BEAM DIAGNOSTICS AT SDUV-FEL

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Abstract

The Shanghai Deep Ultraviolet FEL(SDUVFEL) began to commissioning since September 2009. In this paper, we present the instrumentations on the proof-of principle experiment of FEL physics study. The different beam diagnostics monitors for measurement of beam current, beam position and beam profile are briefly described, and the diagnostics data acquisition architecture is present too.

INTRODUCTION

The Shanghai Deep Ultraviolet FEL facility is consist of 40MeV injector ,160MeV Linac section, two-stage modulator -radiator section, six 1.5m undulators section and driving/seeding laser system[1] as shown as Figure 1.

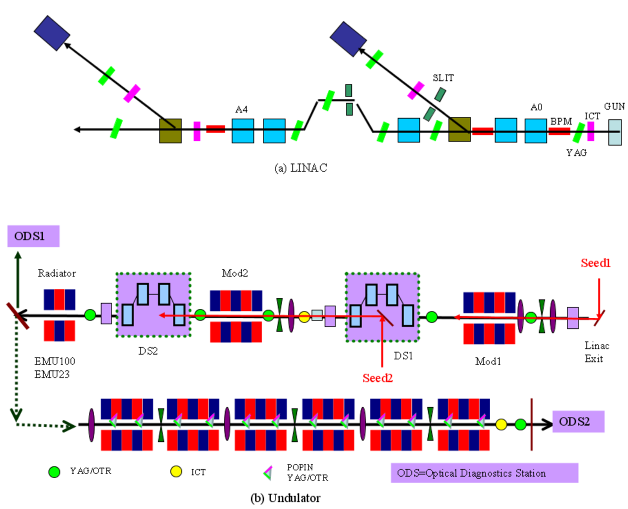

Figure 1: The layout of SDUV-FEL.

The injector and linac are upgrade from the 100MeV Linac which is the prototype of the pre-injector of Shanghai Synchrotron Radiation Facility(SSRF).The thermalcathode gun is replaced with photocathode gun as well as the buncher of linac.In addition,the magnetic bunch compressor is used to obtain the shorter electron bunch length which is necessary for FEL generation.

A two-period radiator undulator prototype has been fabricated and measured, and six 1.5m radiator sections are installed. Using the recently proposed echo-enabled harmonic generation (EEHG) free-electron laser (FEL) scheme, it is shown that operating the Shanghai deep ultraviolet FEL (SDUV-FEL) with single-stage to higher harmonics is very promising, with higher frequency up—conversion efficiency, higher harmonic selectivity and lower power requirement of the seed laser.

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DIAGNOSTICS DESCRIPTION

Overview

Most of the SDUVFEL electron beam diagnostic monitors was designed specially for FEL facility,except the BPM and ICT monitor and some screen monitors of Linac duo to the budget.The layout of the SDUVFEL electron beam diagnostics monitors are showed as Figure 1 and table 1:

Table 1: SDUVFEL Diagnostics Monitors

	Linac	Undulator
BPM	3	
ICT	4	2
YAG/OTR	7	7
POP-IN YAG/OTR		12
SCRAPER	2	

Beam Position Monitor

The Beam position monitor ,with 4 one-end-shorted 60 degree stripline electrode[2], has been chosen to install on the linac. The stripline length of BPM was chosen to 150mm,because the signal frequency which BPM electronics deal with is chosen to 500M. The electrode of BPM is located on the horizontal plane and vertical plane respectively.

The Libera electronics for each BPM are installed. The Libera is the digitalized BPM processing electronics adopted by most of 3^{rd} generation synchrotron radiation facilities recently. Libera is an all-in one solution that enables accurate beam position monitoring, trouble-free commissioning. It can obtain the beam position both on the horizontal plane and vertical plane ,at the same time, it also get the beam charge parameter after calibration by other beam charge monitors as shown as Figure2.

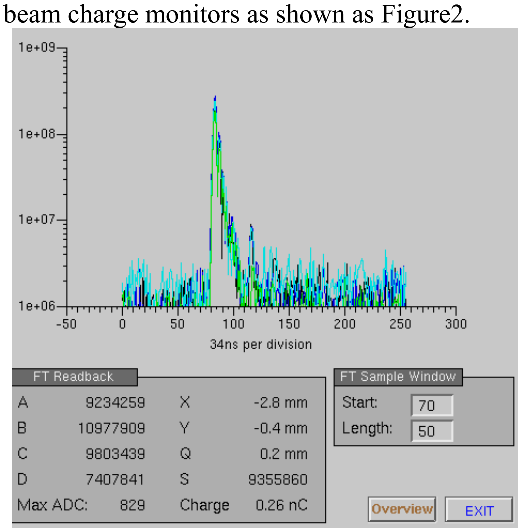

Figure 2: The BPM results from Libera.

