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1. Cluster 0_2^+ state in the ^{8}He nucleus

Neutron-excess or neutron-deficit nuclei began to attract the great interest of scientists decades ago (see, for example, [1, 2]). The neutron-excess ^{8}He nucleus can be represented as an alpha particle (^{4}He nucleus) surrounded by four additional neutrons. It was theoretically predicted that additional neutrons can form two pairs (dineutrons) and create condensate. In this 0_2^+ state, the ^{8}He nucleus has spin zero, has positive parity, and looks like a ^{12}C nucleus in the cluster Hoyle 3α state. Z H Yang (Peking University, China and RIKEN Nishina Center, Japan) et al. [3] have become the first to reveal the 0_2^+ state of ^{8}He nuclei, which confirmed the theoretical prediction. The experiment was performed in the RIKEN Nishina Accelerator Center, where an intense ^{8}He beam with an energy of 82.3 MeV per nucleon collided with polyethylene $(CH_2)_n$ and carbon targets. The inelastic interaction products were registered using a drift chamber and neutron detectors. Observed was the emission of strongly correlated neutron pairs, which, along with the high intensity of the isoscalar monopole transition, testified to the 0_2^+ state of the nuclei with a statistical confidence of over 5σ.

2. Room-temperature multiexcitons

In some molecular qubits, the process of splitting the singlet state into two triplets under photoexcitation is observed, when the coupling of triplets through exchange interaction leads to the formation of a multiexciton — a quintet with four entangled spins designated as ^{5}TT. Quantum transitions between ^{5}TT and triplet states are of interest for application in quantum information. However, until recently, ^{5}TT could only be realized at cryogenic temperatures below 75 K. A Yamauchi (Kyushu University, Japan) et al. have managed to obtain for the first time room-temperature ^{5}TT with the quantum coherence time of more than 100 ns [4]. This was achieved by confining chromophore-based molecular qubits (a penthacene compound) within a porous metal-organic framework consisting of both metal and organic ligands. The framework suppressed the movement of molecules, increasing the coherence time. ^{5}TT states were manipulated with microwave pulses and were read using spectroscopy of nuclear magnetic resonance. Switching to room temperatures significantly increases the prospect of using ^{5}TT in quantum information facilities. For excitons, see [5, 6].

3. Electroluminescence in liquid argon

Electroluminescence is light emission from a substance in response to the action of electric fields. In noble gases, the excimer mechanism of electroluminescence in strong fields (transitions between states of electron excitation in atoms) and bremsstrahlung of drifting electrons scattered by neutral atoms may occur. In the latter case, radiation in the visible and near-IR ranges is possible in a weak field below the excitation threshold. Electroluminescence is well studied in the gas phase, whereas in a liquefied noble gas (xenon) it was reliably observed in only one experiment at an electric field strength of over 400 kV cm^{-1}. Researchers from the G I Budker Institute of Nuclear Physics SB RAS and Novosibirsk State University have recorded for the first time electroluminescence in liquid argon in a single-phase liquid time-projection chamber and showed that it has a bremsstrahlung mechanism [7]. Ionization in the chamber was generated by X-rays, and drifting electrons caused electroluminescence when they entered a high electric field. Photons were detected by a silicon photomultiplier after they left liquid argon. The mechanism of bremsstrahlung by neutral atoms was evidenced by the relatively low electric field of 30 to 90 kV cm^{-1} in which the radiation appeared. In addition, the lack of pressure dependence ruled out electroluminescence in gas bubbles as the main mechanism. The described experiment, supported by the Russian Science Foundation, grant no. 20-12-00008, showed good agreement with the theory, when the cross section for momentum transfer (unlike the cross section for energy transfer) was used in calculations. Electroluminescence in a liquid inert gas is important, in particular, for designing high sensitivity detectors of dark matter and low-energy neutrinos.

4. Non-Gaussian statistics in laser-induced breakdown spectroscopy

Laser-induced breakdown spectroscopy (LIBS) is based on particle evaporation from a sample surface under the influence of powerful laser pulses and measurement of the spectrum of the resulting optical breakdown plasma. Compared to laboratory spectroscopy, this method is less accurate, but it is widely used owing to the possibility of a remote ultrafast analysis. In LIBS, data are continuously collected and averaged. The distribution of measurement results most often has a Gaussian normal form, but in some cases the distribution is non-Gaussian, which may affect the result of data processing. Although the non-Gaussian character in LIBS has been discussed theoretically and has been noticed in previous experiments, its impact on the LIBS results has never been studied. V N Lednev (GPI RAS) and his co-authors have systematically studied for the first time the influence of signal statistics on the quality of LIBS [8]. In

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their experiment, the emission of Nd:YAG laser pulses with a wavelength of 1064 nm was focused with a quartz lens onto the sample surface. The glow of the plasma plume was collected from the side and transferred to a spectrograph equipped with an intensified CCD camera. Measurements showed that it is only the plasma emission that had a Gaussian distribution, while other signals (energy distribution of laser pulses, atomic line intensity, and background plasma emission) did not follow it. This circumstance affects the LIBS method sensitivity assessment and may turn out to be important in its practical application, especially in critical technologies (rolling in blooming and in smelters), when repeated measurements are precluded or obstructed.

