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Analogue feedforward for SOLEIL electromagnetic insertion devices

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Abstract. Now that the machine and beamlines are in operation, new requirements have been identified. On the machine, a significant effort is under way to improve beam orbit stability. Among the sources of noise which perturb the electron beam, the effect of the undulators’ transient electromagnetic fields has been identified. On beamlines using electromagnetic insertion devices, fast variation of the electromagnetic field is required. In order to improve this performance, a new implementation of the control system for the electromagnetic insertion devices (HU256, HU640 and EMPHU) was designed. This new control is based on a set of boards developed at SOLEIL, called “SPI BOARD PACKAGE”.

1. Introduction
This paper describes enhancements to control of insertion devices. Firstly, we will present an overview of the “SPI BOARDS PACKAGE”. We will then describe the architecture for upgrading the control of undulators, and explain the improvement to beam orbit stability. Finally, we will present the work done to improve the speed of the variation of magnetic field of insertion devices, which will be useful for dichroism experiments.

2. Overview of the SPI BOARDS PACKAGE
This development has been specified in order to improve the performance and reliability of the machine and beamlines. The requirements identified are: beam stability improvement [1] (FeedForWarD(FFWD) for HU256, HU640), faster and more reliable control for insertion devices (HU640 and EMPHU), synchronization of data acquisition between equipment: monochromators, insertion devices, detectors (i.e. Pilatus, CCD, camera), nanopositioning… In order to provide a modular solution, the SOLEIL electronics group has developed a set of boards known as the “SPI BOARDS PACKAGE” [2]. This package of boards allows us to embed process-specific functions and to manage synchronizations at low level. It gives us a platform to develop solutions with simple, reliable and durable tools. In the SPI board package architecture (Figure 1), the boards can be connected together in a daisy chain and communicate with the controller via a SPI (Serial Peripheral Interface) Bus. Communication with the SOLEIL control system is via Ethernet. Each board can be connected with others as needed. The package also enables us to deliver solutions for applications with an analogue interface (SPIDAC/SPIADC) or motion interface (SPIETBOX).

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3. Description of undulator control upgrade

The initial implementation of the control of insertion devices used high level software communicating with the undulators power supplies via Profibus. This control system has reached its limits, because the synchronization of the undulator power supply tracking perturbs the beam orbits. Moreover, this implementation is not able to increase the electromagnetic field switching rate. In order to achieve these goals, a new architecture based on a configuration with SPICONTROLLER and SPIDAC has been designed, as described in Figure 2. The process to control undulators is embedded at low level in the microcontroller. It manages the FFWD, generating analogue signals synchronously to drive undulator power supplies. FFWD tables are calculated comparing close orbit distortion to magnetic measurements in order to compensate the field integral leading to a residual orbit distortion smaller than a few µm. Moreover, the SPICONTROLLER platform allows a faster control of power supplies to be implemented, thus enabling fast switching of magnetic fields. In this architecture, TANGO high level software is used to configure the SPICONTROLLER.

This implementation has been validated first on HU256 to improve beam orbit stability and is now in commissioning on HU640 and EMPHU to permit rapid switching of polarization.

3.1. Improvement of the beam orbit stability

Each HU256 undulator [3] is driven by a total of fifteen power supplies including three main power supplies, four correction power supplies and eight so-called modulation power supplies. The main power supplies generates the 256 mm period, 3 m long periodic magnetic field, which makes the electron beam radiate. The correction power supplies are used to cancel the residual closed orbit distortion caused by the undulator magnetic defects. The modulation power supplies allow field modulation to modify the radiated spectrum's characteristics.

The three HU256 undulators used to be driven using the Profibus interface with high level software, but many transient variations could be observed on the electron beam orbit, perturbing the radiation stability for all the beamlines as shown in Figure 3. An analysis determined that these effects were caused by insufficient synchronization between the different power supplies. The upgrade with the SPICONTROLLER improves the synchronization of the power supplies, decreasing the transient perturbation to the orbit by half as shown in Figure 3, and thus reducing use of the SOLEIL storage ring fast orbit feedback. This application has now been working for a year, even if some improvement is still being worked on.
4. Improvement for dichroism experiment.

