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NARROW BAND COHERENT EDGE RADIATION AT UVSOR-III

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Abstract

Edge radiation in the long wavelength region can be an interesting new light source because of its properties of highly collimation and radial polarization. Recently a dedicated beam-line for edge radiation was constructed at UVSOR-III. Coherent radiation from electron bunches after the interaction with the amplitude modulated laser was successfully observed at the beam-line. Intensity of the radiation as functions of the electron beam current and THz wavelength was measured. Spatial distribution of the radiation intensity was also measured. The pattern was not reproduced by a calculation.

INTRODUCTION

Coherent synchrotron radiation (CSR) in THz region can be produced from an electron bunch shorter than the radiation wavelength. Because of high radiation power, being proportional to the square of number of electrons in the bunch, CSR can be a new tool for various applications. However, in typical storage rings, electron bunch length is longer than THz wavelength. But they succeeded in producing CSR by shortening bunch length using special condition of storage rings called low-alpha operation [1]. Laser bunch slicing is another technique for producing CSR by creating mm or sub-mm dip structure in electron bunch [2]. In both cases, broad band CSR with wavelength longer than the bunch length or the dip structure is produced.

At UVSOR storage ring, we demonstrated that, by injecting amplitude modulated laser pulses into the ring, quasi-monochromatic and tuneable terahertz (THz) CSR can be produced [3]. In this method, periodic micro-density structure of THz scale was created on the electron bunch, as the result of the laser-electron interaction in an undulator. In the experiment, the radiation from a bending magnet where electrons are moving along a circular trajectory, is extracted. As a next step we planned to extract the radiation from edges of bending magnets, where electrons experience rapid change of the magnetic field. The radiation is called edge radiation and has distinctive features as compared to normal synchrotron radiation: highly collimation even in long wavelength region, annular radiation pattern and radial polarization [4]. Applying our technique of amplitude modulation laser, intense narrow band edge radiation is expected to be generated. Moreover, radially polarized light can be converted to Z-polarized one by using a high NA lens [5]. Novel new applications of the radiation, such as surface science and solid state physics are expected.

In this article, we describe a new beam-line for edge radiation and some preliminary results from the experiments to characterize narrow band coherent edge radiation.

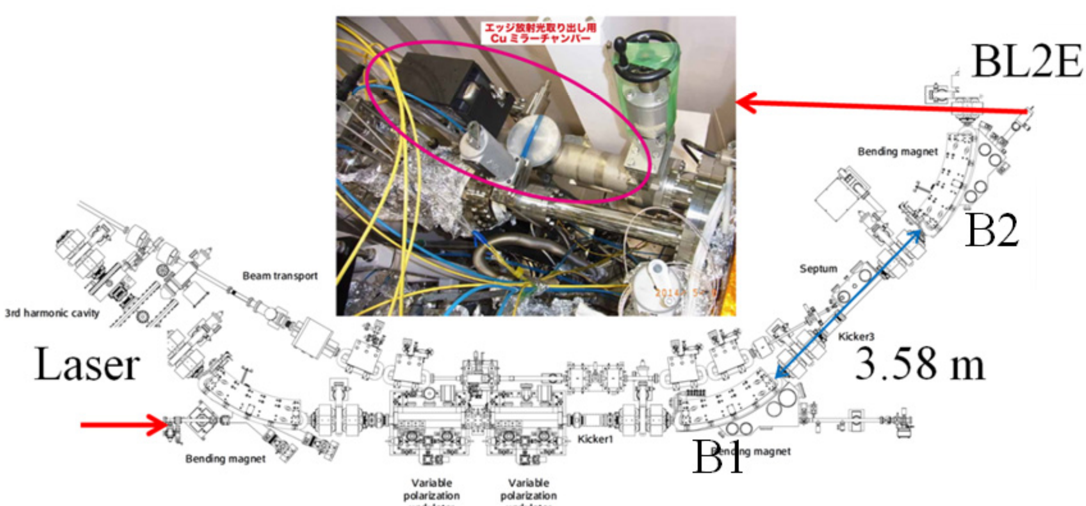

Figure 1: Drawing of UVSOR-III storage ring around undulator 1U [6] and a photograph of BL2E beam-line for detection of edge radiation.

