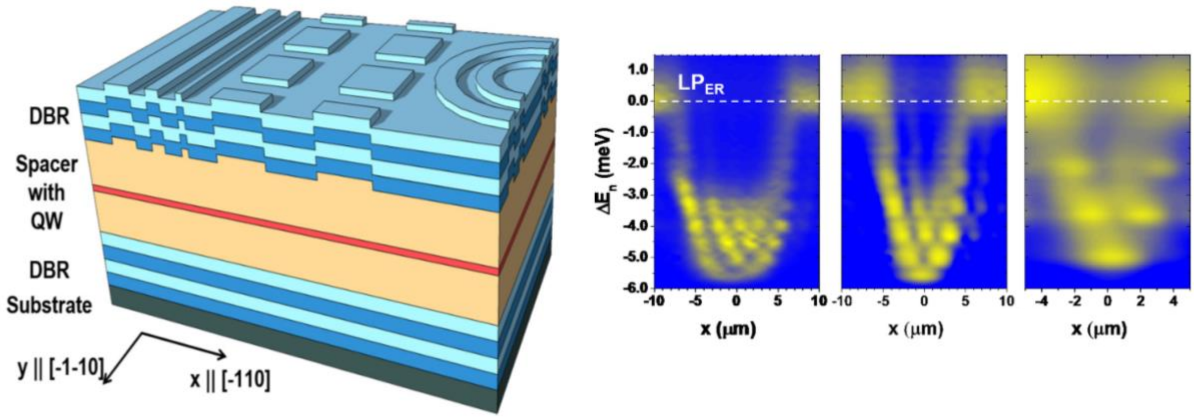
SAWtrain Research Highlight 9:
“Quantum confinement of exciton-polaritons in a structured (Al,Ga)As microcavity”

Microcavity polaritons (MPs) are quasiparticles resulting from the strong coupling between excitons and the light field in a microcavity. The strong coupling splits the energy states in an upper energy branch (upper polariton, UP) and lower energy branch (lower polariton, LP), characterized by the Rabi splitting. Their microscale wavelengths pave the way for manipulation by microstructures, in contrast to the structures on nanoscale required for exciton confinement. In this publication, we study the quantum confinement of exciton-polaritons in a structured (Al,Ga)As microcavity. Such a structured microcavity is schematically shown in Figure 1a. First, a distributed Bragg reflector (DBR, dark and bright blue layers) is grown by MBE on a GaAs(001) substrate. Secondly, a GaAs quantum well structure (red) is grown inside an (Al,Ga)As cavity spacer (yellow). The surface of the cavity spacer is subsequently structured by photolithography and wet chemical etching. As a result, the cavity resonance of the etched areas is blue-shifted with respect to the non-etched areas. Since this cavity blue-shift results in a blue-shift of the MP energy, this technique allows for the confinement of MPs in non-etched microstructures.



(a) **(b)**

Figure 1 (a) Schematic overview of a structured microcavity. The blue layers depict the DBR, the yellow layer depicts the spacer layer and the red layer depicts the quantum well structure. (b) Confined LP energy states in non-etched wire mesas with a width of w=10µm (left), w=6.4µm (center) and w=3.2µm (right). LP_{ER} *depicts the reference energy, which is the LP energy in the etched area.*

We investigated the energy levels of MPs which are confined in non-etched wire mesas along the [-1-10] direction. Figure 1b shows photoluminescence images of the LP corresponding to confined MPs in wires with a width w of respectively 10 µm (left), 6.4 µm (center) and 3.2 µm (right). The reference energy ΔE_n=0 refers to the LP energy in the etched area. Confinement of the non-etched LP is clearly observed by its discrete energy levels and was observed up to a width of $w = 15\ \mu m$. In this paper, we developed a model for the optical confining potential to take into account the specific shape of the overgrown lithographically defined structures, which resulted in equidistant energy levels for small wire widths and parabolic energy levels for large wire widths, as confirmed by the experimental results. Furthermore, we observe condensation of MPs confined in square-like traps above the condensation excitation threshold of 12 kW/cm^2.

In conclusion, we studied the quantum confinement of microcavity polaritons by microstructures in both 2D and 3D traps, as well as the condensation of MPs in 3D traps.

Publication: Alexander S. Kuznetsov, Paul L. J. Helgers, Klaus Biermann, and Paulo V. Santos, “Quantum confinement of exciton-polaritons in a structured (Al,Ga)As microcavity”, Physical Review B 97, 195309 (2018)
https://doi.org/10.1103/PhysRevB.97.195309

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 642688.