STATUS OF THE FIRST COMMISSIONING OF THE SHINTAKE MONITOR FOR ATF2 *

T. Yamanaka†, S. Komamiya, M. Oroku, The University of Tokyo, 7-3-1, Hongo, Bunkyo, Tokyo, 113-0033, Japan
Y. Kamiya, T. Suehara, ICEPP The University of Tokyo, 7-3-1, Hongo, Bunkyo , Tokyo, 113-0033, Japan
S. Araki, Y. Honda, T. Kume, T. Okugi, T. Tauchi, N. Terunuma, J. Urakawa, KEK, 1-1 Oho, Tsukuba, Ibaraki, 305-0801, Japan

Abstract

Commissioning of the ATF/ATF2 project started in winter of 2008 to 2009, with the aim of studying beam optics, diagnostic instrumentations, and tuning processes for around 37 nm beam size. The project is the realistic scaled down model of the ILC final focus system, and also, studies in the project offered important findings for future accelerator physics. In this paper, we will present the status of the first commissioning of the Shintake monitor for ATF2. The monitor is located at the virtual interaction point (the focal point) of the ATF2 to measure beam size. A measurable ranges in design are from 6 micron down to 20 nm in vertical and down to several microns in horizontal. This wide range allows us to use this monitor from the beginning of the beam tuning process. The monitor scheme was originally proposed by T. Shintake and verified using around 60 nm beam at FFTB project[1]. We upgraded the detector system for ATF2 of smaller beam size and implemented a laser wire scheme for horizontal beam size measurement.

INTRODUCTION

To explore TeV-scale physics with high precision, the International Linear Collider (ILC), which collide several hundreds GeV energy electron and positron beams, is proposed[2]. The vertical beam sizes of electron and positron beams need to be focused in nanometer scale to achieve high luminosity at ILC.

The Accelerator Test Facility (ATF) was constructed at KEK in Japan to realize such a small beam size. The performance of a damping ring for linear collider is studied here and beam operation has been continued to 2008 summer. It achieved the vertical normalized emittance ($\gamma\varepsilon_y$) less than 2.8×10^{-8} rad·m at beam energy 1.3 GeV[3]. This is the lowest normalized emittance of electron beam ever measured and satisfies the ILC requirement.

ATF2 is an extension of ATF to complete the test of the ILC beam delivery system including the final focusing system[4]. By utilizing very low emittance beam provided from ATF damping ring, ATF2 aims to focus the vertical beam size to 37 nm at the virtual interaction point. The construction of ATF2 was almost finished and its beam operation started at the end of 2008.

* Work supported by KEK
† yamanaka@icepp.s.u-tokyo.ac.jp

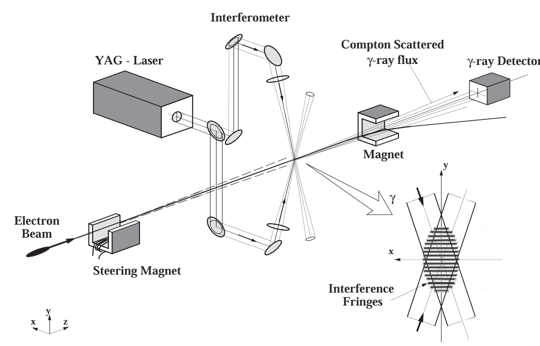

Figure 1: Schematic of the Shintake Monitor[5]

Shintake Monitor

To measure 37 nm vertical beam size to be realized at ATF2, we constructed the beam size monitor called the Shintake monitor. It was proposed by T. Shintake[5] and used at the Final Focus Test Beam (FFTB) experiment at SLAC[1]. There 70 nm vertical beam size was measured.

Figure 1 shows the schematic of the Shintake Monitor. The split laser beam is crossed at the interaction point with the electron beam. Then electron beam passes through the interference fringe and the inverse Compton scattering occurs. If the electron beam size is small relative to the fringe pitch, the number of scattered photon at the peak of the fringe and the valley of the fringe differ significantly. On the other hand, if the beam size is comparable to the fringe pitch, the electron beam interact with the portion of the peak and valley at the same time. Then the number of scattered photons does not change so much when the fringe position moves against the electron beam. By using this difference, the electron beam size is measured.

