OTR BASED MONITOR OF INJECTION BEAM FOR TOP-UP OPERATION OF THE SPRING-8

S. Takano*, M. Masaki, T. Masuda and A. Yamashita
Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo 679-5198, Japan

Abstract

We have developed an optical transition radiation (OTR) based monitor of injection beam at the SPring-8. The monitor has been installed near the injection point of the storage ring downstream of the beam transport line from the booster synchrotron. A screen made of an aluminum coated polyimide film is used as a non-destructive OTR radiator. A CCD camera with an electric shutter is used to observe the OTR image of the injection beam. The electric shutter is synchronized with the external injection trigger signals. At every injection, the image signal from the CCD camera is captured and analyzed by a personal computer, and the position, size and intensity of the injection beam are recorded by the real-time database of the SPring-8 control system. The OTR screen monitor provides real-time and non-destructive diagnostic tool useful for the top-up operation of the SPring-8.

INTRODUCTION

The 8 GeV electron storage ring of the SPring-8 is a third generation synchrotron light source operating since 1997. In May 2004, the so-called top-up operation started to realize practically infinite life time of the storage ring beam [1]. In the top-up operation, continuous beam injections at short time intervals keep the beam current approximately constant. In order to monitor the injection beam to the storage ring non-destructively and continuously in the top-up operation of the SPring-8, we have developed an OTR based screen monitor.

OTR SCREEN MONITOR

The injection section of the SPring-8 storage ring is shown schematically in Fig.1. The electron beam from the booster synchrotron is injected at the full energy of 8 GeV. We have installed the OTR based screen monitor in a vacuum chamber of the beam transport line near the injection septum magnet #5. In the end part of the beam transport line, downstream of the septum magnet #7, the injection beam goes through a vessel filled with helium at atmospheric pressure. We have two fluorescent screen monitors instead of OTR ones there, because intense Cherenkov radiation could disturb observations by contaminating transition radiation. The fluorescent

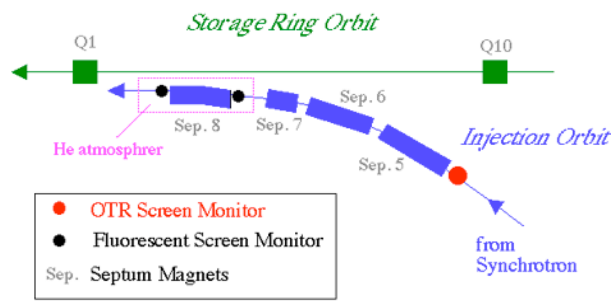

Figure 1: Injection section of the SPring-8 storage ring.

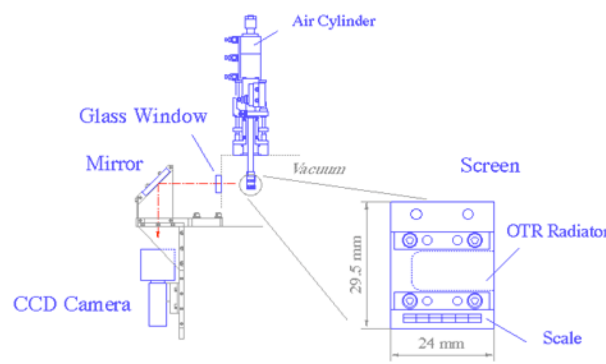

Figure 2: Set up of the OTR screen monitor.

screens are destructive to the injection beam, and they are retracted from the beam orbit during periods of top-up injections.

The setup of the OTR screen monitor is shown in Fig. 2. The OTR screen consists of a frame made of brass and a radiator made of an aluminum coated polyimide film. The thickness of aluminum and polyimide are about 0.5 μm and 50 μm, respectively. Scales for calibration are marked on the lower part of the screen holder. The screen is actuated by an air cylinder, which has three operating positions for 1) beam observation, 2) scale calibration, and 3) retraction. The screen is set at an angle of 45˚ with respect to beam direction. Backward OTR directed horizontally is transmitted in the atmosphere through a glass window and is deflected by a mirror downward, towards a CCD camera. To protect the camera from radiation damages, it is shielded by a cover made of lead. The OTR image of the injection beam is observed by the camera through a lens (F=1.3, f=75mm). The CCD camera has an electric shutter, which is synchronized

* Email:takano@spring8.or.jp

with the external injection trigger signals. The image signal from the CCD camera is captured and analyzed by a personal computer

PROFILES OF INJECTION BEAM

Fig. 3 shows an image of ordinary (non-collimated) injection beam observed with the OTR screen monitor. The charge in the beam is 6×10^{-10} C. Fig. 4 shows corresponding beam profiles projected on the horizontal

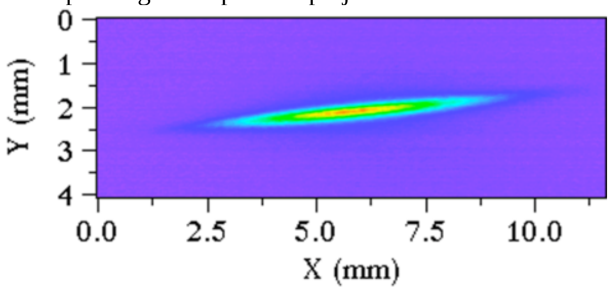

Figure 3: An image of ordinary (non-collimated) injection beam observed with the OTR screen monitor.

