Chiral metamaterials with Parity-Time symmetry

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The concept of Parity-Time (PT) symmetry, which was first introduced in connection with quantum physics [1], denoting systems with Hamiltonian commuting with the product of Parity and Time operators (such Hamiltonian although non-Hermitian has the potential to present real eigenvalues), was quite soon transferred to optics; in optics, PT-symmetric systems are offered for a relatively easy practical realization, by properly combining loss and gain media. The realization of PT-symmetric optical systems allowed the demonstration, even experimentally, of a variety of novel and interesting phenomena, including unidirectional invisibility, loss-induced transparency, simultaneous coherent perfect absorption and lasing, etc. [2,3]

Many of the above mentioned phenomena were observed by combing the PT-symmetry concept with metamaterials, i.e. artificially structured materials with uncommon electromagnetic properties, e.g. permittivity and/or permeability of very large, near zero or negative values. Such a combination seems quite promising in terms of novel phenomena and associated possibilities for electromagnetic wave control.

In the work discussed here we investigated a category of metamaterials which are highly unexplored in connection with PT-symmetry, that of chiral metamaterials [4], i.e. metamaterias in which the structure can not be superimposed with its mirror image with translations and rotations. (Chiral metamaterials, due to the large optical activity and circular dichroism that can present, show advanced possibilities for wave polarization control.) What we examined, in particular, are: (a) the possibility to combine chirality and PT-symmetry, which was not clear taking into account the currently known and reported required conditions, (b) the material parameter conditions necessary to achieve PT-symmetry in chiral media, and (c) the unique physical phenomena that become possible in PT-symmetric chiral systems. We found that such phenomena not only include all the effects that are possible in non-chiral PT-symmetric systems but also can combine those phenomena with waves of arbitrary polarization, from linear to circular. Moreover, direction dependent polarization and propagation effects were observed, which empower PT-symmetric chiral metamaterials with unique power in the wave propagation and polarization control.

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