NEW LIGHT AND MATTER ROUTER

A router is an essential device for transmitting information using electromagnetic radiation: it couples a certain amount of energy on a transmission line, allowing the signals to be used in other circuits. Researchers from the Autonomous University of Madrid have reported for the first time a device that allows doing the same with matter.

An optical microcavity is a structure formed by two highly reflective mirrors that enclose an optical medium, for example a semiconductor. Its small dimensions allow the observation of quantum effects. The coupling in these structures of electromagnetic radiation (light, photons) with charge excitations in the semiconductor (matter, excitons) gives rise to new particles, called polaritons.

Polaritons share properties of their constituents, such as the ability to interact with each other (practically absent in photons), providing extraordinary opportunities for the control and manipulation of light.

An international collaboration led by the Autonomous University of Madrid (UAM), in which the universities of Würzburg and Jena (Germany), Saint Petersburg (Russia), Saint Andrews (UK) and Reykjavik (Iceland) participate, has built microcavity wave guides where polaritons propagate, achieving the transfer of particles between two arms of a router.

This is the first demonstration of a device that allows the redirection of matter, similar to what is routinely done today with light. It is a pioneering work that paves the way to manipulate matter and obtain new devices totally based on polaritons; such as lasers, logic gates, transistors and integrated circuits, with features that even today are difficult to imagine.

Quantum routers

Electromagnetic radiation routers are widely used in our environment and have very diverse applications, such as providing sampling signals for evaluation, feedback, combination of power supplies to and from antennas, provision of connections for distributed cable systems such as TV and separation of transmitted and received signals on telephone lines.

At a more sophisticated stage, semiconductor photonic circuits, in particular GaAs-based directional couplers, are being developed to realize integrated photonics at the quantum level and manipulate single-photon or entangled photon states, key elements for quantum photonics technologies.

The work, published in Advanced Optical Materials, required overcoming a large number of technical and scientific challenges: from the fabrication of the microcavities by molecular beam epitaxy and the etching to sculpt the waveguides by means of reactive ions, maintaining the high optical quality of the materials, up to the experimental measurements, which literally require the realization of videos with a resolution of picoseconds (a picosecond is one billionth of a second, 1 ps = 10^{-12} s) and the simulation of the results, to understand the experiments and the influence of the different parameters involved (width and length of the guides, injection energy and propagation of the polaritons, interference phenomena, etc.).

To understand the difficulties to be faced, it is enough to consider, for example, that the separation between the arms of the device in its coupling region is only 1.5 μm (1 μm is one millionth of a meter, 10^{-6} m), that is to say one-tenth of the thickness of a very fine human hair (15 μm), keeping in the engraving process the quality of the semiconductors and, above all, of their surface regions so that the propagation of the polaritons and their coupling can be carried out.

The experimental measurements also required a high level of sophistication, using high vacuum conditions, low temperatures close to absolute zero (10 K), lasers that provide pulses of 2 ps duration and detectors that allow filming with high temporal resolution, simultaneously recording the location of polaritons in space, their speeds, as well as their energy of propagation.

The work, which has been featured in Advanced Optical Materials, was funded by the MINECO project MAT2017-83722-R and is signed by UAM researchers Elena Rozas, Dolores Martín and Luis Viña.

Bibliographic reference:

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