SOVIET PHYSICS USPEKHI VOLUME 14, NUMBER 3 NOVEMBER-DECEMBER 1971

53

Meetings and Conferences

JOINT SCIENTIFIC SESSION OF THE DIVISION OF GENERAL PHYSICS AND ASTRONOMY OF THE USSR ACADEMY OF SCIENCES AND OF THE DIVISION OF NUCLEAR PHYSICS

(28–29 October 1970)

Usp. Fiz. Nauk 104, 167-172 (May, 1971)

A scientific session of the Division of General Physics and Astronomy and of the Division of Nuclear Physics of the USSR Academy of Sciences was held 28 and 29 October 1970.

The following papers were delivered:

1. S. S. Polikanov. Isomerism of Nuclear Shapes.
2. V. M. Lobashov. Weak Nucleon-nucleon Interactions.
3. A. A. Abrikosov and S. D. Beneslavskiĭ. Possible Existence of Substances Intermediate between Metals and Dielectrics.
4. R. A. Zhitnikov. Research on Optical Orientation of Atoms and Its Use for the Development of Quantum-electronics Devices.
5. V. B. Anzin, M. S. Bresler, V. G. Veselago, Yu. V. Kosichkin, G. E. Pikus, I. I. Farbshteĭn, and S. S. Shalyt. Experimental Observation of Magnetic Breakdown in Semiconductors.
6. L. A. Artsimovich. The problem of Controlled Thermonuclear Fusion.
7. M. S. Rabinovich. Stellarator Program.
8. O. N. Krokhin. Use of Lasers for Plasma Heating.
9. L. I. Rudakov. Use of Powerful Electron Beams for the Problem of Controlled Thermonuclear Fusion.

We publish below the brief contents of some of the delivered papers.

S. M. Polikanov. Isomerism of Nuclear Shapes.

More than 20 spontaneously-fissioning isomers have been synthesized by now. Experimental investigations of the properties of these isomers have shown that the energy of the isomers is quite large (~ 3 MeV) and the spin is small (does not exceed several times h).

These results have made it possible to advance the hypothesis that spontaneously-fissioning isomers are shape-dependent. This assumption is additionally confirmed by experimental results of a study of the radiative capture of neutrons, leading to the formation of the spontaneously-fissioning isomers ^{242}Am and ^{244}Am.

Calculations with account taken of shell effects and large deformations, carried out by Strutinskiĭ, led to the appearance of an additional minimum of the potential energy at large nuclear deformations.

Within the framework of this model, the isomer states are interpreted as lower states in the second potential well.

Further experimental investigations of spontaneously-fissioning polymers should be aimed mainly at obtaining spectroscopic information. Great interest attaches also to searches for new regions of existence of shape-dependent isomers.

R. A. Zhitnikov. Research on Optical Orientation of Atoms and Its Use for the Development of Quantum-electronics Devices.

Optical pumping (optical orientation of atoms), discovered by A. Kastler in 1949, has now become an independent rapidly growing field of radio spectroscopy[1,2]. In addition to a large number of new scientific results, optical pumping has contributed much to quantum electronics (quantum frequency standards, quantum magnetometers, quantum gyroscopes).

The communication is devoted to the results of research on optical pumping, carried out at the A. F. Ioffe Physico-technical Institute of the USSR Academy of Sciences, and also to work on the use of optical pumping for the development of new quantum-electronics devices.

One of the trends in this research was the study, with the aid of optical pumping, of the nature of interactions of excited alkali-metal atoms with inert-gas atoms[3-5]. These investigations were carried out by observing the behavior of resonance signals of the ground state of optically-oriented alkali-metal atoms as functions of the pressure and nature of the inert gas. The use of a rotating radio-frequency magnetic field has made it possible to separate the hyperfine-structure component in the magnetic-resonance signal[5]. A reversal of the sign of the optical-pumping resonance signal was observed with increasing pressure of the inert gas, owing to the mixing phenomenon (collision relaxation) in the excited state of the alkali-metal atoms. Investigations carried out on rubidium isotopes have made it possible to assess the role of nuclear spin in collision relaxation. The cross sections of such relaxation and the constants of the Van-der-Waals interaction between rubidium atoms and atoms of different inert gases were determined[5]. A theory of the observed phenomena was developed[4].

During the course of the study of optical orientation of helium-4 atoms, new phenomena were observed, consisting of an influence of the spin orientation of the metastable helium atoms on the intensity of all the optical lines emitted by the atoms of the helium gas-discharge cell, and on the electron density in the plasma of this cell[6].

The explanation of these phenomena possibly lies in the fact that the main process of production of electrons in a helium plasma is ionization of the metastable atoms as they collide with one another[9]. The electron yield in such processes depends on the mutual spin orientation of the colliding metastable atoms. There-

---

[1] S. M. Polikanov, Usp. Fiz. Nauk 94, 43 (1968) [Sov. Phys.-Usp. 11, 22 (1968)].

[2] V. M. Strutinsky and S. Bjornholm, Dubna Symposium, Nuclear Structure, p. 431 (1968).

[3] S. M. Polikanov and G. Sletten, Nucl. Phys. A151, 656 (1970).

fore the electron density in the plasma and the associated intensity of light emission by the atoms should depend on the degree of spin orientation of the metastable atoms. Apparently, a competing process of opposite sign is also present here, and leads with increasing discharge intensity to a reversal of the sign of the resonant change of the radiation intensity[6]. It is possible that this process is the optical transition $2^3S_1 \rightarrow 2^3P_1$ with subsequent decay $2^3P_1 - 1^1S_0$, leading to a drop of the concentration of the metastable atoms; this drop increases with increasing discharge intensity.

