takes place with two characteristic energies, $\Omega_F = T_c\gamma_F(\kappa a)^{z_F}$ and $\Omega_{AF} = T_c\gamma_{AF}(\kappa a)^{z_{AF}}$ ($\gamma_F \sim \gamma_{AF} \sim$ 1 κ is the reciprocal dimension of the ferromagnetic fluctuations). In the dipole region, the onset c the ferromagnetic fluctuation leads to a large increase of the system energy because of the syster magnetic field, and accordingly to a decrease of the time of its decay, i.e., to a decrease of z_F. Th dipole forces act on the antiferromagnetic fluctuations indirectly, via the magnetization fluctu ations, so that the change of z_{AF} should be weaker. It may turn out here that $z_{AF} > z_F$, i.e., th antiferromagnetic fluctuations have a much longer lifetime than the ferromagnetic ones, and fror the point of view of the latter, constitutes so to speak an external random static field. In this case to determine z_F we can use the arguments of the preceding section, and the characteristic energy c the ferromagnetic fluctuations will be described by the formula (2) with $g \sim 1$.

In conclusion, I wish to thank I.D. Luzyanin and V.P. Khavronin for the opportunity c reading[2] prior to publication, and S.L. Ginzburg for a large number of interesting discussions.

[1] E. Riedel and F. Wegener, Phys. Rev. Lett. **24**, 730 (1970).
[2] G.B. Teĭtel'baum, Pis'ma Zh. Eksp. Teor. Fiz. **21**, 339 (1975) [JETP Lett. **21**, 154 (1975)].
[3] S.V. Maleev, Zh. Eksp. Teor. Fiz. **66**, 1809 (1974) [Sov. Phys. JETP **39**, 889 (1974)].
[4] I.D. Luzyanin and V.P. Khavronin, this issue, preceding paper.
[5] A.M. Polyakov, Zh. Eksp. Teor. Fiz. **57**, 271 (1969) [Sov. Phys. JETP **30**, 151 (1970)].
[6] M.E. Fisher and A. Aharony, Phys. Rev. **B 8**, 3323 (1973).

Observation of undulating radiation with the "Pakhra" synchrotron

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An experiment aimed at observing undulating radiation with the "Pakhra" synchrotron in the visible region of the spectrum is described.

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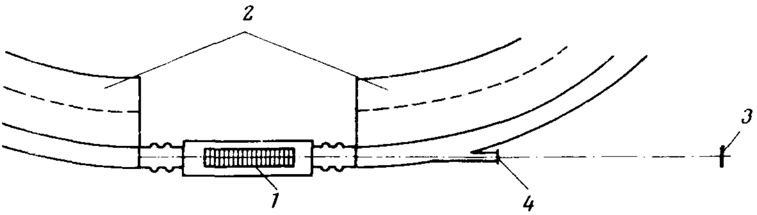
The feasibility of obtaining narrowly-directed polarized monochromatic electromagnetic ra ation uncovers great research possibilities in high-energy physics, in solid-state spectroscopy, molecular physics, in solid-state spectroscopy, in molecular physics, in biology, in photochemist and in many other branches of science. The possibility of using the radiation of relativistic charg particles in periodic electromagnetic fields of undulators has been discussed in[1–4]. A sufficien detailed theoretical investigation of the properties of undulator radiation can be obtained in[5] a in the literature cited therein. Up to now, undulator radiation was observed in electron beams linear accelerators in the energy range 3–100 MeV [6–8] and in a 3.6-GeV electron beam extract from a synchrotron.[9]



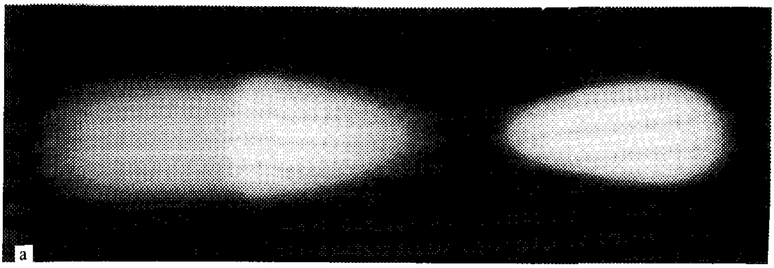
IG. 1. Experimental setup: 1—undulator, 2—magnetic circuit of accelerator, 3—photographic late, 4—quartz window.

