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ЦЕНТРАЛЬНЫЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ
ИНФОРМАЦИИ И ТЕХНИКО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ
ПО АТОМНОЙ НАУКЕ И ТЕХНИКЕ

ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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GENERATION OF COHERENT INDUCED UNDULATOR RADIATION

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GENERATION OF COHERENT INDUCED UNDULATOR RADIATION

A device is constructed for the generation of coherent induced undulator radiation on the 7.5 MeV microtron beam. First results of radiation measurement in the infrared range are presented.

Yerevan Physics Institute
Yerevan 1984

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ГЕНЕРАЦИЯ КОГЕРЕНТНОГО ВЫНУЖДЕННОГО ОНДУЛЯТОРНОГО ИЗЛУЧЕНИЯ

Создана установка по генерации когерентного вынужденного ондуляторного излучения на пучке микротрона 7,5 МэВ. Проведены первые измерения излучения в инфракрасном диапазоне.

Ереванский физический институт
Ереван 1984

Papers devoted to induced undulator radiation are considered in surveys [1,2]. The quantity of such papers continues to increase and at present it is over a hundred. However, a noticeable lagging is observed in the quantity of experimental works from theoretical ones. Despite the numerous projects of the construction of sources of coherent induced undulator radiation, which are quite often of practical importance, the experimental results of only one device, constructed at Stanford [3] are widely known. Important results have been obtained in 1983 at Orsay, where investigators managed to detect the amplification of the external laser beam. Apparently, in the nearest future they will accomplish the generation regime.

Such a situation is explained, in part, by the fact that the requirements to accelerators for the construction of needed devices are rather strict (high current density and high monochromaticity of electron beam). It is therefore no mere chance that the first device was constructed at the Stanford superconducting linear accelerator with its unique parameters.

Investigations on the generation of coherent induced undulator radiation were begun at EPI in 1980. As a result, at present a demonstrational device is constructed on the microtron beam for the generation of coherent induced undulator radiation.

The device allows to carry out more detailed investigations of undulator operation and define the most optimal parameters of certain units.

The basic parameters of the experimental device are as follows:

energy of electrons	7.5 MeV
length of the undulator magnet period	1.6 cm
radiation wavelength	30-40 μm
length of undulator magnet	200 cm
number of undulator periods	125
magnetic field amplitude on the undulator axis	to 4000 Oe
length of optical cavity	290 cm
electron beam current in micropulse	0.2 A
duration of the electron beam current macropulse	3 μs
electron beam diameter	5 mm
mirror loss coefficient	0.02
diffraction loss	0.02
amplification with account of loss	0.18
expected general amplification	10^8
expexted maximum pulse power	100 W

The layout of laser device and its general view are presented in figs. 1 and 2, respectively.

The undulator magnet is a pulsed, ironfree, helical one with the internal diameter 16 mm. The 20 kW and 20 kA modulator is assembled on the basis of a mercury ignitron by the scheme with the total discharge of storage volume. The discharge half-period time is 20 μs, the charge time is 5 s.

The extracted microtron beam is focused to the undulator magnet input by means of two quadrupole lenses, bending and correcting magnets. The size of the beam is later on maintained due to the 400 Oe longitudinal magnetic field. The emittance of the extracted microtron beam is in vertical 10^{-3} cm mrad, and in horizontal $2 \cdot 10^{-2}$ cm mrad, therefore, in the horizontal direction the beam is diaphragmed, which leads to the loss of $\sim$60% of the extracted microtron beam. On the device output the size of the beam is controlled by a sectioned Faraday cup.

In order to decrease the diffraction loss in the optical cavity a spherical mirror with the radius of curvature 3 m is used. The second mirror is a plane one with a central hole for the radiation extraction. The spherical mirror has a system of remote displacement along the optical cavity axis for the tuning of the optical cavity length (it should be multiple of the microtron accelerator system wavelength). The accuracy of the adjustment of the optical cavity length depends on the required number of radiation reflections in the cavity and the length of the electron beam micropulse. At given values of these quantities (reflection number $\sim$100, current micropulse length 1 cm and optical cavity length 2.9 m), the accuracy of the adjustment of the optical cavity length is $2 \cdot 10^{-3}$.

