EXPERIMENTAL RESEARCH OF THE RELATIVISTIC ELECTRON BEAM RADIATION IN THE STORAGE RING

I.S. Guk, A.S. Tarasenko
National Science Center "Kharkov Institute of Physics and Technology" Kharkov, Ukraine
e-mail: guk@kipt.kharkov.ua

In 1969 - 1989 on the storage ring N-100 the cycle of works on an experimental research of the relativistic elektron beam radiation in energy range of from 50 up to 100 MeV and the stored particle number - from one electron up to $3.6*10^{11}$ was carried out. The basic results of these researches are described. On the basis of existing (N-100) and projecting in NSC KIPT storage rings it is put forward the offer to create the national metrological standards in infrared, visible, ultraviolet and x-ray spectrum.
PACS: 12.20.-m, 13.40.-f, 13.60-Hb, 13.88.+e

1. INTRODUCTION

The quantum and classical theory of the synchrotron radiation (SR) allows to calculate the spectral and angular characteristics of radiation, if the electron energy E and curvature radius of a trajectory R is known with accuracy to corrections caused by feedback at radiation [1]. The real electron movement in the storage rings results to change the radiation characteristics because of betatron and synchrotron oscillations. The cycle of works executed in 1969 - 1989 on the storage ring N-100 was devoted to experimental study of electron beam parameters influence on SR properties. More high, than at synchrotrons, electron beam parameter stability had allowed to fulfill more exact measurements of SR characteristics in wide range of electron energy and of the circulating current.

2. EXPERIMENTAL RESEARCH OF SR SPECTRAL DENSITY

SR spectral density is universal function of the relation critical wavelength λ_c and supervision wave length λ [1,2]. The dependence of spectral density radiation was investigated on N-100 at change of this relation from 3.6 up to 0.6. The measurements were carried out at minimally possible intensity of an electron beam - from one up to twenty circulating electrons. The scheme of experimental installation is submitted in Fig 1.

Through a special window SR was abstracted from the storage ring vacuum chamber 1 and then through limiting diaphragm 2 and interference light filter 3 got on the photomultiplier photocathode 4, that operated in the single photon mode counting.

The diaphragm size and distance up to point of radiation were chosen by such a manner that all vertical radiation cone coincided with uniformity of sensitivity photocathode area. The photomultiplier pulses were amplified and counted by the counter 6. Electronic timer 7 fixed the counting time. The quantity of circulating electrons was determined by SR that was registered by

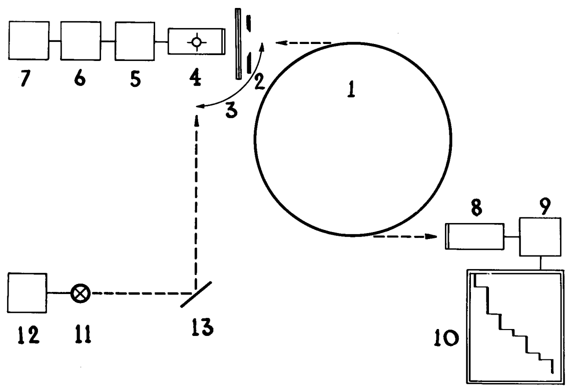

Fig 1. *The experimental installation circuit*

photomultiplier 8, in total current mode operating. The photomultiplier signal was amplified by direct current amplifier 9 and was sent on recording potentiometer 10. The electrons number change by one was resulted to stepped change of photomultiplier current that was fixed on the recording potentiometer diagram. For SR spectral distribution research the electron energy in the storage ring was changed within the limits of 50-100 MeV. After realization of measurements with SR, photomultiplier 4 was turned, the diaphragm with smaller size was located and the photocathode was lighted by a photometric lamp 11 that was calibrated by model of absolutely black body.

The results of SR spectral density distribution measurements are given on Fig. 2. The measurements were carried out for wavelengths 382.2 nm (1) and 501.5 nm (2). The theoretically designed dependences of SR spectral density for the same wavelengths were equated to the exactest experimental measurements at energy 98 MeV.

For comparison the absolute fluxes of SR and lamps, calibrated by absolutely black body model (ABB), two groups of measurements were carried out. The first group was carried out for wave length 501.5 nm with

