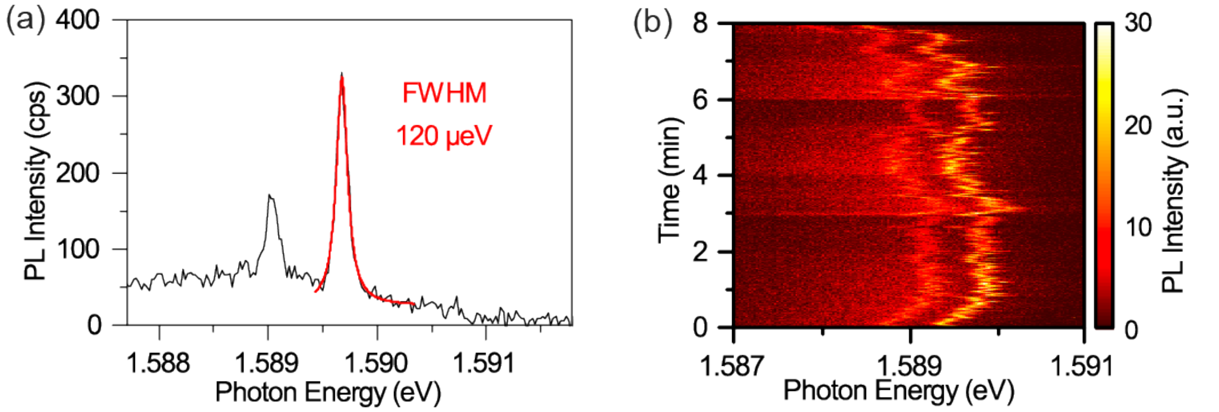

Figure 2. Photoluminescence spectrum of localized excitons. a) High resolution spectrum with 1800 lines/mm grating. b) Spectral diffusion over 8 minutes.

Conclusion

With the help of the Andor iDus 420 CCD camera attached to a Shamrock 750 spectrograph we have characterized single-photon emitters in atomically thin WSe_2.

References

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