PERFORMANCE ESTIMATION

Upgrade from FFTB

The Shintake monitor at ATF2 is an upgrade from the one used at FFTB. The major modification is the wavelength of the laser. At FFTB, 1064 nm of Nd:YAG laser

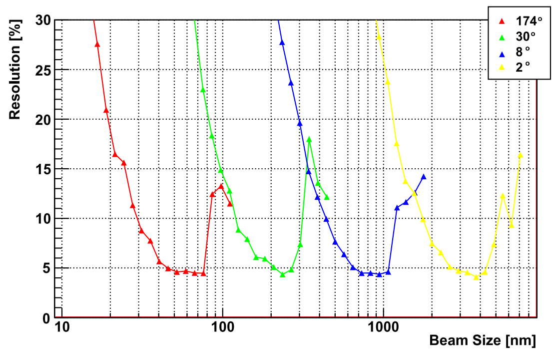

Figure 2: Expected resolution curves of beam size measurement in different crossing angles

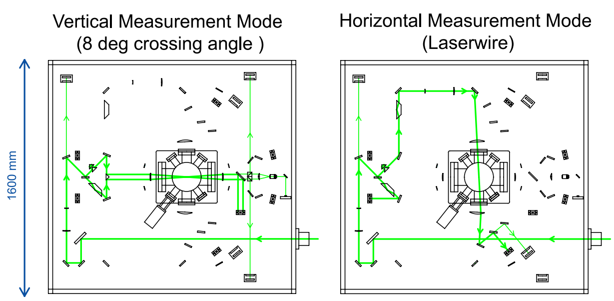

Figure 3: The Shintake monitor optics design

was used. At ATF2 the second harmonics of Nd:YAG laser, 532 nm, is used to measure smaller beam size.

The other improvement is the implementation of many laser crossing angle modes. The measurable range of the Shintake monitor is not so wide if we use fixed fringe pitch. However by changing the laser crossing angle and so the fringe pitch, measurable range can be altered. The former Shintake monitor used two crossing angles, 174° and 30°. They can measure the vertical beam size form 40 nm to 750 nm with the reasonable resolution. We add two crossing angle modes 8° and 2°. With these crossing angle modes we expect to measure the vertical beam size from 25 nm to 6 μm within 12 % resolution. Figure 2 is the expected resolution curves calculated from the electron beam and laser jitters.

Furthermore, to achieve high stability of the interference fringe, other monitoring devices are introduced to the laser optics[6] [7].

Figure 3 shows the optics design of the Shintake monitor for ATF2. The left figure is one of the vertical measurement modes (the interferometer mode), crossing angle of 8°. The right one shows the optics for the horizontal beam size measurement. In horizontal we use different measurement method called laserwire, which scans the electron beam by very thin focused laser beam. Since the horizontal beam size at the interaction point at ATF2 is relatively large (2.8 μm in design) beam size can be measured with this method.

COMMISSIONING

Our commissioning started from the detection of inverse Compton scattered photons comes from the interaction point. We used the horizontal measurement mode optics (right of Fig. 3). Difficulty to detect Compton scattered photons at ATF2 is low S/N ratio. The average energy of Compton scattered photons is 15 MeV with 532 nm light and 1.3 GeV electron. During the measurement the background photons, which is thought to be the bremsstrahlung photons originating from the beam pipe hit by electron beam halo, also detected at the gamma-ray detector. This background photons have relatively high energy because of high electron beam energy. To detect the signal photons in such a high background codition, we designed the layered CsI(Tl) scintillation detector[8]. By using the difference of the energy deposit ratio in each layer, that is the shower development in the detector, the amount of signal photons can be obtained by fitting even if large amount of background photons exist.

To detect the Compton signal, the following procedure was used.

1. reduce the background photons by tuning the electron beam orbit
2. direct the beam angle at the gamma-ray detector position
3. adjust the timing of the pulsed laser and the electron beam pulse
4. check the laser beam and the electron beam position on the screen monitor

1st. Beam Orbit Tuning

Although our gamma-ray detector has high separation capacity, there is a limit. If the background level is much higher than Compton signal, we cannot measure anything. To reduce the background, the electron beam must be centered to the beam pipe to avoid the beam halo incident on the wall. This was performed by using steering magnets and turned the beam to the center of the magnets through the whole ATF2 beam line.

2nd. Beam Direction Tuning

Even if the Compton scattering occurs, scattered photons will not be detected as long as the beam directs at the different point from the gamma-ray detector. To direct the beam there, beam positions at the interaction point and 80 cm downstream are monitored by beam profile monitors. By moving the quadrupole focusing magnet, the beam orbit can be changed and this change can be seen on them.

After the tuning, coming of the gamma ray can be checked by taking a Polaroid photograph in front of the detector.

