Multiple evidence for room-temperature strong coupling in a hybrid WS2/gold nanodisk-system

Geisler, Mathias; Cui, Ximin; Jessen, Bjarke Sørensen; Bøggild, Peter; Mortensen, N. Asger; Wang, Jianfang; Wubs, Martijn; Xiao, Sanshui; Stenger, Nicolas

Publication date: 2018

Citation (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
Multiple evidence for room-temperature strong coupling in a hybrid WS$_2$/gold nanodisk-system

Mathias Geisler$^{1,2}$, Ximin Cui$^3$, Bjarke S. Jessen$^{2,4}$, Peter Bøggild$^{2,4}$, N. Asger Mortensen$^{2,5}$, Jianfang Wang$^3$, Martijn Wubs$^{1,2}$, Sanshui Xiao$^{1,2}$, Nicolas Stenger$^{1,2}$

$^1$DTU Fotonik, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
$^2$Centre for Nanostructured Graphene (CNG), Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
$^3$Department of Physics, The Chinese University of Hong Kong, Shatin, Hong Kong SAR, China
$^4$Department of Micro- and Nanotechnology, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
$^5$Center for Nano Optics, University of Southern Denmark, Campusvej 53, Odense M 5230, Denmark

Corresponding author: Mathias Geisler, mgei@fotonik.dtu.dk

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).