DEVELOPMENT OF J-arc SYNCHROTRON RADIATION MONITOR AT SuperKEKB LINAC

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Abstract

SupreKEKB Linac injector generates and accelerates electron beam and positron beam for SuperKEKB High Energy Ring (HER) and Low Energy Ring (LER) injection. At the same time, Linac also undertakes the electron beam injection tasks for Photon Factory (PF) and Photon Factory Advanced Ring (PF-AR). Four rings simultaneous injection has been realized from phase II commissioning. During 4 ring simultaneous injection, non-destructive beam measurements are important for high quality injection, one synchrotron radiation monitor (SRM) is con-structed after the last bending magnet of Linac J-arc section. Two dimensional and pulse by pulse beam profiles have been obtained successfully and applied for non-destructive beam adjustment from 2020c. operation. In this work, the design and operation results of J-arc SRM are introduced.

INTRODUCTION

KEK Linac injector has achieved the 4 rings simultaneous injection from 2019 for SuperKEKB HER and LER, PF ring and PF-AR [1]. The layout of Linac injector is shown in Fig. 1. Two kinds of electron source are located at the start point of Sector A, one is thermionic gun for generating primary electron beam to generate positron beam at Sector 1, and electron beams for PF and PF-AR. The other one is RF gun which is the electron source of SuperKEKB HER. All the electron beams are accelerated and passed the J-arc to the later sectors for continuous acceleration. Certainly, screen monitors are installed in the J-arc section, but the screen cannot be inserted during the simultaneous injection. Therefore, non-destructive beam monitoring system is necessary to ensure highly efficient for simultaneous injection. SRM is the best candidate to realize the continuous non-destructive measurements of beam profiles at J-arc.

LINAC J-arc SRM

About 20 years ago, Dr. Mitsuhashi constructed one J-arc SRM for KEKB project [2]. The synchrotron radiation light of primary electron beam was observed successfully. After that, there was no maintenance for the SRM even after the Great East Japan earthquake. We decided to rebuild the SRM from the end of 2018, but the work was postponed by the fire accident of Linac in April 2019. The rebuilt work was started from the summer maintenance of 2019 and the synchrotron radiation lights of the electron beam generated by RF gun and primary electron beam were observed successfully. After that, software and monitor panel were developed for commissioning. The SRM monitoring system is being applied all day during the commissioning. In this section, the experimental setup and data analysis results will be introduced.

SR Light Extraction Setup

As shown in Fig. 2, the 180° arc of J-arc section has 6 bending magnets which can bend the beam of 30°. The bending radius of these bending magnets is 3.57 m. Electron beam energy at J-arc section is 1.5 GeV. Due to the space limitation, the light source of synchrotron radiation is selected at the entrance of the 6th bending magnet, which is marked in the Fig. 2. All the existing vacuum duct and mirror supports are reused in our experiment, but the mirrors, lens, and the other optical components are exchanged due to the long-term aging damages. According to the space and imaging condition, single lens imaging layout is designed again for the new SRM optics system.

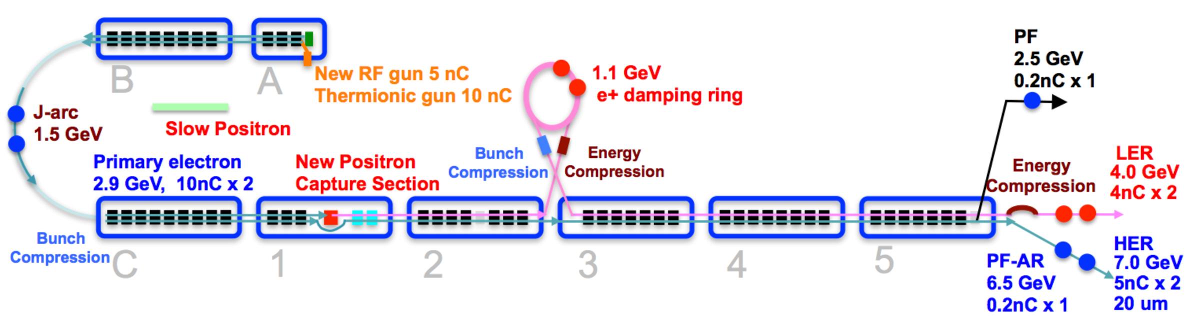

Figure 1: Layout of SuperKEKB Linac injector.

