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Photonic crystals: Surface effects

Photonic crystals are of intense interest for their ability to modify the properties of light. Now, Kenji Ishizaki and Susumu Noda at Kyoto University[1] introduce an entirely new field of photonic crystal research by demonstrating the use of the surface — not the volume — of photonic crystals for novel schemes of light–matter interaction.

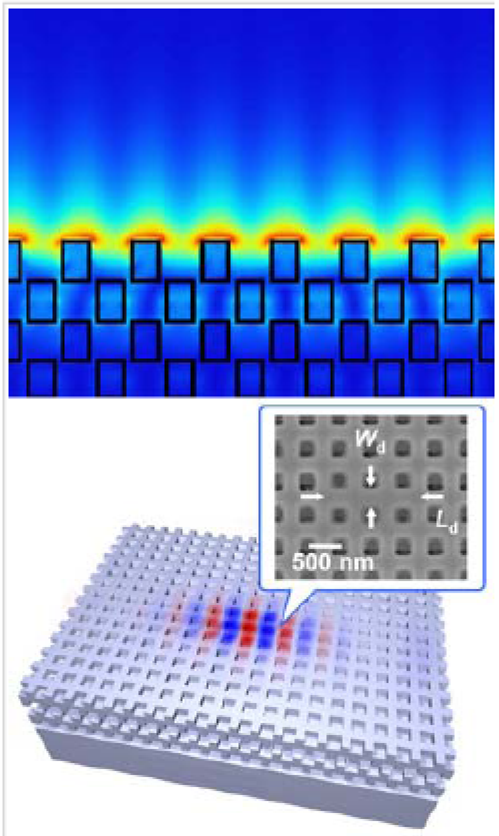

Fig. 1: Surface modes of photonic crystals. (Upper) Calculated distribution of photonic surface modes in a photonic crystal (black squares). (Lower) Concentration of light by a defect on the surface. The light mode is depicted in blue and red.

Photonic crystals are highly periodic structures, except for their surfaces, which break their otherwise perfect symmetry. Hence, light modes at the surface of a photonic crystal can show very different behavior compared to that in the interior of the crystal. According to Noda, the systematic use of surface modes "could lead to photonic circuits with various advanced functions that can be implemented on the surface of 3D photonic crystals, for example in chemical sensing."

The researchers fabricated a three-dimensional (3D) photonic crystal consisting of a stack of eight layers of gallium arsenide (Fig. 1). Light was coupled into the photonic surface states through a prism. At matching frequencies, the light propagated along the surface of the photonic crystal for up to 385 μm.

Pre-designed defects in the periodicity of the photonic crystal surface produced the spatial localization of photons. The quality factor, which is a metric of the efficiency of the trapping of light at the defects, was significantly higher than that for surface plasmons — a conceptually related approach using metal surfaces and electronic excitations. Such highly resonant defect structures could find applications in areas such as chemical sensing.

The large quality factor is the result of a fundamental advantage of photonic crystals over schemes such as surface plasmons. Unlike true crystalline materials, photonic crystals do not absorb significant amounts of light, greatly reducing losses. This is also why the surface modes have such long propagation lengths.

Based on their pioneering demonstration, Noda is clear about the road map for further improvements. "First, we will increase the number of stacked layers to improve the quality of the photonic crystals and to further reduce losses. Then we can work on more complex schemes, such as photonic circuits on the surface of these crystals."

Reference

1. Ishizaki, K. & Noda, S.* Manipulation of photons at the surface of three-dimensional photonic crystals. *Nature* **460**, 367 (2009). | article

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This research highlight has been approved by the author of the original article and all empirical data contained within has been provided by said author.

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