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BEAM-LINE FOR EDGE RADIATION

We have constructed a new beam-line called BL2E for edge radiation on an extension line of a short straight section as shown in Fig. 1. At the beam-line, edge radiation from the edges of two bending magnets, B1 and B2, that are separated by 3.58 m, can be observed. The beam-line is very simple one composed by a water cooled copper mirror coated with gold in a vacuum chamber and a quartz window. Radiation incident to the mirror is reflected by 90 deg. and is transmitted to outside of the chamber through the quartz window. After passing the window, the radiation is transported to experimental station by an aluminium mirror.

After installing the chamber, we could observe edge radiation in the visible region. The radiation exhibits an annular pattern with radius of about 5 mm at the window position, which is consistent with the edge radiation theory. Looking at the visible radiation, we aligned the mirror and the detector for detection of invisible THz edge radiation.

EXPERIMENTAL SETUP

Experiments to produce narrow band coherent edge radiation is made with the storage ring operated in 600 MeV single bunch mode. The narrow band CSR is produced from an electron bunch whose density is periodically modulated. The density modulation is created as a result of the interaction with an amplitude modulated laser in an undulator. In the experiment a stretched laser pulse with pulse width of 300 psec-FWHM is extracted from Legend-Cyro/COHERENT (Pulse energy ~ 10 mJ, pulse width 100 fsec-FWHM) and send to a Michelson interferometer system where quasi-sinusoidal temporal modulation is attained [3]. The laser pulse is focused inside of the undualtor U1 whose resonant wavelength is adjusted to the laser wavelength (Fig. 1). The pulse energy is around 2 mJ after the pulse modulation system.

The CSR from BL2E is detected with an InSB hot electron bolometer (QMC Instrument Ltd) and the data is recorded using a digital oscilloscope. At the beam-line BL2E, there is no tool to measure a wavelength of the narrow band CSR. Therefore we make a calibration of the wavelength using FTIR at beam-line BL1B before experiments at BL2E. During the experiments, we observed a strong fluctuation of CSR pulse intensity because of pointing stability of the laser after a long transportation (~ 30 m). In actual measurements, we record the data more than 100 times and use the averaged value.

EXPERIMENT

Beam Current Dependency

As is well known, CSR intensity is proportional to the square of number of electrons in the bunch or stored beam current in a storage ring. We measured the edge radiation intensity from BL2E as a function of the beam current. The wavelength was chosen to 20 cm^{-1} by tuning the Michelson interferometer system. Figure 2 shows the pulse height of the THz radiation measured by the bolometer as a function of the beam current. Apparent tendency that the intensity of the radiation is proportional to the square of the beam current can be seen. This is a strong evidence that the radiation is coherent radiation from the electron bunch.

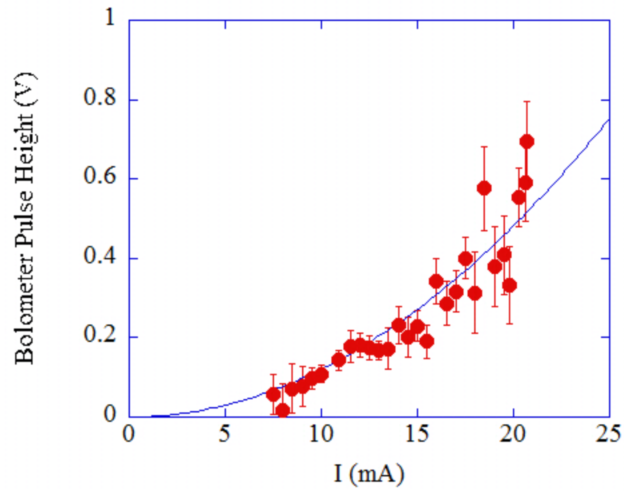

Figure 2: Edge radiation intensity as a function of beam current. The solid line is a quadratic curve obtained by fitting the data.

Wavelength Dependency

By tuning the Michelson interferometer system, we can choose the wavelength of the narrow band CSR freely. We measured the edge radiation intensity as a function of the wavelength. Figure 3 shows the experimental result. We also calculate the efficiency for production of CSR taking into account of optical parameters of UVSOR-III magnetic lattice [7].

