BEAM DIAGNOSTICS WITH VISIBLE SYNCHROTRON RADIATION AT NEWSUBARU

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Abstract

We have constructed two optical monitors using visible synchrotron radiation (SR) from bending magnets (BM) for beam diagnostics in the NewSUBARU storage ring. The visible SR is observed by a CCD camera and acquired image data is processed by a real-time image processing system based on PC and LabVIEW. Measurement of visible SR spot size provides an electron beam size and emittance. The measured horizontal emittance of 38nmrad is in good agreement with designed value. In this paper the detail of visible SR monitor and the results of measurements of electron beam size and emitance are shown.

1 INTRODUCTION

Observation of visible SR is one of useful tools for beam diagnostics [1]. The transverse beam size $\sigma_{x,y}$ is obtained by forming an image of the beam cross section by means of emitted SR. To evaluate the emittance $\varepsilon_{x,y}$ from $\sigma_{x,y}$, the lattice functions $(\alpha,\beta,\gamma,\eta)$ at the source point have to be known. We can use following relations

$$\sigma_X = \sqrt{\varepsilon_X \beta_X(s) + \eta^2(s)\sigma_\delta{}^2},$$
$$\sigma_Y = \sqrt{\varepsilon_Y \beta_Y(s)} \qquad (1)$$

where σ_δ is energy spread, $\beta_{X,Y}$ betatron function, η dispersion function. The vertical dispersion is usually small and can be neglected. The obtained resolution is limited by diffraction effect $\sigma_{dif}=0.206(\lambda^2\rho)^{1/3}$ and depth of field effect $\sigma_{dof}=0.34(\lambda^2\rho)^{1/3}$ where λ is observed wavelength and ρ is radius of curvature of electron orbit.

2 VISIBLE SR MONITOR

2.1 General Layout

There are two visible SR monitor, SR1 and SR2, near BM7 and BM10 respectively. The general layout of SR1 is shown in Fig.1. Visible component of SR from the entrance of BM is extracted through the M0 mirror (Au-coated copper block) and a quartz window. In SR1 several mirrors are used in order to guide the radiation to the experimental hall, where adjustment of optical components such as neutral density filter, polarization filter and band pass filter can be performed. The mirrors inside the tunnel can be remote-controlled from the control room using optical GPIB converter OMRON Z10 and optical GPIB cable. A small CCD camera for mirror calibration is equipped near each remote-controlled mirror.

As for SR2, a CCD camera for observation of SR is located inside the tunnel.

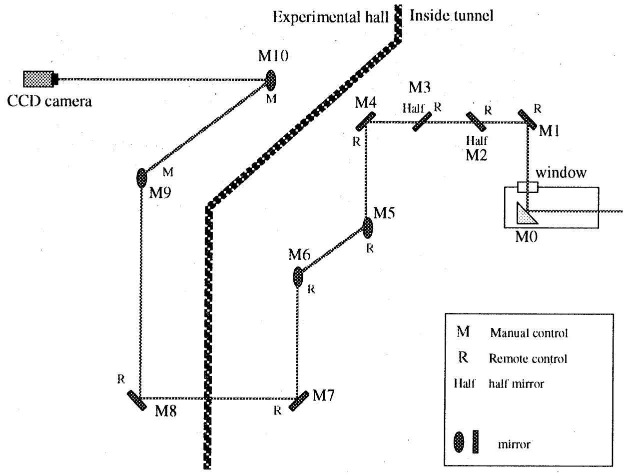

Figure 1: Basic layout of SR1.

2.2 PC based image acquisition and processing

(Hardware)

A PC with a Pentium III processor and National Instruments (NI) PCI-1408 PCI card was used for image acquisition and processing. The analogue video signal in NTSC format of a standard CCD camera in the experimental hall is transmitted to the PC in the control room by coaxial cable. The entire image frame of data can be acquired to the PC at a rate of 30 Hz.

