HIGH RESOLUTION SR PROFILE MONITOR AT ATF2 EXTRACTION LINE

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Abstract

The profile monitor using visible light of the SR at ATF2 extraction line has been developed. KEK-ATF is a facility to produce extremely low emittance beam for the linear collider. The emittance in the damping ring is $\varepsilon_x=1\times10^{-9}$m and $\varepsilon_y=1\times10^{-11}$m, respectively. The ATF2 extraction line is a transport line to study the Final focus system for the linear collider. The expected beam size at the profile monitor is 230 μm in horizontal and 13 μm in vertical. We used a wide aperture optical system and an apodization filter to reduce the diffraction limit of the optical system. The design and the results of the preliminary measurement are reported.

INTRODUCTION

The damping ring (DR) of the Accelerator Test Facility(KEK-ATF) was built to generate extremely low emittance beams and the ATF2 is a Final Focus System(FFS) proto-type for linear collider [1]. The beam energy is 1.3GeV. The design emittances are $\varepsilon_x=1\times10^{-9}$m and $\varepsilon_y=1\times10^{-11}$m, respectively, when assumed 1% coupling. The FFS is aiming to obtain nano-meter spot sizes and same level of the position stability. Many kinds of monitors[2][3] and tuning tools[4] are also developing for the FFS not only the beam spot size monitor[5].

We constructed a profile monitor using the visible light of the Synchrotron radiation from the third bending magnet at the extraction line, which is located at 10m downstream of the extraction point in the DR. We called EXT-SR as the monitor. The expected beam size at the location is 230μm in horizontal and 13μm in vertical, respectively (beta-x=14.3m, beta-y=16.5m and eta-x=-0.2m). It is difficult to measure such a small vertical beam size for the diffraction-limited resolution due to the opening angle of the SR. The opening angle of the SR is described as $1/\gamma$, in the case of the KEK-ATF, the opening angle is 0.4 mrad. However, the SR distribution has large tails outside of the opening angle. We designed a large aperture optical system to collect the whole of the SR distribution and the apodization filter, which has a possibility of a high-resolution profile monitor. This monitor is not focus on the precise measurement of the vertical beam size. The EXT-SR is non-destructive monitor, which can measure the beam property at same time with the other monitors located at the downstream of the extraction line. Some of the emittance growth source, for example, xy-coupling, orbit jitter, momentum spread, etc., come from the DR or the extraction part. It is very significant to understand the beam property at the location. The EXT-SR will be used not only for the profile monitor, but other purpose.

-Beam hallo measurement by using coronagraph [6]; to understand the beam tail is significant to evaluate the background signal of the wire scanner and the beam spot size monitor.

-Beam position measurement by estimating the centroid position of the profile [7]; the evaluation of the shot-by-shot beam position fluctuation is useful to find out the jitter source or the instability in the DR.

-Momentum spread measurement [8]; the intra-beam scattering effect in the DR increases the momentum spread. The location of the EXT-SR is a large dispersion area in horizontal. The measured beam size is expressed by

$$\sigma_{meas} = \sqrt{\sigma_x^{\,2} - \left(\eta_x \, {}^{dp}\!/_{p}\right)^2} ,$$

$\eta_x \, {}^{dp}\!/_{p}$ is dominant for the measured horizontal beam size at the location. Therefore the momentum spread can be estimated from the horizontal beam size.

The design and the preliminary measurement of the EXT-SR are described in the following sections.

OPTICAL DESIGN

The beam parameters of the ATF2 at the normal operation are summarized at Table 1. The source point of the SR is the entrance of the third bending magnet (BS3X) of the ATF2. The bending radius of BS3X is 3.9m. The optical system of the EXT-SR consists of an objective lens (achromat lens, f=2000mm), a band pass filter (80nm bandwidth at 500nm), a polarized filter and a magnifier lens (x5). The layout is shown in Fig. 1.

