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Exploring strong light-matter interactions in monocrystalline gold nanodisks coupled to tungsten disulfide

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Tailoring the interaction between excitons in semiconducting materials and electromagnetic fields focused inside optical cavities is the cornerstone of many applied and fundamental researches in nanophotonics. The coupling strength between matter and light can range from the weak to the strong regime, where light and matter can no longer be treated independently but instead as hybridized states sharing both properties of light and matter. In order to reach that regime, the coherent energy exchange between the excitons and the optical field must happen faster than any dissipation processes. With the recent discovery of new low-dimensional materials such as transition metal dichalcogenides (TMDC), hosting excitons with binding-energies above 0.3 eV and exhibiting large transition dipole moments, it has been shown experimentally, in combination with plasmonic nanostructures, that it is possible to reach the strong-coupling regime at room temperature [1, 2].

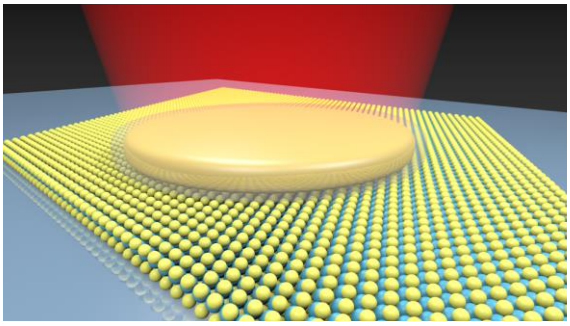

Figure 1 : Monocrystalline nanodisk coupled to WS_2. Adapted with permission from ref. [3]. Copyright 2019 American Chemical Society.

Here, we report the observation of strong coupling at room temperature between plasmons in monocrystalline gold nanodisks deposited on top of tungsten disulfide (WS_2). With dark- and bright-field spectroscopy we show for monolayer WS2 a clear Rabi splitting of 108 meV which is at the onset of the strong coupling regime. We use multilayer WS_2 to push this coupling deeper into the strong-coupling regime and reach a splitting as high as 175 meV. To our knowledge, this is the highest Rabi splitting reported for TMDC materials coupled to plasmonic cavities [3]. This investigation could lead to the design of novel ultra-compact and efficient light sources.

[1] J. Wen, *et al.*, "Room-Temperature Strong Light-Matter Interaction with Active Control in Single Plasmonic Nanorod Coupled with Two-Dimensional Atomic Crystals," Nano Lett. **17**, 4689-4697 (2017).
[2] M. Stührenberg, *et al.*, "Strong Light-Matter Coupling between Plasmons in Individual Gold Bi-pyramids and Excitons in Mono- and Multilayer WSe2," Nano Lett. **18**, 5938-5945 (2018).
[3] M. Geisler, *et al.*, "Single-Crystalline Gold Nanodisks on WS_2 Mono- and Multilayers for Strong Coupling at Room Temperature," ACS Nanophotonics **6**, 994-1001 (2019).

Nicolas Stenger is currently an Associate Professor with the Department of Photonics Engineering at the Technical University of Denmark. Previously, he received his MSc in 2004 and PhD in Condensed Matter Physics in 2008 from the University of Strasbourg, France, before embarking on invisibility cloaking research as a postdoctoral fellow at the Karlsruhe Institute of Technology, Germany. In 2012 he moved to Denmark and was awarded a fellowship from the Lundbeck Foundation to explore quantum effects in plasmonic nanostructures. Nicolas is a member of the Center for Nanostructured Graphene (DTU CNG) and his research activities are mainly focused on strong light-matter interactions between plasmonic cavities and semiconducting two-dimensional materials.