Dispersion coding of ENZ media via multiple photonic dopants

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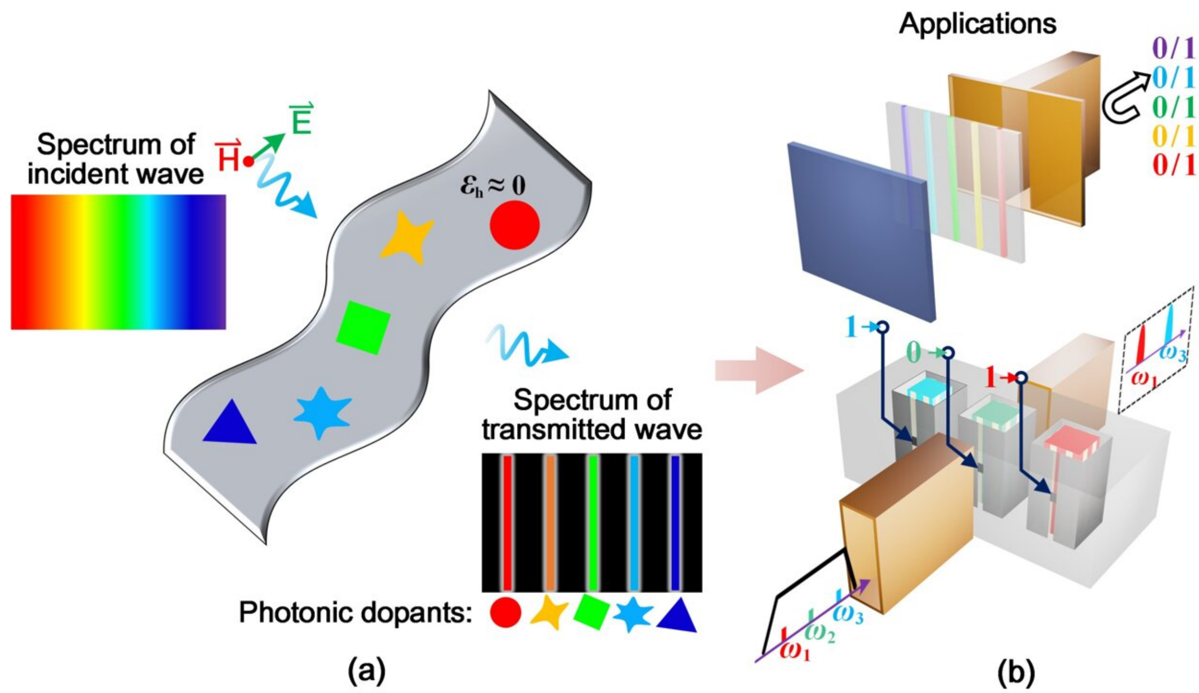

(a) Conceptual sketch of dispersion coding for the ENZ medium, where multiple arbitrarily-located dielectric dopants in an ENZ host act as noninteracting resonators to modulate the light at their individual resonant frequencies. (b) Applications of the dispersion coding including radio-frequency tagging and multi-frequency dynamic filtering. Credit: Ziheng Zhou et al

Media with small permittivity, i.e., the epsilon-near-zero (ENZ) media, have drawn a great deal of attention from the fields of physics, materials science, and engineering. The wavelength in ENZ medium is in principle infinitely stretched, which induces spatially static while temporally oscillating wave dynamics.

There has long been a drive to attain the flexible manipulation of ENZ media and create real-world applications. Recent years have seen the rise of metamaterials, where researchers use periodically-arranged artificial units or resonators to control the effective constitutive parameters of the composite medium. However, it remains a mystery how an ENZ medium comprising multiple resonators would behave, and how those resonators interact through the ENZ background.

In a paper newly published in *Light: Science & Applications*, a team of scientists, led by Professor Yue Li from Department of Electronic Engineering, Tsinghua University, China, joining forces with the Public University of Navarre, Spain, and the University of Pennsylvania, U.S., revealed an exotic phenomenon in ENZ media.

They demonstrated that multiple densely-packed dielectric rods, named photonic dopants, can offer noninteracting resonant modes while still being coupled to the external environment. The behavior of these "noninteracting resonators" was counterintuitive and it contrasted with that of conventional microwave and optical resonators. Both the theory and experiments showed that ENZ medium comprising multiple dielectric dopants can exhibit a "comb-shaped" dispersion of the effective permeability function, and, remarkably, each "tick" in the frequency comb could be associated with one specific dopant and can be altered independently.

The scientists proposed the technique of dispersion coding for ENZ media. By choosing the presence or absence of each dielectric dopant, one can independently control the responses of the ENZ medium at a series of frequencies. The scientists presented two interesting applications of the dispersion coding.

The first is the optical tagging where different combinations of dielectric dopants can represent different information series, and the second is a digitally reconfigurable comb-profiled filter. The scientists summarize the key points of the technique of dispersion coding for ENZ media:

"(1) As an important difference from the periodic metamaterials, the effective parameter (effective permeability) of the doped ENZ medium is entirely determined by the characteristics of the unit cells, i.e., the dielectric dopants, and not by their positions. (2) The contributions from the noninteracting dielectric dopants to the whole ENZ medium are additive, which substantially simplify the design of artificial composite materials."

"In the future, the technique of dispersion coding can be used for the muti-frequency analog signal processing in terahertz and even optical regimes. Since the shape of ENZ media as well as the spatial arrangement of dielectric dopants have no influence on the effect of dispersion coding, one is able to realize ultra-compact and highly-integrated devices for the high-frequency signal processing and filtering," the scientists said.

More information: Ziheng Zhou et al, Dispersion coding of ENZ media via multiple photonic dopants, *Light: Science & Applications* (2022). DOI: 10.1038/s41377-022-00892-8

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