Novel Cavities: Bound States in the Continuum in Dielectric Resonators

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In the last 10 years, an intense research effort has been devoted to bringing all-optical signal generation and processing on chip to realize true photonic integrated circuits (PICs). Cavities are an essential building block of PICs because they provide enhanced light-matter interaction. Currently, the most mature platform is silicon on insulator (SOI), which is used in cavities such as ring resonators and photonic crystal defect resonators. We explore a new type of cavity, compatible with SOI, based on bound states in the continuum (BICs) and demonstrate it experimentally.

In 1929, Von Neumann and Wigner showed theoretically that certain quantum potentials can surprisingly have bound states above the continuum threshold. States above threshold usually acquire a finite lifetime through tunneling and become quasi-bound states or resonances. However, it is possible for certain peculiar resonances to achieve an infinite lifetime, they do not decay at all even in the presence of open decay channels. In 1985, Friedrich and Wintgen showed that BICs could be interpreted as resonance trapping. In this picture, two resonances interfere and one traps the other turning it effectively into a bound state. BICs are essentially a wave phenomenon and also appear in electromagnetics. As a proof of concept, we have designed and measured a BIC in the microwave range using a periodic metasurface.

BICs are intrinsically sensitive to perturbations because they result from perfectly destructive interferences and, as such, exist only at a single point in phase space. This is very useful for sensing applications but detrimental for most others. To obtain an extended BIC, we designed a system with two quasi-degenerate BICs. We achieved this by considering a unit cell with two resonators, a disk and a ring. Odd modes of the disk resonator interfere and lead to one BIC and even modes of the ring resonator interfere and lead to another BIC. As a result, there is an extended region of phase space where the quality factor tends to infinity. Experimentally, we use ceramic resonators of high-permittivity (ε_r=43) and, to limit the fabrication dispersion inherent to a large array, we made the measurements in a rectangular metallic waveguide (X-band, 8.2-12.4 GHz). It is possible because such a guided setup is equivalent to an infinite array at oblique incidence as shown by image theory. We explored phase space along a line, by varying the inner radius of the ring resonator, and showed the presence of two avoided resonance crossings (ARCs). ARCs occur when two modes interfere and are a signature of BICs (T. Lepetit and B. Kanté, Phys. Rev. B, 90, 241103(R), 2014).

Dielectric resonators can be made at optical frequencies on a SOI platform and BICs are thus amenable to transfer at the nanoscale. This novel concept provides new avenues of investigation for footprint reduction of cavity-based devices.