# FAST POLARIZATION SWITCHING AT THE SLS MICROSPECTROSCOPY BEAMLINE POLLUX

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*Abstract*

PolLux is a new microspectroscopy facility which will be operated at a bending magnet at the Swiss Light Source (SLS). It offers spectroscopy with sub-$\mu$m spatial resolution for polymer science and magnetism. First user operation is scheduled for summer 2006. One of the novel envisaged options of the beamline is the usage of circular polarized light. The circular polarization will be generated by a localized angular vertical steering of the electron beam within the bending magnet. This is accomplished by means of the global fast orbit feedback system of the SLS which allows to stabilize the electron beam to the sub-$\mu$m level up to frequencies of $\approx$100 Hz. Due to the adapting coupling compensation involving dedicated adjacent skew quadrupoles, this steering becomes practically transparent to the other beamlines. Polarization switching rates of a few Hz are within reach.

## INTRODUCTION

In the plane of a storage ring the radiation emitted by a dipole is horizontally polarized. The polarization becomes increasingly circular when the observer moves out of this plane. At the same time the photon flux is reduced since the photons are confined within a narrow cone. Thus in order to get the polarized light into a dipole beamline one can either move parts of the beamline or steer the electron beam instead. At the SLS the latter method has been adopted for the dipole beamline PolLux [1] since the global fast orbit feedback (FOFB) [2] allows for local orbit manipulations with sub-$\mu$m accuracy. The new microspectroscopy beamline is located in the arc of sector 7 of the SLS (see Fig. 1). For a maximum electron beam angle of $\pm$300 $\mu$rad it is expected to achieve about $\pm$80% of circular polarization [3].

## IMPLEMENTATION

The steering is accomplished by means of a vertical asymmetrical bump consisting of four successive dipole correctors (4-bump) which are part of the standard SLS orbit correction system. For a $\pm$300 $\mu$rad steering the inner corrector pair is excited up to $\pm$240 $\mu$rad (maximum strength $\pm$870 $\mu$rad) leading to an orbit excursion of $\pm$450 $\mu$m (see Fig. 2). While the generated spurious vertical dispersion of $\approx$5 $\mu$m is negligible, the generated betatron coupling is not. The present operating emittance coupling of 0.5% changes by $\pm$15% which is not acceptable for the SLS user operation [4]. Thus a local coupling compensation scheme is envisaged which utilizes two adjacent

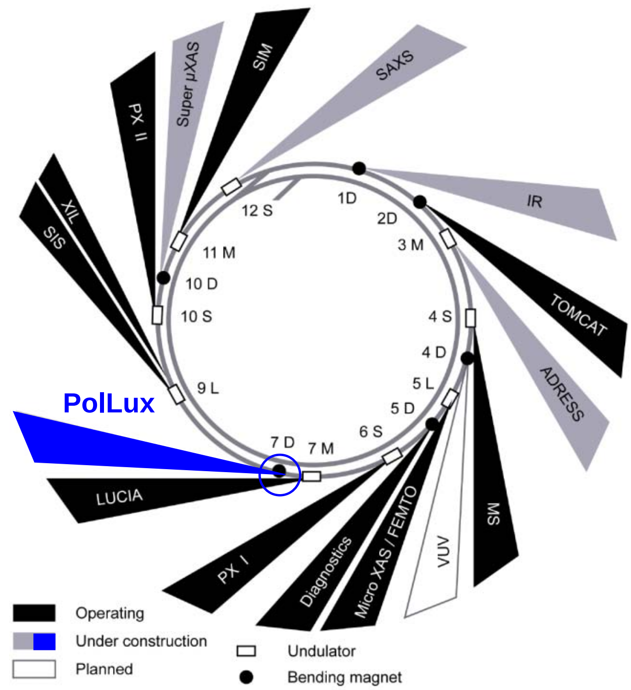


Figure 1: Schematic layout of the Swiss Light Source (SLS). The new microspectroscopy beamline PolLux (blue fan) is located in the arc of sector 7 employing the light emitted by a central 14° bending magnet (blue circle).

skew quadrupoles (see Fig. 2) which compensate for the skew quadrupole components generated by the sextupoles within the bump. The spare (i.e. not used in a dipole corrector configuration) extra windings of two sextupoles are employed as betatron coupling correctors. Coupling reduction factors of $\approx$10 are achievable exciting the correctors up to $\approx$4 mrad/m. Fig. 3 depicts the beam ellipse twist before and after coupling correction. The twist is determined from the calculation of generalized sigma matrices described in [5] within the computer code TRACY [6].

