Design of Profile Monitors for ATF

T. Naito, H. Hayano, M.Kikuchi, J. Urakawa, and M. Yoshioka
M. Oyamada*, S.Urasawa*, T.Nakazato*, T.Yamakawa*

KEK, National Laboratory for High Energy Physics,
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 Japan
***Laboratory of Nuclear Science, Tohoku University,**
1-2-1 Mikamine, Taihaku-ku, Sendai-shi, Miyagi-ken, 982 Japan

Abstract

A profile monitor using a fluorescent screen is designed and tested. A random shutter camera and a video analyzer system are used for the measurement with shot by shot. In order to realize high resolution, a thin fluorescent screen and a high magnification lens system are designed. An another type of profile monitor using optical transition light is also described in this paper.

I. INTRODUCTION

The Accelerator Test Facility (ATF) consists of 1.54 GeV Linac and Damping ring is under construction for development of accelerator components to realize the Japan Linear Collider (JLC). The beam parameters of the linac are following, repetition rate: 25Hz, charge number: $2x10^{10}$ electrons/bunch, bunch number: 20 bunches/shot, bunch space: 2.8 ns.

The main purpose of this facility is to make a low emittance and multi-bunch beam. Precise monitors and control systems are required. To monitor the beam size and the position in the linac, fifteen screen monitors will be installed with other monitors(wire scanners, strip line BPMs, etc.). The screen monitor has an advantage compared with the wire scanner. It can measure the beam profile and position shot by shot.

An optical transition light(OTR) will be observed when a metal screen is used instead of fluorescent screen at the energy over several ten MeV. A wave form of OTR is the same as bunch shape, we can measure profiles of each micro bunch by using a fast shutter camera with image intensifier and 3ns gate.

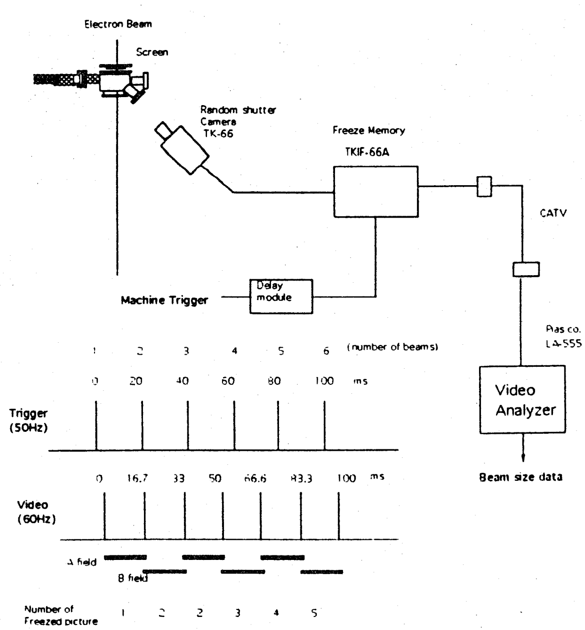


Fig. 1 Screen monitor system

II. SCREEN MONITOR SYSTEM

The system configuration is shown in Fig. 1. The screen monitor system consists of a fluorescent screen(alumina with chromium oxide: AF995R), an actuator, a random shutter camera, a freeze memory and a video analyzer. The screen is inserted to the beam line by the air actuator. The random shutter camera can memorize the light from the fluorescent screen when a beam hits the screen with shot by shot. The camera is synchronized to a machine trigger. The image which is frozen by the timing of machine trigger is converted to a video signal with a video cycle(60 Hz). The video signal is sent to the control room by the CATV system. The video analyzer calculates the peak position(X,Y) and beam size(1σ) by gaussian fitting in real time. Twiss parameters and emittances are measured by this system.[1]

III. EXPERIMENT AT TOHOKU UNIV.

The prototype of the screen monitor, wire scanner, strip line BPM were tested at Tohoku Univ. Linac.[2] The beam parameters and beam shapes using a amorphous core CT is shown in

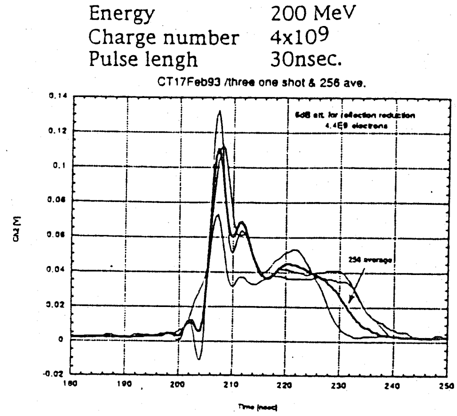
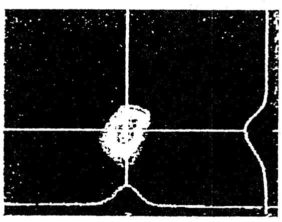