5. Underwater lidar

Lidar is a remote sensing method using laser locators capable (like radio locators) of probing scattering objects, both massive and loose (clouds, plumes, nets) and determining the distance to them. Important applications of lidars are measuring aerosol concentration in the air and remote probing in agriculture [9]. However, lidar can also operate in liquid, although strong scattering imposes considerable restrictions on its operation under such conditions. At the same time, lidar can reveal objects in liquid, inaccessible to usual hydrolocators, and provide high-precision underwater navigation. A group of researchers from Prokhorov Institute of General Physics, Space Research Institute, RAS, and the Moscow Technical University of Communications and Informatics has demonstrated for the first time lidar operation on a double pass through a layer of water 9 m thick [10]. The lidar device used a pulsed diode-pumped Nd^{3+}:YAG laser emitting at a wavelength of 532 nm with a pulse repetition rate of 4 kHz and, for the first time, with an eye-safe radiation energy density of $\sim 1\ \mu\text{J cm}^{-2}$. Previously, lidar devices exceeded this threshold and their use was prohibited. The authors opened a new era [11] of sensing the environment without eye protection from damage using a gated receiver. Here, the lidar backscattering signal was recorded by a single-photon avalanche photodiode (SPAD) detector with a gain of $\sim 10^6$. Thanks to such a high gain of the detector and noise suppression using gating, it was possible to achieve a signal-to-noise ratio of ~ 35 in the described experiment. In a new study by the same group, supported by the Russian Science Foundation, grant no. 23-42-10019, underwater detection of objects through a layer of water 18 m thick was achieved for the first time, and the path traveled by photons was 36 m in water and 14 m in air [12].

6. Influence of an electric field on branching streams of light

In a disordered medium, branching wave propagation is possible due to a combination of diffraction and caustic formation. Such propagation has been discovered in various wave systems, for example, for electron waves in semiconductors. In the optical range, it was revealed by A V Startsev and Yu Yu Stoilov in 2002 [13]. S Chang (Xiamen University, China) et al. have demonstrated a branching stream of light in a liquid crystal and a method of its control with an electric field [14]. A thin plate of liquid crystal was placed between two glass plates doped with indium and tin oxide. In a liquid crystal, there are many inhomogeneities and defects of different scales, responsible for branching light propagation along its plane. If electric voltage is applied to the outer plates, the electric field between them causes restructuring of the liquid crystal, which leads to shifts of branching trajectories and even to branching shutdown. Moreover, this process turned out to be reversible — the branching returned to its previous form when the electric field was switched off. This method may possibly find application in fundamental studies, as well as in technical optics and photonics.

7. Kr and Xe clusters between graphene layers

Under normal conditions, stable structures do not appear in free noble gases because of their chemical inertness. Two-dimensional atomic crystals of noble gases with van der Waals interaction have previously been realized at cryogenic temperatures on the surface of metals and at higher temperatures between graphene layers and a substrate. However, under such conditions, it is difficult to observe a spatial distribution of atoms. M Langle (University of Vienna, Austria) and his co-authors managed to place crypton and xenon atoms between two graphene layers, thus allowing such an observation [15]. Atoms penetrated the bilayer when it was irradiated with low-energy Kr and Xe ions. A study using transmission electron microscopy showed that atoms inside the bilayer form clusters at room temperature and a pressure of 0.3 GPa. Clusters with the number of atoms $N < 9$ are well described by a van der Waals interaction, while larger clusters demonstrate some deviations caused, perhaps, by deformations in the graphene lattice. All the observed Xe clusters with $N \approx 100$ remained firm, whereas Kr clusters with $N \approx 16$ were close to liquid in their properties.

8. Star clusters in the early Universe

The galaxy SPT0615-JD1, which is at the redshift $z \sim 10.2 \pm 0.2$, has been observed using the James Webb space telescope when the Universe was ~ 460 mln years old [16]. Interesting details in its structure were seen because the light of the galaxy experienced gravitational lensing on the galactic cluster located at $z = 0.972$ on the line of sight. The telescope revealed 5 individual star clusters in the galaxy, ≈ 1 pc in size and located in a region smaller than 70 pc. These clusters emit $\approx 60\%$ of the host galaxy's FUV radiation and have 5% solar metallicity. The cluster masses are $\approx 10^6 M_{\odot}$, and their age is less than 35 million years. The surface density of stars in the clusters is three orders of magnitude higher than that of typical star clusters in the local Universe. The discovered clusters could possibly be predecessors of modern globular clusters. A surprising number of large galaxies in the early Universe had already been observed before, but their stellar components remained unresolved because of their remoteness. Observation of star clusters is a significant step in this direction. Such clusters may have influenced the reionization of the Universe.

9. Extremely distant galaxies

The JADES Origin Field program for identification of the Ly-α break at red shifts $z \sim 12$ and source filtration at smaller z, which can imitate light from distant galaxies, is being implemented with the James Webb telescope. In the framework of this program, eight candidate galaxies have been observed (without photometric confirmation so far) at

$z = 11.5-15$, and their luminosity function was estimated [17]. These z values go back to epochs when the Universe was only about 300 Myr old. The revealed galaxies have radii of 50 to 200 pc, stellar masses of $\sim 10^7-10^8 M_\odot$, and star formation rates of $10^5-10^6 M_\odot$ yr^{-1}. At the same time, no galaxies have been found at $15 < z < 20$, which establishes upper limits for early galaxy formation. The density of the number of galaxies in the Universe decreases about 2.5 times from $z = 12$ to $z = 14$. The reason for the surprisingly large number of galaxies at large z is not yet known. An explanation may lie in the nonstandard spectrum of cosmological density perturbations with a certain excess on small scales [18].

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