Theoretical discovery of transparent particles that break the previously accepted limit of visibility

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Transparent particles with extraordinarily high refractive indices can become almost invisible at wavelengths longer than the particle size, an A*STAR-led theoretical study has shown. The discovery challenges the accepted wisdom around the limits of light scattering and visibility, and could lead to a new class of 'invisible' materials.

The scattering of sunlight from gas molecules in the atmosphere is what makes the sky look blue, allowing us to effectively see what would other be a transparent medium. This process, known as Rayleigh scattering, occurs when molecules or particles are smaller than the wavelength of light that hits them. It has long been accepted that all particles undergo Rayleigh scattering, and that the minimum amount of scattering occurs when the refractive index—a measure of the 'slowness' of light passing through a medium compared with a vacuum—is less than two. Water, air and glass all meet this condition, suggesting that the Rayleigh scattering that makes the sky blue is the least visible state physically achievable.

Boris Luk'yanchuk and colleagues from the A*STAR Data Storage Institute, in collaboration with researchers from the Australian National University, have now upset this status quo with the discovery that Rayleigh scattering can be suppressed in transparent particles at wavelengths longer than the particle scale if their refractive index is extraordinarily high.

"There have been many attempts to reduce scattering," says Luk'yanchuk. "For example, suppression of the back reflection of radar signals has been widely studied as part of the development of stealth technology. Yet even very small transparent particles have some degree of scattering. We have been able to reveal a new phenomenon that could be used to design ultra-transparent optical materials."

Rayleigh scattering occurs when light is absorbed by a molecule—producing a separation of positive and negative charges known as an electric dipole—and re-emitted by the dipole at the same energy. This can occur at all wavelengths, but is more efficient at short wavelengths, which is why the sky is more blue (short wavelength) than red (long wavelength).

"In our theoretical study we found that for very high refractive index materials, the contribution of the electric dipole becomes vanishingly small," explains Luk'yanchuk. "Specifically, we found that the electric dipole mode in small particles of such materials is suppressed by the emergence of another dipole mode, resulting in ultra-weak scattering below the Rayleigh limit. The challenge now is to find or develop materials with a high enough refractive index at the wavelength of interest to suppress Rayleigh scattering."

More information: Boris Luk'yanchuk et al. Suppression of scattering for small dielectric particles: anapole mode and invisibility, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* (2017). DOI: 10.1098/rsta.2016.0069

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