Fig. 2 Beam shape of Tohoku Univ. Linac



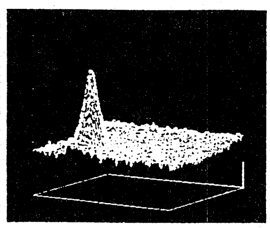
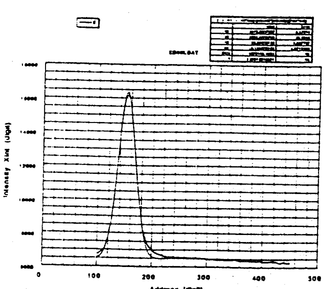


Fig. 3a Beam profile Fig. 3b 3D distribution



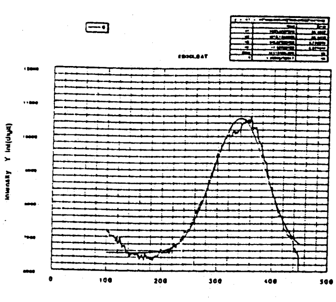


Fig. 4a Beam profile(X) Fig. 4b Beam profile(Y)

Fig. 2. The camera is set to 40 cm distance from the beam line. The screen is viewed by f=75mm(F1.8) and x2 magnifier lenses. The view area is 8.8 x 6.6 mm and a magnification is almost 1. The thickness of the screen is 130μm in this test. The total system error is estimated about 50μm.

A. Beam size measurement

The beam profile and the three dimensional intensity distribution of the linac beam are shown in Fig. 3a, 3b. The projection of X and Y direction is shown in Fig. 4a, 4b. From these data, we calculated the peak intensity, the center position and the beam size(1σ) using a gaussian fitting. The results were σ_x = 300μm in the case of focused beam in X direction.

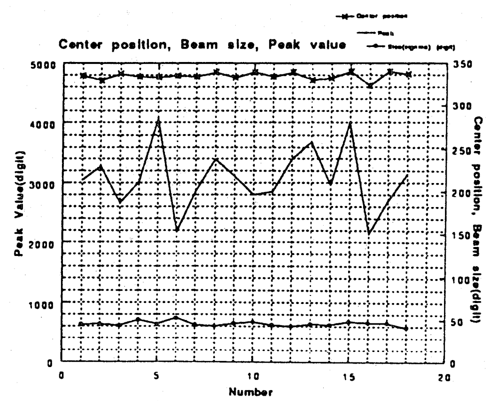


Fig. 5 Fluctuation of beam profile

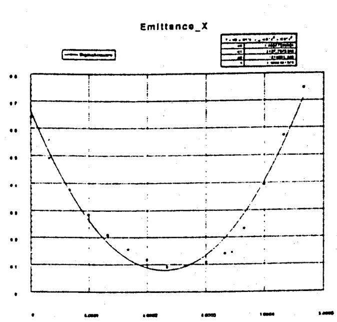
Time domain fluctuation of the beam intensity was observed from the wave form of the CT in Fig. 2. The transverse fluctuation was measured by this monitor. Fig. 5 shows the fluctuation of peak value, center position, and beam size. The fluctuation of each value of Y direction was 40% for peak value, 3% for center position, 8% for beam size. The fluctuation of X direction was almost the same as Y direction. The fluctuation of center position and the beam size were small compared with the peak value. We thought it was caused by the fluctuation of the gun grid pulser.

B. Emittance measurement

Emittance is estimated by measuring each beam size at each current of the upstream Q magnet. The spot size at the screen is given by σ-matrix as the function of strength of the Q magnet(k) [3],

$$\sigma_{11}^{s} = A(k-B)^2 + C.$$

The measured size is fitted to a parabola function. The square of spot size versus strength of Q magnet for X and Y direction is plotted in Fig. 6a, 6b. The optical matching was not adjusted, thus the spot size is not well focused in Y direction. From these fitting value, the emittace(ε_x, ε_y) and



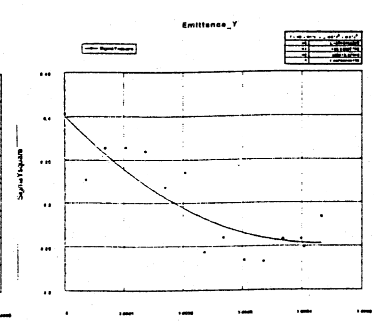


Fig. 6a
Square of beam size
versus strength of Q(X)

Fig. 6b
Square of beam size
versus strength of Q(Y)

