Physics – Uspekhi 55 (10) 1059 – 1060 (2012)

PACS number: **01.90.+g**

Physics news on the Internet (based on electronic preprints)

DOI: 10.3367/UFNe.0182.201210l.1136

1. Measuring masses of superheavy nuclei

To measure the masses of heavy atomic nuclei, an indirect method of studying fragments of their α decays is typically applied; however, this method leads to large errors in the case of superheavy nuclei. Masses of the nuclei ^{252,253,254}No and ^{255,256}Lr have been measured with high accuracy at the Helmholtz Center for the Study of Heavy Ions in Darmstadt (Germany) by measuring the cyclotron frequencies of their motion in a magnetic field. The nuclei produced at the GSI accelerator were captured in a Penning trap and rotated in the magnetic field. Cyclotron frequencies measured by the resonance technique in the same trap were compared with the cyclotron frequency of $^{133}Cs^+$ ions whose mass is known very accurately. Several dozen nuclei were investigated in this manner, and their masses were measured to within 15 keV. The knowledge of the masses of nuclei makes it possible to draw model-independent conclusions on their binding energy, which results in their mass defect. The binding energy is largely determined by the effects of filling nucleonic shells, which also affect the stability of nuclei. Consequently, the results obtained may help to clarify the issue of the 'island of stability' — the area on the 'charge–number of neutrons' diagram in which nuclei are conjectured to possess sufficiently long lifetimes.

Source: *Science* **337** 1207 (2012)
http://dx.doi.org/10.1126/science.1225636

2. The uncertainty principle for measurements

The Heisenberg uncertainty relation as adaptable to the measurement process is written down in the form $\varepsilon(A)\eta(B) \geqslant \hbar/2$, where $\varepsilon(A)$ and $\eta(B)$ are measurement errors of variables A and B in such a way that $\varepsilon(A)$ and $\eta(B)$ are typically associated with the quantum uncertainties $\sigma(X) = (\langle\psi|X^2|\psi\rangle - \langle\psi|X|\psi\rangle^2)^{1/2}$ in the quantum state ψ of the system, although this identification has never been rigorously proved. Another formulation of the uncertainty principle in Robertson's general form reduces to $\sigma(A)\sigma(B) \geqslant \langle\psi|[A,B]|\psi\rangle/2$, where $[A,B]$, the commutator of operators, is an exact consequence of quantum-mechanical postulates. However, M Ozawa proved in a theoretical paper in 2003 that this last expression cannot be applied in a straightforward manner to the process of measurement in the general case, and that a more correct uncertainty relation for measurements takes the form $\varepsilon(A)\eta(B) + \varepsilon(A)\sigma(B) + \sigma(A)\eta(B) \geqslant \langle\psi|[A,B]|\psi\rangle/2$. In particular, this expression does not forbid, in principle, two conjugated variables to be measured, with the product of uncertainties less than $\hbar/2$. In most cases, this clarification is not essential, but the result may change if the measurement technique is in some way correlated with the state of the object being measured. This conclusion has been confirmed by L A Rozema (University of Toronto, Canada) and his colleagues in an experiment on quantum teleportation of qubit states built of the polarization states of photons. The states of a correlated pair of photons were determined prior to their strong interaction with the measuring device using so-called weak measurements. As a result, an accuracy of measurements better than allowed by the uncertainty principle in Heisenberg's formulation has indeed been achieved. The conclusion is that even though the above results leave the fundamental principles of quantum mechanics unperturbed, they represent an important clarification of the meaning of the uncertainty principle as applicable to the process of measurement. These results may prove important for quantum cryptography, as well as for gravitational wave interferometers operating at the very limit of measurement accuracy.

Source: http://arXiv.org/abs/1208.0034

3. The study of electronic bonding in single molecules

L Gross (IBM laboratory in Zürich) and his colleagues have been able for the first time to experimentally distinguish between individual electron bonds in a single organic molecule. Single molecules had already been studied using atomic-force microscopes before, but it was only possible to characterize their chemical properties for the molecule as a whole. The new experiment involved an atomic-force microscope with a CO molecule at the very end of the STM tip. Numerical simulations by the density functional method allowed the researchers to identify effects capable of distinguishing between bonds of different orders, strengths, and lengths. It turned out that the increased density of the electron cloud or higher bond order led to stronger repulsion owing to Pauli's exclusion principle, which results in higher image contrast in the microscope (greater frequency shift in tip vibrations). Furthermore, higher-order bonds look shorter on the images due to the changed tilting of the CO molecule at the tip end. Thanks to these attributes, it was possible to distinguish between electron bonds differing in order by 0.2, and in length by only 0.03 Å. This method led to successful characterization of electron bonding in molecules of polycyclic aromatic hydrocarbons and in fullerene C_{60} molecules.

Source: *Science* **337** 1326 (2012)
http://dx.doi.org/10.1126/science.1225621

4. Plasmon needle beams

J Lin and his colleagues in the USA, Singapore, and France have been able to generate surface plasmons (quasiparticles corresponding to collective oscillations of the electron gas) in the form of a thin (needle) beam propagating along a metal surface to distances of up to 80 μm without noticeable diffraction. The experiment confirmed the validity of new plasmonic solutions to Maxwell's equations found earlier by

Uspekhi Fizicheskikh Nauk **182** (10) 1136 (2012)
DOI: 10.3367/UFNr.0182.201210l.1136
Translated by V I Kisin

members of the same research team. Plasmons were generated by a grid consisting of two sets of parallel grooves on the surface of a gold film, intersecting at an angle of 10° between normals to the grooves. Two plane plasmon waves were excited by laser pulses and sent in the directions of the normals. The interference of these waves led to the formation of a needle beam with the profile represented as a product of a cosine and a Gaussian: hence the name cosine-Gauss plasmon beams. Plasmons propagated along a straight line along the gold surface and were observed with an optical near-field microscope. Generation of needle plasmons may find applications in plasmon nanoelectronics as a way to reducing losses in signal transmission.

Source: *Phys. Rev. Lett.* **109** 093904 (2012)
http://dx.doi.org/10.1103/PhysRevLett.109.093904

5. Gas cloud near a black hole

A gas cloud has recently been discovered near the center of our Galaxy; it is gradually approaching the central black hole Sgr A^*. The closest approach to the minimum distance of 10^{-3} pc could be observed by mid-2013, at the same time as the anticipated growth in X-ray activity due to the accretion of gas. It is already obvious that the cloud is being deformed by the gravitational tidal forces of the black hole. The nature of the cloud and the cause of its movement in the direction of the black hole are not yet known. A collision of two stars was discussed as a possible scenario. R A Murray-Clay and A Loeb of the Harvard–Smithsonian Center for Astrophysics suggested a new hypothesis. In their model, the cloud is a protoplanetary disk of a gas and dust mixture around a weak (and hence invisible) star. The star and its disk were initially in a ring-shaped cluster of young stars, whose inner edge lay at a distance 0.04 pc from Sgr A^*. Having experienced gravitational scattering on another star, the disk and the star changed orbit and began to approach the black hole. Tidal forces and the background UV radiation cause the expansion of the disk which leaks gas and thus forms the visible cloud. Given that hundreds of exoplanets around other stars have been found in recent years, the new hypothesis appears quite plausible. The Murray-Clay–Loeb model predicts a certain form of growth in the luminosity of the cloud as it approaches the black hole. This prediction could be tested fairly soon in the nearest months.

Source: *Nature Communications* **3** 1049 (2012)
http://dx.doi.org/10.1038/ncomms2044

Compiled by *Yu N Eroshenko*
(e-mail: erosh@ufn.ru)