Subwavelength Imaging in Photonic Crystals

- Amplification of near-field without negative refractive index
- Interplay between propagating and evanescent waves

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How to amplify evanescent waves *in general*?

Consider first one frequency and one incident wavevector.

The poles of transmission are bound photon states, from which two mechanisms of amplification can be deduced.

1). Resonance to bound states on a single interface leads to exponentially large transmission (Pendry 2000).

2). Resonance to bound states in a slab gives *infinite* (arbitrarily large) transmission.

In a negative-index slab with $\varepsilon=-1$ and $\mu=-1$, 1) holds true for *every* evanescent wave, and 2) is *completely absent*.

However, 2) is easier to realize than 1) in photonic crystals.
Amplification of evanescent waves at one frequency

Bound photon states can exist in a continuous range of wavevectors in a slab of photonic crystal, with carefully tuned $|\omega - \omega_0(k)|$
Computed bound photon spectrum in a model crystal
Interplay between propagating and evanescent waves (1)

moderate subwavelength limit

(a) \( \omega = 0.193 \ (2\pi c/a) \)

(b) 

(c) 

(d)
Interplay between propagating and evanescent waves (2)

extreme subwavelength limit

(a) \( \omega = 0.191 (2\pi c/a) \)

(b) 

(c) 

(d)
Interplay between propagating and evanescent waves (3)

enhanced surface resonance limit
Different regimes of interplay on the band structure

- Moderate subwavelength
- Enhanced surface resonance
- Extreme subwavelength
Conclusions

1). Subwavelength imaging is possible in general, and superlenses and can be constructed based on photonic crystals. The theoretical limit of the resolution of such devices is the crystal surface periodicity, rather than the wavelength.

2). The appearance of the image of a superlens differs greatly from that of a conventional lens and depends extremely sensitively on the bound photon bands. Various effects of interplay between propagating and evanescent waves can be realized within a single photonic-crystal system.