RELATIVISTIC ELECTRON FACILITY FOR EDUCATION AND RESEARCH AT HIROSHIMA UNIVERSITY*

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Abstract

The Relativistic Electron Facility for Education and Research (REFER) at Hiroshima University accepts a 150 MeV electron beam from a microtron, the injector to the 700 MeV storage ring of the Hiroshima Synchrotron Research Center, and keep it circulating for 2.5ms without a RF acceleration. It acts as a beam stretcher and has been used for the following researches: 1) X-ray generation from an internal multiple foil crystalline target due to the parametric X-radiation (PXR) and the resonant transition radiation (RTR). 2) Laser backward Compton scattering. 3) Coherent pair creation from Si crystal by 150 MeV bremsstrahlung. 4) Study of the Ter-Mikaelian effect in the low energy part of the bremsstrahlung in an extracted electron line. 5) A novel scheme of beam stabilization by the induction coil. This paper reports the experimental results and the current status of the REFER electron ring.

1 INTRODUCTION

There has been a growing interest in applications of relativistic electron beam from small devices to industrial [1], medical [2], and scientific [3] fields in recent years.

The REFER electron ring is a compact electron circulating ring for application research of the relativistic electron beam and for education of beam physics [4]. The device was installed at Venture Business Laboratory, Hiroshima University 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 the REFER is utilized for investigation and education of the beam physics, development of new X-ray sources such as PXR, RTR generation, and Laser backward Compton scattering, and study of the particle physics such as an experiment of the coherent pair creation, etc.

Detail of the REFER electron ring is described in the next section. Section 3 is devoted to the presentation of the experimental results at the REFER. Last section summarizes the current status of the REFER.

2 REFER ELECTRON RING

The 150 MeV electron beam generated by the microtron at Hiroshima Synchrotron Radiation Center is injected to the REFER electron ring. Figure 1 shows the layout of the REFER electron ring. The injection beam has typically 1 μs in bunch length, peak current upto 10 mA and pulse repetition rate of 2-100 Hz. Multi-turn injection into the 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 mm to zero with time in 1 μs to avoid collisions of circulating electrons to the injection septum magnet.

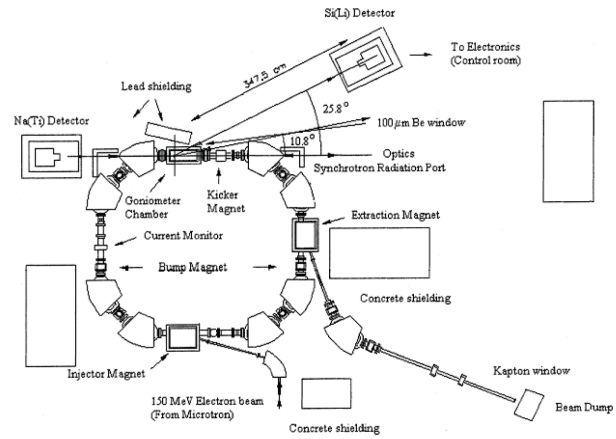

Figure 1: REFER electron ring.

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. In summary, the REFER acts as a beam stretcher and has been used for the several researches described in next section last year.

3 RESEARCH AT REFER

3.1 Parametric X-Radiation

X-radiation generated by electrons passing through silicon crystal targets of different thicknesses (49.2, 164.4 and 1644.0 μm) and accurately aligned 10 and 100 layers of 16.4 μm thick monocrystalline silicon foils was measured at the REFER [7, 8]. A clear intensity enhancement was observed, when compared to the intensity of PXR from single crystal targets of equivalent thickness at 14.4

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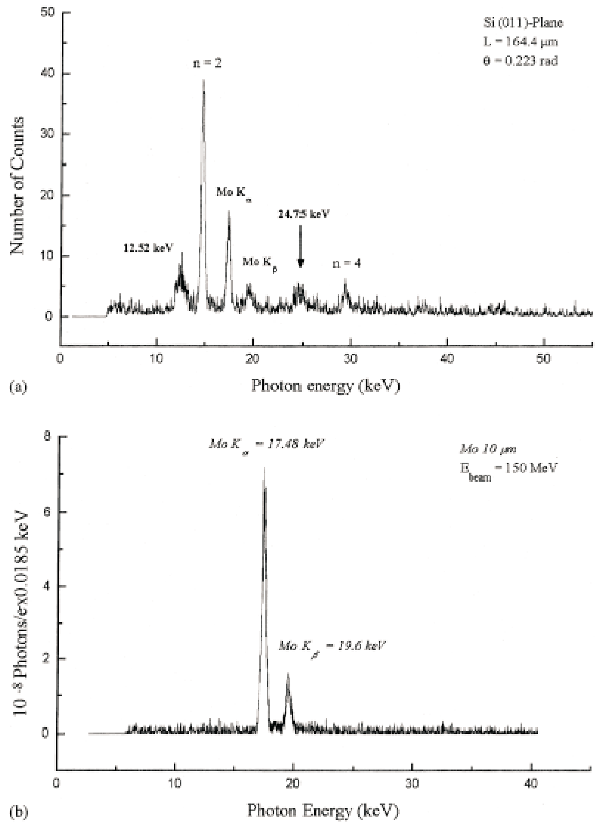

Figure 2: (a) PXR from (011) plane in 164.4 μm silicon crystal with the amorphous Mo target. (b) Spectrum from the amorphous Mo target [8].

and 28.8 keV. K. Chouffani *et al.* believed that this enhancement results from the diffraction of transition radiation from individual surfaces of the foils off the crystallographic planes [7]. When the molybdenum foil was used for electron beam normalization, they observed an unidentified peak at 12.5 keV and its second harmonic. Figure 2 (a) shows PXR spectrum from 164.4 μm silicon single crystal with the amorphous molybdenum foil. We plan to investigate the unidentified peaks using the electron beams from the REFER extraction line in 2001.