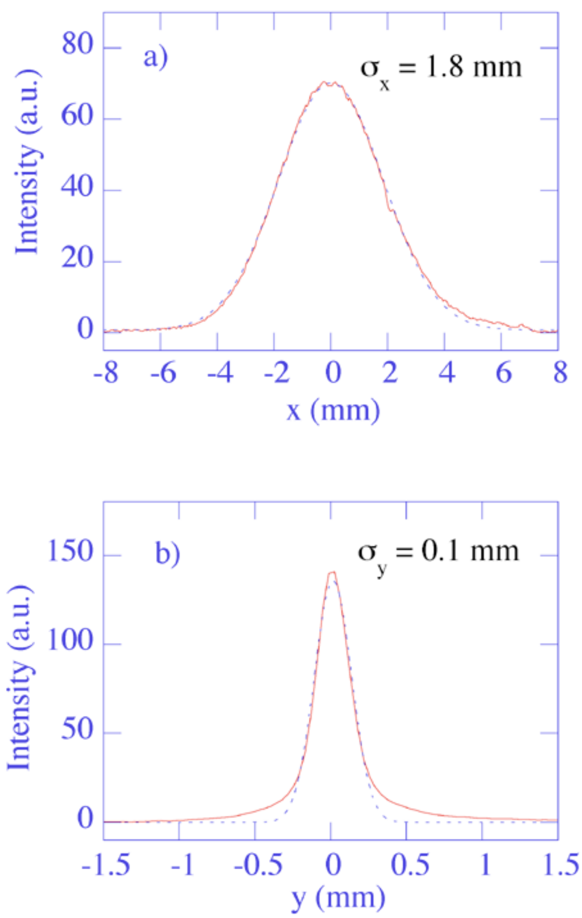

Figure 4: Horizontal (a) and vertical (b) profiles of ordinary injection beam (solid curves) as well as fitted Gaussian curves (dashed curve).

(x) and vertical (y) axes of the coordinates of the injection beam as well as fitted Gaussian curves. Here we defined the major axis of the beam as horizontal and minor axis as vertical.

In the top-up operation of the SPring-8, injection beam to the storage ring is collimated horizontally by two scrapers installed upstream of the beam transport line from the booster synchrotron [1, 2]. The two scrapers have orthogonal phase relation in a horizontal betatron oscillation and reduce horizontal emittance of the

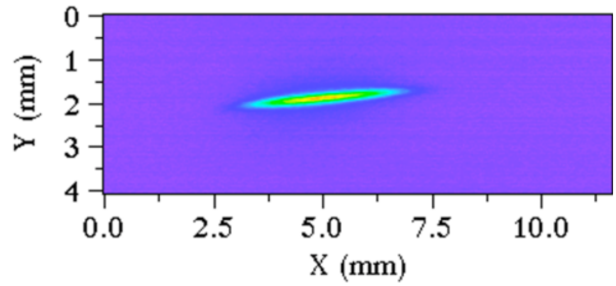

Figure 5: An image of collimated injection beam observed with the OTR screen monitor.

