Self-hybridization within non-Hermitian localized plasmonic systems

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In any situation described by a Hermitian equation (mechanics, acoustics, quantum mechanics, electromagnetism), the usual approach in linear physics is to apply the concept of eigenmodes. However, many systems of importance are not Hermitian, but nevertheless can be advantageously described in terms of eigenmodes. A first class consists in open systems, for which energy is dissipated at infinity e.g. lasers cavities or propagating surface plasmons. A second class is represented by LSPs. In this case, the structure of the constituting equation is non-symmetric. Nevertheless, a complete basis of eigenmodes can be deduced by using the concept of quasi-normal modes (QNM). For these two classes of problems, the price to pay to get an eigen-decomposition is that the basis is bi-orthogonal instead of being orthogonal. Bi-orthogonality has a few famous and exciting consequences, including the existence of "exceptional points" (EP) where both the energy and wavefunctions coalesce. However, as we will see further, LSPs present non-Hermiticity beyond any dissipation consideration. They therefore constitute an ideal platform to explore this recently booming field of research.

Interestingly, bi-orthogonality enables eigenmodes of different orders within a single particle to interact. This phenomenon of self-hybridization is particularly non-intuitive because eigenmodes of a system are usually not overlapping and therefore unable to interact. It would correspond for example to the hybridization between s and p orbitals within a single atom, and not between two atoms. In a recent paper [1] and using e-beam lithography combined with electron energy loss spectroscopy (EELS), we experimentally demonstrated self-hybridization within a silver cross when the length of one arm is tuned (see figure 1).

In this conference, we will theoretically and numerically describe the physics of plasmonic bi-orthogonality. We will show that one can draw an analogy between the plasmonic eigenproblem and the physics of open quantum systems. We will detail the conditions to achieve a plasmonic self-hybridization and give experimental examples.

[1] Lourenco-Martins et al., Nature Physics 89, 2017

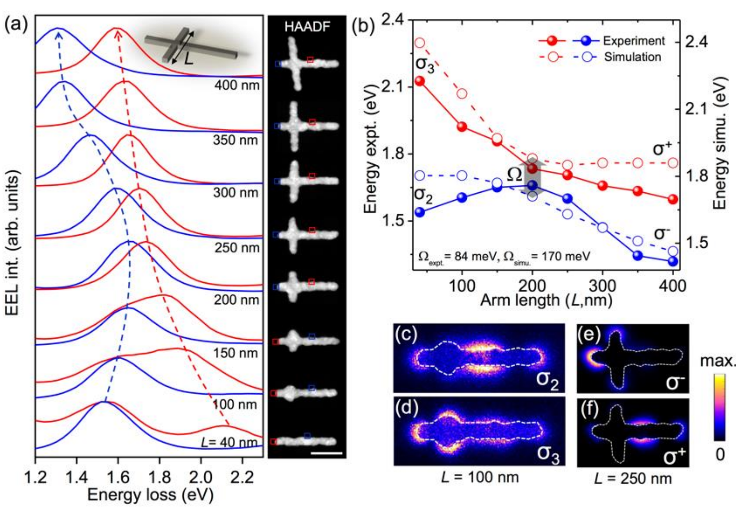

Figure 1. (a) EELS spectra for different crosses (see dark field image in inset, scale bar is 200 nm) taken at positions indicated by blue and red squares. (b) Experimental and simulated energy of the modes in a) as a function of the arm length L. Experimental energies have been deduced by Gaussian fit. (c-d) EELS filtered maps measured at energies corresponding to an uncoupled case for L= 100 nm. (e-f) EELS fitted maps for the coupled case at L = 250 nm