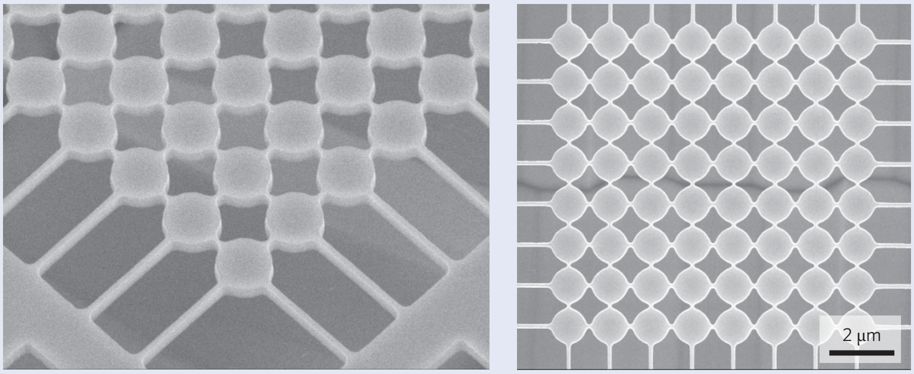
FUNDAMENTAL OPTICS

Photonic bound states

Bound states in the continuum (BICs) are counterintuitive eigenmodes of a system that exist within a continuous spectral range where energy leaks out of the system, but they themselves are localized resonances that do not decay. BICs are a general wave phenomenon and have been reported in a range of environments including acoustic waves in air, water waves, elastic waves in solids and also electromagnetic waves.

So far, experimental observations of BICs have been limited to passive systems and the realization of BIC lasers has remained elusive. Now, Ashok Kodigala and co-workers at the University of California San Diego, USA have reported lasing action from an optically pumped BIC cavity (pictured) at room temperature (*Nature* **541,** 196–199; 2017).



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The BIC cavity had a four-fold symmetry and was composed of a periodic array of semiconductor cylindrical nanoresonators ($In_xGa_{1-x}As_yP_{1-y}$ multiple quantum wells that exhibit optical gain around the telecommunication wavelength of λ = 1.55 μm) suspended in air. The nanoresonators were interconnected by a network of supporting bridges to ensure the mechanical stability of the system. The structure was fabricated using electron-beam lithography and reactive ion etching to define the cylindrical nanoresonators, followed by a wet etching step to create the membrane. The period of the structure and the thickness of the nanoresonators were 1.2 μm and 300 nm, respectively.

The system was modelled using a three-dimensional finite-element-method eigenfrequency solver. Three modes with appreciable quality factors, one doubly degenerate mode (modes 1 and 2) and one singly degenerate mode (mode 3) were discovered. The quality factor of modes 1 and 2 depended strongly on the radius of the nanoresonators and reached a maximum at an optimum radius of 528.4 nm. At this optimum radius, modes 1 and 2 completely decouple from the radiation continuum and thus became so-called resonance-trapped BICs. It should be noted that modes 1 and 2 were much less sensitive to symmetry-breaking perturbations than mode 3. "This is of utmost importance in device design as fabrication tolerance will have less impact on resonance-trapped BICs than on modes that rely on symmetry protection," commented Kodigala.

The lasing action from the BIC cavity was experimentally observed at room temperature. The BIC cavity was excited by a pump laser (λ = 1.064 μm, pulse duration of 12 ns) and spectral emission was recorded as a function of both the pump power and the radius of the nanoresonators. Lasing action occurred at a wavelength of 1.5514 μm with a detection-limited linewidth of about 0.33 nm. As theoretically predicted, the threshold power became minimum close to the optimum radius of 528.4 nm. The corresponding threshold power was 56 μW.

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