Amorphous photonic lattices: disorder, band gaps, and effective mass

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Abstract:

Conventional intuition in solid state physics holds that, in order for a solid to have an electronic band gap, it must be periodic, allowing the use of Blochs theorem. Indeed, the free-electron approximation implies that Bragg scattering in periodic potentials is a necessary condition for the formation of a band gap [1]. But this is obviously untrue: looking through a window reveals that glassy silica (SiO_2), although possessing no order at all, still displays a band gap spanning the entire photon energy range of visible light, without absorption. In our presentation, we present the first experimental study of amorphous photonic lattices: a 2D array of randomly-organized evanescently-coupled waveguides (Fig. 1a). We will demonstrate that the bands in this medium, comprising of inherently localized Anderson states [2], are separated by gaps, despite the total lack of Bragg scattering (Fig. 1b). Further, amorphous photonic lattices support the existence of strongly localized defect states, whose widths is much narrower than the Anderson localization length (ensemble average over transport via the Anderson states comprising the bands), as shown in Fig. 1c. Finally, we prove the existence of a region of negative effective mass (anomalous diffraction). Superimposing a weak spatial modulation on the random potential (refractive index) causes a wavepacket with a negative effective mass to move opposite to the direction it would have moved had it had positive effective mass.

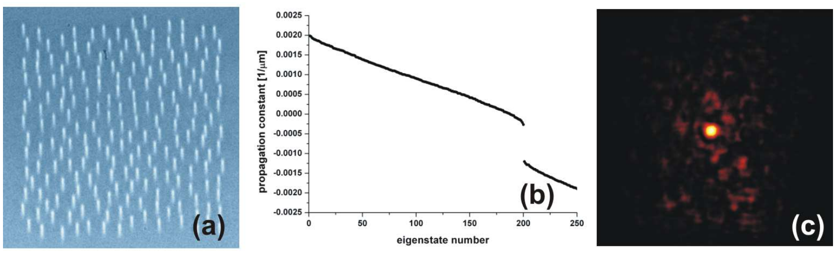

Fig. 1: (a) Microscope image of the front facet of an amorphous waveguide lattice. (b) Eigen spectrum of this lattice, showing a clear band gap. (c) A highly localized defect state, residing in this gap.

References:

1. N. Ashcroft and D. Mermin, *Solid State Physics.* Brooks Cole, USA (1976).
2. T. Schwartz et al., Nature **446**, 52 (2007).