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LUMOS: A VISIBLE DIAGNOSTIC BEAMLINE FOR THE SOLARIS STORAGE RING

R. Panaś[1], A. Curcio[1], A. I. Wawrzyniak[1]
Solaris National Synchrotron Radiation Centre, Jagiellonian University, Kraków, Poland

Abstract

LUMOS is a diagnostic beamline which operates in the visible region. It was installed in the Solaris storage ring during summer 2019. The first light was observed at the beginning of December 2019. During 2020 the beamline was commissioned and equipped with a streak camera setup. Currently, LUMOS allows to analyze far-field and near field images of synchrotron light for transverse beam profile measurements. Moreover, using the streak camera setup, it is also possible to investigate the bunch length, the filling pattern and the longitudinal beam profile changes with respect to the different condition (ramping, 3rd harmonic cavities tuning, etc.). In this paper the optical setup is presented along with the measurements conducted with it.

LUMOS LAYOUT

The LUMOS beamline in Fig. 1 has a similar configuration to the existing diagnostic beamline at MAX IV 1.5 GeV storage ring. The source point for LUMOS is the center of the bending magnet in cell 12 of the Solaris storage ring. A mirror is used to direct the visible and UV part of the synchrotron light. The mirror, made of silicon carbide (SiC), is 40 mm high, 100 mm wide. The distance from the center of the bending magnet to the planar SiC mirror is 2.5 m. 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 is inserted before the mirror. The mirror reflects the visible light by 112° 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 have been installed. They will be used to measure the vertical beam sizes with pi-polarized synchrotron radiation [1] and with the obstacle diffractometer method [2].

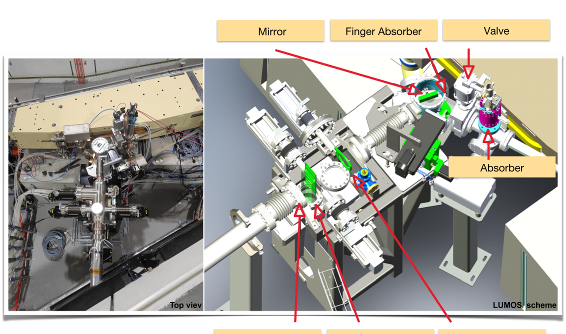

Figure 1: LUMOS top view and scheme.

TIME-RESOLVED DIAGNOSTICS

To measure the longitudinal beam profile of electrons circulating inside the Solaris storage ring a device is needed that can measure light pulses on a timescale of the ps. By means of the streak camera model SC-10 [3] provided with the S25 photocathode, a gating option and two sweeping units, we are able to obtain longitudinal beam profile and filling pattern: this information is available to the Operators in the control room. In Fig. 2, we can observe the evolution of the longitudinal beam profile during the beam current decay in the ring. The evolution of the longitudinal profile shows a two peaks' structure after injection, which mutates into a single peak with Gaussian profile and finally again into a double peak profile. The dependence upon the electron current decay also shows a bunch compression at later times after the injection. Indeed, it is clear that for higher currents stored inside the storage ring, the electron bunch length increases. This kind of diagnostic is very useful for RF-cavity tuning and instabilities' studies. The longitudinal beam profile can be shaped by tuning the resonant frequency of the Landau passive cavities. Nevertheless, the shown results correspond to a particular stable configuration of the beam stored in the ring.

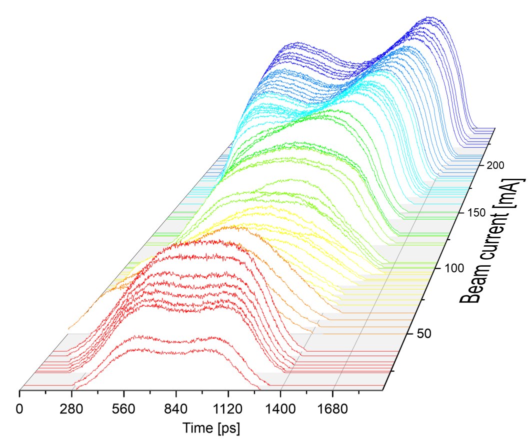

Figure 2: Evolution of longitudinal electron beam profile versus the stored electron current.

In Fig. 3, we report the signals' chain along with an electron filling pattern's image from streak camera. Both the sweep units are needed to acquire such an image. At the same time also a signal and a delay generators are used. The first sweep unit SSU11-10 generates a fast sweep in the vertical direction. The synchroscan mode is characterised by

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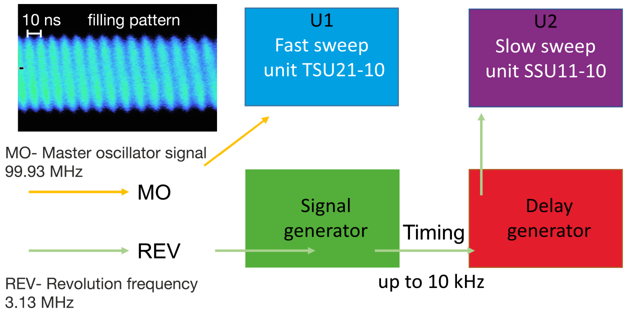

Figure 3: Signals' chain for the time-resolved beam diagnostics in the LUMOS beamline together with a measurement of the electron filling pattern stored in the SOLARIS ring.

a high frequency sinusoidal deflection voltage. The deflection frequency is in direct relation with the pulse repetition frequency of the light source witch is the Master oscillator frequency: 99.93 MHz. Together with the streak camera allows the measurement of the average longitudinal electron beam profile. The second sweep unit TSU21-10 provides a triggered sweep in the horizontal direction: it is working with frequency up to 10 kHz and if joined to the first sweep unit allows to observe separated bunches (the filling pattern inside the storage ring).

