# Lighthouse effect in a semiconductor microcavity

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The lighthouse effect consists in the continuous control of light emission by a local degree of freedom of light. Recently discovered in the field of ultrafast optics [1], it is currently used to provide state of the art attosecond pulses in ultrafast spectroscopy experiments.

Beyond ultrafast optics, the possibility to continuously control the direction of light using a passive integrated component could lead to an important breakthrough in the development of emitters, sensors or optical switches. [2]

We report on the discovery of a lighthouse effect in a double microcavity semiconductor heterostructure. [3] At low temperature (10 K), fundamental excitations of this structure, formed of quantums wells embedded in coupled distributed Bragg reflector microcavities, are exciton-polaritons. These quasi-particles are half light, half-electronic excitations and consequently interact with one another. The use of coupled microcavities allows to design the polaritonic branches [4] such that degenerate parametric scattering of polaritons created by pumping at normal incidence is possible. Consequently, this device is a degenerate parametric oscillator in which, when the OPO threshold is reached, patterns in the real and Fourier space are observed. [3] In specific experimental conditions, we have discovered that a single signal-idler beam pair is observed which is systematically emitted in the direction perpendicular to the linear polarization of the incident pump (see figure 1). We have thus demonstrated a lighthouse effect using microcavity polaritons.

Theoretical investigation show that, as a general case, a lighthouse effect cannot be obtained using a linear device (for these have polarizer-like behaviors). Moreover, a perfect azimutal lighthouse effect is possible only if the device properties are rotational invariant. In our experiment, the nonlinearity is provided by the optical parametric oscillation threshold in a degenerate and triply resonant configuration.

A simulation based on linear stability analysis provides an closer insight in the process explaining the directivity of emission. However, very general time-dependent real-space simulations for the excitonic polarization and cavity electric-field dynamics [5] fails at explaining the long-term stability of the 2-spot pattern in the experimental conditions, even when the small oscillations of the laser pump amplitude which are observed experimentally are taken into account. Investigations to fully understand the exact process at stake are in progress. A complete understanding of the precise mechanism could lead to the rise of a new class of photonic integrated components whose applications range from sensor technology to telecommunications.

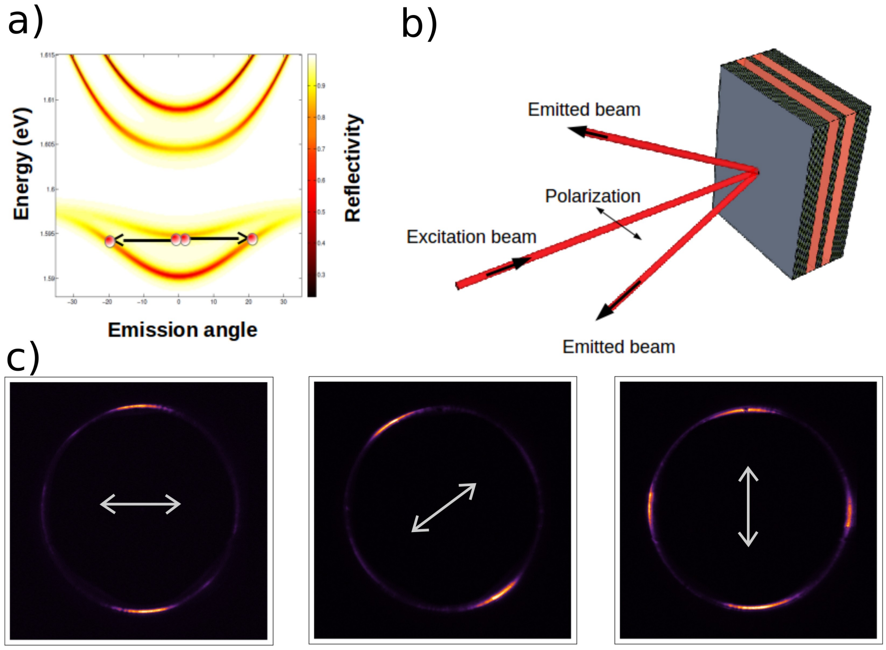


Figure 1: a)  Exciton-polariton branches dispersion and the parametric scattering process at stake, b) Schematic representation of the experimental configuration. c)  Fourier space of the emission for 3 incident linear polarizations indicated by a white arrow. The pump spot (hidden) has a 50µm diameter. A signal-idler beam pair is observed in the orthogonal direction to the incident pump polarization. In the case of a vertically-polarized excitation, an extra signal-idler beam pair is observed in tbe direction of the pump polarization, indicating that rotational invariance of the device's physical properties is imperfect. A polarization-dependent reflectivity measurement confirms this last point.

This project is supported by NSF, DFG, and $PC^2$.

[1] J.A. Wheeler et al., *Attosecond lighthouses from plasma mirrors*, Nat. Phot. 6, pp 828-832 (2012), note that in this case, the lighthouse effect is radial and the control degree of freedom is the wavefront profile.
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[5] P. Lewandowski et al, Formation and control of transverse patterns in a quantum fluid of microcavity polaritons, Proc. SPIE 8984, Ultrafast Phenomena and Nanophotonics XVIII, 89840X (March 7, 2014); doi:10.1117/12.2037174