The resolution of the beam position measurement for the Linac electron beam with the Libera electronics is about 10 micrometer level.

Charge Monitor

Six integrating current transformers(ICT), which is a non-destructive measurement of the beam charge during normal operation, were distributed alone the SDUVFEL facility. One ICT is installed after the photocathode gun to measure the electron charge from the gun,and the others are installed along the linac and undulators to measure the electron beam transfer efficiency. The commercial ICT-055-70 device from BERGOZ company was used. The signal from the ICT is connected directly to the oscilloscope (Model:Tek7104)from Tektronix company, then the beam charge can be obtained by using the integration function of oscilloscope. The beam charge change from gun to undulator is shown as Figure 3.

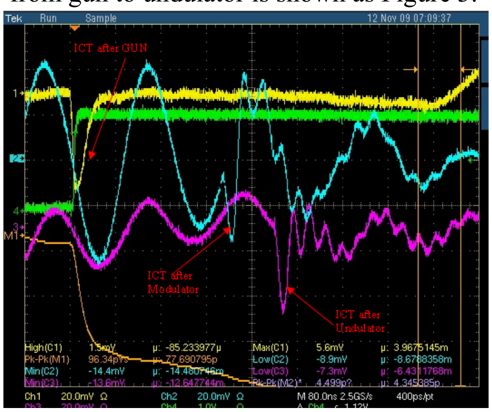

Figure 3: The ICT signals at DUFFEL.

Figure 3 shows that there is single periodical noise, which is produced by the klystron of the linac section,on the second and the third ICT monitors located at undulator,on the other hand,there is not such noise on the first ICT behind the photocathode gun,but there is big dark current signal on it. The beam charge transfer efficiency can be measured roughly from these ICT signals.

Beam Profile Monitor

The beam profile monitor is a main diagnostics tools during the commissioning of the SDUV-FEL experiment s. It has three position for test. One is the calibration screen, The beam profile monitor is not only used to measure the electron beam transverse shape and size,but also to synchronize the seeding laser and electron beam on spatial domain and temporal domain respectively.So all beam profile monitor is designed as shown as Figure4 with four stages pneumatics screen monitor.One screen which material is YAG:Ce crystal plate is used at the initial commissioning and at low beam charge situation, another screen which material is made from 100nm aluminium deposited on a polished silicon wafer[3], generating optical transition radiation(OTR)when electron hits on it, is used to measure beam energy spread and beam emittance respectively,because the OTR represents a linear radiation source while YAG screen has the saturation problem.

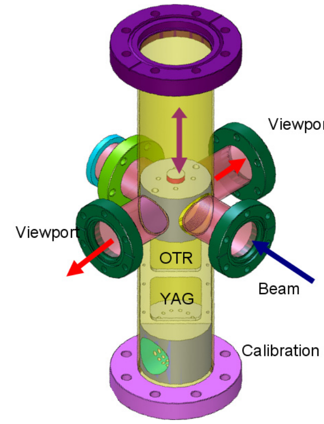

Figure 4: The structure of beam profile monitor.

At modulator locations,the OTR screen is used to obtain the beam arrive time signal for synchronization of seeding laser with electron beam.

The last screen is calibration screen where holes array radius is 1mm and spacing is 5mm.It is used for calibrate the optical relay and CCD image acquisition system. The light of beam can be extracted from both viewport,at the modulator location, the energy of seeding laser is so huge to damage the CCD camera ,so the beam image can be obtained from backside viewport. The camera is located below beam pipe 1.1 meter through planar -mirror optical relay to reduce the radiation damage. The viewport flange can be replaced conveniently with crystal viewport flange where the ultrviet light is need to extract from the screen.

