Room-Temperature Quantum Statistical Plasmonic Metacrystals

In new work, our team introduced quantum statistical plasmonic metacrystals, a novel class of room-temperature quantum materials that can transmit or block light according to the quantum statistics of multiphoton fields.[1] These metacrystals are composed of nanoscale gold antennas, or meta-atoms, whose optical near fields mediate interactions among many photons. The resulting multiparticle dynamics form allowed and forbidden quantum statistical bands, analogous to the electronic bands of semiconductors and the optical bands of photonic crystals.[1,2]

Quantum metasurfaces have enabled compact manipulation of light fields, including single photons and entangled photon pairs, through degrees of freedom such as frequency, polarization and orbital angular momentum.[2] However, the statistical fluctuations that distinguish coherent, thermal and superthermal light have been much harder to control directly. The quantum statistical plasmonic metacrystal represents the first quantum material that is sensitive to the quantum fluctuations inherent to all forms of light, providing a compact platform for controlling many-body states of light.[1,2,3]

By controlling the geometry and arrangement of the metacrystal's nanoscale gold antennas, or meta-atoms, we demonstrated a deterministic method for engineering these bands and guiding the transport of fragile many-body quantum states.[1] Multiphoton fields whose second-order coherence falls within an allowed band are transmitted with little statistical distortion, whereas fields in forbidden bands are suppressed or driven toward the nearest allowed statistical state.[1]

Our team experimentally prepared tunable multiphoton light with second-order coherence spanning coherent, thermal and superthermal statistics and injected these fields into the plasmonic metacrystal. The transmitted light was analyzed using photon-number-resolving detection, allowing us to compare input and output photon-number distributions and directly identify how the metacrystal reshaped the quantum statistics of the transmitted field.[1]

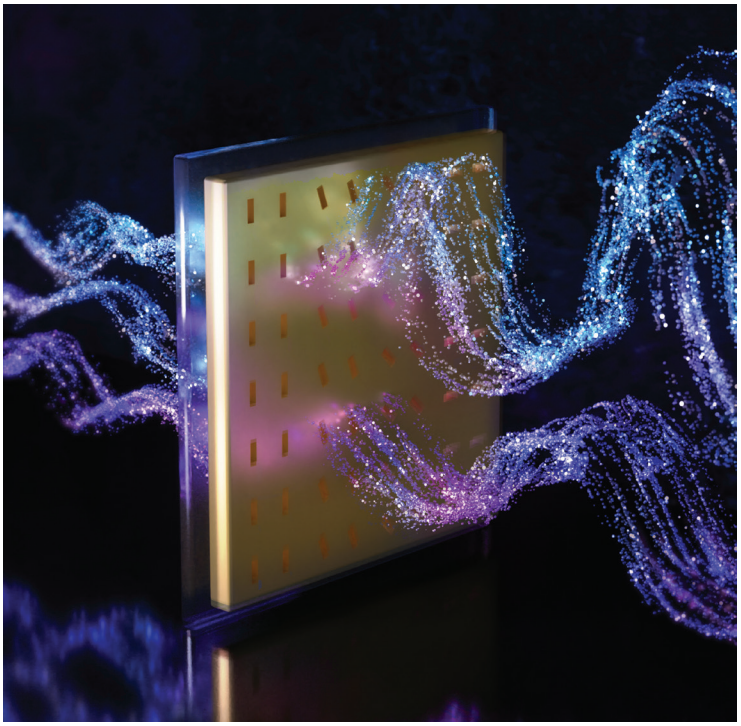
We believe that the first room-temperature quantum material sensitive to the quantum coherence of light could transform energy harvesting. Since the efficiency of solar energy conversion depends on the coherence properties of sunlight, this material enables direct manipulation of its quantum coherence, opening new opportunities for more efficient solar energy technologies.[4] More broadly, room-temperature coherence-sensitive quantum materials could redefine the design of next-generation optoelectronic devices, enabling robust and scalable quantum technologies that operate under ambient conditions.[3,4] OPN

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The first room-temperature quantum material sensitive to the quantum coherence of many-body photonic fields. Its behavior arises from allowed and forbidden statistical bands that enable selective sensitivity to light with different degrees of quantum coherence.