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## **Novel phenomena in nano-photonic systems of macroscopic sizes**

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### **ABSTRACT**

Nanophotonic techniques can enable numerous novel and exciting phenomena. However, in order to make use of these opportunities for many applications of interest (e.g. energy, or displays), one has to have the ability to implement nanophotonic structures over large scales. In this talk, I will present some of our recent theoretical and experimental progress in exploring these opportunities.

**Keywords:** Photonic Crystals, Nanoparticles

### **1. INTRODUCTION**

Transparent displays can be useful for applications ranging from advertising, storefront window displays, car windshield or aircraft cockpit window displays, to window showcases and visual arts. However, such a technology has not become widespread because existing solutions are limited. Using nanoparticles with wavelength-selective scattering of light, we created a new type of transparent display. We design nanoparticles that interact only with light of a targeted wavelength, and embed these nanoparticles into a transparent thin film. The ambient light consists of a broad spectrum of wavelengths, most of which do not interact with the nanoparticles; therefore, the thin film is mostly transparent to the ambient light. However, this transparent thin film can act as the screen of our display system, because we can display images or videos on this thin film by projecting light of the targeted wavelength from a laser projector or a LED projector with a wavelength matching the resonance wavelength of the nanoparticles.

### **2. TRANSPARENT DISPLAYS ENABLED BY RESONANT NANOPARTICLE SCATTERING**

To demonstrate the concept described above, we construct a blue-color transparent display made of silver nanoparticles embedded in a polymer film. A picture of this demonstration is shown in Figure 1. This approach has several advantages including wide viewing-angle, low cost, scalable to large areas, compatible with existing commercial projectors, and ease of setting up and applying to glass surfaces.

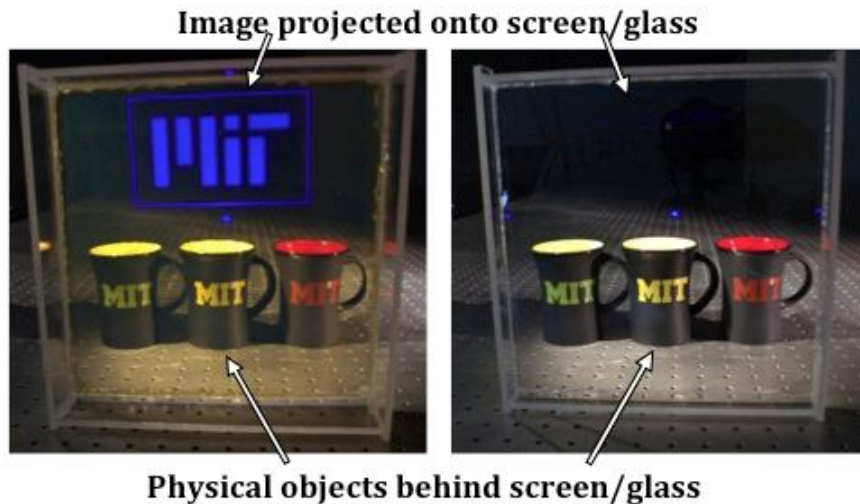


Figure 1: Demonstration of the new transparent display. Photographs showing a sample transparent projection screen (left) and a regular piece of glass (right). Three cups are placed behind both screens to visually compare the transparency. A laser projector projects a blue MIT logo onto the transparent screen and the glass; the logo shows up clearly on the transparent screen, but not on the regular glass.

### 3. SCATTERING DARK STATES IN NANOSTRUCTURED PARTICLES

Nanostructures with multiple resonances can exhibit a suppressed or even completely eliminated scattering of light. This is called a scattering dark state. We describe this phenomenon with a general treatment of light scattering from a multiresonant nanostructure that is spherical or nonspherical but subwavelength in size. Using temporal coupled-mode theory<sup>1</sup>, we find that when multiple resonances are in the same channel (i.e., same angular momentum and polarization), coherent interference always leads to scattering dark states in the low-absorption limit. This universal result is independent of system details such as the radiative decay rates, method of coupling, nature of the resonances, number of resonances, and the multipole involved. The coupling between resonances is inevitable and can be interpreted as arising from far-field or near-field. This is a realization of coupled-resonator-induced transparency in the context of light scattering, which is related to but different from Fano resonances. We provide explicit examples with numerical simulations; one such example is shown in Figure 2. Such scattering dark states can have various potential applications including wavelength-selective transmission, slow light, and the transparent resonant scattering screen mentioned above.

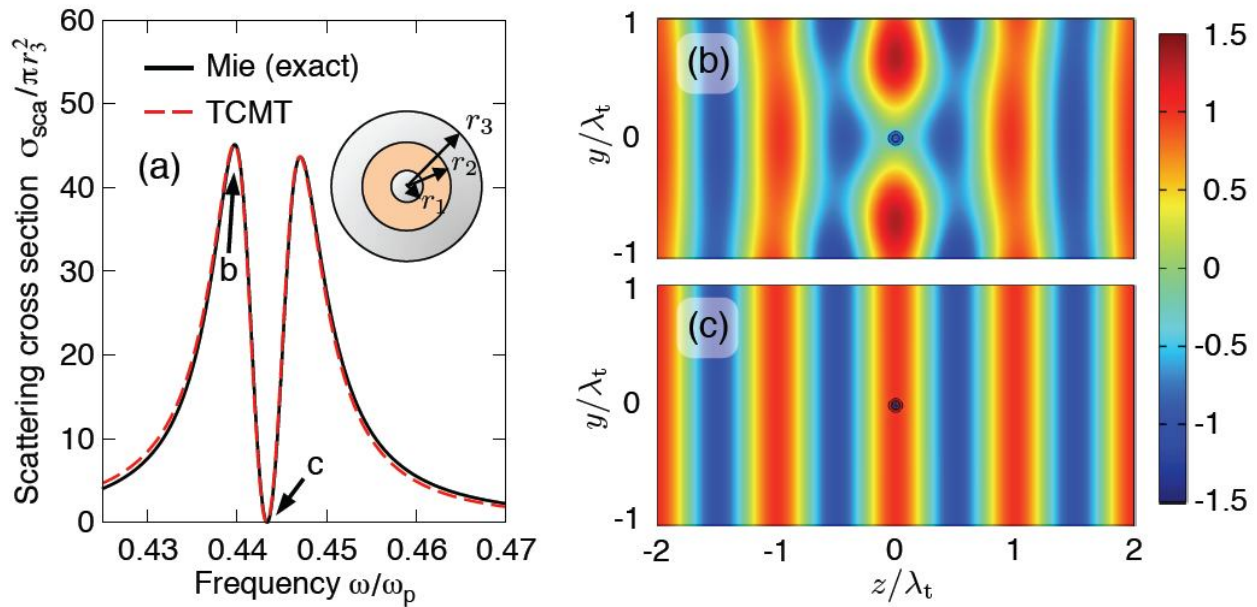


Figure 2: Scattering dark state in a doubly resonant nanosphere without absorption loss. (a) The particle's scattering cross section in air, calculated by the Mie solution (black solid line) and the temporal coupled-mode theory (red dashed line). The inset schematically shows the particle's composition: concentric metallic core, silica spacer, and metallic shell. The metal is described by the Drude model with plasma frequency  $\omega_p$  and negligible damping. (b,c) Steady-state electric-field pattern with an incident planewave that is (b) at the resonant frequency and (c) at the transparency frequency.

## REFERENCES

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