

A round-up of recent papers in the field of photonics published by the physical sciences division of the Nature Publishing Group.



Climbing the Jaynes–Cummings ladder and observing its \sqrt{n} nonlinearity in a cavity QED system

Nature **454**, 315–318 (2008)

The field of cavity quantum electrodynamics (QED), traditionally studied in atomic systems, has gained new momentum by recent reports of quantum optical experiments with solid-state semiconducting and superconducting systems. In cavity QED, the observation of the vacuum Rabi mode splitting is used to investigate the nature of matter–light interaction at a quantum-mechanical level. However, this effect can, at least in principle, be explained classically as the normal mode splitting of two coupled linear oscillators. It has been suggested that an observation of the scaling of the resonant atom–photon coupling strength in the Jaynes–Cummings energy ladder with the square root of photon number n is sufficient to prove that the system is quantum mechanical in nature. Here we report a direct spectroscopic observation of this characteristic quantum nonlinearity. Measuring the photonic degree of freedom of the coupled system, our measurements provide unambiguous spectroscopic evidence for the quantum nature of the resonant atom–field interaction in cavity QED. We explore atom–photon superposition states involving up to two photons, using a spectroscopic pump and probe technique. The experiments have been performed in a circuit QED set-up, in which very strong coupling is realized by the large dipole coupling strength and the long coherence time of a superconducting qubit embedded in a high-quality on-chip microwave cavity. Circuit QED systems also provide a natural quantum interface between flying qubits (photons)

and stationary qubits for applications in quantum information processing and communication.



Ultrasensitive hot-electron nanobolometers for terahertz astrophysics

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The submillimetre or terahertz region of the electromagnetic spectrum contains approximately half of the total luminosity of the Universe and 98% of all the photons emitted since the Big Bang. This radiation is strongly absorbed in the Earth's atmosphere, so space-based terahertz telescopes are crucial for exploring the evolution of the Universe. Thermal emission from the primary mirrors in these telescopes can be reduced below the level of the cosmic background by active cooling, which expands the range of faint objects that can be observed. However, it will also be necessary to develop bolometers—devices for measuring the energy of electromagnetic radiation—with sensitivities that are at least two orders of magnitude better than the present state of the art. To achieve this sensitivity without sacrificing operating speed, two conditions are required. First, the bolometer should be exceptionally well thermally isolated from the environment; second, its heat capacity should be sufficiently small. Here we demonstrate that these goals can be achieved by building a superconducting hot-electron nanobolometer. Its design eliminates the energy exchange between hot electrons and the leads by blocking electron outdiffusion and photon emission. The thermal conductance between hot electrons and the thermal bath, controlled by electron–phonon

interactions, becomes very small at low temperatures ($\sim 1 \times 10^{-16} \text{ W K}^{-1}$ at 40 mK). These devices, with a heat capacity of $\sim 1 \times 10^{-19} \text{ J K}^{-1}$, are sufficiently sensitive to detect single terahertz photons in submillimetre astronomy and other applications based on quantum calorimetry and photon counting.



Towards non-blinking colloidal quantum dots

Nature Mater. **7**, 659–664 (2008)

At a single-molecule level, fluorophore emission intensity fluctuates between bright and dark states. These fluctuations, known as blinking, limit the use of fluorophores in single-molecule experiments. The dark-state duration shows a universal heavy-tailed power-law distribution characterized by the occurrence of long non-emissive periods. Here we have synthesized novel CdSe–CdS core–shell quantum dots with thick crystalline shells, 68% of which do not blink when observed individually at 33 Hz for 5 min. We have established a direct correlation between shell thickness and blinking occurrences. Importantly, the statistics of dark periods that appear at high acquisition rates (1 kHz) are not heavy tailed, in striking contrast with previous observations. Blinking statistics are thus not as universal as thought so far. We anticipate that our results will help to better understand the physico-chemistry of single-fluorophore emission and rationalize the design of other fluorophores that do not blink.

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