TRANSVERSE DIAGNOSTICS

The main role of the setup placed on the optical table in the experimental hutch is to guide the visible synchrotron light from the source point to the streak camera as well as to visualize near and far field images. Presented in Fig. 4 is the optical setup of LUMOS consisting of a peryscope, a band pass filter centered at 500 nm, a half-wave-plate to rotate the polarization plane, a polarizing beam splitter to distribute the light intensity into polarization states along two orthogonal directions and lenses to transport the light and form images on the CCD cameras.

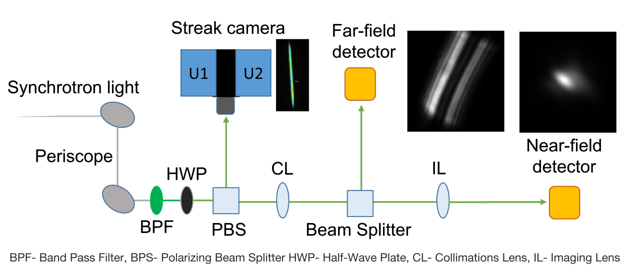

Figure 4: Current optical setup scheme for LUMOS.

With this scheme it is possible to obtain near-field patterns of visible synchrotron light, corresponding to the image of the source, i.e. the electron beam, as well as to obtain angular patterns of visible synchrotron light (also called far-field patterns) which might allow other kind of emittance, current and energy diagnostics in the future. This kind of diagnostics might be implemented after a thorough study of the correlation of the far-field pattern versus the stored electron current, the ramped energy and the beam emittance. The far field pattern can be characterized in therms of light intensity as well as angular aperture of the two radiation lobes. These two quantities can be eventually correlated with other beam parameters in the machine. The use of a polarizing beam splitter after the half-wave-plate provides the possibility to obtain near and far-field patterns of visible synchrotron light for a selected polarization. The distinct features of the near and far fields patterns for the horizontal and vertical polarization, together with the different decay trends of the light intensity stored in the two polarization versus the decay of beam current in the SOLARIS ring might provide further methods of beam diagnostics. These aspects are currently under test and the feasibility of such a diagnostic approach for SOLARIS has not been yet demonstrated. For now a direct diagnostics of the beam emittance can be provided by the near-field images of the beam at the source plane. In fact, the horizontal and the vertical beam sizes can be retrieved by fitting with a 2D Gaussian profile the beam image, while deconvolving the image with the corresponding point-spread function also considering the proper magnification M of the imaging system [4]. The corresponding formula for this kind of analysis is:

$$\sigma_i^2 = \frac{(\sigma_i^{im})^2 - \sigma_{PFS}^2}{M^2}, \quad (1)$$

where σ_i is the beam size in the horizontal or vertical plane, respectively (i = x,y), σ_i^{im} is the measured image size in the horizontal or vertical plane (exploiting the proper conversion from pixel to millimeters) and σ_{PFS} is the point spread function (PSF) contribution, that is going to be measured soon. Once the beam sizes are known, the beam emittance is retrieved according to the formula:

$$\epsilon_i = \frac{\sigma_i^2 - (\eta_i \delta_E)^2}{\beta_i}, \quad (2)$$

where β_i and η_i are the betatron and dispersion functions at the source plane, ϵ_i and δ_E are the emittance and the relative energy spread of the electron beam. Having online measurements of beam emittance would surely help, for example, in properly tuning the passive Landau cavities thus improving the beam stability in the storage ring. The real layout of the diagnostic setup is finally shown in Fig. 5.

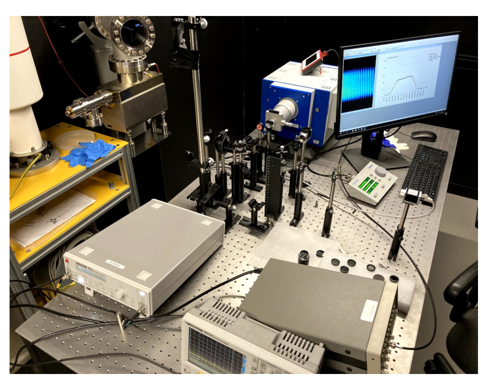

Figure 5: Photo of the diagnostic setup in the LUMOS hutch.

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SUMMARY

The LUMOS diagnostic beamline operates with synchrotron radiation in the visible range. Currently the used wavelength is 500 nm. Detected by means of a the streak camera it enables diagnostics of the electron beam longitudinal profile. With a second sweep unit in synchroscan mode it is possible to visualize the electron filling pattern in the storage ring. Transverse beam profiles can be measured with near field images. A proper post-analysis supported by calibration of the imaging system in terms of the point spread function and of the magnification, as well as the knowledge of the optical functions at the source plane and of the beam energy spread, can finally provide an online measurement of the beam emittance in two main directions, horizontal and vertical, i.e. in the plane of revolution in the ring and in the orthogonal one. The angular distribution of the visible synchorotron radiation is instead obtained through far field images. We have discussed possible applications of the information related to far-field patterns of visible synchrotron radiation. In the near future it is planned to retrieve the emittance based on transverse profile of the beam and compare it with the value measured in the existing PINHOLE [5] diagnostic beamline, working in the X-ray region.

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