Temperature dependent photoluminescence lifetime of atomically thin WSe_2 layer

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Atomically thin layers of semiconducting transition metal dichalcogenides are believed to make a vital contribution to future technological applications and are widely investigated on the grounds of many interesting phenomena observed in monolayers [1, 2]. In particular, knowledge about dynamics of excitonic complexes is crucial for optoelectronics and valleytronics applications.

Here we report detailed studies of photoluminescence dynamics related to excitonic complexes in tungsten diselenide (WSe_2) monolayers measured as a function of temperature and excitation power with the use of time-integrated and time-resolved spectroscopy under pulsed excitation. In photoluminescence spectrum of a typical WSe_2 monolayer two different types of components are observed: short-lived lines corresponding to free states and long-lived lines related to localized states. Moreover, for some monolayers a third type of feature is observed which presents behaviour intermediate between long and short lived states. However, its origin is still not clear. The long-lived features exhibit strong decrease of intensity with the increase of the temperature, which may be related to opening of non-radiative recombination channels, either for relaxed or excited excitonic states. In the former case the lifetime of the luminescence features should be strongly affected by the sample temperature, while in the latter case the lifetime should remain temperature-independent. In our experiment we determine which effect is dominant.

We investigate the intensity and lifetime of photoluminescence peaks related to localized excitonic states as a function of temperature. We determine that the decrease of their intensity is directly proportional to their lifetime, thus this effect can be attributed to opening of additional recombination channels for relaxed excitonic states. Additionally, in order to comprehend the origin of the photoluminescence feature of the intermediate lifetime, we conduct polarization-resolved photoluminescence measurements in magnetic field. This experiment sheds some light on this issue, which is of great interest in recent literature [3, 4].

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