Probing the ultimate polariton interactions in WS_2 monolayer based exciton polariton platform

L. Polimeno[1], F. Todisco[1], R. Mastria[1], M. De Giorgi[1], A Fieramosca[1], M Pugliese[1], D. Ballarini[1], D Sanvitto[1]

[1]*CNR Nanotec, Institute of Nanotechnology, via Monteroni, 73100, Lecce, Italy.*
laura.polimeno@nanotec.cnr.it

Exciton polaritons are hybrid quasi-particles resulting from the strong coupling between photons and excitons in semiconductors, offering potential for advanced optoelectronic and quantum technologies that function at room temperature. Recently, atomically thin transition metal dichalcogenides (TMDs) have gained significant attention due to their unique optical and structural properties. TMD monolayers, with strong quantum confinement and high excitonic binding energies (up to 1 eV), maintain excitonic resonances at room temperature (RT). Their atomic thickness and in-plane oriented dipole make them ideal for exploring strong light-matter interactions in various platforms, including microcavities, waveguides, metasurfaces, and nanostructures.

The aim of the work is to maximize the strong light-matter interaction between the optically confined mode and the TMD excitonic resonance, thereby enhancing the cooperativity of the system.
For this purpose, we present two different approaches that can work at RT and are based on the use of a tungsten disulfide (WS_2) monolayer as the active material.
In the first case, we minimize the photonic losses by exploiting the very long lifetime offered by the Bound state in the continuum (BIC) [1]. We obtain strong light–matter interaction enhancement and large exciton–polariton nonlinearities at RT by coupling monolayer tungsten disulfide excitons to a topologically protected BIC and optimizing for the electric-field strength at the monolayer position through Bloch surface wave confinement [2] (Fig. 1).

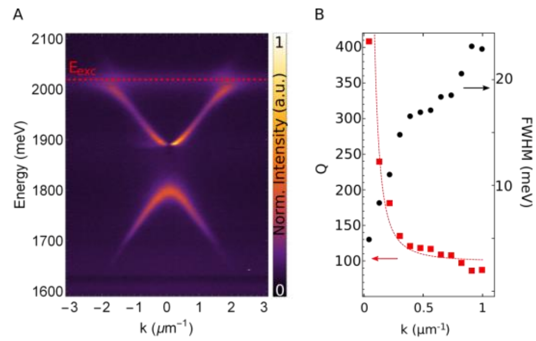

Fig.1. A) Upper BIC-like mode strongly coupled with the WS_2 monolayer exciton (blue line), as observable from the anticrossing, and weakly coupled lower lossy mode. B) Q-factor values (black dots) and polariton linewidths (red squares) plotted as a function of the in-plane momentum.

In the second approach, we develop a novel fabrication method for integrating a suspended WS_2 monolayer within the middle of a resonant planar microcavity, thereby minimizing excitonic losses. This platform experimentally demonstrates a twofold enhancement of strong coupling at room temperature, due to reduced overall losses compared to similar systems based on dielectric-filled microcavities (Fig. 2). Furthermore, the minimized losses in the surrounding environment significantly amplify nonlinear polaritonic interactions, achieving a record exciton interaction constant that approaches the theoretically predicted value.

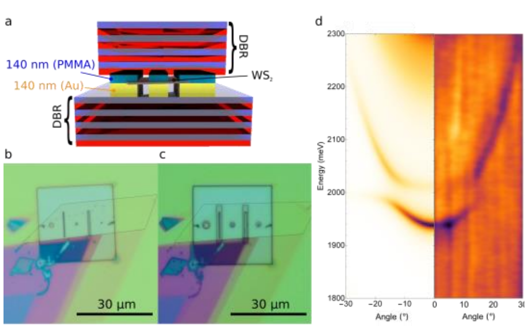

Fig.2. a) Sketch of the planar microcavity. The WS_2 monolayer is suspended.
Real space image of the sample b) after mechanical transfer and c) after writing the top PMMA using EBL. d) Comparison between the theoretical simulation and the experimental reflectivity in Fourier space of the suspended region.

References

[1] Ardizzone, V., et al. "Polariton Bose–Einstein condensate from a bound state in the continuum." Nature, 447-452, (2022).
[2] Polimeno L., et al. "Strongly enhanced light–matter coupling of monolayer WS2 from a bound state in the continuum." Nature Materials, 964-969, (2023).