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Multiple evidence for room-temperature strong coupling in a hybrid WS_2/gold nanodisk-system

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The discovery of 2D materials with their strong in-plane bonds and weak out-of-plane van der Waals-interaction holds great promise for many technological applications. Especially the transition metal dichalcogenides (TMDCs, e.g. $MoTe_2$ or WS_2) with their semiconducting nature and strong optical response have sparked significant interest. The optical response in these TMDCs is dominated by the excitons, i.e. hydrogen-like electron-hole excitations, which are stable even at room temperature due to the reduced screening by surrounding material in the 2D as compared to a 3D environment. Indeed, for excitons in bulk semiconductors cooling to cryogenic temperatures is typically needed.

Combining the excitons with a strong cavity mode leads to new, dressed states with a characteristic split, the Rabi splitting, between the two new modes of the system. Recent years have shown an increased use of plasmonic particles as optical cavities, despite their low quality factor. This shortcoming is counteracted by the strong, subwavelength field confinement which increases the interaction strength to the tens and hundreds of meV range, allowing it to alleviate the otherwise large dampening normally associated with plasmonic resonances. With a sufficiently large coupling between the 2D excitons and the particles, the strong coupling regime can be reached.

The strong coupling between monolayer TMDCs and plasmonic particles has been reported typically by only the scattering spectra [1]. However, recent investigations show this experimental evidence is not enough for determining the coupling regime, since a manifestation of the splitting in both the scattering and absorption of such a plasmon-exciton coupled system is necessary [2].

In this work, we use thin (~8 nm) chemically synthesized gold nanodisks [3] deposited on a mechanically exfoliated monolayer of the TMDC WS_2 to unambiguously show the strong coupling regime both in the scattering and reflection spectra. These results are furthermore backed up by finite element method-simulations. The ability to consistently reach and confirm the strong coupling regime is an important step towards future applications.

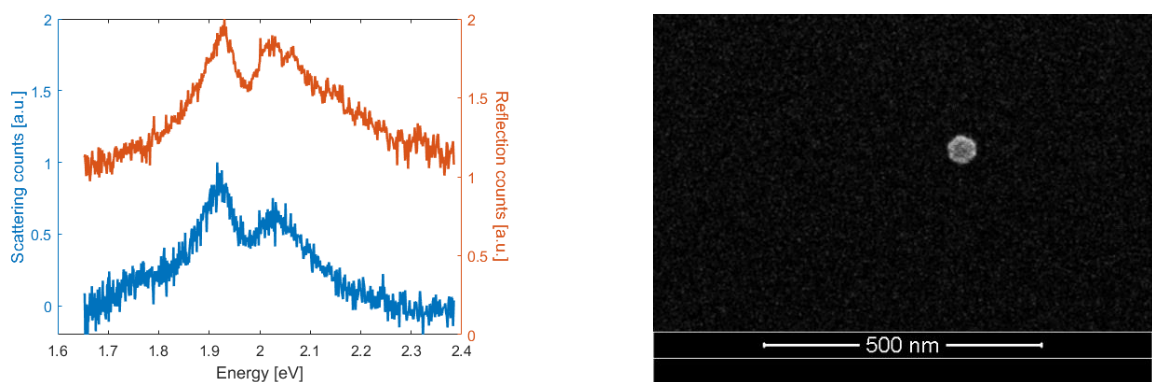

Fig. 1: a) Scattering (blue) and reflection (red) spectrum of a single nanodisk on monolayer WS_2. The Rabi splitting is clearly visible in both spectra. **b)** Scanning electron microscope image of the particle used for the spectra in **a)**.

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