The capacity to localize light into a small region of space is of paramount importance in many areas of modern science. We developed a mechanism to store a quantized ‘bit’ of light — with a very precise amount of energy — in an open core–shell plasmonic structure with a nonlinear optical response. Notwithstanding the trapped light state is embedded in the radiation continuum, its lifetime is not limited by the radiation loss.

**GENERAL MOTIVATION AND OBJECTIVES**

The natural modes of oscillation of a physical system can be usually split into two categories: the bound modes — which form the discrete spectrum — and the extended modes — which form the continuous spectrum. Usually the discrete and the continuous spectra do not overlap. For example, the allowed energy levels of the hydrogen atom are split into two disjoint subsets: the discrete negative energies (bound states) and the continuous positive energies (free-electron states). Having a spatially localized state in a spectral region where the modes are inherently delocalized is contrary to common sense. Surprisingly, it was shown by John von Neumann and Eugene Wigner in 1929 that bound states embedded in the continuum are technically known as embedded eigenstates — are really allowed within the framework of the usual wave theories.

**CHALLENGE**

The confinement of light into a small space region may enable a variety of breakthroughs such as all-optical memories. Therefore, it is interesting to extend the concept of ‘embedded eigenstate’ to optics. Until recently all the known configurations to localize light in the radiation continuum with infinite lifetime required infinitely extended material structures. Indeed, light is an object difficult to tame. No matter how elaborate and intricate are the material constructions that may be elaborated and intricate are the material constructions that may be used to screen it from the exterior environment, there is always some residual coupling with the radiation continuum, and hence light — not absorbed by the material walls — always finds its way out.

**WORK DESCRIPTION AND ACHIEVEMENTS**

We introduced a novel approach to trap light in a bounded open cavity with suppressed radiation loss. Under some strict conditions, plasmons — that is, charge density waves in metals — may enable the formation of embedded eigenvalue states in finite sized cavities. The light trapping can be attained with a two-layer spherical structure designated by ‘meta-atom’ (Fig. 1 left). The meta-atom shell is ideally formed by a plasmonic material with vanishing permittivity and the core is a regular dielectric. The trick to let the incoming light in the meta-atom but to not fly afterwards relies on a nonlinear effect that squeezes the light wavelength in the core until it reaches a critical value for which the light is perfectly screened by the plasmons. Furthermore, in the same manner as the energy levels of regular atoms are quantized, the amount of energy trapped in the meta-atom has a very precise value. The optical meta-atom can trap a light ‘bit’ when illuminated by an incoming light pulse (Fig. 1, right), for a time limited only by the effects of material absorption. In practice, the loss effects can be compensated with a gain element similar to what is used in lasers. It is envisioned that with such a strategy the meta-atom may function as a basic one-bit optical memory. We partially validated some of the proposed ideas at micro frequencies. Specifically, we designed, fabricated and tested an edge resonator formed by the interface of a waveguide region that behaves effectively as a regular dielectric with vanishing permittivity, and a waveguide region that emulates the response of a plasmonic material with negative permittivity. Interestingly, the proposed open resonator supports highly confined plasmonic-type resonances (Fig. 2). It is expected that this pioneering study may pave the way for a future demonstration of a fully operational meta-atom at microwave frequencies.