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DIAGNOSTIC BEAMLINES AT THE SOLARIS STORAGE RING

A. Kisiel, M. Ptaszkiewicz*, S. Cabala, A. Marendziak, A. Wawrzyniak†, I. Zadworny and T. Zbylut
Solaris National Synchrotron Radiation Centre, Krakow, Poland

Abstract

Precise measurement and control of the electron beam emittance is a very important input to characterize the performance of any accelerator. Synchrotron radiation has been widely used as diagnostic tool to measure the transverse and longitudinal profile. Beam characterizations at the Solaris National Synchrotron Radiation Centre are provided by two independent diagnostic beamlines called PINHOLE and LUMOS beamline, respectively.

The PINHOLE beamline, depicts the electron beam by analyzing the emitted X-rays. However this method is predominantly applied to the middle and high energy storage rings. At Solaris storage ring with the nominal energy of 1.5 GeV and critical photon beam energy of c.a. 2 keV, the design of the beamline was modified to provide sufficient X-ray photon flux for proper imaging.

Second diagnostic beamline LUMOS, which will be operates in the visible region, was installed during summer shutdown 2019 and will be commissioned in next few months. The optical diagnostic beamline will be used not only for measure the transverse beam profile, but also for the bunch length measurements and study longitudinal beam dynamics.

Issues discussed include the general design philosophy, choice of instrumentation, and actual performance.

INTRODUCTION

The Solaris storage ring is designed to have small emittance (6nm rad), a 100 MHz pulsed electron beam, and maximum stored current of 500 mA, in order to produce bright beam of synchrotron radiation. More details about the machine layout and design can be found in [1–4] whereas the main storage ring design parameters are presented in Table 1.

Solaris has been operating with the beam in the storage ring since May 2015 and currently services two beamlines (PEEM/XAS with two end-stations, and UARPES with one end-station). Four beamlines are under construction (PHELIX, XMCD, SOLCRYS and SOLABS), two other (FTIR and POLYX) have received funding and will be installed and commissioned in next few years.

DIAGNOSTIC BEAMLINE PINHOLE

The first PINHOLE X-ray diagnostic beamline was installed and commissioned in the Solaris storage ring in the mid of 2018. This beamline has been designed to measure the transverse beam profile and to monitor the emittance and their stability during the beam decay. The source point for the PINHOLE diagnostic beamline is the center of the bending magnet in cell 1 of the Solaris storage ring. The X-ray light is extracted from the source through a vacuum window. After exiting window, the X-ray passes through the pinhole cross and reaches the scintillator crystal where is converted to the visible light. The optical light from scintillator is imaged by a CCD camera.

Table 1: The SOLARIS Storage Ring Main Parameters

Parameter	Value
Energy	1.5 GeV
Max. current	500 mA
Circumference	96 m
Main RF frequency	99.931 MHz
Harmonic number	32
Horizontal emittance (without insertion devices)	6 nm rad
Coupling	1 %
Tunes Q_x, Q_y	11.22, 3.15
Natural chromaticity ξ_x, ξ_y	−22.96, −17.14
Corrected chromaticity ξ_x, ξ_y	+1, +1
Electron beam size (straight section centre) σ_x, σ_y	184 µm, 13 µm
Electron beam size (dipole centre) σ_x, σ_y	44 µm, 30 µm
Momentum compaction	3.055×10^{-3}
Total lifetime of electrons	13 h

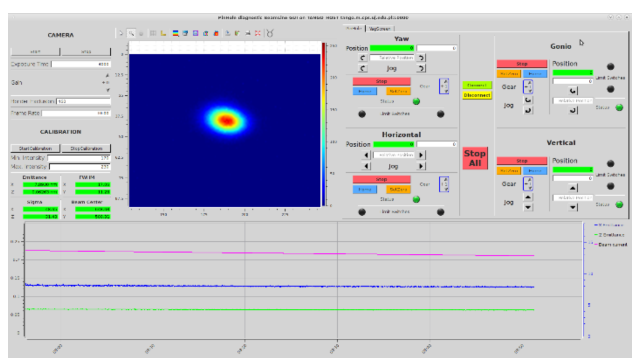

Figure 1: PINHOLE diagnostic Beamline GUI.

