Photonic Crystal - TMD Structures as Perfect Absorbers in the Strong Coupling Regime

Eleonora Kraus[1,*], **Janmie M. Fitzgerald**[1], **Ermin Malic**[1],

[1]Fachbereich Physik, Philipps-Universität Marburg, 35037, Germany

Photonic crystals (PhCs) are a well-established alternative to Fabry-Pérot (FP) cavities when studying exciton polaritons and the strong coupling region. For practical applications it is advantageous to efficiently feed energy into polaritons with no loss. It is therefore desirable to design metal-free and ultra-compact devices that can enhance absorption in the strong coupling regime. It has been demonstrated that structures consisting of PhC slabs and transition metal dichalcogenides (TMDs) [1] can achieve a perfect absorption in the weak coupling regime [2] and in the strong coupling regime via multi-port excitation. [3] However the existence of 100% absorption has yet to be demonstrated for single-port excitation in the strong coupling regime. Based on rigorous coupled wave simulations and coupled mode theory we have theoretically demonstrated that PhC-TMD structures (Fig. 1a) can function as perfect coherent absorbers in the strong coupling regime. Here, two photonic modes with opposing symmetries, with respect to the mirror plane of the PhC slab, simultaneously couple to the A1s exciton of a WS_2 monolayer, with the system being in the strong coupling regime. In Fig. 1b two distinct pairs of upper and lower polaritons can be observed and the absorption reaches 100% where the resonances overlap. Another characteristic phenomenon of PhC slab - TMD structures is the coexistence of strongly and weakly coupled excitons within a single unit cell. This observation of two different exciton species, reflected as upper and lower the polariton branches with a Rabi splitting of approx. 25meV and the energetically constant weakly coupled A1s exciton peak, can be attributed the drastically varying electric field amplitudes in PhCs.

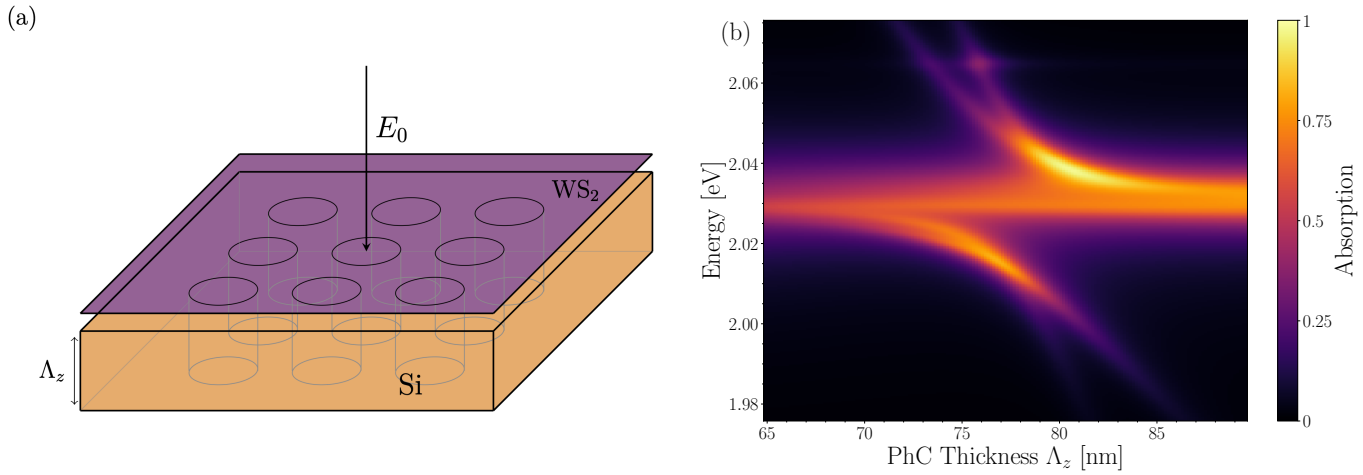

Figure 1: (a) Schematics of the studied WS_2 monolayer placed on top of the Si-based 2D photonic crystal slab. (b) The absorption spectrum over the incident energy and the PhC thickness as a detuning parameter for the system in (a). It can be observed that 100% absorption is achieved and that two different photonic modes simultaneously strongly couple to the A1s exciton without any exciton-mediated interaction between them. Additionally the optical response of the weakly coupled A1s exciton remains visible independet of the photonic crystal thickness.

References

[1] T. Mueller, E. Malic, *npj 2D Mater Appl* **2**, 29 (2018)

[2] J. R. Piper, V. Liu, S. Fan. et. al. *Appl. Phys. Lett.* **104**, 251110 (2014).

[3] S. Zanotto, F. Mezzapesa, F. Bianco *et. al. Nature Phys* **10**, 830–834 (2014)

*E-mail: elliek@riseup.net