SESAME STORAGE RING DIAGNOSTICS AND COMMISSIONING

H. Al-Mohammad, K. Manukyan, SESAME, Allan, Jordan

Abstract

SESAME Storage Ring is a 2.5 GeV Synchrotron Light Source in Allan, Jordan. The commissioning of the Storage Ring has been done in spring 2017. The storage ring is equipped with 64 BPMs whereas 48 connected to Libera-Brilliance+, three fluorescent screens, one FCT, one DCCT, four BLMs, two Bunch by Bunch kickers and one Synchrotron Radiation Monitor. This paper gives an overview of the Diagnostics elements and our experience during the commissioning.

INTRODUCTION

The SESAME Storage Ring (SR) shown in Fig. 1 is a 2.5 GeV Light Source of 133.2 m circumference composed of 8 DBA cells with dispersion in all straight sections (8*4.4 m and 8*2.4 m), offers a maximum capacity of 25 beamlines [1]. The RF system consists of four 500 MHz ELETTRA cavities powered by four 80 kW Solid State Amplifiers [2]. A 800 MeV Booster Synchrotron (original from BESSY I) injects the beam into the SR with 1 Hz repetition frequency. The SR main parameters are listed in Table 1.

Table 1: Storage Ring Main Parameters

Energy (GeV)	2.5
Circumference (m)	133.2
RF Frequency (MHz)	499.654
Repetition freq.(Hz)	1
Betatron tunes Q_X / Q_Y	7.23 / 6.19
Horizontal emittance ε_x (nm.rad)	26
Momentum compaction factor	0.0083
Circulating Current(mA)	250
Energy loss per turn (keV)	603

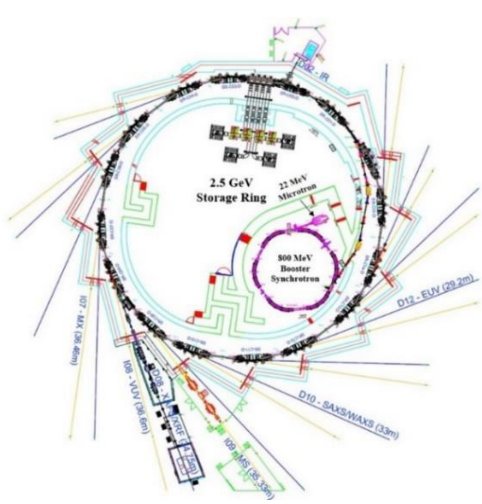

Figure 1: SESAME Facility.

Commissioning of the Microtron had been done in 2012, commission of the Booster in 2014 and of the SR in 2017. Throughout the commissioning, the Diagnostics components are key elements to check SR performance a set of equipment's are installed in the machine in order to measure electron beam current, transverse shape, position inside the vacuum chamber and orbit, tune, chromaticity and emittance. In the following, we present the different diagnostics elements installed in the SR and our experience during the commissioning.

BPM SYSTEM

There are 64 button type beam position monitor (BPM) in SR, which are distributed around the ring as 4 BPMs/cell, two of them flanking the bending magnet and two at beginning and end of the straight sections, 48 of them are connected to Libera Brilliance + [3] and one BPM is connected to a Spectrum Analyser. The BPMs are connected to the Libera B+ by low attenuation RF cables with different lengths (20 m-45 m). 8 Libera B+ units are equipped with GDX (Gigabit Data eXchange) module for FOFB which will be done by using 32 BPM, 4 GDX modules are donated from Instrumentation Technologies as a support to SESAME project. For early stage of the commissioning (first turn(s)), the BPMs could not be used for indication of beam position, due to the low beam intensity, but ADC buffer data and sum signal were used to indicate the passage of the beam. The signal of BPM1 for the first turns is shown in Fig. 2 exemplarily. Once a beam of about mA was stored, transverse beam position could be evaluated and orbit correction was done via SVD method using initially the theoretical and later the measured response matrix. By doing beam based alignment and tuning RF frequency it was possible to correct horizontal orbit to 0.3mm and to 0.17 mm rms, as shown in Fig. 3 [1] then BPMs can be calibrated in positon relative to magnet centres.

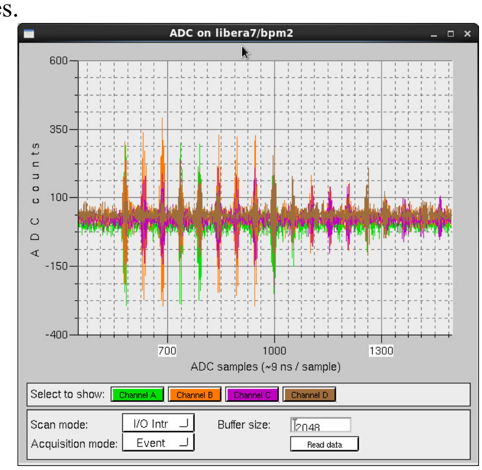

Figure 2: ADC Buffer Data for Few Turns in SR.