POP-IN Monitor

In six 1.5m undulator section,the vertical space of vacuum chamber is only 7mm,so the normal beam profile monitor can not be used. BNL-DUV-FEL type Pop-in monitors[4] ,as shown as Figure5, in undulator is

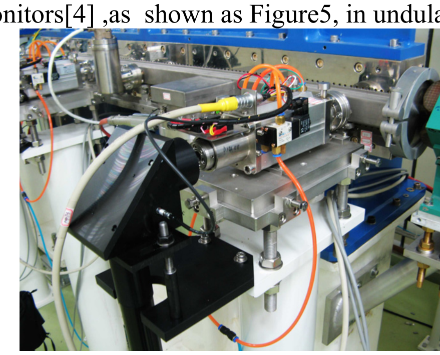

Figure 5: The POP-IN monitor of SDUVFEL.

used for FEL lasing experiments. Each pop-in monitor has two inserting positions, which are used for two different purposes : in first position electron beam is blocked by YAG crystal(Cerium doped)which size is about 4.6mmX6.5mm,then the electron beam position can be obtained by the optical relay and CCD camera. A lens which focus length is 350mm is used so as the magnification of the imaging system is 1:1. The real position of beam can be calibrated by dedicated alignment laser;in second position pop-in monitor is inserted less so that a 45 degree mirror reflects FEL light to other side of undulator. Light power is detected by a photodiode.

The GigE Vision camera is adopted based on following two main advantages: First, digital signals can be transmitted much more stably than analog signals over long distance. Second, The GigE CCD camera gain parameter can be adjusted remotely according to the beam intensity during commissioning. The layout of the beam profile monitor control is shown as Figure 6.

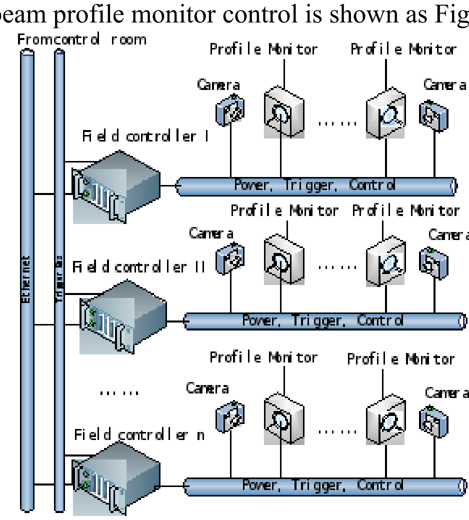

Figure 6: layout of profile monitor control system

The profile control system is simple and flexible based on two filed buses[5]: The industrial Ethernet for communication between control room and cameras; The trigger bus for synchronization with electron beam. Basler scA640-70gm CCD cameras were chosen for all profile monitors. The CCD sensor size of this camera is 659*494 by 7.4μm square pixels and it has a 12 bits ADC.The screen is moved pneumatically which is controlled by Ethernet based IO controller MOXA E2210 module .

Figure 7 shows two different beam images. The left one was from the Pop-in monitor, and its resolution could be 14 microns. The right one is from the profile monitor at the exit of the undulator.

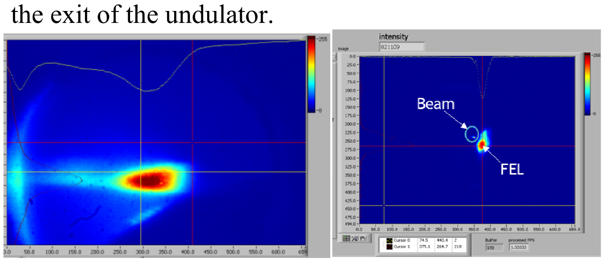

Figure 7: The electron beam images from POP-IN monitor(left) and profile monitor(left)

Scraper

There are one scraper in the middle of bending magnet compress(BMC), The scraper,which is controlled by Galil's DMC-21x3 Ethernet motion controller, can be moved from two directions step by step pass through all vacuum chamber which rang is 125mm. A YAG screen behind the scraper can be moved by step motor. The positions of the scraper and YAG screen can be read out by encoder.

The beam diagnostics software is based on EPICS architecture that is adopted by many accelerator facility . IOC of profile control is developed with LabVIEW running on WindowsXP,then the EPICS records of profile measurement communicate with LabVIEW through SharedMemory IOC[6] software package.

The operator interface of beam diagnostics system is written by EDM tool, but some application programme, such as emittance and energy spread measurement, are written by Matlab, so the codes can be exploited directly between beam diagnostics and physics group.

CONCLUSIONS

The beam diagnostics system started to work since September 2009. The use of industrial Ethernet based devices simplified the design of the diagnostics electronics system. The alignment of Pop-in monitor will be improved in the future,and the cavity BPM will be installed on the undulators as well as the beam length measurement will be established.

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