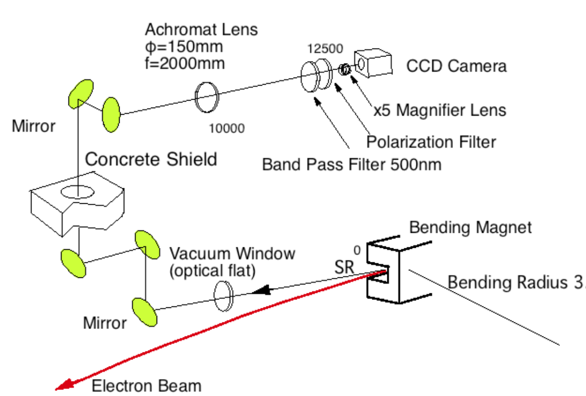

Figure 1: Layout of the EXT-SR monitor.

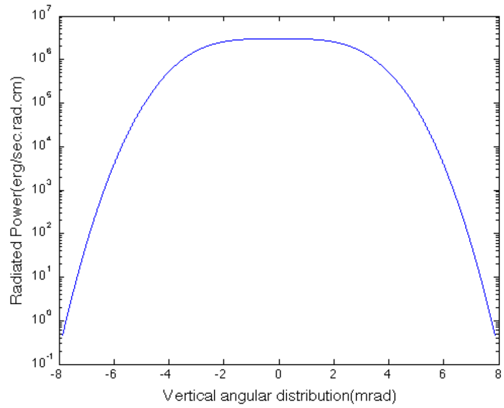

Figure 2: Angular distribution of the SR from the bending magnet (Energy=1.3GeV, Bending radius = 3.9m, Wave length (λ)=500nm, Sigma-mode polarization).

Table 1: Parameters of the ATF2 Beam

Beam energy	1.3 GeV
Charge /bunch	1×10^{10} electrons
Number of bunches	1~10
Repetition rate	0.78~3.12 Hz
Bending radius	3.9 m

The magnification ratio from the source point to the CCD is 1.25. There are 5 mirrors between the source point and the objective lens to guide the SR. All of mirror has λ/10 flatness and made by quartz. There is no deformation by the SR power for the first mirror, because of the very low power density of the SR. The angular distribution of the SR for visible light is plotted in Fig. 2. The tail of the distribution exceeds +/-8mrad. We used a 150mm diameter objective lens to collect the whole of the SR distribution. The objective lens is located at 10m downstream from the source point and 15mrad of the SR distribution can be collected. We plan to apply an apodization filter to obtain a flat-intensity distribution in entrance pupil. This improves the resolution of the monitor. The comparison of the calculated diffraction with and without apodization filter is shown in Fig. 3.

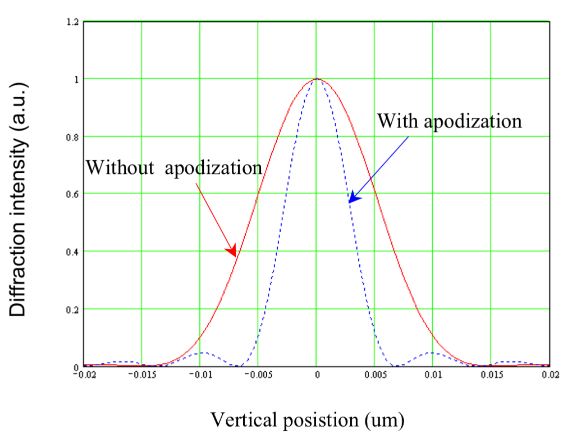

Figure 3: Calculated diffraction.

Figure 4: Picture of the SR line; The visible light of the SR is guided by using three mirrors in the accelerator room. The mirrors are set in the black duct to avoid the background light.