The described phenomena could be observed also following optical pumping of helium-3 atoms in the metastable state. Experiments on helium-3 atoms are presently being performed to verify the proposed explanations of the nature of these phenomena.

Optical orientation of metastable neon and xenon atoms was obtained both with circularly polarized and unpolarized light. These investigations of optical pumping of inert-gas atoms in the P state, which are of considerable theoretical interest, are presently being continued.

Work on the development of new quantum-electronic devices based on optical orientation of atoms is presently being performed at the Physico-technical Institute of the USSR Academy of Sciences.

A new type of quantum magnetometer, namely a self-generating quantum magnetometer with optical orientation of metastable atoms of helium-4 (GSM-4)[7], has been developed. This magnetometer has many advantages over the existing instruments. Thus, unlike the magnetometer based on alkali-metal atoms, the helium magnetometer has a simple resonance line, a linear connection between the magnetic field and the resonant frequency, and a weak independence of the temperature. Compared with the existing helium magnetometers, based on the scheme of automatic tuning of the generator frequency, the self-generating magnetometer GSM-4 has the advantages of simplicity, compactness, and reliability, which are ensured by a spin generator[7].

A model was also developed of a self-generating magnetometer based on optical orientation of the nuclear moments of helium-3 (GSM-3). This magnetometer has many advantages when it comes to perform measurements under static conditions.

A special procedure was developed for constructing absorbing cells capable of producing simultaneous optical orientations of helium atoms and alkali-metal atoms in a single cell[8]. Methods were also developed for stabilizing magnetic fields with the aid of spin generators with optical pumping of alkali-metal and helium atoms. These results can be used for the development of new types of nuclear quantum-gyroscopes with optical pumping.

The main results of the paper were published in[3-8].

---

[1] C. Cohen-Tannoudji and A. Kastler, Progr. in Optics 5, 3 (1966).

[2] T. Carver, Science, 141, 599 (1963).

[3] R. A. Zhitnikov, P. P. Kuleshov, and A. I. Okunevitch, Phys. Lett. 29A (5), 239 (1969).

[4] A. I. Okunevich and V. I. Perel', Zh. Eksp. Teor. Fiz. 58, 666 (1970) [Sov. Phys.-JETP 31, 356 (1970)].

[5] R. A. Zhitnikov, P. P. Kuleshov, A. I. Okunevich, and B. N. Sevast'yanov, ibid. 58, 831 (1970) [31, 445 (1970)].

[6] B. N. Svast'yanov and R. A. Zhitnikov, ibid. 56, 1508 (1969) [29, 809 (1969)].

[7] V. F. Afanas'ev, R. A. Zhitnikov, and P. P. Kuleshov, Geomagnetizm i aëronomiya 10, 183 (1970).

[8] R. A. Zhitnikov and A. I. Kravtsov, Zh. Tekh. Fiz. 40, 2131 (1970) [Sov. Phys.-Tech. Phys. 15, 1662 (1971)].

[9] M. V. McCusker, L. L. Hatfild, G. K. Walters, Phys. Rev. Lett. 22 (no. 16), 817 (1969).

V. B. Anzin, M. S. Bresler, V. G. Veselago, Yu. V. Kosichkin, G. E. Pikus, I. I. Farbshteĭn, and S. S. Shalyt. Experimental Observation of Magnetic Breakdown in Semiconductors.

Besides interband magnetic breakdown, which is observed in a large number of metals, there have been also theoretical studies of intraband magnetic breakdown, when the carriers execute internal transition between trajectories pertaining to different valleys of the same energy band, something possible if the energy spectrum has a saddle point.

In the present paper it is established, as a result of the investigation of the Shubnikov-de Haas (SH) effect in tellurium single crystals, that the energy spectrum of the valence band of tellurium has a saddle point located 2 meV away from the edge of the band, and intraband magnetic breakdown of the carrier trajectories was observed for Fermi energies close to the saddle-point energy. It was shown that the hole dispersion law is described by the expression

$$\varepsilon = Ak_z^2 + Bk_\perp^2 - \sqrt{\Delta^2 + c^2k_z^2}, \tag{1}$$

and the numerical values of the parameters were determined from the experimental data[1,2].

According to (1), at a hole concentration $P_{cr} = 6 \times 10^{16}$ cm^{-3} (corresponding to the saddle-point energy) in a magnetic field $H \perp C_3$ (C_3 is the trigonal axis of the crystal), the carriers describe trajectories with self-intersection.

Zil'berman and Azbel'[3,4] have shown that such a motion cannot be considered in the quasiclassical approximation; a quantum-mechanical analysis indicates in this case the possibility of simultaneous realization of two trajectories—a complete dumbell-like and almost elliptical one, encompassing approximately half as large an area, this being the consequence of the carrier tunneling from one quasiclassical orbit to another (intraband magnetic breakdown).

For the model under consideration, magnetic breakdown at $p > p_{cr}$—breakdown of the neck of the dumbell—leads to the appearance of additional intersections at $H \perp C$[1,2]. At $p < p_{cr}$, the carrier jumps over from one elliptical orbit to another and forms a trajectory that encircles approximately double the area.

In the exact solution, such a qualitative picture corresponds to splitting, in the magnetic field, of the system of levels for one ellipsoid into two subsystems, corresponding to two types of carrier orbits in the magnetic field. As a result it becomes possible to ob-