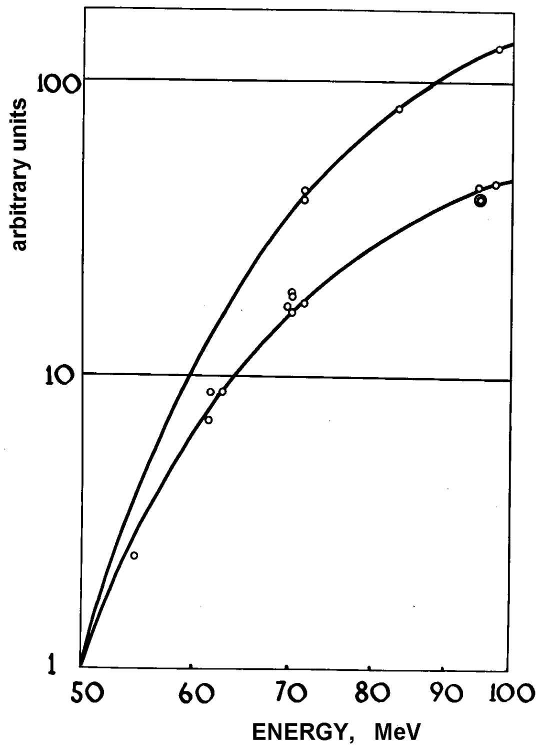

Fig 2. SR spectral density

use SI 8-200U lamp at string temperature 2388 K and SR with electron energy 61.8, 70.4, 91.5 MeV. The second group was carried out for wavelength 492 nm with use SI 10-300 lamp at temperature 2018 K and SR with electron energy 70.17 MeV. The obtained experimental results testify, that the absolute value of SR spectral density coincides within the limits measurement accuracy of (~15 %) with calculated one [2].

3. EXPERIMENTAL RESEARCH OF THE ANGULAR AND POLARIZING SR CHARACTERISTICS

The greatest influence the electron betatron oscillations affect on angular and polarization SR characteristics.

In order to receive experimental data with better accuracy, than it was receive in the earlier researches, the following procedure of measurement was chosen [3]: SR was extracted from the storage ring vacuum chamber through thin, optical homogeneous windows on the channel exits. The preliminary measurements of the window optical characteristics before its on channels installation have confirmed birefringence and rotation of polarization plane absence; the special actions were taken for exception of mechanical pressure in glass emergence were accepted at windows mounting on channels.

The photomultiplier photocathode moved. with 1 mm step perpendicular to the orbit plane on distance L from a point of radiation. The interference light filter and polaroid were installed before 0.25 (0.5) mm diameter diaphragm near to the photocathode. The current value in the storage ring was fixed with another photomultiplier by SR with accuracy better than 0.5 %; the relative mistake of the radiation stream definition in angular distributions did not exceed 2.5 %.

In work [3] angular distributions of σ and π SR component that were measured in an energy range from 65 up to 100 MeV are given. The obtained experimental data testify the necessity to take into account the sizes and electron beam divergence influence on SR angular distributions.

Because there was no common opinion in literature about nature of angular distribution SR linear polarization component asymmetry, the influence of different factors (the beam axis position, the median plane position, magnetic field gradient value and others) on this effect was investigated [3,4].

On Fig. 3 the typical diagrams of π component angular distribution for electron energy: 69,3±0,2 MeV and 96,8±0,3 MeV are given. As it follows from the carried out measurements, the essential inequality of peaks is observed, and the ratio of intensity in the peaks does not depend fro factors that were pointed above.

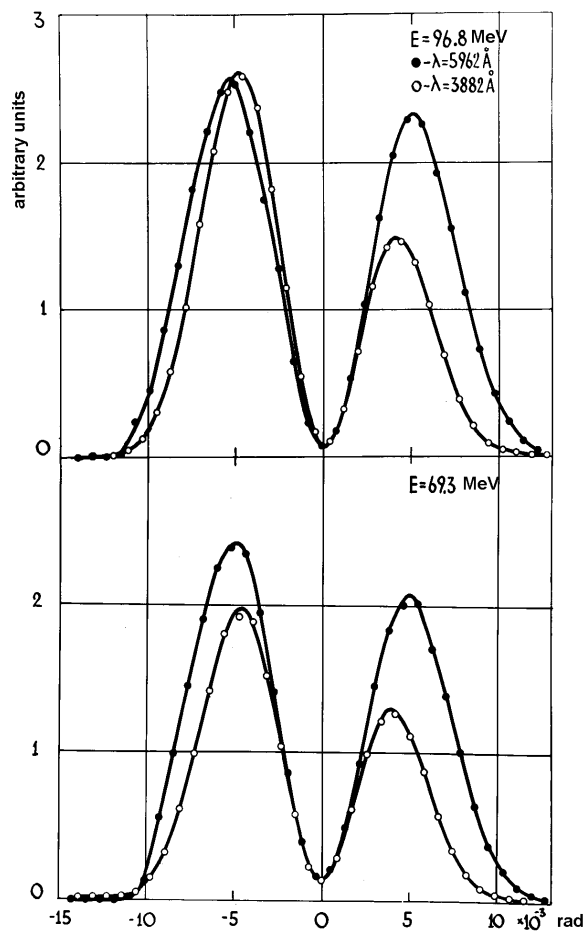

Fig. 3. The measured angular distributions of SR π-component

For real experimental conditions the π-component angular distributions were calculated by averaging "ideal" SR angular distribution, of electron moving around circular trajectory, over Gaussian electron density and speed direction distributions in vertical with dispersion σ_z and σ_θ accordingly. The obtained results testify, that it is impossible to obtain considerable difference of π-component peaks ratio from one under reasonable values of electron beam density and electron speed direction asymmetry. Obtained results testify that the electron dynamic peculiarity is not the reason of SR π component distribution asymmetry.