The acquired image is processed in a homemade developed software. This software consists of three layers: Taurus based GUI, TANGO Controls devices and PLC program. The PINHOLE diagnostic Beamline GUI on TANGO HOST is shown in Figure 1. Among the available options, the program fits Gaussian curves to determine the beam sigma's and calculates emittance, beam position and other parameters. All this data is stored in historical database.

* marta.ptaszkiewicz@uj.edu.pl
† adriana.wawrzyniak@uj.edu.pl

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For the storage ring with a low electron beam energy (typically less than 1 GeV), X-ray pinhole technique is not applicable due to the lack of substantial X-ray radiation from the dipole magnet. At Solaris storage ring the design of the beamline was modified to provide sufficient X-ray photon flux for proper imaging. More details about the PINHOLE beamline can be found in [5] . The X-ray flux is high enough to measure the emittance with lower beam currents (even <10 mA with longer camera exposure time). However, during an injection and early ramping stage, in the energy range between 535 - 1200 MeV, the beam is not visible. The beamline was optimized for operating with smaller than nominal (500 mA) stored beam current, what is crucial for the decaying beam operation mode in Solaris. PINHOLE diagnostic beamline is now available to monitor beam size during operation. Operators can monitor such beam parameters as source position, transverse beam profiles, emittance and skew in real time. Knowledge of these parameters allows to correct beam instabilities, and a stable beam improves the quality of measurements that are carried out on beamlines. Typical plots for measured beam emittance during the decay of beam current for thirteen hours is shown in Figure 2.

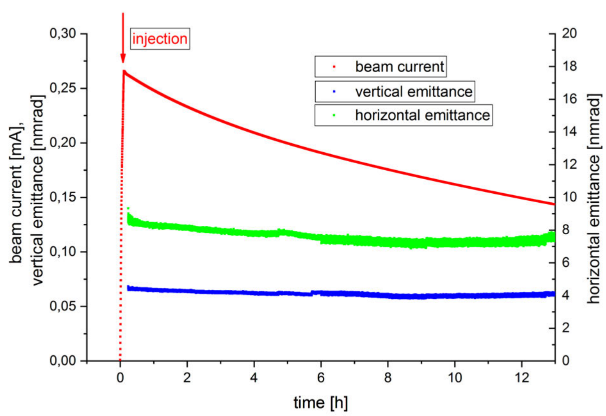

Figure 2: Horizontal (green dots) and vertical (blue dots) emittance measured continuously over ca. 13 hours.

DIAGNOSTIC BEAMLINE LUMOS

Another method to determine the transverse beam profile is imaging with visible to ultraviolet (vis-UV) SR. The second diagnostic beamline LUMOS, which will be operated in the visible region, was installed in the Solaris storage ring in the summer of 2019. The new beamline has a similar configuration to the existing diagnostic beamline at MAX IV 1.5 GeV storage ring. LUMOS will enable a wide range of new optical diagnostic measurements. For the first time, it will be possible to measure beam profile in the Visible and near-UV range at Solaris. Visible and near-UV SR can be used to measure vertical beam sizes with very good resolution in the sub pm rad range. For this purpose imaging with pi-polarized SR [6] and with the obstacle diffractometer method [7] will be used. Horizontal beam size will be measured by imaging SR with a wide horizontal opening angle and wavelength in the near IR. Top view of diagnostic beamline LUMOS is shown below in Figure 3.

