Physics – Uspekhi **63** (5) 521 – 522 (2020)

PACS number: **01.10. – m**, **01.30. – y**, **01.90. + g**

Physics news on the Internet (based on electronic preprints)

Yu N Eroshenko

DOI: https://doi.org/10.3367/UFNe.2020.04.038751

1. Measurement of 0.1-Hz optical resonance

W Qu et al. [1] (Fundan University, China) have developed a method based on weak quantum measurements which they used to measure a resonance line less than 0.1 Hz wide. Laser pulses were transmitted through the gas of ^{87}Rb atoms in a magnetic field. Pulses with different circular polarizations induced transparency with a phase shift, resulting in the transparency of the medium having the form of narrow resonance in the region of pulse overlapping. The output pulses were registered by two detectors, and the correlation signal controlled the acousto-optical modulator at the input through the feedback loop. This allowed weak quantum measurements of the narrow resonance. This method was used to design a magnetometer with a sensitivity of 7 fT Hz$^{-1/2}$. Such magnetometers can be applied in various areas, including medicine.

2. Spectroscopy of molecules inside helium nanodroplets

Femtosecond time resolution spectroscopy allows the investigation of the dynamics of fast electron transitions, including those in photovoltaic processes and in photosynthesis. One of the important areas is the spectroscopy of molecules surrounded by other substances, e.g., in solutions. Transfer of energy generated in photoionization to the surrounding matter prevents the molecule from fragmentation, but, at the same time, the environment has a strong effect on the molecule, hampering the measurement of its own properties. B Thaler et al. [2] (Graz University of Technology, Austria) have revealed that for In_2 molecules inside superfluid helium nanodroplets this problem does not occur, because the influence of helium is very weak. Nanodroplets were obtained through helium sputtering from a nozzle to a vacuum chamber and then, through indium vapor transmission through the chamber, on the average two indium atoms got into each nanodroplet, thus forming a molecule. Nanodroplets were illuminated by laser pulses, and then from the spectrum of ejected photoelectrons two types of dynamics were found, namely, In_2 ejection from the nanodroplets and In_2 molecule vibration with a period of 0.42 pc inside the nanodroplets. Vibrations lasted for tens of pc and recommenced each 145 pc with a smaller amplitude. The vibration damping was due to dephasing. The perturbations due to superfluid helium in the course of vibrations were 10 to 100 times lower compared to any other solvent.

3. New class of semiconductors

Ordinary silicon with a cubic crystal lattice is widely applied, but it has an indirect forbidden band when the conduction band and the valence band are displaced relative to each other and photon emission is impossible. Hence, light sources for microelectronics cannot be designed on the basis of ordinary silicon. E M T Fadaly et al. [3] (Eindhoven University of Technology) have revealed that, upon modification of the crystal lattice to hexagonal, the silicon-germanium alloy hex-$Si_{1-x}Ge_x$ becomes a direct-bandgap one for $x > 0.65$. This was shown in calculations by the density functional method and was then confirmed experimentally. The technologically complicated problem of obtaining an alloy with a hexagonal structure and a low defect density was solved using a GaAs substrate with precipitated Si and Ge. Photoluminescent spectroscopy showed the presence of a narrow emission peak with temperature dependence and a recombination time of ~ 1 ns, typical of direct-bandgap semiconductors. Thus, this study demonstrated a new class of semiconductors that can underly the creation of light sources integrated directly into silicon chips. This paves the way for nanoelectronics, photonics, and information technologies. For the application of semiconductors, see [4, 5].

4. Anisotropy of the Universe?

The Standard Cosmological Model is based on the assumption that the expansion rate and other properties of the Universe are identical in all directions. Although anisotropic cosmological models have already been long considered, the large-scale isotropy of the real Universe has hitherto almost never given rise to doubt. The strongest evidence of isotropy comes from observing relic radiation. If the trivial dipole anisotropy due to the motion of the Solar System relative to relic radiation is excluded, then the Universe looks practically isotropic, except for some asymmetries that can be statistical fluctuations and Cold-spot type anomalies. For perturbations in relic radiation, see the review by O V Verkhodanov [6]. K Migkas et al. [7] (University of Bonn, Germany) have realized a new sensitive method of research that unexpectedly showed the presence of statistically significant large-scale anisotropy of the Universe. The relation between X-ray luminosity and a hot-gas temperature in different directions in galactic clusters was examined. Together with independent red shift determination, this method gives model-independent

