Nanoparticle-derived All-dielectric Metamaterial Superlens

Bing Yan[1], **Wen Fan**[2], **Liyang Yue**[1], **Zengbo Wang**[1], **and Limin Wu**[2]

[1]School of Electronic Engineering, Bangor University, Bangor LL57 1UT, United Kingdom
[2]Department of Materials Science, Fudan University, Shanghai 200433, China

Abstract— We propose and demonstrate a new class of all-dielectric metamaterial superlens constructed from 3D assembly of high-index nanoparticles (TiO_2, ZrO_2, Si). The fundamental physics lies in the unusual high efficiency of direct conversion of evanescent waves into propagation waves by the composite media. In Figure 1(a) 3D full wave FDTD simulation was presented for a conventional homogenous material slab and a composite metamaterial slab made from the proposed concept. The simulation reveals that evanescent wave decays quickly from source in homogenous media (Fig. 1(c)) but can be effectively converted into propagating wave in nanoparticle-formed slab. The underlying science originates from evanescent wave scattering by nanoparticles, which behaves quite differently from the case of propagating (e.g., plane) wave scattering by nanoparticles. Many interesting physics awaits discovery in such dense scattering media. We performed simulation for super-resolution imaging and discovered the nanoparticle slab and perform as a super-resolution lens (superlens) which can resolve point sources separated by 45 nm (See Figs. (c)–(f)), i.e., 45 nm resolution. The resolution limit can be further pushed by using other nanoparticles, with higher index and engineered shapes.

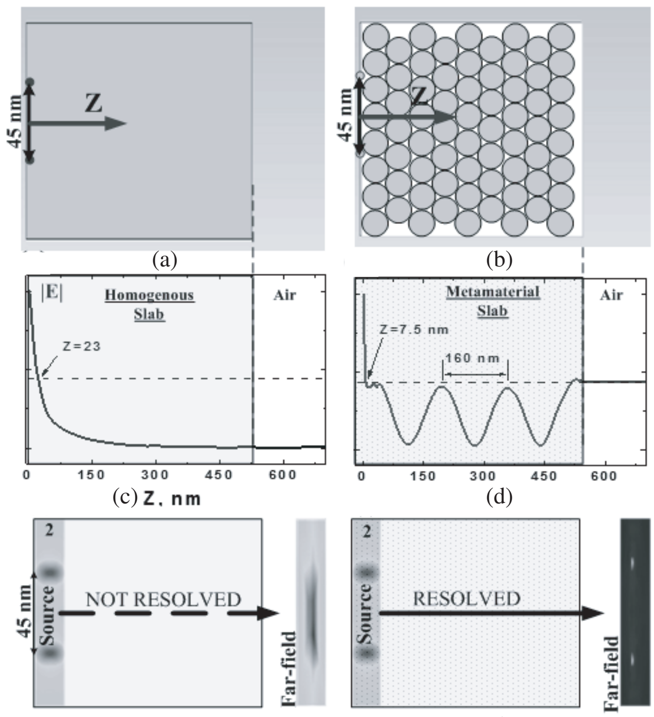

Figure 1: Novel concept. (a) Conventional material slab vs (b) nanoparticle metamaterial slab derived from high-index nanospheres, imaging performance evaluated using point sources separated 45 nm. (c) In homogenous material, the amplitude of evanescent waves of point sources decays exponentially. Most energy lost within first 50 nm distance from sources. (d) However, in nanoparticle artificial medium, evanescent waves interact with nanoparticles and turn into propagation waves which travel outward to far-field. A periodicity of 160 nm was observed; the periodic wave is a signature of propagating waves (e)–(f) two point sources cannot be resolved by conventional slab but successfully resolved by the new artificial medium. (Wavelength 550 nm, particle diameter 15 nm, refractive index: 2.55).

Experimental evidences on the proposal will be given during the presentation. Our work provides a new route to design novel functionality metamaterials for super-resolution applications.