Unidirectional photoluminescence outcoupling via surface plasmons

Alina Muravitskaya[1], **Sergei Kostcheev**[2], **Anne-Laure Baudrion**[2], **Pierre-Michel Adam**[2], **Ali Adawi**[1], **Jean-Sebastien Bouillard**[1], **Artur Movsesyan**[3]

1. Department of Physics and Mathematics, University of Hull, Cottingham Road, HU6 7RX, UK
2. Light, nanomaterials, nanotechnologies Laboratory, CNRS EMR 7004, University of Technology of Troyes, F-10004 Troyes Cedex, France
3. Department of Physics and Astronomy, Nanoscale and Quantum Phenomena Institute, Ohio University, Athens, OH 45701, USA
E-mail: a.muravitskaya@hull.ac.uk

Control of the emission directionality and intensity of quantum emitters is crucial for single-photon sources and integrated photonics. In the last two decades, surface plasmon polaritons (SPPs) found numerous applications in multiple optical elements (SPP-waveplates, mirrors, lenses, beam-splitters), and are a promising tool for controlled surface plasmon coupled emission. Emitters couple to SPPs in the near-field, latter can propagate over tens of micrometers in the visible range, and be reflected, transmitted, or scattered by surface defects or gratings. Although previous studies focused on the modification of the photoluminescence of emitters inside the plasmonic gratings,[1–3] here, we report on the unidirectional emission at controlled angle from emitters positioned outside a plasmonic array on a gold film. In this case, the emitters photoluminescence is coupled to the plasmonic array through the excitation and propagation of SPPs on the smooth underlying gold film.

A series of plasmonic nanoparticle arrays of different periods was fabricated on a continuous gold film with a 15 nm SiO_2 spacer layer (Fig. 1, inset). The whole sample was homogeneously covered with a thin layer of CdSe/ZnS quantum dots. Focused excitation of the quantum dot layer results in a localized SPP source. When the diffraction-limited excitation is positioned outside the array, the emitters couple to SPPs, which propagate on the gold film and, upon reaching the array boundary, interact with the periodicity of the structure, resulting in a directional outcoupling of the photoluminescence (Figure 1a). Using spatial filtering and Fourier space imaging techniques, we extract the angle-resolved emission diagram (k-space map) only from the plasmonic array region area and filtered the main emission spot. In this case the emission outcoupling is totally governed by the grating properties and, consequently, its polarization and outcoupling angle are directly controllable (Figure 1b). In opposition to emitters positioned inside the array, here the emission is not symmetrical, due to the selective interaction with the array SPP Bloch modes in only one direction.

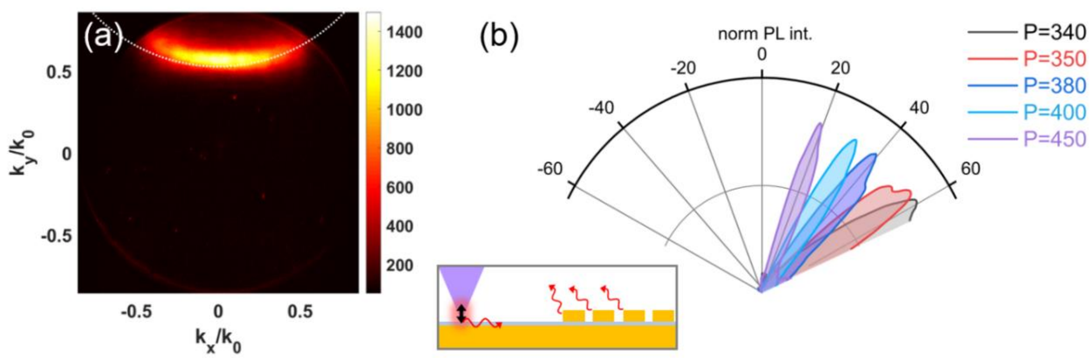

Fig. 1 (a) Filtered k-space map of emission decoupled by array (period P=380 nm) at 633 nm. (d) Angular diagram of the normalized emission from arrays of different pitches excited by the laser focused d=15 μm far from the structure for k_x=0. Inset: schematics of the structure, vertical cut.

The directional emission intensity depends on the distance between the excitation spot and array edge. Although the intensity falls exponentially, the emission pattern stays unaltered for the distances up to 30 microns. The angle-resolved photoluminescence maps had an indication of the interference pattern, in particular small oscillations in intensity and line-shape. Theoretical analysis revealed that this effect results from the interaction between the light scattered by the edge of the array and the light transmitted inside and decoupled by the grating.

In conclusion, we demonstrate unidirectional photoluminescence decoupling from a plasmonic array while the emission source is placed outside the grating at a distance from 1 to 30 microns, which is of interest for novel optoelectronic integration strategies, directional single photon sources and sensing applications.

References

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