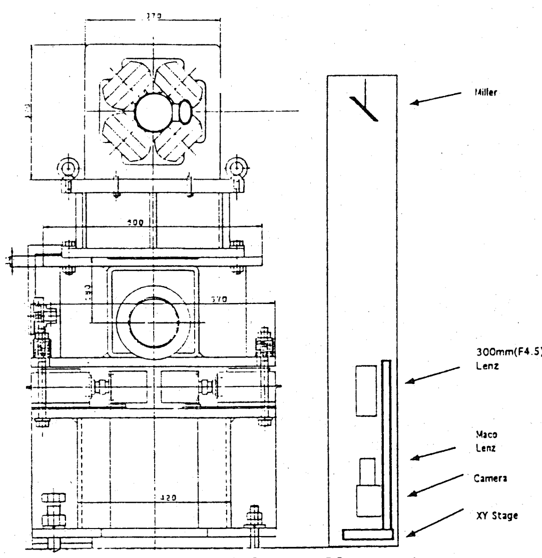


Fig. 7 Set up of the profile monitor

the normalize emittnce(ε_{nx}, ε_{ny}) are
$\varepsilon_x = 2.16 \times 10^{-7}$ m rad ($\varepsilon_{nx} = 8.45 \times 10^{-5}$ m rad) and
$\varepsilon_y = 1.05 \times 10^{-7}$ m rad ($\varepsilon_{ny} = 4.13 \times 10^{-5}$ m rad).
These values are agreed with the result of the wire scanner.

IV. OPTICAL DESIGN FOR ATF

The cross section of the beam line at the screen monitor is shown in Fig. 7. To protect the CCD camera from radiation damage, the camera is set under the beam line. The distance of the camera and beam line is about 1.5m. An object lens of f=300mm(F4.5) and f=38mm(F2.8) macro lens as a x3 magnifier are used to make view area 10 x 7.5 mm. Achievable resolution of this system is following.

Deffraction limit

Reyleigh limit of the lens is indicated by

$$\varepsilon = 0.61\frac{f}{h}\lambda .$$

The limit is ε = ~15 μm at the wave length λ = 700 nm.

Resolution of CCD

The size of one cell of the CCD is

σ_{rx} = 10mm / 768cells = 13 μm and

σ_{ry} = 7.5mm / 247cells = 30 μm.

Thickness of screen

We calculate two effect of screen at the case of the thickness = 100 μm.

1) The effect of defocus to the light from deepest area when the camera is focused on surface is σ_d =~1.5 μm.

2) The effect of view angle of 45 degree(it affect only in X direction) is σ_a = ~30 μm.

The overall resolution is about 50 μm.

V. OTR PROFILE MONITOR

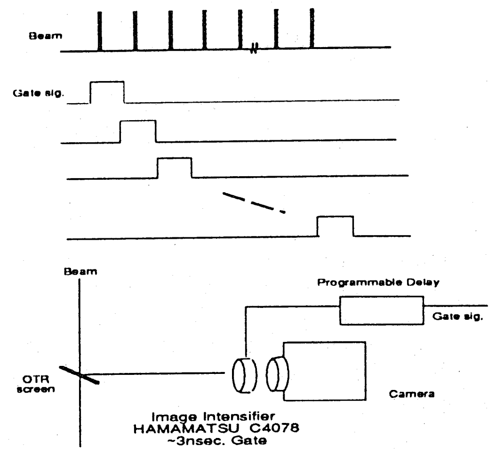


Fig. 8 OTR profile monitor

Fig. 8 shows measurement scheme and timing chart. A metal screen is used instead of the fluorescent screen to observe OTR. A fast camera with image intensifier(HAMAMATSU C4078) has 3ns gate time and 1 x 10^6 of photon gain. The gate is distinguishable each bunch in ATF. The programmable delay select gate timing correspond to each bunch timing. At the point of the downstream of analyzer magnet(90 degree bend), this monitor will be installed to monitor energy spread of each bunch.

VI. SUMMARY

Fluorescent screen profile monitor is designed and tested. The system resolution is about 50 μm. OTR profile monitor is designed to measure the each profile of the multi-bunch.

VII. ACKNOWLEDGMENTS

We would like to express our thanks to Professors K. Takata and S.Takeda for their encouragement. We acknowledge Dr. K. Furukawa for his help and Mr. T.Matsui(A.T.C.) for his technical support of this experiment.

References

[1] F.J.Decker, "Beam Size Measurement at High Radiation Levels", SLAC-PUB-5481 May 1991

[2] H.Hayano, et. al, "WIRE SCANNER BEAM SIZE MONITOR FOR ATF", in this proceedings

[3] M.Ross et. al, "HIGH RESOLUTION BEAM PROFILE MONITORS IN THE SLC", SLAC-PUB-3640 April 1985

[4] M.Ross et al, "AUTOMATED EMITTANCE MEASUREMENTS IN THE SLC", SLAC-PUB-4278(1987)