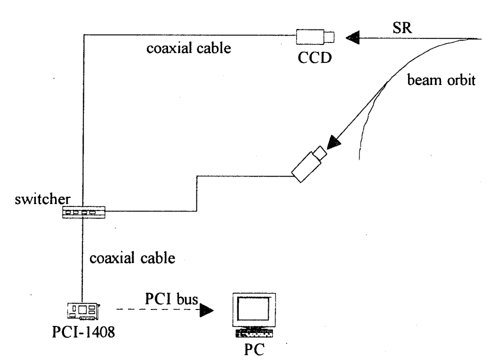

Figure 2: Hardware configuration.

(Software)

An operating system running on the PC for image processing is Windows NT. The image acquisition and processing application was developed with NI LabVIEW and IMAQ Vision software. IMAQ Vision provides complete functionality for scientific analysis. By image processing of SR the standard deviation of r.m.s. beam size and shift of beam center can be measured in real time. The speed of image processing is about a few frames per second. Typical image from the CCD camera and its processed image are shown in Fig. 3. The resolution of image processing is 0.073

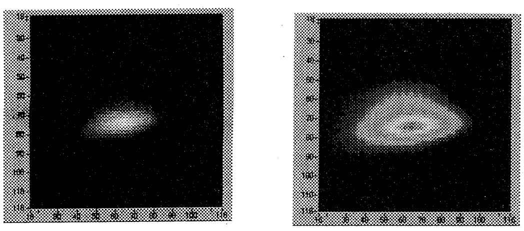

Figure 3: Before (left) and after (right) an image processing of the visible SR.

3 BEAM SIZE AND EMITANCE MEASUREMENTS

Theoretically speaking, the increase of energy spread is proportional to the third power root of the stored current $I_b^{1/3}$ in single bunch mode, $\sigma_\delta=AI_b^{1/3}$. From eq.1 the square of horizontal and vertical beam sizes are given by

$$\sigma_X^2 = \varepsilon_X\beta_X(s) + \eta^2(s)A^2I_b^{2/3},$$
$$\sigma_Y^2 = \varepsilon_Y\beta_Y(s) \qquad (2)$$

Thus the natural emittance can be calculated from beam size with zero current. Using band pass filter of 400 nm and polarization filter to select only σ-mode of SR, the transverse beam sizes were measured with varying stored current in single bunch mode (Fig.4). From this figure we have beam sizes at zero stored current of σ_x^2=0.12mm^2 and σ_y^2=0.031mm^2. Subtracting the diffraction error and depth of field error, σ_{dif}=0.0165mm and σ_{dof}=0.0272mm, respectively, we have σ_x^2=0.119mm^2 and σ_y^2=0.03mm^2.

Assuming designed betatron functions at the source point β_x=2.49m and β_y=10.6m, we have horizontal and vertical emittances, ε_X=38 nm*rad and ε_Y=2.9 nm*rad. These values are in good agreement with designed ones [2].

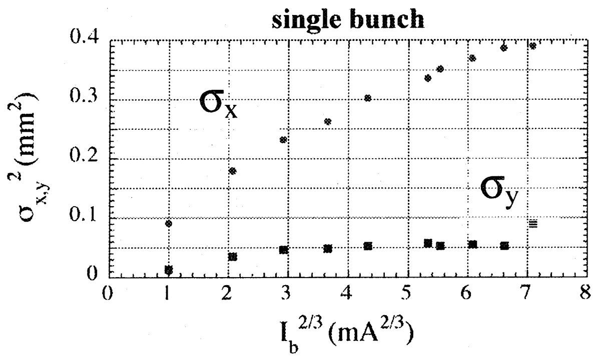

Figure 4: Horizontal and vertical beam sizes versus stored current.

4 REFERENCES

[1] A. Hoffman, F. Meot, NIM A203, pp.483 (1982).

[2] A. Ando, Y. Fukuda, S. Hashimoto, "Beam size blowup and energy widening in NewSUBARU", NIM A, *to be published.*