DIAGNOSTICS DURING SESAME BOOSTER COMMISSIONING

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Abstract

SESAME* is a 2.5 GeV synchrotron radiation facility under construction at Allan (Jordan), consisting of a 20 MeV Microtron as pre-injector and an 800 MeV Booster Synchrotron. The pre-injector and booster are originally BESSY-I machine with some major changes within power supplies and diagnostics tools. The diagnostic tools are: Fluorescent Screens, BPMs, DCCT, FCT and Synchrotron Radiation Monitor. The Booster had been commissioned in 2014. The installed tools allowed to determine current, orbit, tune, chromaticity and emittance. Set up of the diagnostics and results are presented in this paper.

INTRODUCTION

The SESAME Microtron (MM22) generates an electron beam suitable for injection through Transfer line 1(TL1) into the Booster Synchrotron. The timing system is based on the event generator and receiver system from Micro Research Finland [1], with 1 Hz repetition frequency. The SESAME Booster has a FODO lattice with 38.4 m circumference the main parameters are listed in table 1.

Table 1: Booster Main Parameter

Circumference (m)	38.4
RF frequency (MHz)	499.654
Revolution freq. (MHz)	7.807
Repetition freq.(Hz)	1
Ramping time (ms)	630
Injection/Extraction Energy (MeV)	20/800
Beam Current (mA)	7
H/V Tunes υ_x/υ_y	2.21/1.45
H/V Emittances* ε_x (nm.rad)	180/300
Straight sections β-func.(H/V) (m)	5.2/2.9

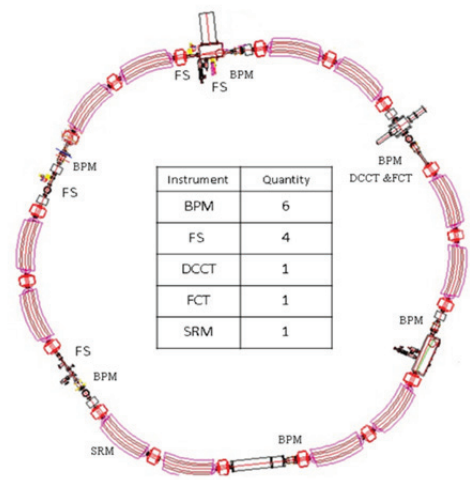
*Different optics program give different values (Beta 300 nm, Elegant 180 nm).

In order to properly check the Booster synchrotron performance, the set of diagnostics equipment described in Fig. 1 is installed in the machine. Next, we present the diagnostics elements installed in the Booster and our experience during the commissioning.

* Synchrotron Light for Experimental Science and Applications in the Middle East

FLUORESCENT SCREENS

Fluorescent Screens (FS) are installed in Booster ring which have Aluminium Oxide screens and analog cameras connected to a signal switcher which allows monitoring one camera on the TV monitor in control room. This setup includes manually controlled focus and zoom lenses originally from BESSY-I. All FS are activated pneumatically.



Instrument	Quantity
BPM	6
FS	4
DCCT	1
FCT	1
SRM	1

Figure 1: Booster Diagnostics Components.

We placed one FS to monitor the beam path along the Transfer line 1 from the Microtron to Booster (TL1), while 4 more are installed in the Booster to ease the first commissioning goals (injection, first cell, full turn).

Measurements of Microtron emittance were done by Quadruple scan method [2] Fig. 2 shows the results for vertical plane.

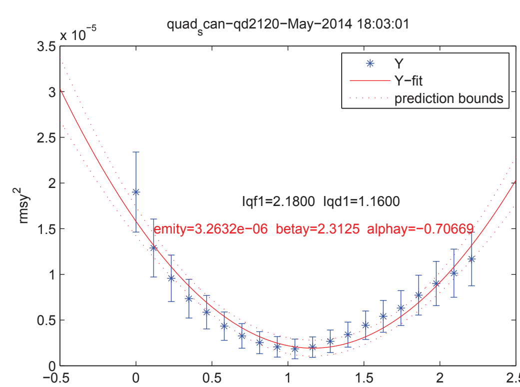


Figure 2: Emittance Measurement of the Microtron in TL1, $\varepsilon_{x/y}$ = 2.6 / 5.2 nmrad.