In order to obtain the required gain, the undulator magnetic field strength should be increased due to weak microtron current. On the other hand, at strong fields of substantial value is the magnetic field homogeneity by the undulator transverse cross section. The allowance for the field inhomogeneity may be defined as follows:

$$\Delta\lambda/\lambda = \frac{K}{1+K^2/2}\cdot\frac{\Delta H}{H} < 1/N \;; \qquad K = 10^4 \Lambda H$$

where λ is the radiation wavelength, H is the undulator magnetic field strength, Λ is the undulator period length, N is the number of undulator periods.

The calculation and measurements have shown that the field distribution has the form presented in fig.3 [4]. From this distribution one may define the permissible diameter of the electron beam at a given strength of the undulator magnetic field.

Dependences of the gain G and the laser output on the undulator magnetic field strength are presented in fig.4. When choosing the strength of magnetic field, one should take into account the sensitivity of the detection system as well. Proceeding from these considerations, investigation at the field strength of 2000 Oe is the most promising.

At the maximum possible power 100 W and duration of radiation power growth 2 μs, the radiation energy in the pulse is $5\cdot10^{-6}$ J. With consideration of window loss, it corresponds to the energy of about 10^{-6} J in the pulse hitting the detector. Pyroelectric detectors of the sensitivity 10^{-7} J in the pulse are used for radiation recording. In this range of radiation we know no other simpler and more sensitive detector. Besides the insufficient sensitivity, pyroelectric detectors have also a piezoelectric effect which substantially deteriorates the signal-noise ratio.

At present a useful signal in the form of a 10% addition to noise levels is observed on the laser output with the noise instability being 50%. Such an addition corresponds to the radiation energy $2 \cdot 10^{-7}$ J or power 10 W in the impulse. By means of band filters it has been proven that the radiation wavelength is in the range 20-40 μm. The thin paper screen installed on the device output, completely absorbed the radiation.

The next goal in the device development is the improvement of the radiation recording system.