Since only one pass of the beam through the undulator was used in these studies, the obtained ndulator-radiation intensity was low. However, if the undulator is placed in the straight-line gap f the synchrotron, then, by using multiple passage of the particles through the undulator, the average) intensity of the undulator radiation can be increased by several orders of magnitude. This ossibility was discussed previously in[3] and[10]. In this paper we describe experiments aimed at bserving electron emission in an undulator placed in the straight-line section of the orbit of the Pakhra" synchrotron.[10]

The experimental setup is shown in Fig. 1. The undulator has 20 periodicity elements. The ength of each element is 4 cm. The magnetic field is produced by a single-turn flat winding ontaining an odd number of series-connected parallel (in space) conductors oriented perpendicuar to the beam axis. The winding is placed in the grooves of the magnetic circuit, which is made in e form of a ferromagnetic comb.[11] The undulator winding is fed with pulses with maximum rrent amplitude 8 kA and pulse duration 2 msec. The plane of the undulator is located 25 mm way from the plane of the equilibrium orbit. The amplitude of the transverse periodic magnetic eld decreases with increasing distance from the plane of the undulator. Therefore, for most fective generation of the radiation, it is necessary to bring the beam as close as possible to the ndulator plane. In the present design, owing to the influence of the return lead for the current, an homogeneous constant radial component of the magnetic field appears on top of the transverse eriodic magnetic field.

The radial component produces a vertical shift of the circulating beam. Under the experimenl conditions, this shift amounted to about 1 cm towards the undulator. At an undulator-winding rrent 3 kA, the obtained shift of the synchrotron beam corresponds to an undulator magnetic ld amplitude 360 Oe. Our experiments have shown that the appearance of the radial component the magnetic field does not cause a loss of electrons accelerated in the synchrotron, if the dulator field is turned on at an electron energy exceeding 350 MeV. The conditions of our periment were chosen such that the undulator radiation was in the optical wavelength band. The dulator and synchrotron radiation were registered in the wavelength range 2000–5000 Å with e aid of "spectral" photographic plates of type 2, which were placed perpendicular to the axis of e platelying gap at a distance 440 cm from the undulator center. The maximum electron energy s determined by the instant when the high-frequency voltage on the accelerating resonator of the nchrotron was turned on. The pulsed magnetic field of the undulator was turned on and reached maximum value shortly (~0.1 msec) prior to the turning off of this voltage. This operating gime makes it possible to obtain undulator radiation from practically monoenergetic electrons.

Figure 2a shows a photograph of the synchrotron radiation from electrons with maximum ergy 175 MeV (with the undulator turned off). The left-hand band corresponds to emission from electron beam leaving the far (relative to the photographic plate) quadrant of the synchrotron amber, while the right-hand band corresponds to emission from the electron beam entering the



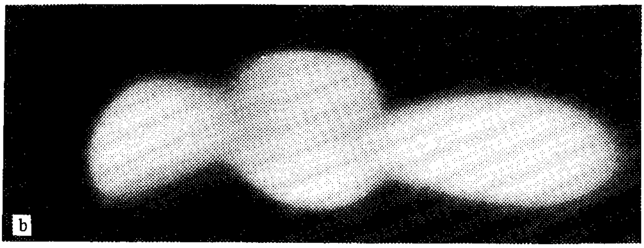


FIG. 2. a) Photograph of synchrotron radiation of electrons from the turning magnet of tl synchrotron. Energy 175 MeV. b) Photograph of synchrotron and undulator radiation of tl electrons, energy 175 MeV.

next quadrant of the chamber. The photograph shows clearly the minimum of the distribution the radiation intensity in the horizontal plane; this minimum corresponds to the beam axis in tl straight-line gap. The observed break between the bands is due to the fact that in the stray fields the linear gap (which rotates noticeably the electron-velocity vector) the emission of the electroı at this energy falls in the infrared region of the spectrum and is not registered by the photograph plate. A photograph of the radiation with the undulator turned on is shown in Fig. 2b. It is see that a bright spot, corresponding to emission from the electrons in the transverse periodic magnet field of the undulator, has appeared at the location of the minimum of the radiation intensity (Fi 2a).

