Light-matter interaction can turn opaque materials transparent

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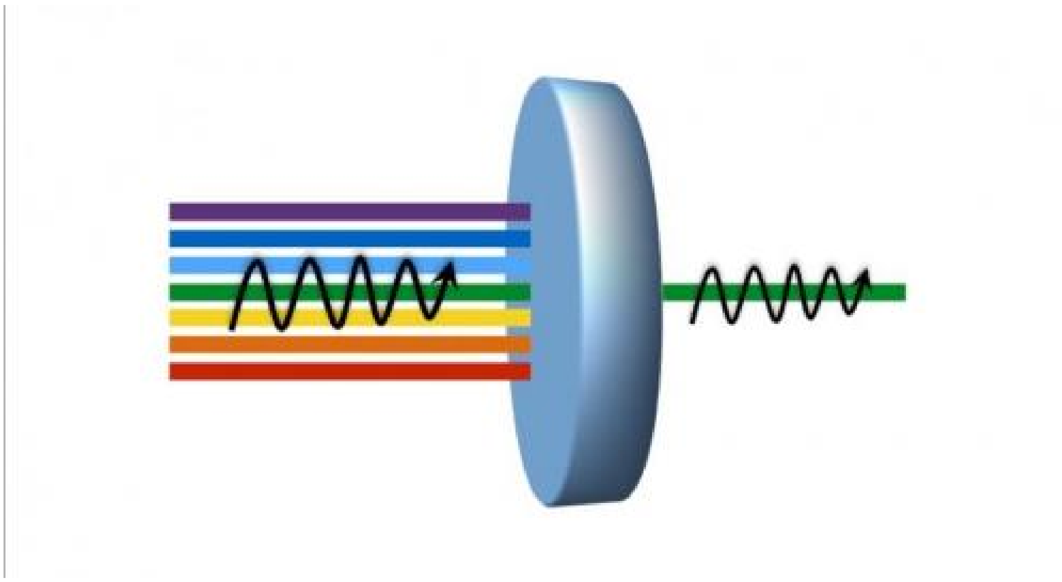

Illustration of a thin, dense vapor of quantum emitters (blue disk) interacting with an incident electromagnetic field. Physicists have shown that strong dipole-dipole interactions in the quantum emitters can be used to manipulate the light scattering and turn opaque objects transparent. Credit: Puthumpally-Joseph, et al. ©2014 American Physical Society

(Phys.org) —All objects' colors are determined by the way that light scatters off of them. By manipulating the light scattering, scientists can control the wavelengths at which light is transmitted and reflected by objects, changing their appearance.

In a new study published in *Physical Review Letters*, researchers have developed a new method for manipulating light scattering. They theoretically show how to induce transparency in otherwise opaque materials using the complex dipole-dipole interactions present in a large number of interacting quantum emitters, such as atoms or molecules. This ability could have several potential applications, such as producing slow light or stopped light, along with applications in the field of attosecond physics.

"The significance of our work is in the discovery of a very neat phenomenon (dipole-induced electromagnetic transparency [DIET]), which may be used to control light propagation in optically active media," coauthor Eric Charron, Professor at the University of Paris-Sud in Orsay, France, told *Phys.org*. "We showed how light scattering by a nanometric size system, collectively responding through strongly coupled two-level atoms/molecules, can be manipulated by altering the material parameters: an otherwise opaque medium can be rendered transparent at any given frequency, by adequately adjusting the relative densities of the atoms/molecules composing it."

As the scientists explain, light scattering is very well understood when dealing with individual quantum emitters; that is, single atoms or molecules. But the physics becomes much more complex when dealing with two or more interacting emitters. In this case, the electromagnetic field experienced by an emitter depends not only on the light beam striking its surface, but also on all of the electromagnetic fields radiated by all of its neighbors, which in turn are affected by the emitter in question.

Each quantum emitter can have a dipole, meaning a positive side and a negative side, due to an uneven distribution of electrons within the emitter. In a dense "vapor" of many quantum emitters, strong dipole-dipole couplings can then occur. The collective effects usually result in an enhancement of the light-matter interaction, although a very complicated one.

Here, the researchers have theoretically shown that strong dipole-dipole interactions in a dense vapor of quantum emitters can be used to manipulate the spectral properties of the light scattered by the emitters. In particular, the medium may become transparent at a particular frequency that can be controlled to a certain extent.

The scientists explain that, on the most basic level, DIET results from destructive interference between the electromagnetic waves emitted by the quantum emitters. DIET is also closely related to another phenomenon, called electromagnetically-induced transparency (EIT). EIT is also based on destructive interference, but it is induced by a laser instead of dipole-dipole interactions.

The scientists expect that DIET could have many of the same applications as EIT, which include the generation of slow light or stopped light by interactions with the medium. Slow light has a variety of optical applications, including information transmission, switches, and high-resolution spectrometers. Also, in the field of attosecond physics, DIET could potentially be used to generate high harmonics in dense atomic or molecular gases.

The researchers anticipate that DIET can be experimentally implemented in a few different ways, including in atomic vapor confined in a cell as well as in ultracold dense atomic clouds. However, both systems still face challenges for demonstrating DIET, which must be addressed in the future.

"Currently our goal is to hunt for the observation of DIET in multilevel atomic or molecular systems," Charron said. "Each emitter will behave as a series of oscillating dipoles, and this is expected to yield a series of transparency windows, thus opening the way for more elaborate and flexible manipulation strategies. We will publish new results on this topic in *Arxiv* in the next few weeks. Moreover, DIET offers yet another way to slow the light due to strong anomalous dispersion. We thus plan to develop the study of slow light with DIET in the near future, with potential applications for information processing."

More information: Raiju Puthumpally-Joseph, et al. "Dipole-Induced Electromagnetic Transparency." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.113.163603 . Also at arXiv:1407.1970 [quant-ph]