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1. Indefiniteness of the order in quantum events

In quantum mechanics, the temporal order in quantum events (for instance, an impact on a system) can be indefinite and, moreover, a quantum superposition of different system evolution histories with an opposite causal order of events may take place. This theoretical prediction has been confirmed in an experiment performed by K Goswami (Queensland University, Australia) and colleagues. Photons came to two interferometer arms through a polarization splitter. In the first or second arm (depending on the polarization), quantum operations were performed on them using inverting prisms at different time instants. A criterion was formulated which, using the results of signal measurements at the interferometer output, suggested a conclusion concerning one causal order of events or another or the indefiniteness of this order. Since the photon coherence length exceeded the arm length, the smearing of the photon wave function in time exceeded the time interval between quantum operations. For this reason, the forward and reverse orders of operations were undistinguished. The indicated criterion was used to demonstrate this indistinguishability at the confidence level of 18σ.

Source: *Phys. Rev. Lett.* **121** 090503 (2018)
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2. Creation of a quantum entangled state using metamaterials

Metamaterials are said to be artificial periodic arrays of different elements. V G Veselago was the first to consider their unique electromagnetic properties in his paper in *Usp. Fiz. Nauk* **92** 517 (1967) [*Sov. Phys. Usp.* **10** 509 (1968)]. A variety of these metamaterials, a metasurface, is a two-dimensional array of subwave microantennas. T Stav and colleagues from the Technion — Israel Institute of Technology — have used a dielectric metasurface for the first time to generate entanglement between the spin and the orbital angular momentum of a single photon, and between the spin of one photon and the orbital angular momentum of another photon. When passing through a metasurface, the electromagnetic wave front takes the form of a spiral, and quantum entanglement appears owing to the Pancharatnam–Berry phase that provokes coupling between the spin and the orbital angular momentum of the photon. The presence of entanglement was shown by way of complete quantum tomography of photons in projections of their states onto the basis of orbital angular momenta and onto the basis of polarizations. This allowed nonlocal correlations which cannot exist in a classical light wave to be revealed. Metasurfaces may find wide application in quantum optics to generate entangled states of photons and to control them.

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3. Unidirectional quantum steering

The conception of Einstein–Podolsky–Rosen steering (EPR steering) was proposed by E Schrödinger in 1935. This effect consists in steering the reduction of a wave function of a distant system by choosing the measuring basis for the nearby system. The effect of one-way Einstein–Podolsky–Rosen steering, when reverse steering is impossible, was first demonstrated by D J Saunders and co-authors in 2010, but the experimental methods were based on additional assumptions concerning quantum states or the process of their measurement that restricted the applicability of the obtained results in general. In their experiment, N Tischler (Griffith University, Australia) et al. have demonstrated for the first time two-qubit one-way steering without additional assumptions, which makes their experiment an exhaustive demonstration of the given effect. The new experiment was based on an extremely high-quality source of photons in two-qubit Werner states. These photons were sent between two stations along paths with steerable artificial loss. The measurement of photon states allowed performing unidirectional quantum steering without significant limiting assumptions.

Source: *Phys. Rev. Lett.* **121** 100401 (2018)
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4. Radiative heat transfer by far-field radiation

The theory of radiative heat transfer between bodies formulated by Max Planck bounds from above the efficiency of heat transfer (the blackbody limit). However, this limitation only works when the radiation wavelength is much smaller than the size of the macroscopic bodies and the distance between them. It has already been experimentally discovered that at the inverse ratio of scales the heat exchange in the near field may exceed the indicated limit. Theoretical calculations show that an analogous enhancement is also possible in the far field. This conclusion was first confirmed experimentally by D Thompson (University of Michigan, USA) and colleagues. The heat transfer was investigated in a vacuum between plane plates that were much less thick than the wavelength and were in thermal contact with resistors. An alternating current passing through the resistor at the first plate heated it periodically. The heat was transferred to the second plate in a radiative way. Measured were the oscillations of current running through the second resistor and occurring owing to the thermal modulation of its resistance. A heat transfer was reached that exceeded the blackbody limit by two orders of magnitude. The heat transfer rate agrees well with calculations done in the framework of fluctuation electrodynamics.

Source: *Nature* **561** 216 (2018)
https://doi.org/10.1038/s41586-018-0480-9

5. Laboratory simulation of astrophysical jets

Plasma processes proceeding in space bodies are often so complicated that they defy a theoretical description. For example, an exhaustive magnetohydrodynamic theory of the formation and propagation of plasma jets in the nuclei of active galaxies and in young stars has not yet been formulated. These phenomena can be clarified in laboratory experiments performed in plasma facilities. Such studies are being carried out within the Plasma Focus facility at the NRC 'Kurchatov Institute' (Moscow, Russia) with the participation of researchers from FIAN (Lebedev Physical Institute) and MIPT (Moscow Institute of Physics and Technology). The experiments PF-1000 (Poland) and KPF-4 (Abkhazia) have a similar aim. In these setups, plasma appears under the influence of electric discharge and is ejected as a directed beam. At the Kurchatov Institute, narrow collimated jets were obtained with transverse dimensions kept at the level of several centimeters in propagation up to 100 cm, the plasma velocity exceeding 100 km s^{-1}. The important role of radiative cooling was established and the plasma parameters and the magnetic field distribution in the jets were measured. These data will possibly provide insight into jet stabilization mechanisms, and, owing to dimensionless parameters, the experimental results can also be scaled to astrophysical objects.

Source: *Int. J. Mod. Phys. D* **27** 1844009 (2018)
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