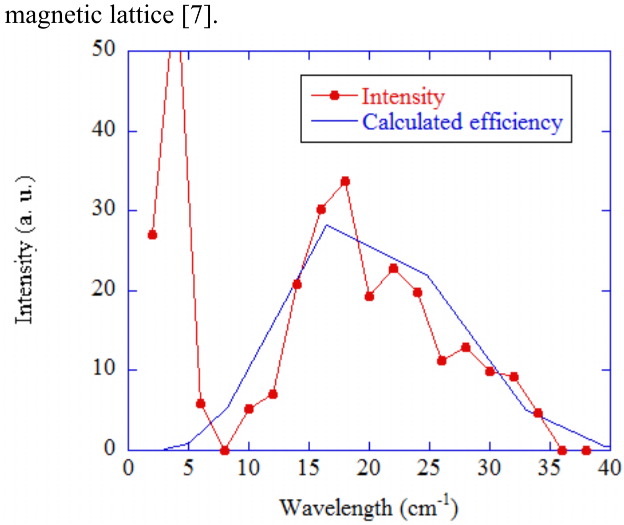

Figure 3: Radiation intensity versus wavelength.

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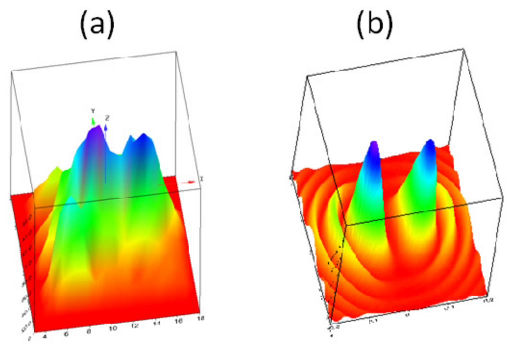

Figure 4: Spatial distribution of horizontal polarized componet of edge radiation: (a) experiment (b) calculation.

The efficiency is compared with the experimental result in Fig. 3. As seen in the figure, they agree well. The degradation of sinusoidal density modulation due to finite beam emittance depends on the wavelength and limits the highest wavenumber observed at the beam-line. Low wavenumber region (< 5 cm^{-1}), CSR from the electron bunch after several turns of the storage ring is expected to dominate [7].

Spatial Distribution

We observed spatial intensity distribution of the edge radiation by scanning the bolometer position which is located at distance of about 7 m from the radiation source point. In the experiment, we employed a polarizer to extract only horizontal polarized component. Figure 4 shows preliminary result of spatial distribution at the wavelength 20 cm^{-1}. Calculated distribution using a code SRW [8] is also shown in Fig. 4. In the spatial distribution obtained in the experiment, two peak separated in the horizontal direction can be recognized as expected by the calculation. However, the shape of the distributions does not show good agreement. We think the spatial distribution is possibly affected by diffraction due to the narrow beam duct.

SUMMARY AND OUTLOOK

We have constructed a beam-line for narrow band coherent edge radiation. Experiments to characterize the radiation were made. The experimental results of beam current and wavelength dependency of the radiation intensity were reproduced by calculations. Spatial distribution of the radiation was also measured but the preliminary result was not reproduced by the calculation clearly. We are planning to perform experiments in various THz wavelengths.

REFERENCES

[1] J. Feikes et al., “Compressed Electron Bunch for Operating Bessy II in a Didicated Low Alpha Mode”, EPAC’04, Lucerne, Switzerland (2014).
[2] M. Katoh et al., “Observation of Intense Terahertz Radiation Produce by Laser Bunch Slicing at UVSOR-II”, EPAC’06, Edinburgh, Scotland (2006).
[3] S. Bielawski et al., Nature Physics, 4 (2008) 390.
[4] R. A. Bosch, Nucl. Instr. and Meth. A 386 (1997) 525.
[5] K. S. Young et al., Optics Express 7 (2000) 77.
[6] S. Tanaka et al., “Construction and Commissioning of Coherent Light Source Experiment Station at UVSOR”, FEL’12 Nara, Japan (2012).
[7] C. Evain et al., Phys. Rev. ST Accel. Beam 13 090703(2010).
[8] O. Chuber et al., “ Accurate and Efficient Computation of Synchrotron Radiation in the Near Field Region”,EPAC’98, Stockholm, Sweden (1998).