ICFO

SUMMER LECTURE: Why is refractive index so small?

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Blue Lecture Room

It is interesting to observe that all known materials have an index of refraction that is of order unity at visible wavelengths. This is quite different than any other material property (such as density, conductivity, specific heat), which can vary by orders of magnitude, and depends on the system being a gas vs. solid, insulating vs. conducting, etc. Strangely, there is no deep underlying theory of why refractive index has this seemingly universal property. This is despite the immense technological importance that an ultrahigh index material would have, as the index describes how much the wavelength of light can be reduced, and thus directly determines the minimum footprint of optical devices.

Separately, it is well-known within quantum optics that a single, isolated atom can have an extraordinarily strong response to near-resonant light, as characterized by a scattering cross section that is much larger than its physical size. Substituting this known result into standard electrodynamics formulas for material refractive index results in a predicted index of 10^5 at the densities of a solid! In this lecture, we will explore why these textbook formulas break down. We will also discuss our ongoing efforts to develop a more fundamental theory of refractive index, which fixes the shortcomings of previous theories, and which reveals that the low refractive index observed in everyday life is not necessarily a fundamental limit. Our theory combines ideas from diverse fields like quantum optics, quantum chemistry, and non-perturbative multiple scattering of light, which suggests why an answer to the refractive index problem might have been so elusive in the past.

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