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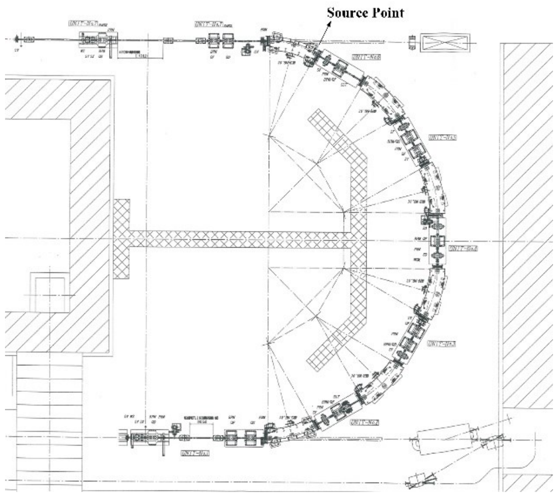

Figure 2: Location of SR source point at J-arc.

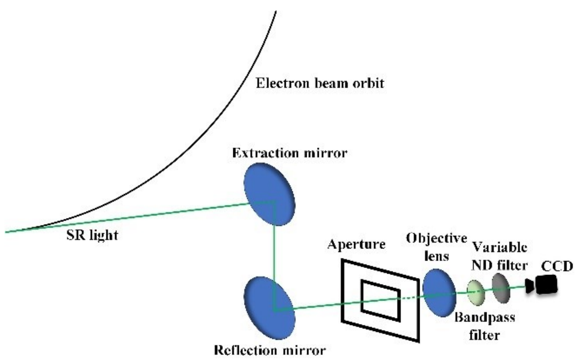

Figure 3: Outline of the imaging optics layout.

The optics layout of SRM is shown in Fig. 3. One quartz extraction mirror is fixed in a vacuum chamber at the 1340 mm from the source point position. Due to the low radiation power of SR at J-arc is very low (~0.01 W) so it is no need to use water cooling system for the extraction mirror. High optical surface quality of λ/10 aluminium coating is coated for the extraction mirror and reflection mirror for decreasing the wavefront distortion.

Imaging System

After reflecting, the SR light is sent to the imaging line which is set inside a dark box fixed on the floor. As entrance pupil, one aperture is placed before the object lens for decreasing the diffraction and focusing field to enhance imaging quality. Meanwhile, a diffraction limited doublet lens is used as objective lens for imaging, whose diameter and focusing length are 80 mm and 300 mm respectively. Because the SR light is wide band incoherent light. A bandpass filter with band width of 2 nm is applied to obtain a quasi-monochromatic ray at the wavelength of 500 nm. One variable ND filter is applied to optimize the intensity of the image. It can be adjusted to the optimized status by remote control for primary electron beam imaging and HER electron beam imaging respectively.

The CCD camera is set on a linear stage at the direct focusing point of the objective lens along the direction of ray propagation. The CCD camera can be moved ±37.5 mm for adjusting the image distance for the best imaging. According to the distance from the light source position to the lens position, the conjugation ratio of the objective lens is 0.14. This conjugation ratio is large enough for the beam size imaging and small enough for CCD resolution, that's why additional magnification lens is not necessary and single lens imaging is just adopted in our system. By the way, a dichroic polarizer is not applied here to select the σ-polarization component, the reason is the total radiation power is very low so there is no need to remove the π polarization for beam size measurement.

The optical dark box is shieled by lead blocks to avoid the radiation damages to optical components and CCD camara, all the remote-control units and drivers are placed in a special place where is surrounded by lead blocks.

Observation and Calibration

The first observation of primary electron beam and HER electron beam was achieved in 2019c operation, as shown in Fig. 4. The two-dimensional distribution can be seen clearly. Especially, the existed beam tail of HER electron beam at the J-arc source point is known.