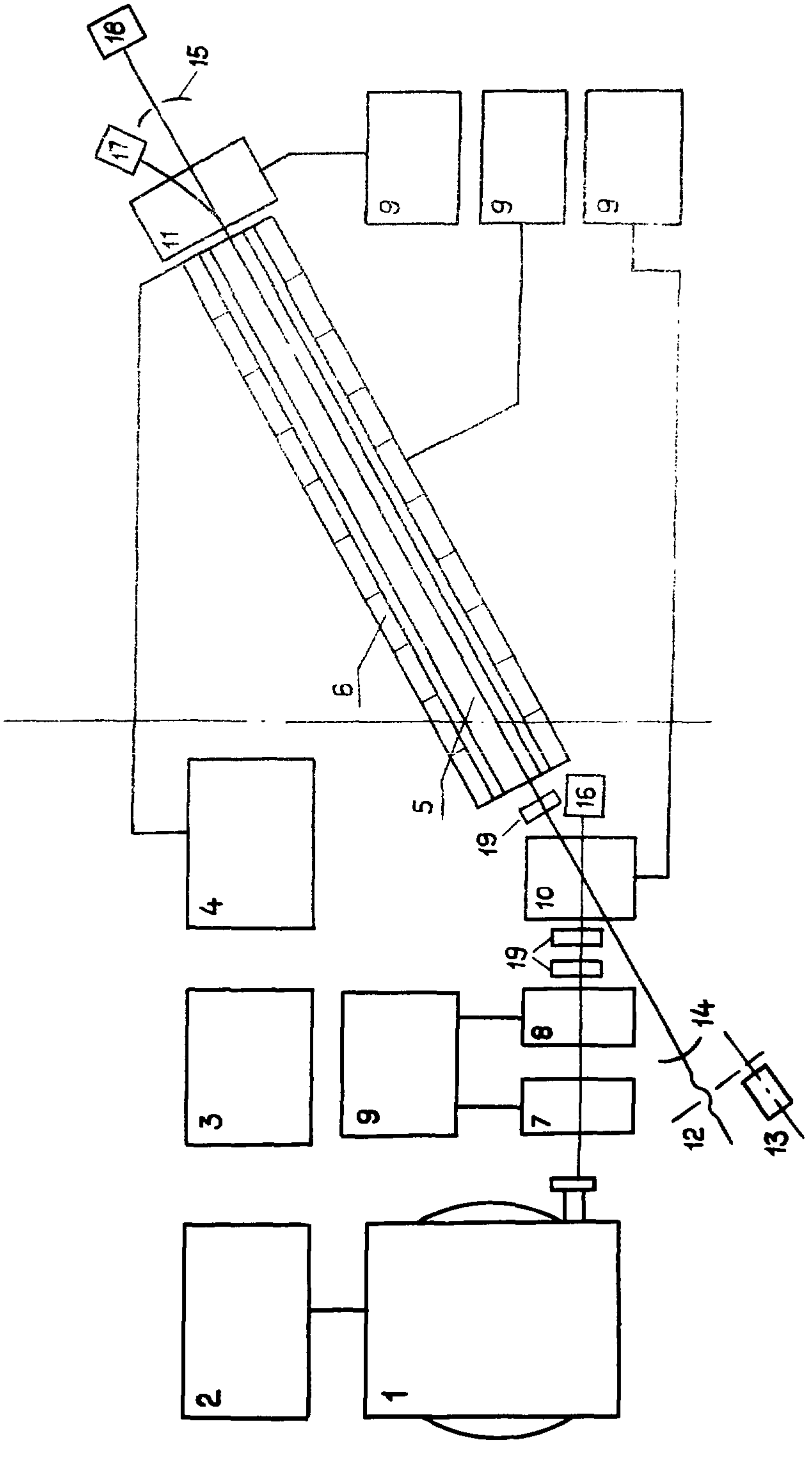


Fig. 1

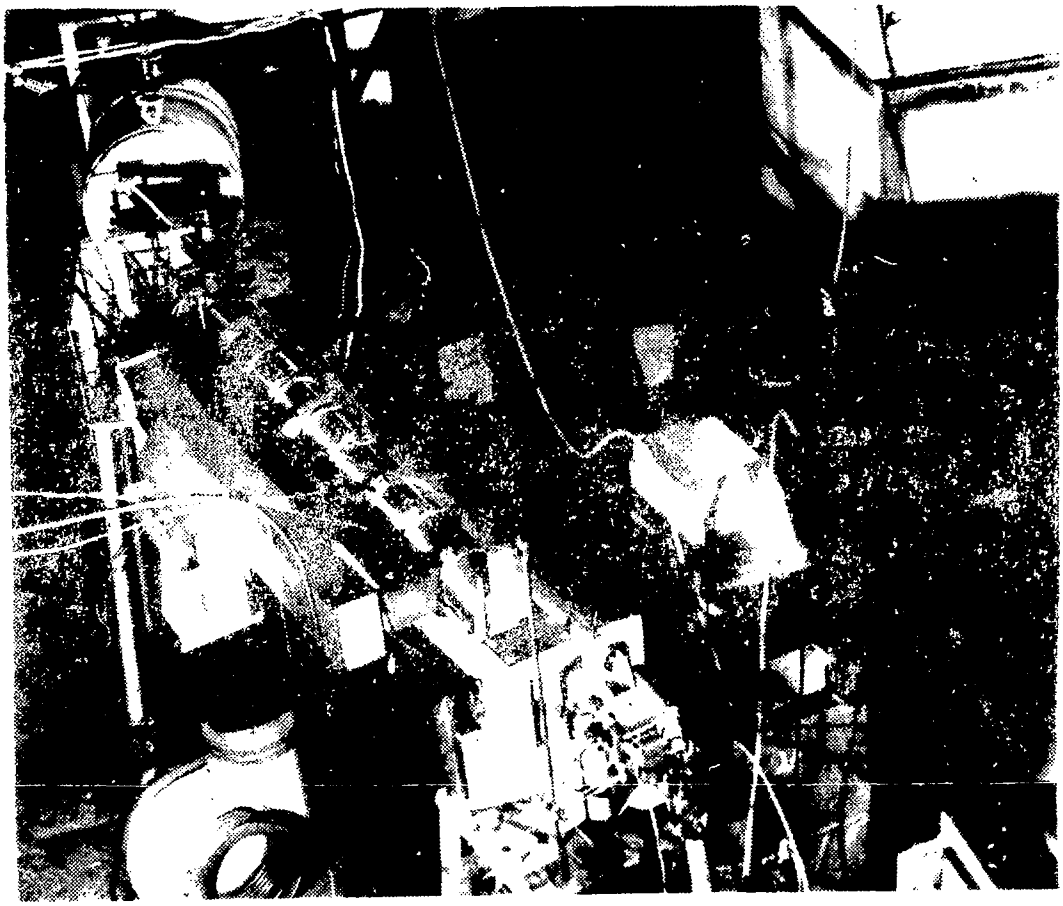
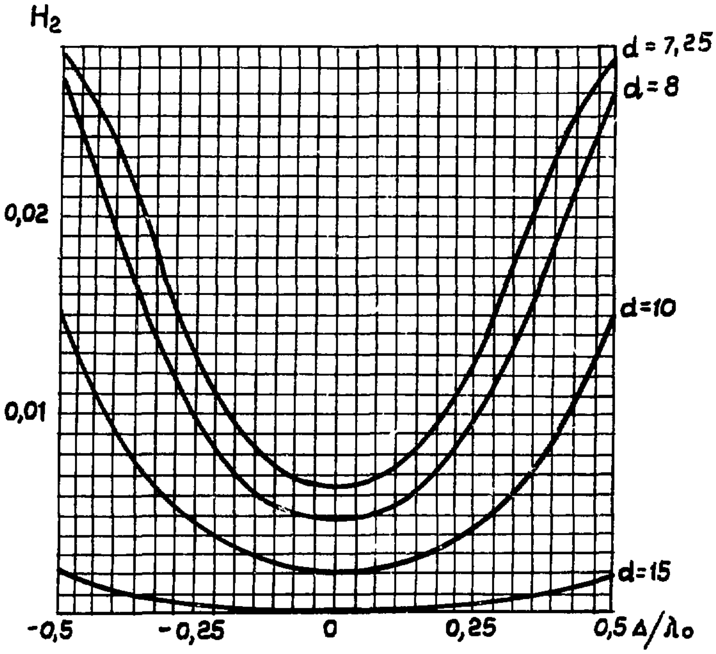


