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Current Status of REFER at Hiroshima University

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Abstract

REFER (Relativistic Electron Facility for Education and Research) electron circulating ring at Hiroshima University Venture Business Laboratory is a small electron ring, 13.7 meters in circumference. This device is used for development of an x-ray source based on possible new principles such as parametric x-ray generation and for education in beam physics. This paper reports the current status of the REFER electron ring.

1. Introduction

Relativistic electron beam accelerators have so far been developed mainly for investigation in the elementary particle physics. On the other hand, there has been a growing interest in applications of relativistic electron beam to another fields in recent years. For instance, one of the expected application is development of x-ray sources for industrial[1], medical [2,3] and scientific[4] field. For these applications, small devices are required.

REFER electron ring is a compact electron circulating ring for application research of the relativistic electron beam and for education of beam physics. This device was installed at Hiroshima University Venture Business Laboratory in 1997. The electron beam energy is 150 MeV, which is generated by the microtron [5] at Hiroshima Synchrotron Radiation Center [6]. A beam extraction line is attached to the REFER electron ring. The electron beam can be slowly extracted from the main ring. The electron beam at REFER is utilized for investigation and education of the beam physics, development of new x-ray source such as parametric x-ray (PXR) generation / laser backward compton scattering (LBS), development of x-ray detectors, etc.

Detail of REFER electron ring is described in the next section. Section 3 summarizes the present status of REFER.

2. REFER Electron Ring

Figure 1 shows an arrangement of magnets in REFER electron ring. The electron ring consists of four short drift spaces (0.5 meters long), four long drift spaces (1.5 meter long * 2 and 2 meters long * 2) and eight bending magnets. Circumference of the ring is 13.7 meters. Four couples of the bending magnets are arranged at corners of the ring so that four long drift spaces are secured. Combined function type bending magnets (n value = 0.5) are used. The bending angle of each bending magnet is 45 degrees and the curvature of bending is 0.75 meters. Horizontal and vertical tune of REFER electron ring is 1.25 and 1.25, respectively, under this configuration. An injection septum magnet, an extraction kicker magnet and a target chamber are placed in the drift spaces of 2 meters long. Two bump magnets, an extraction septum magnet, a beam scraper and a beam absorber are placed in the drift spaces of 1.5

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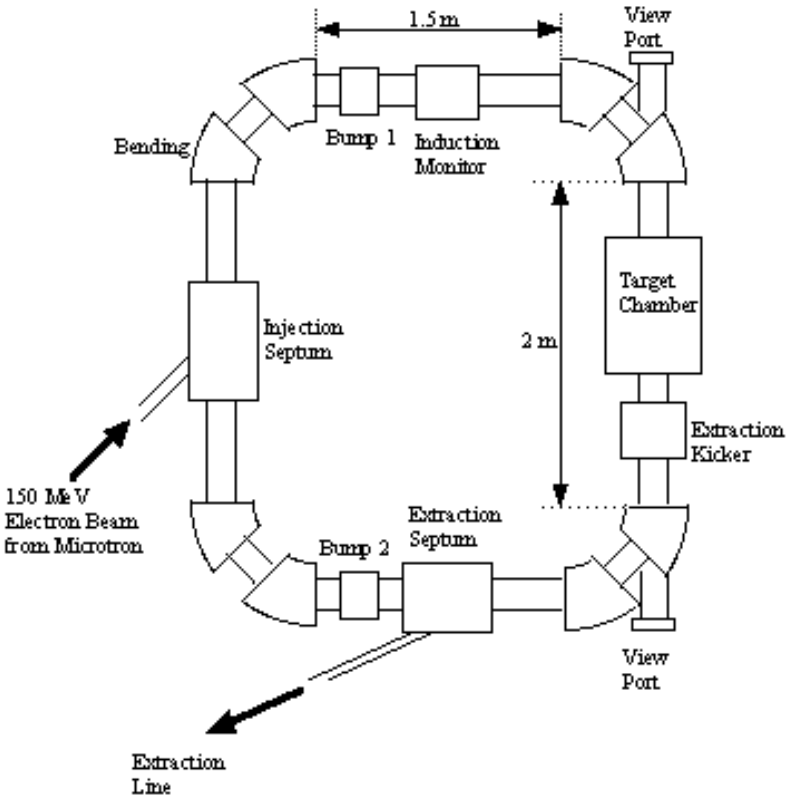

Figure 1. Configuration of REFER electron circulating ring.

meters long. A goniometer in the target chamber holds internal target and controls position and angle of the target. Two view ports is arranged at both ends of the long drift space. Vacuum of 1x10-7 is created by seven sputter ion pumps and a turbo molecular pump.