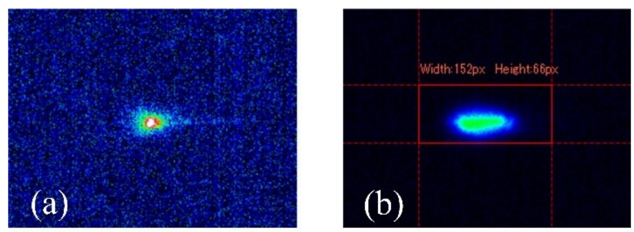

Figure 4: (a) Observed beam profile of HER electron beam; (b) beam profile of the primary electron beam at J-arc.

In order to measure the beam size of electron at J-arc, calibration is essential to carry out soon. The typical calibration method for SRM is building local bump to change the beam orbit, such as SuperKEKB main ring SRMs and Dumping ring SRM. Different from the other SRMs, one local bump can't be built in J-arc section. We tried to build bump in front of J-arc entrance to do calibration, but the accuracy was very rude.

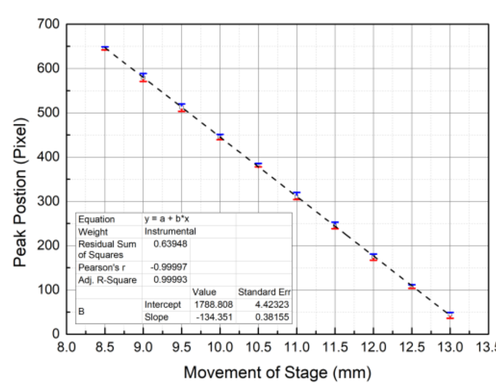

Figure 5: Calibration result of J-arc SRM.

In 2020 summer-maintenance, an additional motorized linear stage was added under the CCD camera. This stage can move along the horizontal direction which is perpendicular to the ray propagation direction. By measuring the pixel change amount on screen after adjusting the stage by 1 mm step, we can get the ratio of pixel to µm. The result is shown in Fig. 5, and the calculated ratio is 1 pixel corresponds to 7.443 µm.

Application in Operation

By use of the conjugation ratio of imaging system and the calibration ratio, we can measure the electron beam size at the source point in the last bending magnet of J-arc section. The results are listed in the Table 1.

Table 1: Measured Two-dimensional Beam Size for HER Electron Beam and Primary Beam Size at the Entrance of the Last Bending Magnet of J-arc

	HER e^- Beam	**Primary e^- Beam**
Horizontal	412±9 µm	1208±11 µm
Vertical	241±34 µm	469±59 µm

From 2020c operation, the SRM operation panel is used during beam operation and commissioning, as shown in Fig. 6. Especially, beams' status can be checked non-destructively by the SRM during 4-ring simultaneous injection. In addition, there is no wire scanner setup in J-arc section, so the two-dimensional beam size can be measured by the SRM. Compare with the wire scanner measurement, instantaneous beam profile could be measured for different electron beams.

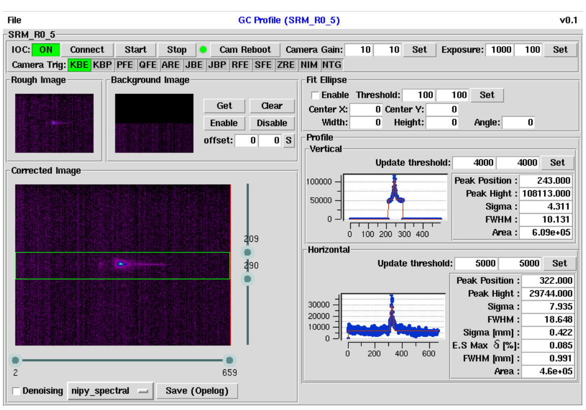

Figure 6: SRM monitoring panel for operation.

CONCLUSION

The SRM at linac J-arc section is rebuilt. One lens imaging layout is adopted for different electron beams' profiles measurement. Accordingly, the calibration for our imaging system has been achieved for beam size measurement. During 4-ring simultaneous injection, it plays important role in continuous non-destructive monitoring for stable operation.

ACKNOWLEDGEMENTS

The authors also thank to Dr. T. Mitsuhashi, Dr. H. Ikeda, Dr. Y. Seimiya, Dr. F. Miyahara and Mr. H. Kumano for their kind supports and operation.

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