SR BEAM LINE AND SOFTWARE CONSTRUCTION

Figure 4 shows the picture of the SR line. Three mirrors in the accelerator room are in the black duct to avoid the background light and both end of the black duct is shielded by using the optical flat to avoid the air turbulence. The first mirror sits on a rock base to avoid the mechanical vibration. The second and the third mirrors are adjustable in angles by the remote control. Other mirrors sit in the optical hut. The objective lens is located at 10m downstream from the source point and the magnifier lens is located in downstream to form the Kepler type telescope. We use a FireWire interfaced CCD camera (IMAGENG SOURCE CO. DMK21BF04) for the observation of the beam image. The camera specifications are 1)pixel size 5.6μm(H), 5.6μm(V); 2)resolution 640(H), 480(V), 3)sensitivity 0.03lx and 4)dynamic range 8bit. This CCD has an electric shutter (100μs minimum) and

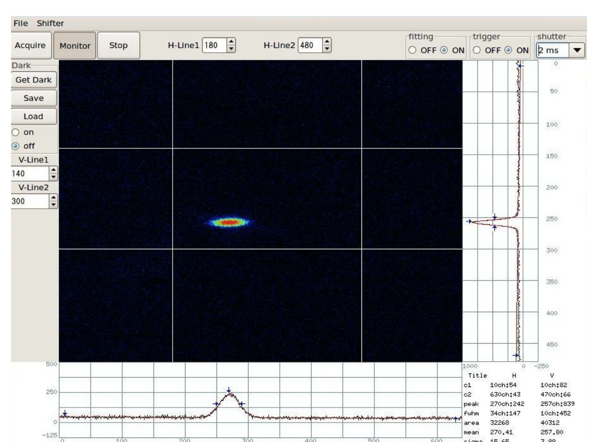

Figure 5: example of the acquired beam profile; the beam size is calculated from the fitting of the projected image in horizontal and in vertical. Two lines at both side of the image are integration area to calculate the projection.

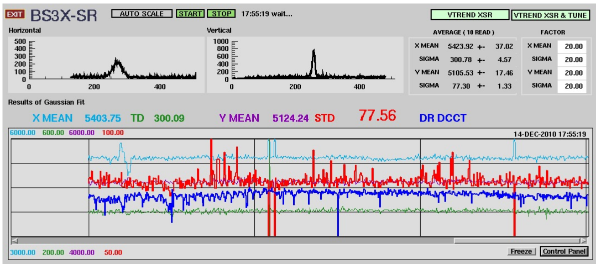

Figure 6: time trend of the beam profile in 10 minutes. Plots show the vertical beam size, the horizontal beam size, the vertical beam position, the horizontal beam position and DR current measured by DCCT.

an external trigger. The external trigger function is required to get the synchronized data acquisition. We have developed a video analyze software and data display with the beam current. The video analyzer uses a linux computer. We use in-house developed software, which is written by using C-language and LIBCD1394 library [9]. The example of the acquired beam profile is shown in Fig. 5. The projection of the beam profile is calculated from the integration of the light intensity between two lines. The position of the line can be set arbitrary location to eliminate the CCD noise. The beam size is calculated from the fitting of the profile with Gauss function in horizontal and in vertical. The acquired data is transferred to the accelerator control computer in real time and set on the database with the time stamp. The correlation of the data can be seen with the other parameter of the accelerator. Figure 6 shows the time trend of the beam profile and the stored current, which is same as extracted charge.

BEAM MEASUREMENT

The preliminary measurement was done without the apodization filter. The estimated diffraction limit from the opening angle of the SR is 20µm. The expected beam size at the EXT-SR is 230µm in horizontal and 24µm in vertical, respectively. The magnification ratio is calibrated by looking a target image at same distance as the source point. The measured beam size was 300µm in horizontal and 80µm in vertical, respectively, at the condition of the extracted beam intensity 1 nC, single bunch. The measured horizontal beam size is almost agreed with the expectation. However, the measured vertical beam size is three times larger than the expectation. We suspect the miss-alignment of the SR line, which reduces the aperture of the SR in this time.

The time trend of the beam profile showed the stable beam position and the beam size in horizontal and in vertical. The dependence of the charge is under analysis.

CONCLUSION

The SR profile monitor was designed and constructed for ATF2 beam line. The preliminary measurement was done without the apodization filter. The video analyzing software was developed and could set the data to the database of the accelerator control.

The resolution test with the apodization filter will be measured for the next step. The other application software will be developed using this hardware.

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