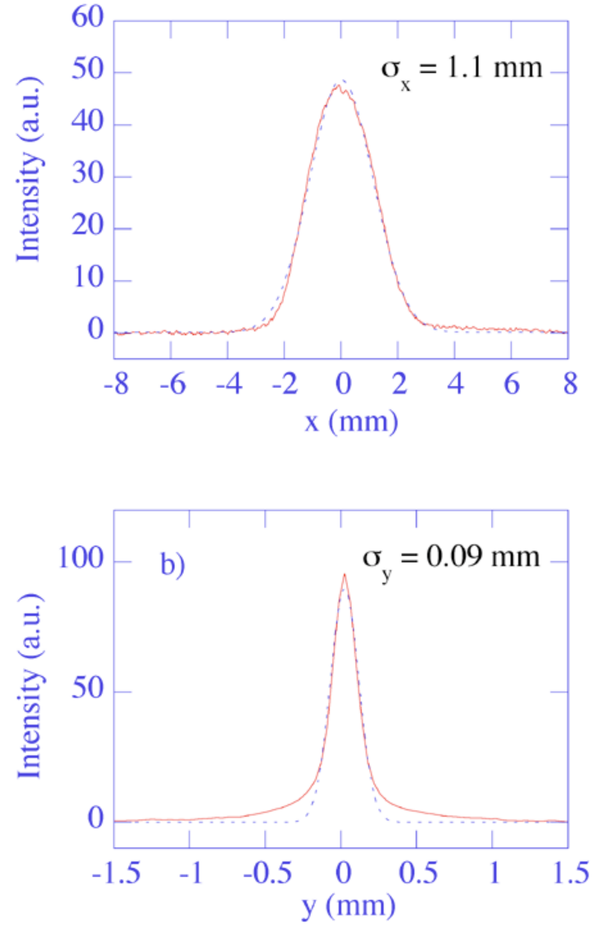

Figure 6: Horizontal (a) and vertical (b) profiles of collimated injection beam (solid curves) as well as fitted Gaussian curves (dashed curve).

injection beam. This enables to bring the injection beam near to the septum wall and to reduce injection beam loss.

Fig. 5 shows an image of collimated injection beam observed with the OTR screen monitor. The charge in the beam is 7×10^{-10} C. Fig. 6 shows corresponding beam profiles projected on the horizontal (x) and vertical (y) axes of the beam coordinates as well as fitted Gaussian curves.

REAL-TIME MONITORING OF INJECTION BEAM

For real-time monitoring of the injection beam, we use an event-driven data acquisition software [3] developed by extending the SPring-8 control software framework MADOCA [4]. At each beam injection to the storage ring, the image signal from the CCD camera is

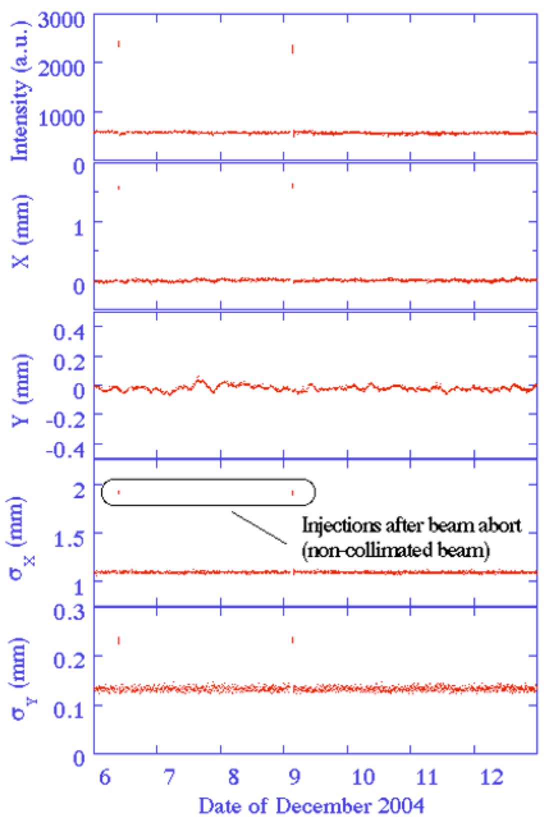

Figure 7: An example of history of injection beam to the storage ring for one week of the top-up operation.

captured and analyzed by the personal computer. Gaussian curves are fitted to one-dimensional beam profiles projected on the horizontal (X) and vertical (Y) axes on the coordinates of the captured image, to obtain intensity I, positions X and Y, and sizes σ_X and σ_Y of the injection beam. Here the sizes σ_X and σ_Y are defined as projections on not the beam coordinates but the image coordinates. The analyzed data are stored into the real-time database [5] of the SPring-8 control system.

An example of time variation of injection beam is shown in Fig. 7 for one week of the top-up operation. The time interval of injections and the charge in the injection beam were one minute and about 2×10^{-10} C, respectively. There were two beam abort events on 6 and 9 Dec. After beam abort, the storage ring was refilled by injecting non-collimated beam, of which the charge was about 7×10^{-10} C.

CONCLUSIONS

We have developed an OTR based screen monitor of the injection beam at the SPring-8 storage ring. The profiles of the injection beam were successfully measured with it. At each injection to the storage ring, the intensity, position and size of the injection beam are recorded by the real-time database of the SPring-8 control system. The OTR screen monitor provides non-destructive and real-time diagnostic tool useful for the top-up operation of the SPring-8.

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REFERENCES

[1] H. Tanaka, et al., EPAC'04, Lucerne, 2004, p.222.
[2] K. Fukami, et al., "Beam collimation system for the SPring-8 Top-Up Operation", APAC'04, Gyeongju, in the press.
[3] T. Masuda, et al., Nucl. Instr. and Meth. A, 543 (2005) 415-430.
[4] R. Tanaka, et al, ICALEPCS'97, Beijing, 1997, p.1.
[5] A. Yamashita, et al., ICALEPCS'97, Beijing, 1997, p.427.