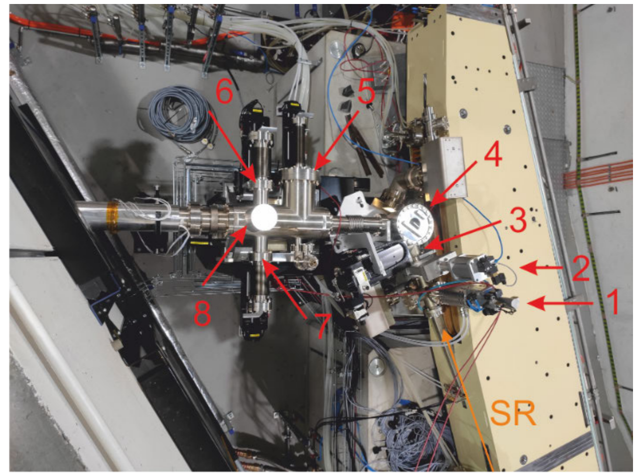

Figure 3: New diagnostic beamline LUMOS – top view: 1 - absorber, 2 – valve, 3 – cold finger unit, 4 – mirror chamber, 5 – lens unit, 6 and 7 – baffle units, 8 – obstacle unit.

A diagnostic beamline LUMOS has been set-up at the BM12 bending magnet of the Solaris storage ring. The source parameters are almost identical to the PINHOLE. The most important element of the new beamline regarding the beam diagnostic is the mirror used to deflect the visible and UV part of the synchrotron light. The mirror, made of silicon carbide (SiC), is 40 mm high, 100 mm wide, has surface flatness specification of $\lambda/10$ at 633 nm. The distance from the center of the bending magnet to planar SiC mirror is 2.5 m. The mirror absorbs most of the synchrotron light, including X-ray radiation. At higher currents, the mirror is protected from an excessive heat load that would otherwise result in its deformation. To achieve this a horizontal absorber (a cold finger absorber) of 4 mm height will be inserted before the mirror. The mirror reflects the visible light by 120° downward. The light passes through the planar-convex (fused silica) lens with a diameter of 72.6 mm. The lens is placed 3 m from the dipole center. Close to the lens two movable horizontal baffles has been installed. They will define the horizontal opening angle. After the baffles a variety of diffraction obstacles has been mounted. The visual part of the dipole radiation will be transported through optical components (mirrors, gray filters, narrow band pass (BP) filters and Glan-Taylor polarizer) mounted on an optical table in the experimental hutch up to several selectable experimental stations (i.e. the CCD cameras, streak camera and fast photodiode). The LUMOS beamline has been designed to measure the transverse and longitudinal beam profiles and sizes. The bunch length can be measured by streak camera located in the experimental hutch. The installed streak camera is the all-purpose model SC-10 with S25 photocathode (with gating option (/PB)) by Optronis [8]. The main unit integrates a streak tube with quartz input window to allow light detection from UV to NIR. The streak camera includes

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also synchroscan sweep unit for the first deflection plates with several sweep speeds 15, 25, 50, 100 ps/mm (with temporal resolution better than 2 ps) and triggered sweep unit for second deflection plates with sweep speeds from 600 ps/mm to 100 ns/mm. The synchroscan unit is operated at the 99.931 MHz main cavity RF. The SC settings need to be well tuned in order to perform precise bunch length measurements. The system will be used to measure some parameters of the bunch like bunch length, longitudinal bunch profile and synchrotron frequency, as it may report a direct derivation of fundamental machine characteristic. Additionally, a fast avalanche photodiode (ADP) will be set up in parallel to monitor the filling pattern of the storage ring.

CONCLUSIONS

Two diagnostic beamlines PINHOLE and LUMOS has been installed in the SOLARIS synchrotron storage ring.

The successful installation and commissioning of the X-ray PINHOLE beamline allows now to measure the emittance and helps in proper 3rd harmonic cavities tuning against the coupled bunch instabilities and avoiding transverse emittance blow-up on uncoupled higher order modes of RF cavities.

The LUMOS beamline will enable a wide range of new optical diagnostic measurements, which play an important role for understanding the machine condition. It is foreseen to take the first beam profile measurements from LUMOS at the end of 2019. It is expected that those observations help enhancing the machine settings to encounter instabilities.

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