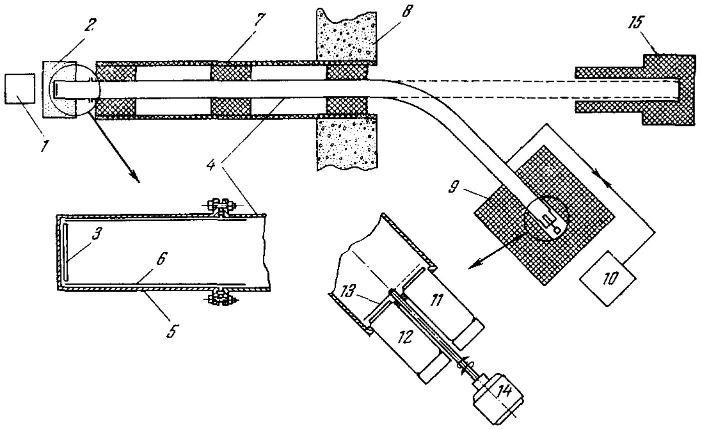

Experimental Setup

1—IBR reactor, 2, 3—moderator (2—paraffin, 3—polyethylene layer 1 mm thick); 4—copper tube with inside diameter 9.4 cm, total length 10.5 m; 5—aluminum tube, 6—cylinder of copper foil; 7—shield (paraffin with boron carbide); 8—two-meter concrete wall of the reactor room; 9—detector shield (paraffin); 10—system for evacuating and filling the tube; 11, 12—detectors (FÉU-13 photomultipliers with layers of ZnS + lithium compound); 13—copper shutter 1.6 μ thick; 14—mechanism for moving the shutter; 15—trap for the direct neutron beam.

at all, its magnitude is smaller than the elementary charge multiplied by 5×10^{-23} cm. The sensitivity of the employed resonance method is limited in final analysis by the time of stay of the neutron in the apparatus, which amounts to $\tau = 2 \times 10^{-2}$ sec. The possibility, noted by Ya. B. Zel'dovich, of storing in a closed cavity very slow neutrons (velocity $v < 5$–8 m/sec), which experience total reflection from the vacuum-medium interface at arbitrary incidence angles[3], makes it possible to realize a time τ on the order of the average radioactive decay time of the neutron (10^3 sec). In principle this should raise the sensitivity of the resonance method of measuring EDM by five orders of magnitude. These arguments have induced a group of physicists in the neutron physics laboratory of the Joint Institute for Nuclear Research (Dubna) to verify the possibility of extracting such ultracold neutrons (UCN) from a reactor and of storing them[4]. The experimental setup is shown in the figure. Neutrons leaving the moderator 3 with velocity exceeding 5.7 m/sec were absorbed upon collision with the walls of the copper tube 4, or else emerged to the outside. The neutrons with lower velocities, experiencing total reflection from the copper, diffused along the evacuated tube to the neutron detectors 11 and 12, and were registered whenever the very thin copper shutter 13 was opened, or else were reflected from the shutter if the latter was closed. Accordingly, the counting rate of the detector decreased sharply when the shutter was closed. Special experiments have made it possible to estimate the diffusion time of the UCN from the moderator to the detector, which turned out to be of the order of 200 sec.

The results of the experiments have shown that UCN are produced and propagate in accordance with the theoretical expectations. This makes it possible to plan experiments on the measurement of the decay period of the neutron and its EDM. It can be assumed that the UCN will find also other applications based on the use of their low energy ($\sim 10^{-10}$ eV), their focusing ability, and other properties.

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G. I. Makarov and V. V. Novikov. Problems in the Propagation of Superlong Radio Waves in the Earth-ionosphere Waveguide Channel.

Radio waves of the superlong band (SLW) propagate in the spherical waveguide channel produced by the earth's surface and the lower part of the ionosphere, which in the frequency range under consideration (1–60 kHz) behaves like a conductor of uneven height, having an anisotropy as a result of the influence of the earth's magnetic field. The properties of the ionosphere and of the earth vary in both the radial and tangential directions, but in most cases the change of the properties of the media in the tangential directions is slow, and in first approximation this circumstance can be disregarded. As a result, the problem of propagation of SLW in the near-earth waveguide reduces mathematically to a construction of the solution of Maxwell's equations with specified sources for a spherically layered medium consisting of three regions. The first region $a \le r \le a + h$ (where a—earth's radius and h—height of the lower edge of the ionosphere over the earth's surface) is a homogeneous isotropic medium with properties practically coinciding with the properties of vacuum. The second region $0 \le r \le a$ is a conducting isotropic medium, the properties of which, generally speaking, depend on the radial coordinate r. Finally, the third region $r > a + h$ (ionosphere) is an *anisotropic conductor* with a *conductivity* that varies with the altitude. Even in such an idealized formulation, it is impossible to construct a strictly analytic solution of the problem, since the variables cannot be separated in Maxwell's equations that describe the field in the anisotropic ionosphere. At the present time there is an approximate analytic solution for this problem, but it still requires further refinement and a quantitative investigation of the limits of its applicability.