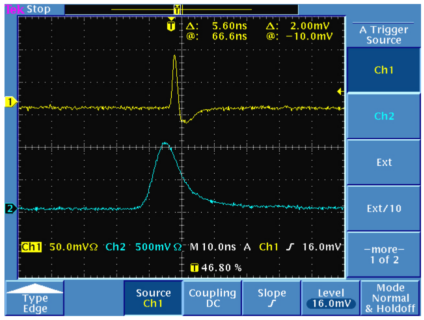

Figure 4: Timing signal on a oscilloscope. Ch1 is the BPM signal and Ch2 is the Si:PIN photo diode signal

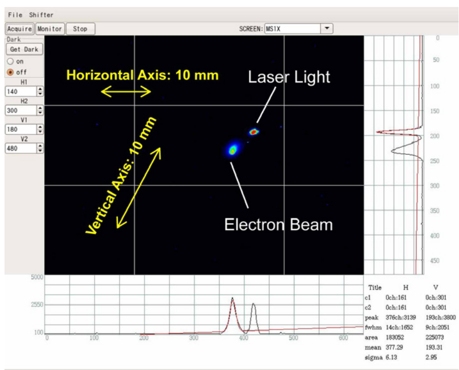

Figure 5: The images on the beam profile monitor

3rd. Timing Adjustment

To collide the electron beam and the laser beam, their emission must be synchronized and adjusted to the appropriate timing. For synchronization the master trigger of the kicker pulse to extract the electron beam from the damping ring is used to the laser Q-switch trigger. To adjust the timing, the electron beam timing is monitored by using a stripline beam position monitor (BPM) signal and the laser timing is monitored by using a Si:PIN photo diode like Fig. 4.

4th. Position Adjustment

Although the scanning can be started up to here, it is difficult to find the signal in wide range. Therefore we installed a beam profile monitor which utilize a fluorescent plate to see the electron beam position. A laser light image can be also seen by diffuse reflection on the plate. By superimposing the electron beam and the laser beam on the screen, it is assured they collide at the interaction point within several tens of microns accuracy . Figure 5 shows the images on the screen.

Scanning

After these procedures, we performed the scanning. Figure 6 shows the result of scanning using the layer distribution information. Fitted convoluted beam size

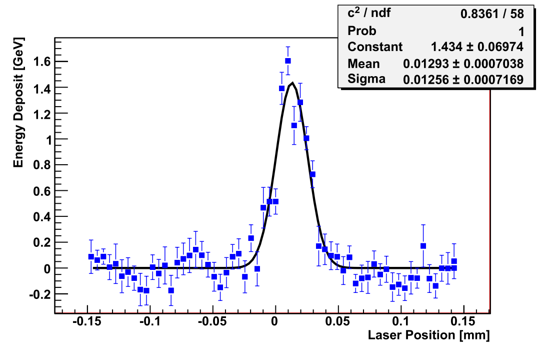

Figure 6: The result of horizontal beam scanning

($\sqrt{\sigma_{ex}^2 + \sigma_{Lx}^2}$, where σ_{ex} is the horizontal electron beam size and σ_{Lx} is the horizontal laser beam size) was 13 μm. Since the horizontal laser beam size at the interaction point was assumed to be around 10 μm, this measurement indicates the horizontal electron beam size is calculated to around 10 μm. This value was consistent with the expected electron beam size at that time.

CONCLUSION

We had developed the Shintake monitor for ATF2. The commissioning of the Shintake monitor has started from the end of last year with horizontal beam size measurement mode. We utilized various devices to detect Compton scattered photons from the collision of the electron beam and the laser light and succeeded it. We will move on to the interferometer optics and plan to measure the modulation of the scattered photons from the next beam time.

ACKNOWLEDGMENT

The authors thank the ATF collaborators for their help during the ATF beam operation and their advices at the meetings.

REFERENCES

[1] T. Shintake *et al.*, Proc. Particle Accelerator Conference 1995, Dallas, USA, Vol.4, pp.2444

[2] J. Brau *et al.*, International Linear Collider Reference Report, ILC-REPORT-2007-001 (2007)

[3] K.Kubo *et al.*, Phys. Rev. Lett. 88, 194801 (2002)

[4] B. I. Grishanov *et al.*, ATF2 Collaboration, ATF2 Proposal, KEK Report 2005-2

[5] T. Shintake *et al.*, Nucl. Inst. Meth. A311, 453 (1992)

[6] T. Suehara *et al.*, ICEPP Report 2008, UT-ICEPP 08-04 `http://www.icepp.s.u-tokyo.ac.jp/papers/reports.html`

[7] T. Yamanaka *et al.*, IEEE NSS Conference Record 2008, Dresden, Germany, pp. 3308-3313

[8] M. Oroku *et al.*, IEEE NSS Conference Record 2008, Dresden, Germany, pp. 2330-2334