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Can we expect great single photon sources from two-dimensional semiconductors?

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Abstract

Two-dimensional transition-metal dichalcogenide (TMD) semiconductors and their heterostructures possess extensive possibilities in material design and band-structure engineering without the usual demands on semiconductor processing. At the same time, their excitonic properties render TMDs extremely useful as light emitters and detectors. In particular, TMD based single-photon sources are promising for their cost efficiency over epitaxially grown quantum dots. Single photon emission can arise from defects, as well as strain-induced local modifications of the band structure. While antibunching has been demonstrated in many cases, limitations of the indistinguishability of the emitted photons remain an open research question.

We explore aspects of TMD-based single photon sources by applying quantum-optical methods on the foundation of TMD material properties, including the interaction with phonons [1]. In this framework, indistinguishability is obtained by numerically computing two-time correlation functions. Implications of our results shown below will be discussed to evaluate the application potential of using TMD nanostructures as single-photon sources. We also address the possibility of cavity engineering, i.e. embedding TMDs into optical cavities, to control not only the spontaneous-emission time, but also emitter coherence [2], leading us to the important question if cavity engineering can be a viable route towards achieving well-performing sources of indistinguishable photons on the TMD material platform.

[1] *Impact of phonon lifetimes on the single-photon indistinguishability in quantum emitters based on 2D materials*, arxiv.org/abs/2501.14656 (2025)

[2] *Engineering the Impact of Phonon Dephasing on the Coherence of a WSe_2 Single-Photon Source via Cavity Quantum Electrodynamics*, PRL **132**, 206903 (2024)