3.2 Laser Compton Scattering

The Laser backward Compton scattering was studied at the REFER. The wavelength and pulse energy of the Nd:YAG Laser beam were 532 nm and 550 mJ/pulse, respectively. Figure 3 shows the counting rate of the Laser backward Compton scattering. The electron beam shifts to inside direction of the ring and the counting rate changes with the Laser injection timing. The intensity and energy of the generated X-ray were about 0.1 photons per bunch and less than 800 keV, respectively. This is first measurement of the Laser Compton scattering at the REFER and we plan to measure its spectrum in 2001.

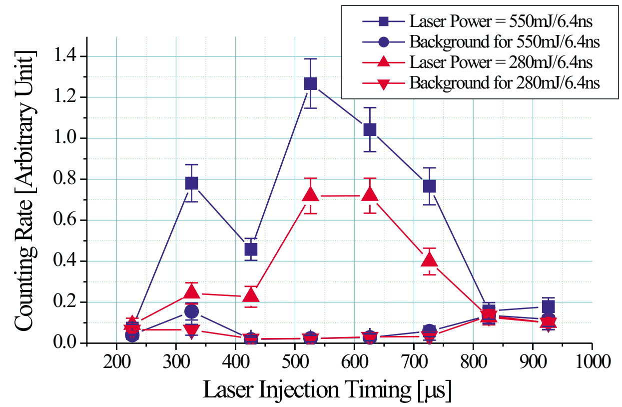

Figure 3: Counting rate of the Laser backward Compton scattering versus Laser injection timing.

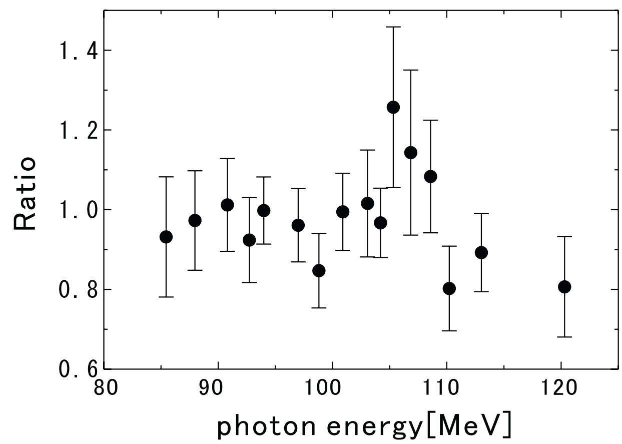

Figure 4: Ratio of the pair cross section with the Si target to with the Al target [9].

3.3 Coherent Pair Creation

The coherent pair creation from Si crystal by 150 MeV bremsstrahlung was measured at the REFER [9]. If a target is a single crystal, due to the periodicity of the nuclear potential, the pair cross section has several sudden increase against non-single crystal. The ratio of the pair cross section with the Si target to that with the Al target is shown in Fig. 4. Y. Okazaki *et al.* observed a peak at 105 MeV in a (111) Si crystal to investigate the interference effect among atomic string. As a result, the statistical quantity was not sufficiency, however, a gentle enhancement was observed at 105 MeV.

3.4 Study of Ter-Mikaelian Effect

The Ter-Mikaelian effect in the low energy part of the bremsstrahlung in an extracted electron line has been studied. It is well known that the cross section of the bremsstrahlung from high-energy electron beam with a single atom diverges in low energy region. According to Ter-

Mikaelian's theory, the effects of the multiple scattering and the polarization cause the reduction of the cross section of the bremsstrahlung in a medium. Using the electron beam with 150MeV energy, which has a negligible effect of the multiple scattering, T. Ohnishi *et al.* plan to measure the polarization effect of the bremsstrahlung.

3.5 Beam Stabilization by Induction Coil

A novel scheme of beam stabilization by the induction coil is being studied [10]. The electron beam in the REFER loses its energy by 59.7 eV per turn due to synchrotron radiation. As the REFER has not acceleration instruments, the beam orbit moves toward the inner wall of the vacuum pipe. It is about 2.5 ms from the injection to the dumping. If the energy loss of the beam is compensated by induction acceleration, the beam can keep circulating for longer time. S Matsuno *et al.* designed a small-sized model of an induction magnet, which has 1/8 cross section of the iron core to be installed. Combining the software for the current form and the small-sized model, the magnetic permeability of the core material was measured to determine the most suitable form.

Table 1: REFER experiments in 2001

Beam Survey from REFER Extraction Line
Scintillation Counter
Parametric X-ray Radiation
Laser Backward Comtopn Scattering
Study of Ter-Mikaelian Effect
Radiated Photon from Photonic Crystal

4 SUMMARY

The outline and the current status of the REFER electron ring were described. In 2000 the REFER has been used for the following researches:

1. X-ray generation from an internal multiple foil crystalline target due to the PXR and the RTR.
2. Laser backward Compton scattering.
3. Coherent pair creation from Si crystal by 150 MeV bremsstrahlung.
4. Study of the Ter-Mikaelian effect in the low energy part of the bremsstrahlung in an extracted electron line.
5. A novel scheme of beam stabilization by the induction coil.

Finally, the REFER experiments planed in 2001 are listed in Table 1.

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