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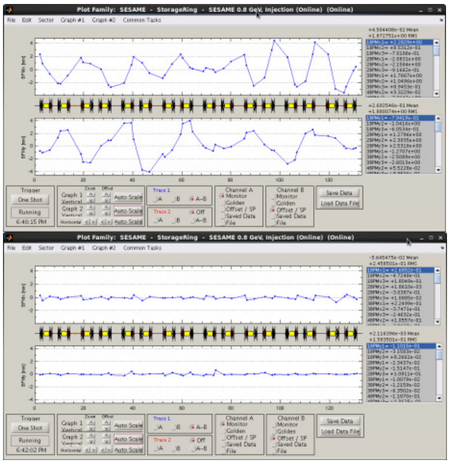

Figure 3: Uncorrected (up) and Corrected closed orbit on Same Scale (down).

TUNE MEASUREMENT

Turn-by-turn data were used to determine both the horizontal and vertical tune by FFT analysis. While the horizontal tune could easily being determined from the injection kick from the beginning, determine the vertical tune measurement was critical at low beam intensity and could only be achieved with a vertical offset of the injected beam. With higher beam intensities both tunes could then be determined from the injection kick or by beam shaker. The injection kicker with reduced strength is further used during ramping of the beam from 0.8 to 2.5 GeV and at 2.5 GeV operation to determine the tunes. Figure 4 shows turn-by-turn data and FFT analysis from BPM1 exemplarily, and same tunes measured by spectrum analyser.

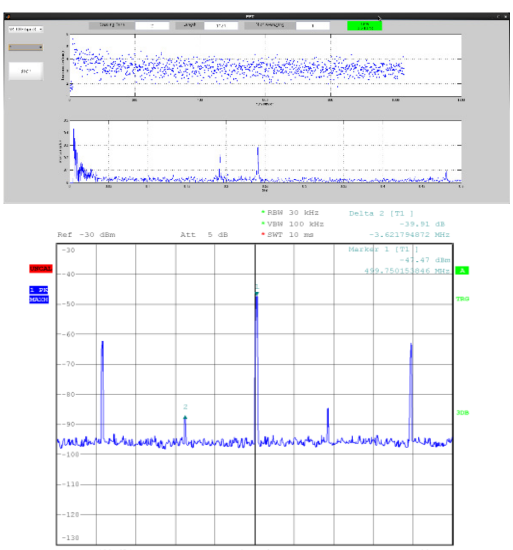

Figure 4: Turn-by-turn data and vertical and horizontal tune (up) and same tunes measured by spectrum analyser picked up by another BPM.

FLORESCENT SCREENS

Florescent Screens (FS) are very useful in the early stage of the commissioning. Four in air FS are installed in the Transfer Line 2 (TL_2) which connects the Booster to the SR. These FS are vertical mounted, pneumatic actuated type with Aluminium Oxide screen material and monitored by Basler CCD camera and Kowa Lenses. In the SR three FS are installed with same specification as in TL_2 but mounted in horizontal direction. The first screen behind the SR injection septum is controlled by stepper motor to see either the injected or the full turn beam. Further screens are installed in cell 6 and 10, by this configuration one FS is in each 1/3 of the ring. Figure 5 shows the FSs installed in TL_2 and SR and Fig. 6 shows the 1st full turn beam in 11th of Jan 2017.

Figure 5: FS installed in TL_2 (left) and motorized one in SR injection section (right).

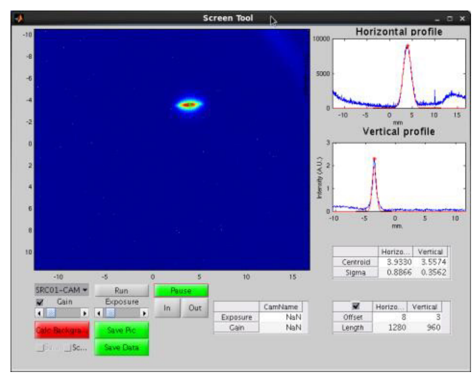

Figure 6: 1st full turn beam on FS in injection section.