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BPM SYSTEM

There are 6 beam position monitor (BPM) in Booster ring, 4 of them are strip line and the others are button type. One BPM block can also be used as a shaker (beam exciter) for tune measurement purpose. The length of the stripes is 15 cm designed for 500 MHz and its odd harmonics. The Booster BPM block diameter is relatively large (150 mm) compared to the beam displacement, and the electrode locations in horizontal and vertical planes are symmetric at 45° with a calibration factor K_x, K_y 28.82 and 28.94 respectively, the calculation is done by Matlab code based on analytical calculations from ALBA [3].

All BPMs are connected to Libera Electron [4] to analyse and calculate the position and detailed machine study. Calibrated and phase matched coaxial cable LMR 198 with variety of length (16 m-35 m) are used depending on the location. All Libera's are controlled via wired LAN and receive a trigger and machine clock from Libera clock splitter which is connected and synchronized to the timing system.

EPICS driver is used for Libera Electron; through it all of Libera modes can be used. Basic modes, which are: first turn, demand mode (Turn by Turn) with AGC and DSC off, zero attenuation and fixed switching mode (3), by using this mode we can measure the betatron tune during ramping.

FCT AND DCCT

In Transfer line 1 (TL1) a fast current transformer (FCT) is installed which is a commercial one (Bergoz [5]) which has a sensitivity of 1.25 V/A, The FCT is installed after the FS, it has a ceramic break with a bypass shield, the FCT is directly connected to an oscilloscope (Agilent X2014A) by coaxial cable (LMR200). Figure 3 shows the output pulse of the Microtron via FCT.

The same type of current transformer is used in the Booster (Bergoz) but with different sensitivity 2.5 V/A, furthermore a DCCT with its electronics from the same manufacturer (Bergoz). The vacuum chamber is interrupted by a thin isolation gasket and both FCT and DCCT are located beside each other in the same cell and share the bypass shield. The shield was designed in-house; it consist of two cylindrical half's of low carbon steel. Figure 4 shows the design of the shield and the already installed DCCT in the Booster.

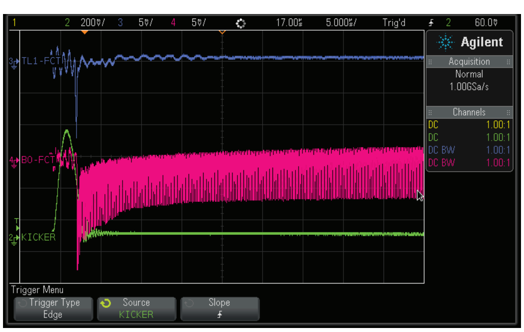

Figure 3: TL1 FCT output (blue), Booster FCT (multi-turn) output (pink) and Kicker Pulse (green).

The most precise Booster current measure is done with the DCCT which has 5 uA/sqrt(Hz) resolution in the 20mA range and temperature drift 5 µA/K typically. Both FCT and DCCT are connected to an oscilloscope via coaxial cables and monitored in the control room Fig.5.

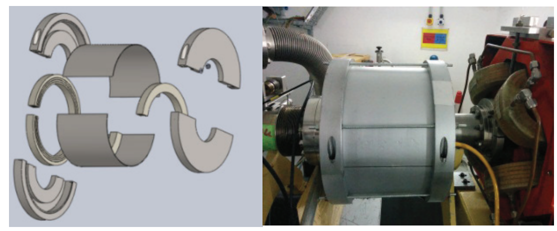

Figure 4: DCCT Shield.

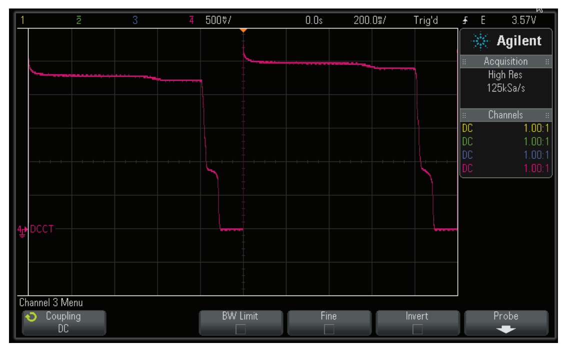

Figure 5: DCCT Reading.

