

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

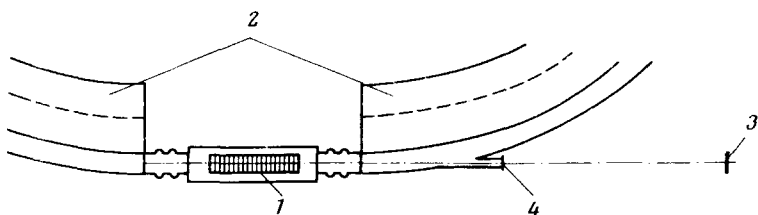


FIG. 1. Experimental setup: 1—undulator, 2—magnetic circuit of accelerator, 3—photographic plate, 4—quartz window.

Since only one pass of the beam through the undulator was used in these studies, the obtained undulator-radiation intensity was low. However, if the undulator is placed in the straight-line gap of 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 possibility was discussed previously in<sup>[3]</sup> and<sup>[10]</sup>. In this paper we describe experiments aimed at observing electron emission in an undulator placed in the straight-line section of the orbit of the Pakhra" synchrotron.<sup>[10]</sup>

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

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

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

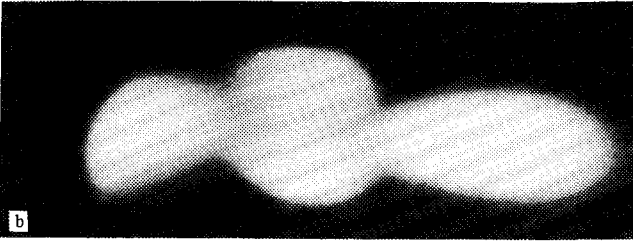
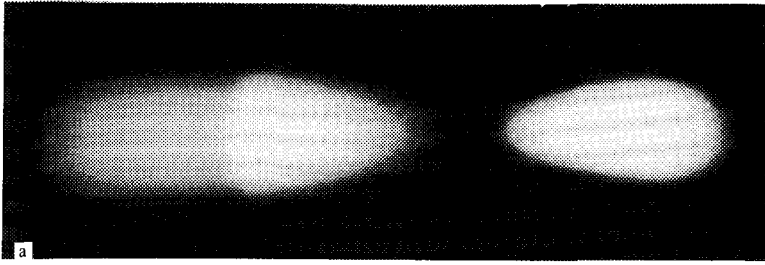


FIG. 2. a) Photograph of synchrotron radiation of electrons from the turning magnet of the synchrotron. Energy 175 MeV. b) Photograph of synchrotron and undulator radiation of the electrons, energy 175 MeV.

next quadrant of the chamber. The photograph shows clearly the minimum of the distribution of the radiation intensity in the horizontal plane; this minimum corresponds to the beam axis in the straight-line gap. The observed break between the bands is due to the fact that in the stray fields of the linear gap (which rotates noticeably the electron-velocity vector) the emission of the electrons 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 seen that a bright spot, corresponding to emission from the electrons in the transverse periodic magnetic field of the undulator, has appeared at the location of the minimum of the radiation intensity (Fig. 2a).

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

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

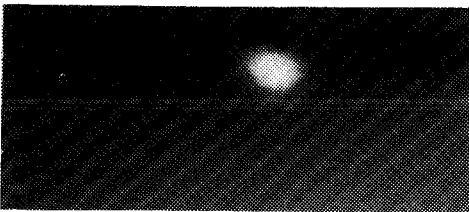


FIG. 3. Photograph of undulator radiation. Energy 100 MeV.

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

It is interesting to note that, as expected, the intensity of the undulator radiation in the plane of 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. Mikhailin for constant interest in the work and N.I. Alekseev and V.A. Karpov for help with the experiment.

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