FCT AND DCCT

In Transfer line 2 (TL_2) a fast current transformer (FCT) from Bergoz Instrumentation [4] is installed which has a sensitivity of 2.5 V/A, it has a standard CF40 ceramic break with a simple bypass shield, the FCT is directly connected to an oscilloscope (Tektronix DPO5104B) by coax-ial cable (TWS240-FR). Figure 7 shows the output of this FCT.

In the SR one FCT and one DCCT from Bergoz are installed beside each other sharing same ceramic break and outside shield as shown in Fig. 8. The ceramic break is a standard curricular CF150 with 22.8 mm length. In order to preserve the impedance for the beam and have a specific capacitance value for the FCT we designed a beam shield having the same shape as the standard vacuum chamber with overlapping lips as break. These lips will form in

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parallel capacitance to ceramic break capacitance so it modifies the total capacitance of the gap. The outer shield is designed to have 2 thin sheets of µ-Metal and soft iron outer layer to improve the shielding from external EMI and RFI.

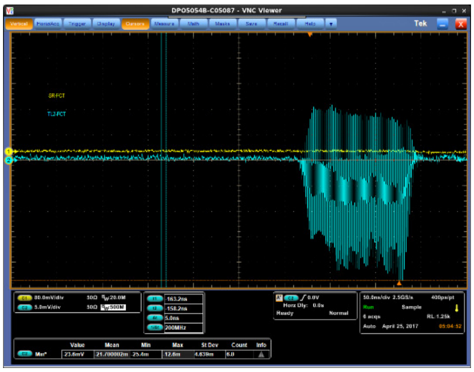

Figure 7: Beam Pulse in TL_2 FCT.

FCT and DCCT assembly are installed in cell 2 in the ring, the FCT is connected directly to Tektronix DPO5104B scope by TWS240-FR coaxial cable while the DCCT connected to Agilent 34410A 6 ½ digit digital multi-meter which is connected via Ethernet connection to EPICS control system. The temperature of the core is fine with the current that we achieved and no need for cooling. Figure 9 shows the first few turns in the SR picked up by FCT.

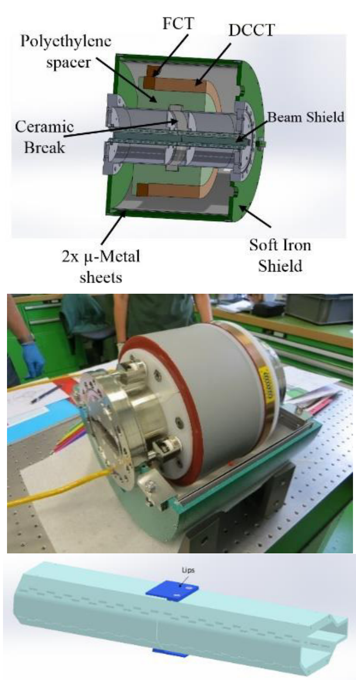

Figure 8: SR FCT and DCCT Assembly in 3D (up) and after assembly (middle) and Beam Shield with the Lips (down).

Figure 9: 1st few turns in the SR by FCT (Left) and DCCT Current.

SRM

There is one synchrotron radiation monitor in the SR which is located in cell 14. SRM used to measure transversal beam size in the ring and monitor transverse instabilities. The challenge here to measure both planes on same SRM, the vertical resolution is limited due to diffraction caused by a crotch absorber in the vacuum chamber. To overcome the diffraction limit and to be able to measure the vertical beam size a double slit was installed to allow interferometry measurements.

Figure 10 shows the layout of the SRM. To measure horizontal beam size a direct imaging method were used. At these stages of the commissioning and operation the complete SRM system including the optical component installed inside the tunnel. So all calibration and optimizing optical lenses and other components were done in the lab.

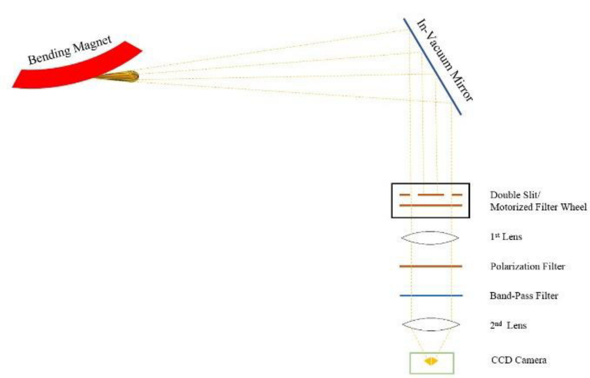

Figure 10: SRM Layout. The radiation produced at the bending magnet BM14 is directed towards the optical beam line using in-vacuum mirror. The distance from the source point to the optical system is 4.5 m.