---

Yu N Eroshenko Institute for Nuclear Research,
Russian Academy of Sciences,
prosp. 60-letiya Oktyabrya 7a, 117312 Moscow, Russian Federation
E-mail: erosh@ufn.ru

Uspekhi Fizicheskikh Nauk **190** 446 (2020)
Translated by M V Tsaplina

results. The data from 313 galactic clusters from the ROSAT All-Sky Survey and Chandra and XMM-Newton surveys were used. In different directions in the sky, the normalization of the temperature-luminosity relation turned out to vary by $16 \pm 3\%$. With $\sim 4\sigma$ confidence, this implies that the Universe is expanding in different directions at different rates. And in combination with the additional data on 842 galactic clusters, the confidence increases to $\sim 5.5\sigma$. The additional anisotropy maximum is displaced by $\sim 50^\circ - 100^\circ$ relative to the axis of the dipole associated with the motion of the Sun. The origin of the discovered anisotropy remains unclear. Absorption of X-rays in gas clouds in a local region of the Universe is weak and cannot therefore serve as an explanation. The anisotropy is possibly due to the inhomogeneity of the dark matter that occupies the Universe or to large-scale matter flows. Proof of the Universe's anisotropy would be of great scientific significance, since it would change the conventional cosmological paradigm; therefore, additional verification and research are needed.

5. Physics of viruses

In modern microbiology, physical methods of research play an exclusively important role. For example, electron microscopes were used to obtain for the first time virus images, X-ray pictures of crystalized viruses helped determine their structure, and scanning atomic-force microscopes allow a detailed examination of the form of the protein viral shell (capsid). Widely investigated in biophysics are virus self-assembly of RNA/DNA and proteins and the mechanical properties of virus particles [8]. All this may be useful in developing effective vaccines and drugs. And vice versa, the methods developed in microbiology find application in nanotechnology. Viruses and virus-like particles can be used in the future, e.g., as a means for delivering drugs to cells and even as blocks in microelectronics. For these and other purposes, it is of importance to understand the physicochemical properties of viruses. J Shang et al. [9] (University of Minnesota, USA) have used in their new study the crystallization and X-ray diffraction method to construct a three-dimensional model of the SARS-CoV-2 protein and to find receptors located on spike proteins responsible for virus entry into the cell. These results are important for both clarifying the evolutionary origin of SARS-CoV-2 and searching for methods of treatment and prophylaxis. For physical processes in microbiology and the physical methods of investigation of biological objects, see also [10–12].

References

1. Qu W et al. *Nature Commun.* **11** 1752 (2020); https://doi.org/10.1038/s41467-020-15557-6
2. Thaler B et al. *Phys. Rev. Lett.* **124** 115301 (2020); https://doi.org/10.1103/PhysRevLett.124.115301
3. Fadaly E M T et al. *Nature* **580** 205 (2020); https://doi.org/10.1038/s41586-020-2150-y
4. Vavilov V S *Phys. Usp.* **00** 000 (1995); *Usp. Fiz. Nauk* **165** 591 (1995)
5. Baranov P G et al. *Phys. Usp.* **62** 795 (2019); *Usp. Fiz. Nauk* **189** 849 (2019)
6. Verhodanov O V *Phys. Usp.* **00** 000 (2016); *Usp. Fiz. Nauk* **186** 3 (2016)
7. Migkas K et al. *Astron. Astrophys.* **636** A15 (2020); https://arxiv.org/abs/2004.03305
8. Buzon P, Maity S, Roos W H, https://doi.org/10.1002/wnan.1613
9. Shang J et al. *Nature*, online publication of March 30, 2020; https://doi.org/10.1038/s41586-020-2179-y
10. Vainshtein B K *Sov. Phys. Usp.* **16** 185 (1973); *Usp. Fiz. Nauk* **109** 455 (1973)
11. Ivanitskii G R et al. *Phys. Usp.* **41** 1115 (1998); *Usp. Fiz. Nauk* **168** 1221 (1998)
12. Tverdislov V A, Malyshko E V *Phys. Usp.* **62** 354 (2019); *Usp. Fiz. Nauk* **189** 375 (2019)