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Making the forbidden allowed: new approaches to light emission

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Quantum electrodynamics (QED) is arguably one of the most successful theories of physics. In the early twentieth century, it was developed in order to provide a basic framework for light-matter interactions. Considering the fact that today is almost 90 years since Dirac's first paper on QED, it may seem surprising that there are still unexplored consequences for the physics of light-matter interaction. It has long been known that the diversity of light-matter interactions accessible to a system seems fundamentally limited by the small size of an atom relative to the wavelength of the light it emits, as well as by the small value of the fine-structure constant. In this talk, we'll discuss how polaritons in recently emerging materials can relax these restrictions on light-matter interaction. We developed a general theory of light-matter interactions [10.1126/science.aaf6308] with two-dimensional systems like graphene supporting plasmon polaritons. These plasmons effectively make the fine-structure constant larger and bridge the size gap between atoms and light. This theory reveals that conventionally forbidden light-matter interactions such as extremely high order multipolar transitions, two-plasmon spontaneous emission, and singlet-triplet phosphorescence processes can occur on very short time scales comparable to those of conventionally fast transitions. Showing a means to access these transitions at very fast rates, we move on to discuss two schemes by which forbidden transitions can be made dominant over allowed transitions. In the first scheme, we imbue polaritons with angular momentum, changing the selection rules for both single-polariton and multipolariton transitions. In the second scheme, we take advantage of the narrow Reststrahlen bands of polar dielectrics to selectively enhance slow transitions like two-photon spontaneous emission processes to the point where they dominate over all other decay mechanisms.