Mode Hybridization in Bianisotropic Waveguides

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In metamaterials, the most general description of material properties is bianisotropic constitutive relation, which governs material response to the electromagnetic fields, as well as the cross terms, i.e., magnetic (electric) dipoles induced by the incident electric (magnetic) field. Conventionally, the cross terms are hidden in the higher order spatial derivatives of the electric polarization since there is an ambiguity of splitting the induced current into polarization and magnetization in the macroscopic electromagnetics. However, by properly selecting the 'gauge field' for the polarization and magnetization, one is able to treat electric and magnetic fields on the same footing, thus be able to employ the duality between electric and magnetic field to simplify the analysis significantly. One might expect exotic behavior of light, or novel photonic devices may exist, due to the extra degree of freedom from material, i.e., the electromagnetic coupling in constituent units or the building blocks.

Here the speaker and his research group study the mode hybridization in bianisotropic waveguide, particularly the mode properties of bianisotropic waveguides with a special emphasis on how the guided x- and y-polarized modes are impacted by bianisotropy. Firstly, for the simplest case corresponding to one special type of bianisotropy, where the x- and y-polarized modes are decoupled, the speaker and his research group find that the bianisotropy turns a mode of undesired polarization from the degenerate pair into leaky mode and leaves the other one unchanged. Secondly, for the coupled cases, corresponding to another special type of bianisotropy, the speaker and his research group find that bianisotropic waveguides can serve as defective systems in which two linearly polarized modes coupled together but with asymmetric coupling strength. By turning the coupling strength and the energy differences between the two modes, it is found that there exists an abrupt phase transition from a real spectrum to a complex spectrum, exactly like what has been investigated intensely in systems with PT-symmetric Hamiltonians. A model based coupled mode theory is developed to explain these phenomenons.