The problem of propagation of SLW was considered by many authors[1-10], who used different ways and approximations for the construction of the solution and for its investigation. There are two ways of constructing the solution (using explicitly or implicitly an approximate separation of the variables of Maxwell's equations in the ionosphere): one is based on the expansion of the solution in the eigenfunction of the radial operator (the normal-wave method), and the other is based on the expansion in the eigenfunctions of the azimuthal operator (the Debye method or the method of multiply reflected waves). The second method of constructing the solution is simpler mathematically, since the azimuthal operator has only a discrete spectrum. With the aid of the Watson transformation, the solution obtained in this way is reduced to a representation in the form of a series of normal waves, which is conveniently used for numerical calculations of the field at large distances from the source ($r > 3000$ km). On the other hand, the expansion of the solution in a series of waves multiply reflected from the surface of the earth and from the ionosphere, which is obtained directly when the second method is used, is convenient for calculations at small distances from the source. It is easy to obtain from this expansion an approximate geometrical representation of the solution in the form of multiply reflected rays, which is valid in the region that is illuminated for this ray. On the other hand, in the shadow region, each individual term of the series of multiply reflected waves can be interpreted as a "diffraction" ray that experiences partial glancing over the earth's surface.

In constructing the solution of the basis of expansions in the eigenfunctions of the azimuthal operator (the Legendre polynomials $\cdot P_n(\cos\theta)$), the decreasing field (the field of the source in free space) is given by a series of normal harmonics, each term of which represents a helical wave[11]. If we consider the successive reflection of the individual helical wave alternately from the earth's surface and from the ionosphere, and if we satisfy the boundary conditions in each reflection with the aid of spherical reflection coefficients of the helical waves, we can obtain a formal solution of the problem in the form of a sum of multiply reflected waves, each of which has been reflected a definite number of times from the earth's surface and from the ionosphere. Each individual wave is represented in turn as a sum of the eigenfunctions of the azimuthal operator[5].

In the described scheme of constructing a solution, it is assumed that upon reflection of a given helical wave numbered n, the reflected field is one helical wave having the same number. This assumption is rigorously satisfied in the case of isotropic media, but in reflection from the anisotropic ionosphere it is in general violated—the reflected field is given in this case by an infinite sum of helical waves. Therefore the solution obtained by this method for anisotropic ionosphere is approximate and corresponds to the "diagonal" approximation of the spherical reflection coefficient from the ionosphere.

In constructing a solution, it is necessary to take into account the change of the polarization of the wave upon reflection from the surface of the anisotropic ionosphere, and to use a spherical reflection coefficient matrix with nonzero non-diagonal elements. The spherical coefficient of reflection from the earth's surface must in this case also be used in matrix form, but with zero non-diagonal elements.

To investigate the solution in the form of a series of multiply reflected waves or a series of normal waves, it is necessary to know the spherical reflection coefficients. These can be written in explicit analytic form only for homogeneous (layered-homogeneous) isotropic media. In the case of inhomogeneous media, and also in the case of an anisotropic ionosphere, it is necessary to resort to numerical calculations of the reflection coefficients (or of the surface impedances). As to the spherical coefficient of reflection from an anisotropic ionosphere, it must be replaced by the coefficient of reflection of a plane wave from a plane-layered medium (or, more accurately, by the coefficient of reflection of a cylindrical helical wave from a cylindrically layered medium). As shown by investigations for an isotropic ionosphere[12], such a substitution ensures high accuracy.

In the investigation of the solution in the form of a series of normal waves, the main difficulty lies in the solution of the characteristic transcendental equation for the eigenvalues of the radio operator. By now, a procedure has been developed for numerically solving this equation[2,8,13,14], and numerous calculations have been made, revealing the main laws governing the propagation of superlong radial waves in the waveguide channel next to the earth.

