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1. Quantum interference in time

In their theoretical work, N J Cref (Free University of Brussels, Belgium) and M G Jabbour (University of Cambridge, United Kingdom) have predicted a new type of quantum interference that must originate from the indistinguishability of identical bosons born at different instants of time [1]. Considered was the interaction of two-photon modes with direct and time reversed ($e^{-i\omega t} \rightarrow e^{i\omega t}$) quantum evolution in the Hong–Ou–Mandel interferometric scheme, in which a splitter was replaced by an optical amplifier of gain 2. The Hong–Ou–Mandel effect has already been observed in experiments with both photons and massive particles and demonstrated boson statistics. The new type of interference in a Hong–Ou–Mandel interferometer must occur because photons cannot be distinguished according to the time of their birth: one cannot say whether old photons exist or the old photons were replaced by a new photon pair produced in the amplifier. This effect is closely related to the Bogoliubov boson transformation occurring in a wide range of physical problems. For this reason, this new effect may take place in many quantum systems. An experimental setup with parametric down-conversion has been suggested for verification of the given theoretical predictions.

2. Mobile fermions in an insulator

P Wang (Princeton University, USA) and his co-authors have reported observation of Landau quantization in a 2D monolayer of tungsten ditelluride (WTe_2) to obtain evidence of the existence of new quasi-particles in this topological insulator [2]. A thin insulating layer of hexagonal boron nitride (hBN) was placed between a WTe_2 monolayer and palladium electrodes. Small sections of hBN far from the sample edges were etched for contacts, allowing the edge effects to be subtracted. Strong magnetoresistance oscillations occurred upon increasing the magnetic field, beginning at ~ 1.5 T. In their form, they resembled Shubnikov–de Haas oscillations in metals, which was unexpected, because charges in insulators exhibit low mobility. With lowering temperature, the oscillations were transformed into discrete peaks, and the Landau quantization regime set in. Although the discovered oscillations have not yet been completely described theoretically, they can testify to the existence of new quasi-particles, i.e., mobile neutral fermions and charge-neutral Fermi surfaces inside an insulating gap in the spectrum. Charge-neutral Fermi surfaces have already been revealed in experiments, but these data remain ambiguous.

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3. Ultra-bright compact photon source

Z Ma (Stevens Institute of Technology, USA) and his co-authors have designed a new effective photon-pair source [3], which may be useful in quantum-information and telecommunication systems. The source was assembled 'on chip' and can therefore be readily integrated with electron facilities. The new source's productivity is two orders of magnitude higher than that of other similar sources. It includes a 700-nm ring lithium niobate microresonator 55 μm in radius fabricated by beam electron lithography and ion fragmentation. The material's polarization properties change periodically along the ring, and at a tangent to it, an optical pumping beam propagates, converting into lower-frequency radiation. Owing to the giant single-photon second-order nonlinearity and the triple resonance, a photon down-conversion of high efficiency and quantum purity occurs in the source. The ultra-bright photon-pair generation rate reaches 2.7 MHz per μW of pumping.

4. Quantum random number generator

D Drahi (University of Oxford, Great Britain) and his co-authors have designed and experimentally demonstrated a new quantum random-number generator [4]. In an optical splitter, the undetermined photon state of an incoming beam is mixed with the vacuum state from the second input channel. The photon passage and reflection in a splitter are random and have a probability of 50%, and therefore the output signal is completely random. In the practical realization of this scheme, broadband photodiodes, linear optical elements bound by optical fiber, and a programmable array of optical cells were used. Not only did the experiment demonstrate a high-rate (8 Gbit s^{-1}) random number generation, but the quality of the sequence of random numbers, i.e., their nondeterminism, was verified. The composable security parameter makes up 10^{-10}, which is important for application in quantum cryptography. Researchers from the Russian Quantum Center in Skolkovo took part in the study. This experiment was successfully performed twice: first in Oxford and then in Skolkovo. For quantum cryptography, see [5, 6].

5. Distant quasar and galaxy

At cosmological redshifts $z \geqslant 7.5$, only two quasars have been known to date. Using the ALMA telescope complex, F Wang (University of Alabama, USA) and his co-authors have discovered another distant quasar, J0313–1806, at $z = 7.6423 \pm 0.0013$, the most distant one yet known [7]. Its z was measured through observation of dust emission in the continuum and the emission lines [CII] formed in the quasar host galaxy. By fitting the spectrum and observation of virial Mg II line broadening, the central black hole has been established to be of mass $(1.6 \pm 0.4) \times 10^9 M_{\odot}$, and the quasar host galaxy shows a high star-formation rate. Quasar J0313–1806 was observed when the Universe was only 670 mln years old. The existence of such massive black holes at such an early epoch is a complication for the theory of their formation, for they would not have had time to considerably gain mass in the course of accretion. The seed black holes with large initial masses may have resulted from a direct collapse of massive gas clouds in early dark matter halos. Galaxies have been observed at still larger z. L Jiang and his co-authors have revealed in [8] a galaxy at $z = 10.957 \pm 0.001$ using the Keck I telescope to identify a doublet of carbon lines and an oxygen line. The observations showed peculiarities in the galactic spectrum, which have not yet been exactly explained. They may be due to either an excess of carbon or the presence of an active nucleus in the galactic center, which contributes to the total radiation from the galaxy. Observations of distant objects advance clarification of the galaxy- and supermassive-black-hole-formation processes.

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