By modeling the influence of phase shift between SR linear polarization components in betatron oscillation presence, it was shown, that error in polarizer angle installation relatively magnetic field direction already at 0.02 rad the observed peak of π-component can have significant value [5,6]. For check the offered model validity the SR angular distributions were measured at various values of a polarizer angle inclination and it is revealed, that the character of SR angular distribution change corresponds the theoretically predicted [5,6].

The offered model allowed determine the value and sign of phase shift from measured ratio of angular distribution peaks. It was ascertained experimentally that the origin reason of shift is the birefringence of the vacuum chamber window material that arises because of the electron bremsstrahlung action [2,5,6]. As it was marked earlier, originally windows had no such shift, and the window mounted outside of the accelerator bunker, did not bring such shift in radiation [3,6].

The carried out researches have allowed to create the mathematical model that allowed to describe SR angular polarizing characteristics with an electron beam parameters accounting, and it also allowed to solve the reverse task – from measured angular distribution to define the electron beam angular spread.

4. PRACTICAL REALIZATION OF OPPORTUNITIES OF AN ABSOLUTE SOURCE

The analysis of the metrological measurements in infrared, visible and vacuum ultra-violet spectrum area has shown, that the storage ring SR is a stable source of radiation, which characteristics can be designed with a high accuracy degree that superior accuracy of other sources, for these purpose used [8]. For realization the metrological opportunities of such source, on the storage ring N-100 it was developed and made specialized monochromator of normal fall for work in a range 40-250 nm [8]. The monochromator was tested on SR beam.

For demonstration broad opportunities of SR as absolute source, the absolute calibration of photo multipliers developed for space researches, with use offered in KIPT new method of radiation receivers absolute calibration without spectral devices application [10], was carried out [9].

5. CONCLUSION

One of the impotent problems for our state worth now before our state, is creation the complete structure of measurements metrological maintenance in infrared, vacuum ultraviolet and x-ray areas of a spectrum.

The carried out cycle of experimental researches the spectral, angular and polarizing characteristics of relativistic electron beam SR allows to make a conclusion that SR is a stable source of radiation, which characteristics can be designed with a high degree of accuracy that exceeds accuracy of other sources, used for these purpose, [8]. The very important factor is the high reproducibility of these characteristics, their independence of concrete installation and external factors. The carried out researches have created, in our opinion, the base for construction in Ukraine the uniform complete measurement system in infrared, visible, vacuum ultraviolet and x-ray range of waves length that bases on use as a primary absolute source SR of the storage ring N-100 in NSC KIPT, a designed Compton source [11], which can be SR source, and a storage ring, created in Kiev [12].

REFERENCES

1. I.S. Guk, A.S. Masmanishvily, A.S. Tarasenko. *Synchrotron radiation storage ring N-100 KIPT SA UkSSR.* Preprint KIPT 76-12, 1976.
2. I.S. Guk. *Experimental research synchrotron radiation of beams relativistic electrons.* Dissertation on competition of a scientific degree of the candidate of physical and mathematical sciences. Kharkov, 1981.
3. P.I. Gladkikh, I.S. Guk. Experimental research π component syncrotron radiation. // *JTP.* 1980, v. 50, №4, p. 890-891 (in Russian).
4. P.I. Gladkikh, I.S. Guk, S.G. Kononenko. Definition of root-mean-square angular distribution of speeds of an electron beam after a π component of SR // *Pis'ma v JTPh*, 1981, v. 7, №1, p. 44-47 (in Russian).
5. P.I. Gladkikh, I.S. Guk. About asymmetry angular distributions of SR // *VANT, series: Technic Phisycal Experiment.* №3(9), Kharkov, 1981, p. 64-66 (in Russian).
6. P.I. Gladkikh, I.S. Guk. *Experimental research of the angular and polarizing characteristics SR of a beam relativistic electrons.* Preprint KIPT 83-13, 1983.
7. P.I. Gladkikh, I.S. Guk. Measurement dispersion of angular disorder of electron beams in cyclic accelerators by SR // *PTE.* 1984, №1, p. 34-37 (in Russian).
8. I.S. Guk, A.N. Savchenko. *About an opportunity of use SR of the storage ring N-100 KIPT SA UkSSR for absolute measurements in a range 500-2500 A.* Preprint KIPT 77-37, 1977 (in Russian).
9. I.S. Guk, G.N. Polyakova, A.I. Ranjuk. Definition of absolute sensitivity of photoreceivers without application of spectral devices // *Jr. Pr. Sp.*, 1981, v. 35, №4, p. 705-709 (in Russian).
10. I.S. Guk, G.N. Polyakova, A.I. Ranjuk. Way of definition of absolute spectral sensitivity of the receiver of radiation a.c. №717560 // *Bulletin OITZ*, №7, 25.02.80 (in Russian)

11. E. Bulyak et al. A Compact X-ray Source Based on Compton Scattering // *Nucl. Instr. & Meth. In Phys. Res.* 2001, A467-468, p. 88-90.
12. P.I. Gladkikh et al. *Project of Ukraine national synchrotron center.* Preprint UNSC 1, Kiev, 2001.