The vertical beam size can be calculated using interferometry, the measurement principle is explained in detail in Ref. [5]. In summary, it is based on the interferogram produced by monochromatic and polarized synchrotron light

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after passing through a double slit. When these two beamlets are focused into a CCD camera, the electron beam size can be inferred from the visibility of the interferogram, which indicates the complex degree of spatial coherence of the photons [6].

According to Equation 1 by determination of the visibility V of an interference pattern the visibility is the normalized intensity difference between maximum and minimum values of the corresponding interferometry.

$$\sigma_y = \frac{\lambda R}{\pi D} \cdot \sqrt{\frac{1}{2} \cdot \ln\left(\frac{1}{V}\right)} \qquad (1)$$

Where λ is wavelength, D is the slit separation and the R is the distance between source point and slit. The calibration where done in the lab, sector start where used to calculate the resolution of optical system (40 µm) and camera calibration factor. The optical components are from Thorlabs [7], a motorized filter wheel (MFW) is installed with six natural density filter and controlled remotely to give us a high dynamic range of measurement and to reduce the light intensity in order to protect the CCD chip of the camera. This MFW used also to make a slit scan inside the tunnel by install a multi slit (with different D) instead of filters to commission the interferometry with the real beam, by this way the best separation between double slit will be known and then implement it in the system for long term then install the filters back again. A polarization filter installed in order to prevent the two polarizations of the synchrotron light from cancelling each other. And since interferometry with synchrotron light requires monochromatic light, a narrow-band band-pass filter has to be implemented in the system [8]. Figure 11 shows the 1st light seen on the camera at injection energy, this photo was taken before few hours of submission of this paper, so the system still under commissioning and need optimization.

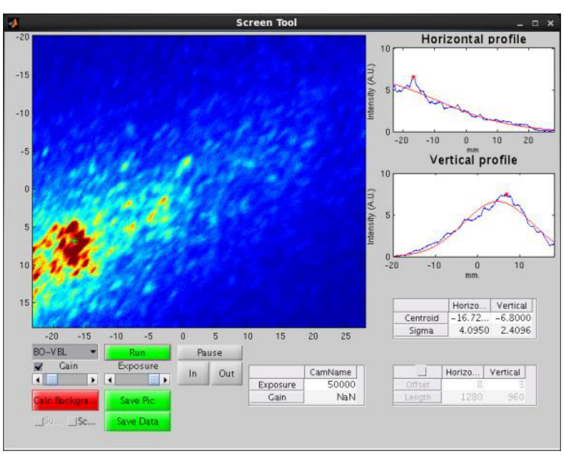

Figure 11: 1st result of SRM at 800MeV which taken before few hours of submission time of this paper, the system need more optimization, alignment and study.

BLM

Four Beam Loss Detectors (BLD) installed inside the tunnel and connected to one Beam Loss Monitor (BLM) installed in the diagnostic rack, this BLM can connect up to 4 BLD at same time, The BLM and one BLD are donated from Instrumentation Technologies to support SESAME project. The BLD are Photo-Multiplier Tube (PMT) type it will detect the visible light photon at its photo-cathode, and the emitted electron will be amplified inside this PMT and an electric current impulse will be created at its anode and this anode's output signal will be transported over a cable to the electronics signal acquisition system. The scintillator rod and the PMT are housed together in a dedicated single, light weight, Aluminium tube structure. This housing maintains the PMT and the rod in a stable and optimum position (for the optical coupling) and has two lids at either end. It is conceived such to make possible an easy, simple and reliable assembly of the components while providing light-tight shielding against ambient light and suitable cable passages [9].

The BLDs are installed in four cells in the machine, two before injection section and two after. Since the cables of these BLD are long (50m) we will move them to other cells and make a round to see the losses in the whole machine. Figure 12 shows the results from these BLDs, it gives us an indication of the big loses in cell 2 (CH-D) compared to the others.

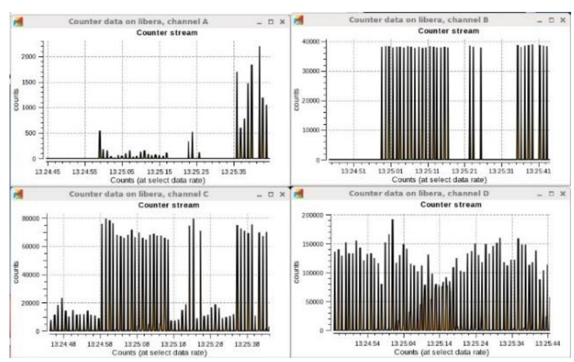

Figure 12: BLDs counts results, channels A,B,C and D are the detectors installed in cells 15,16,1,2 respectively.

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