It follows from a preliminary analysis of the photographs that the intensity of the undulat radiation in a unit angle interval near the undulator axis exceeded by several times the correspon ing intensity of the synchrotron radiation. Account was taken here of the fact that the effecti duration of the synchrotron radiation exceeded by approximately one order of magnitude tl duration of the undulator-radiation pulse.

To verify once more that we are dealing with undulator radiation, the maximum energy of tl

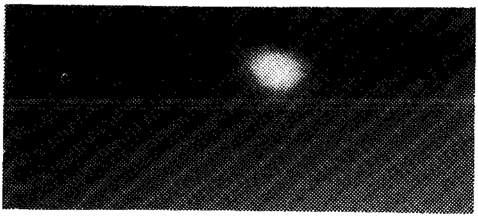


FIG. 3. Photograph of undulator radiation. En gy 100 MeV.

celerated beam of the electrons was chosen to be 100 MeV in one of our experiments, so as to ace the synchrotron radiation in the infrared region outside the sensitivity region of the photo-aphic plate. In this case the emulsion should register only the undulator radiation, the spectrum which, in accordance with the theory, should lie in the visible region under the conditions of our periment. Figure 3, the photograph obtained in such an experiment, demonstrates that only the ıdulator radiation is photographed.

It is interesting to note that, as expected, the intensity of the undulator radiation in the plane the oscillations of the particles is weaker (see Fig. 2b).

We continue our studies of the properties of undulator radiation.

In conclusion, it is our pleasant duty to thank V.V. Mikhaĭlin for constant interest in the work d N.I. Alekseev and V.A. Karpov for help with the experiment.

/.L. Ginzburg, Izv. Akad. Nauk SSSR Ser. Fiz. **11**, 165 (1947).
I. Motz, J. Appl. Phys. **22**, 527 (1951).
.P. Godwin, Springer Tracts in Modern Physics **51**, 1 (1969).
).F. Alferov, Yu.A. Bashmakov, and E.F. Bessonov, Zh. Tekh. Fiz. **42**, 1921 (1972) [Sov. Phys. 'ekh. Phys. **17**, 1540 (1973)]; FIAN Preprint, No. 23, 1972.
).F. Alferov, Yu.A. Bashmakov, and E.G. Bessonov, Tr. Fiz. Inst. Akad. Nauk **80**, 100 (1975).
I. Motz, W. Torn, and R.N. Whiterurst, J. Appl. Phys. **24**, 856 (1953).
.A. Grisheev, V.I. Myakota, V.I. Kolosov, V.I. Beloglad, and P.V. Yakimov, Dokl. Akad. Nauk SSR **131**, 61 (1960) [Sov. Phys. Dokl. **5**, 272 (1960)].
.R. Elias, W.M. Fairbank, J.M. Madey, H.A. Schwettman, and T.I. Smith, Phys. Rev. Lett. **36**, 17 (1976).
.I. Alikhanyan, S.K. Esin, K.A. Ispiryan, S.A. Kapkanyan, N.A. Korkhmazyan, A. Yu. ganesyan, and A.G. Tamanyan, Pis'ma Zh. Eksp. Teor. Fiz. **15**, 142 (1972) [JETP Lett. **15**, 98 1972)].
).F. Alferov, Yu.A. Bashmakov, K.A. Belovintsev, E.G. Bessonov, V.V. Mikhaĭlin, E.I. Tamm, nd P.A. Cherenkov, Proc. 3rd All-Union Conf. on Charged-Particle Accelerators, Nauka, 1973.
).F. Alferov, Yu.A. Bashmakov, K.A. Belovintsev, E.G. Bessonov, A.S. Golovin, and P.A. 'herenkov, Proc. All-Union Conf. on the Development and Practical Utilization of Electron .ccelerators, Towsk, 1975, p. 214.

uclear acoustic echo in cobalt

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Observation is reported of acoustic nuclear spin echo in single-crystal cobalt at a temperature 4.2 K in a magnetizing field 1.8 T.

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Nuclear echo in cobalt is easily observed when the nuclear spins are excited by an electromag-ic field. We know, however, of only one report of observation of nuclear acoustic echo in