### *Feed Forward and Global Fast Orbit Feedback*

Since the previously discussed dipole and skew quadrupole correction values are known for a given bump amplitude a feed forward (FF) can be established to perform the beam steering. The global fast orbit feedback (FOFB) is foreseen to correct only for the remaining residual orbit oscillations induced by the nonclosure of the bump. To this end the orbit reference positions of the two beam position monitors (BPMs) adjacent to the bend-

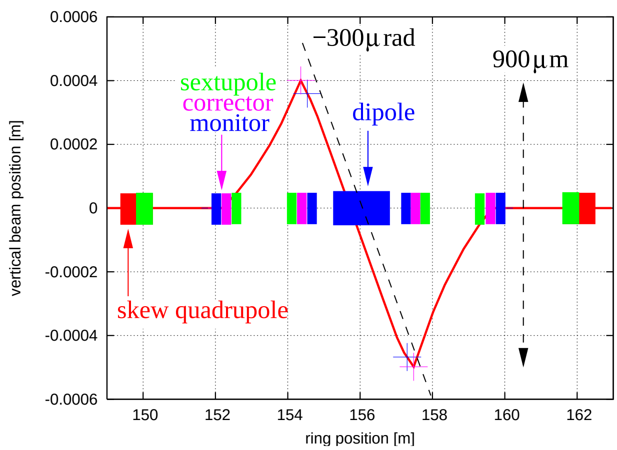


Figure 2: Layout of the vertical asymmetrical "polarization" bump consisting of four successive dipole correctors (magenta bars) for the dipole (thick blue bar) beamline PolLux. Dedicated skew quadrupoles (red bars) are foreseen to locally compensate for the betatron coupling induced by the sextupoles (green bars) within the bump.

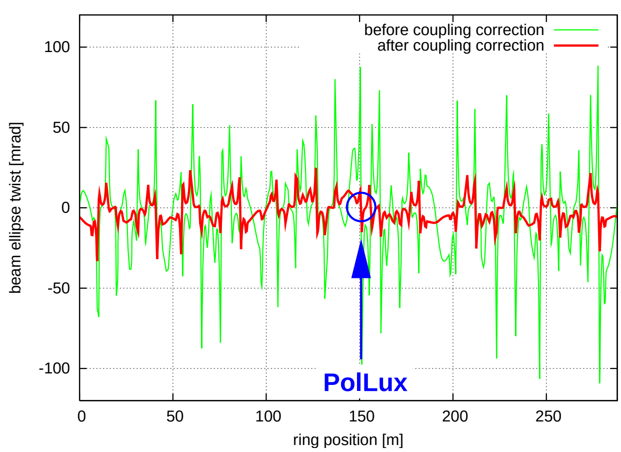


Figure 3: Twist of the electron beam ellipse as a function of the longitudinal SLS storage ring position for a -300 $\mu$rad steering for the PolLux beamline before (green line) and after (red line) betatron coupling correction. The twist has been determined from the calculation of generalized sigma matrices [5] within the computer code TRACY [6]. The arrow denotes the location of the 4-bump for the PolLux beamline.

ing magnet (see blue symbols "+" and blue thin bars in Fig. 2) are adjusted within the FOFB loop in synchronization with the FF which will be implemted as part of the FOFB system. Since it is foreseen to integrate the two vertically sensitive photon BPMs of the PolLux beamline into the FOFB [2] their reference positions will have to be altered accordingly.

The FOFB itself is a distributed system where one digital signal processor is located on the same processor board as the digital BPM system [7]. Every sector of the SLS is equipped with such a digital BPM/FOFB processor board. The FOFB processor in a sector receives the information of 18 BPMs, 6 BPM readings from its own sector and two times 6 BPMs from the adjacent sectors (see Fig. 4).

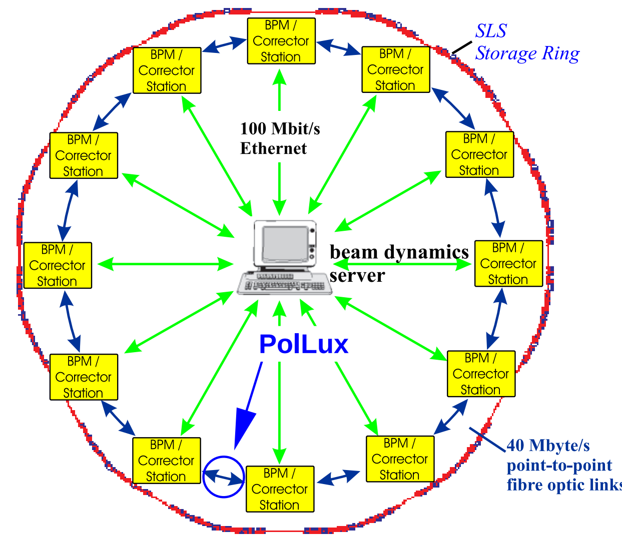


Figure 4: The global fast orbit feedback (FOFB) is integrated in 12 beam position monitor (BPM)/corrector sectors (stations) [2]. The start of the execution of the feed forward (FF) table, which will be implemented as part of the FOFB system has to be synchronized between two FOFB processor boards since the boundary of two sectors is just across the PolLux bending magnet (blue circle).