The 150 MeV electron beam generated by the microtron [5] at Hiroshima Synchrotron Radiation Center [6] is injected to REFER electron ring. The injection beam has typically 1 micro second in bunch length, peak current upto 10 milli ampares and pulse repetition rate of 2-100 Hz. Muti-turn injection into REFER electron ring is performed by the injection septum magnet and the bump magnets. Pulse power generators supply pulse current to coils of those magnets synchronous with beam injection timing. The injection septum magnet puts the beam injected from microtron into the bump orbit. Deviation of the bump orbit from the reference orbit is varied from 30 milli meters to zero with time in 1 micro second to avoid collisions of circulating electrons to the injection septum magnet.

As the present REFER electron ring has no acceleration mechanism, the energy loss of electron beam, 59.7 eV per turn, due to synchrotron radiation is not compensated. Deviation of the electron orbit from the reference orbit increases with time. Therefore, the electrons are lost at vacuum pipes after several ten thousands turns.

An induction monitor observed that the peak current of the circulating electron beam is 10 milli ampares and its life time or bunch length is 3.5 ms. The observed life time agreed with that determined by the radiation loss. Injection efficiency is estimated as 1 - 5 percents. The synchrotron radiation from the electron beam is focused by a system composed of a telescope, spatial filters and lenses onto a CCD camera for beam position and dimensions measurement. The shutter timing and the speed of the CCD camera is controlled

by an external trigger input. Figure 2 shows images of the synchrotron radiation at different timing. The electron beam shifts to inside direction of the ring and its size becomes larger with time as expected. It is interesting to note that the beam separates into upper and lower parts The reason for this beam behavior yet to be understood.

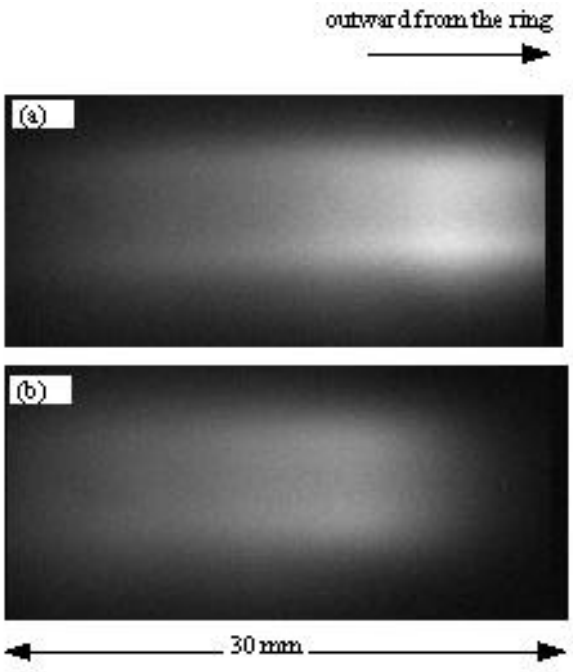

Figure 2 Synchrotron radiation images taken by CCD camera. (a) at t = 0 (just after beam injection) (b) at t= 200 micro seconds. Shutter speed is 50 micro seconds.

The extraction kicker magnet and the beam scraper is used as perturbater for slow extraction. The extraction septum magnet slowly extracts the circulating electron beam. The extracted electron beam is guided by a bending magnet into a extraction line consists of two quadrupole magnets.

3. Summary

Outline of REFER electron ring was described. Equipments around REFER also has been prepared since REFER was installed. The beam extraction line was installed and tested. Electrons of the order of 100 per second was detected at the end of the beam extraction line. Softwares to control the power supplies for the magnets, the goniometer and data acquisition system via computer are developed. The ring is operated 8 hours * 4 days per week under the condition of the repetition rate of 10 Hz and the injection beam current of 2 mA. Total time of beam injection was 400 hours in last year.

The PXR experiment was conducted and successful result of enhancement of x-ray generation was obtained [7,8]. A LBS experiment was prepared and will be conducted in this year. The REFER beam is utilized to investigation of the particle physics such as an experiment of the coherent pair creation from a crystal target. Furthermore, a long pulse induction acceleration is considered as a test bench for development of small betatron. Experiments planned at REFER in this year is listed in Table 1.

Behavior of the electron beam in REFER has not been clear, so more machine study is needed for improvement of beam quality.

Table 1. List of experiments planned in 2000

Coherent pair creation on monocrystalline target
Laser compton scattering
X-ray intensity in Bremsstrahlung from high-energy electrons
Induction accerelation in REFER
Two-track separability of JLC-CDC
Study of beam position control of REFER

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