SRM

The Synchrotron Radiation Monitor is taking the light coming from a bending magnet to obtain a transverse image of the electron beam. This image is then analysed to determine the horizontal and vertical beam size. The beam transverse sizes depend on the lattice parameters and the emittance [6]. Figure 6 shows the photon fluxes produced when an electron beam passes a bending dipole in the Booster at full energy.

Completely new vacuum chambers for the dipole had been fabricated for the Booster ring that gave the possibility to fabricate one of the chambers with a glass window for SRM diagnostics. The SRM is located in cell 3 the distance from the glass window to the centre of the magnet is 80cm. Figure 7 shows the visible light that comes from the SRM 300ms after the injection.

To have more and precise measurements and compare it with what we have installed currently, a new optical system is designed with same setup, the optical gages and mirrors are from ThorLabs [7], tubes and gages are SM2 (2") system with 2 ME2-G01 mirrors.

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Figure 8 shows the measured beam sizes during ramping; the trigger for the camera (Basler acA1300-gm [8]) was varied from the beginning to the end of the ramp. For each step 10 shots from the camera were taken fitted to Gaussian distribution and averaged [9].

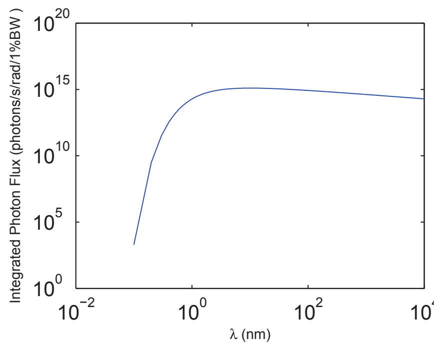

Figure 6: Photon flux from the dipole in the Booster for a beam current 7 mA at full energy.

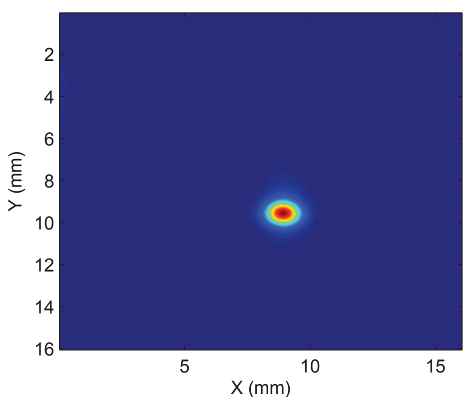

Figure 7: Visible Beam Image After 300 ms of the Injection.

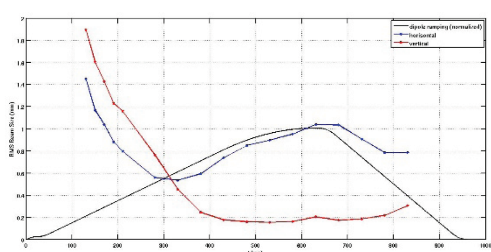

Figure 8: Measured horizontal (blue) and vertical beam size (red) during the ramp, dipole ramping curve (black).

TUNE MEASURMENT

The Booster tune monitor is a diagnostic used to measure the vertical and horizontal oscillation-frequencies (or betatron tunes) of the beam accelerated in the Booster. The beam is accelerated from 20 MeV to 800 MeV in 630 ms. During this ramping cycle, the tunes are not perfectly constant and it is nescessary to precisely measure them along the cycle.To measure the tune the beam is excited using a shaker, the beam position oscillation are recorded using beam position monitors (BPM) by Libera and perform a frequency analysis of these signals in Matlab.

The layout of tune excitation is shown in Fig. 9. The shaker located in cell 1 which also works as beam position monior by RF coaxial switch (TELEDYNE CCS-32). Each stripline will have 2 switches one in the upper stream (Libera and 50 Ω dummy load) and the other in down stream (Amlifier and 50 Ω termination) the switching will be controlled by PLC.