As already mentioned the FOFB will only have to compensate for deviations from the adjusted reference orbit. Only one normalized FF table is required to be stored in the FOFB memory. The additional corrector (including the skew quadrupole) current increments can be derived from the FF table by applying individual scaling factors which will be determined and downloaded to the system by a central "beam dynamics server" during the FOFB initialization process (see Fig. 4). Due to the fact that the standard correctors are used by the FOFB which are strong enough ($\approx$870 $\mu$rad) to cause a beamloss in case of a FOFB malfunction, a security measure has been introduced. It restricts the FOFB to be operated within predefined current windows of the corrector magnet settings which are slowly adapting to the present settings. These current windows will have to be changed accordingly when the bump amplitude is varied. The start of the execution of the FF table has to be synchronized between two FOFB processor boards since the boundary of two sectors is just across the PolLux bending magnet (see blue circle in Fig. 4). The synchronization will be achieved by use of the fast fiber optic links of the FOFB where the start signal will be transmitted within the standard BPM data packet. In order to avoid undesired strong control overshoots during bump variations a smooth transition between setpoints is planned. The slope of the setpoint change is determined mainly by the vacuum chamber cutoff frequency in the vertical plane of ≈800 Hz and the maximum current change rate of the corrector power supplies (see Fig. 5).

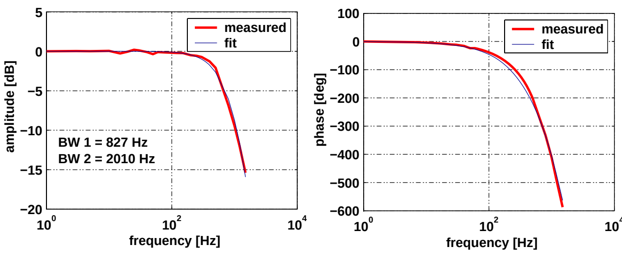


Figure 5: Vertical open loop transfer functions of the global fast orbit feedback (FOFB). The model of the fit consists of a series of a first (bandwidth (BW) 1) and fifth order (BW 2) low pass filters and a time delay [8].

## PERFORMANCE

The maximum frequency at which the bump is allowed to be varied without causing unacceptable perturbations depends on the peak-to-peak bump amplitude and the shape of the temporal change (waveform) within the transition phase. Different waveforms are therefore foreseen. Waveforms with strong higher harmonics need to be avoided since the FOFB has limited frequency dependent horizontal and vertical damping factors (e.g. ≈10 at 10 Hz in the vertical plane, see Fig. 6). Nevertheless it should be feasible to achieve polarization switching rates of up to ≈10 Hz for mostly sinusoidal waveforms with flat tops of varying length at ±300 $\mu$rad, since the FF takes care of most of the steering. As a result the remaining residual orbit oscillations should not exceed a few $\mu$m which would ensure sub-$\mu$m stability with the FOFB running. Suitable sets of parameters will have to be negotiated with the future PolLux beamline users.

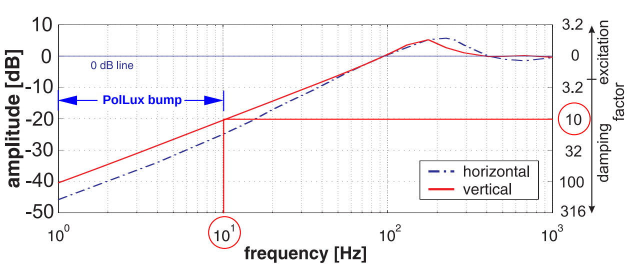


Figure 6: FOFB closed loop transfer function in the horizontal (blue dashed line) and vertical (red line) plane at the SLS [7]. It should be feasible to achieve polarization switching rates of up to ≈10 Hz for mostly sinusoidal waveforms with flat tops of variable length at ±300 $\mu$rad.

## SCHEDULE

Since the dipole correctors defining the 4-bump are part of the standard orbit correction system no additional magnet hardware needs to be installed. For the skew quadrupoles the existing extra windings of two sextupoles without dipole correctors are used which need to be connected to corrector power supplies outside of the tunnel. It is foreseen to do the necessary cabling within the 3rd quarter of 2006. The remaining work mainly concerns changes within the FOFB software architecture. The existing FOFB hardware is utilized for the necessary calculations and for synchronization purposes. It is foreseen to have a fully operational setup by the end of 2006.

## CONCLUSION

With the presented circular polarization switching scheme for the upcoming dipole beamline PolLux at the SLS, which is based on a localized vertical steering of the electron beam within the bending magnet, it has been shown that it is feasible to switch between states of about ±80% of circular polarization at rates of up to ≈10 Hz. At the same time sub-$\mu$m orbit stability is maintained by the global fast orbit feedback system. A pair of dedicated local skew quadrupoles corrects for the betatron coupling induced by vertical orbit excursions within the sextupoles in the vicinity of the bending magnet. As a result the fast switching becomes practically transparent to the other beamlines during SLS user operation.

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