The fact that the problem has many parameters makes it difficult to clarify the qualitative regularities, and therefore great interest attaches to the use of variational methods in order to obtain simple approximate expressions for the eigenvalues of the radial operator. The use of such methods in the case of a plane isotropic waveguide[15] has made it possible to analyze in greater detail the dynamics of the eigenvalues, their dependence on the frequency, on the height of the waveguide, and on the surface impedance of its upper wall, and also to observe the phenomenon of degeneracy of the eigenvalues. Similar investigations for a spherical waveguide have shown that the influence of sphericity on the eigenvalues of the radio operator is determined by the sphericity parameter $S = (kh)^2h/z$, which in the SLW band ranges from several hundredths to several dozen, i.e., the influence of the sphericity is very appreciable in the upper part of the SLW band. In a spherical waveguide, as well as in a plane one, there is the degeneracy phenomenon, which influences the numbering of the normal waves.

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E. A. Konorova and S. F. Koslov. Diamond Detector for Nuclear Radiation.

In spite of the progress made in germanium and silicon detectors for nuclear radiation, there are fields of application where the diamond detector has definite advantages because of its high chemical and thermal stability. The counting properties of diamond have been the subject of a rather large number of investigations[1-3]. These investigations, however, did not lead to the development of a diamond detector—an instrument suitable for practical use.

Natural diamonds are insulators with resistivity 10^{14} ohm-cm and higher. Electric fields up to 10^6 V/cm still produce no breakdown of the crystal. The carrier mobility is large and amounts to 1550 cm^2/V-sec for holes[4] and 2000 cm^2/V-sec for electrons[5]. These properties of diamonds are very favorable for its use as a radiation detector.

However, the use of very strong electric fields is limited by the dependence of the mobility on the field, as in other valent crystals. According to[5,6], the electron drift velocity in diamond reaches its limiting value $10^7 \pm 0.2 \times 10^7$ cm/sec at room temperature in a field of approximately 2×10^4 V/cm. This circumstance was not taken into account in any of the published papers on the counting properties of diamonds, and therefore the treatment of the experimental results was not always satisfactory. Since the electron and hole lifetimes in diamond exceed in very rare cases 10^{-8} sec[5], the maximum depth of the work in the region of the detector is limited to 200—300 μ.

An essential shortcoming of diamond detectors is the polarization of the crystal, since the very low electric conductivity prevents the electric equilibrium from becoming reestablished inside the crystal within the time between pulses. Known methods of eliminating the polarization by heating, illumination, or applying an alternating field are not suitable and have little efficiency. To avoid polarization, we have proposed to use an injecting contact on the side of the diamond opposite to the irradiated side[7]. In the vicinity of such a contact there is maintained an equilibrium of the field and the charge. When this equilibrium is violated by the captured carriers, say electrons produced in the crystal following ionization by the registered radiation, their neutralization is effected by the hole current from the contact (space-charge-limited current).

Sample No.	Thickness, mm	Working voltage	Counting efficiency, %	Energy resolution, %	ε_α *), eV
1	0.15	400	100	5	15.6
2	0.16	600	100	5	15.4
3	0.21	600	100	8	16.2
4	0.27	400	100	9	16.1
5	0.14	600	100	8	16.3
6	0.20	300	100	4	15.9
7	0.20	400	100	10	16.2
8	0.19	200	100	15	16.2
9	0.13	400	100	15	16.6
10	0.40	600	100	5	16.2

*ϵ_α—energy necessary to produce a pair of carriers, calculated from the momentum at the maximum of the curve of the amplitude distribution.

After overcoming many difficulties connected with the development of injecting contacts for diamond, the selection of crystals with necessary lifetime, and others, we have constructed 10 diamond detectors. The properties of these detectors were investigated by registering 5.5-MeV α particles from a $Pu^{238-242}$ source. The obtained results are summarized in the table, the data in which pertain to room temperature.

The working area of the detectors ranged from 2 to 10 mm^2.

The operation of the detectors was investigated by registering particles in the temperature range 300—1000°K. Up to 490—550°K, the properties of the detector remained essentially unchanged, but at higher temperatures, the amplitude of the pulses and the counting efficiency decreased, but the count continued in some cases up to 1000°K.

At the present time we can point out the following fields of application of diamond detectors for nuclear radiations: 1) registration of short-range particles (α particles, protons) at increased temperature, 2) registration of short-range particles in aggresive media—in acids and alkalis, 3) registration of low-energy β particles at room temperature and at increased temperatures, and also in active media (for example, the radiation of tritium in biological objects).

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I. V. Karpova, S. G. Kalashnikov, O. V. Konstantinov, V. I. Perel', and G. V. Tsarenkov. Recombination Waves in Compensated Germanium.

The paper presents data on the observation and investigation of a new type of electric instability in semiconductor plasmas, called recombination waves (RW). The existence of RW was theoretically predicted in[1], where it was shown that waves of carrier density