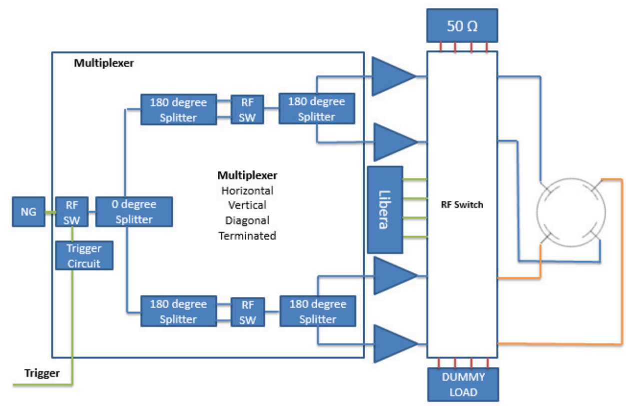

Figure 9: Tune Excitation layout and Switching Between Libera and the Amplifiers.

The source of the excitation is an arbitrary function generator Tek. AFG 3022C, it can give a central frequency and controlled width of white noise on each side.

The amplifer system box consist of amplifers module Modular RF (KMA1040) 50W with frecuency range 200 kHz- 50 MHz 48 dB gain, Mean Well SP-500 power supply and in house designed controller board. The whole system are assembled in 3U rack mounted chassis in the lab.

The tunes can be tracked dynamically during the ramping process across all the turns till 630 ms (full energy of the Booster). To enhance the tune signal after injection a programed code in Matlab started to increase the level of white noise signal as the beam energy increases and synchronize the timing between the Libera and the shaker trigger and shift the time to fit the whole period since Libera electron can take up to 16ms. Figures 10 and 11 show the horizantal and vertical tune the injection and during ramping respectivly.

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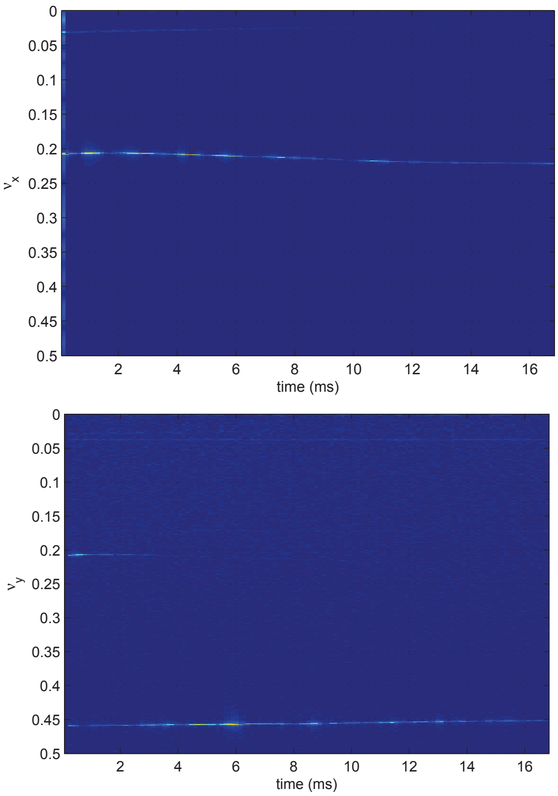

Figure 10: Horizontal (up) and vertical (down) tune at the injection for 16 ms.

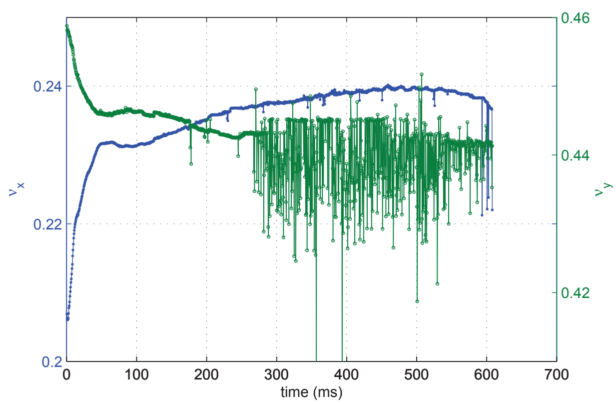

Figure 11: Horizontal and vertical tune during the ramping.

CONCLUSION

The set of diagnostics mentioned in this paper performed satisfactorily and allowed a successful Booster commissioning. Our task now is mainly to perform and upgrade old instruments and make fine adjustments to increase their performance and prepare the new instruments for SR.

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