Fig. 2



$H_2(d, \pi/2, \Delta\lambda_0)$

Fig. 3

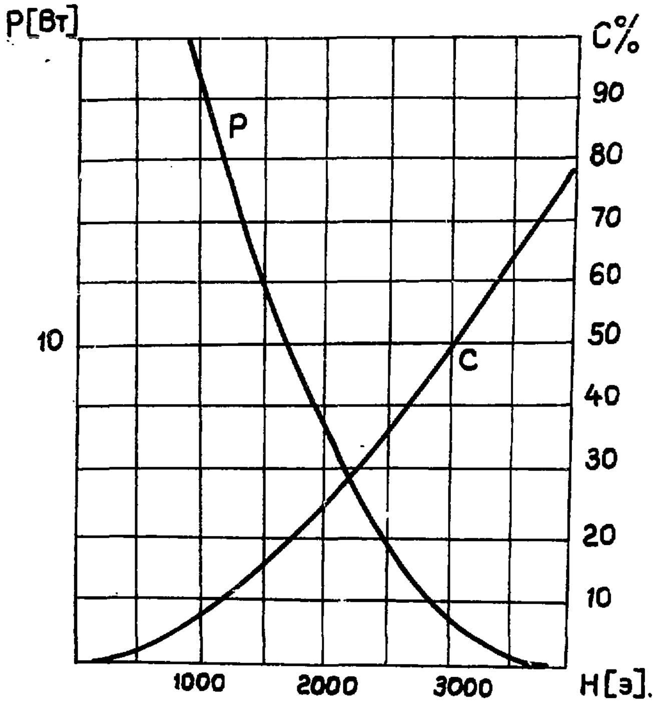


Fig. 4

Figure Captions

Fig. 1 Layout of the generator of coherent induced undulator radiation: 1 - microtron; 2 - high-frequency system of microtron; 3 - control unit; 4 - modulator of the undulator magnet; 5 - undulator magnet; 6 - focusing solenoids; 7,8 - quadrupole lenses; 9 - supply unit; 10,11 - bending magnets; 12 - mirror displacement mechanism; 13 - selsyn; 14,15 - mirrors; 16,17 - Faraday cups; 18 - pyroelectric detector; 19 - correcting magnets.

Fig. 2 General view of the experimental device on the generation of coherent induced undulator radiation.

Fig. 3 Transverse distribution of the undulator magnetic field: λ_0 is the undulator period length; d is the undulator diameter; Δ is the shift from the undulator axis.

Fig. 4 Dependence of the gain G and pulse power of radiation P on the strength of the undulator magnetic field.

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