On beamlines dedicated to dichroism experiments like DESIRS (Dichroïsme Et Spectroscopie par Interaction avec le Rayonnement Synchrotron) and DEIMOS (Dichroism Experimental Installation for Magneto-Optical Spectroscopy) fast switching of polarization is required, in order to reduce acquisition time and improve the quality of dichroism data. In the last few years, to provide fast switching of polarization, significant improvements to the control of HU640 and EMPHU undulators have been made.

4.1. HU640 improvement

HU640 is a 10 m long planar fixed-gap electromagnetic undulator designed to produce VUV radiation light in the range 5-40 eV [4]. It is used by the DESIRS beamline with a particular characteristic of flux and fully variable polarization. It provides new opportunities for the study of molecular chirality and anisotropic properties of matter via different types of dichroism experiments, enabled by the availability of well-calibrated versatile (linear, circular) polarizations of the photon beam, which is a specificity of this beamline. A given tailored polarization of the emitted light by the HU640 is configured by setting its three main parameters: the current driving the horizontal field component and, two additional currents driving the vertical component and the longitudinal phase shift between the transverse components. In order to improve the polarization switching duration, two upgrades were implemented: adjustment of slew rate of power supplies, and upgrade with the SPI BOARDS PACKAGE described above.

This upgrade enhances polarization switching from 40 s down to about 1.6 s. The new control system has now been validated on the machine. One point must be verified, namely the impact of orbit extension that is not corrected with the new control system. On the beamline side, improvement with dichroism measurement must be confirmed, and especially the improvement of the signal-to-noise ratio in the Circular Dichroism (CD) data, and more particularly in the case of the challenging targeted small CD signal, as low as $10^{-3}$ to $10^{-4}$. The circular dichroism refers to the differential absorption of left and right circularly polarized light for a given enantiomer of a chiral molecule, such as amino-acids for instance.

**Figure 4.** Beam orbit variation during switch with 160 points in the correction table. In this configuration, residual perturbations of between 5 to 10 µm of the beam orbit are observed, which is acceptable for the machine and can be eliminated by the machine’s fast orbit feedback.
4.2. **EMPHU control implementation**

SOLEIL built a new 65 mm period Electromagnetic/Permanent Magnets Helical Undulator (EMPHU). It allows rapid (5 Hz) switching of the polarization required for dichroism experiments. This undulator is the second source of the DEIMOS beamline, dedicated to the study of magnetic and electronic properties using polarized light. This undulator consists of 26 periods of 65 mm length. The overall length is 1750 mm. It is made of steel poles surrounded by coils and permanent magnets fixed on two girders. The two girders are attached to a motorized carriage which can move the girders vertically with a gap varying between 14.7 mm and 240 mm. The vertical field is generated by means of main coils powered by a DC current. The horizontal field is generated by permanent magnets. The vertical movement of the girder changes the peak field values (vertical and horizontal).

EMPHU fast polarization switching rate is expected to reduce the noise resulting from environmental conditions. At the moment for dichroism acquisition the sample is scanned twice: once with right polarization then with left polarization. Between two scans of the sample, the environmental conditions can change: beam orbit drift, temperature around sample, even the sample itself. Those conditions can introduce noise in the measurement which can be reduced by switching the polarization faster. The undulator has now been installed and initial tests in Figure 4 and 5, show that after a switch done in 200 ms between 350 A and -350 A, the vertical field integral stays at 0.15 G.m and the horizontal perturbation of the orbit position is 10 µm. The correction scheme established in the lab is giving very encouraging results. The effects on the electron beam illustrated stay within the tolerance. However, the next step for the machine will be the optimization of the correction in order to reduce use of fast orbit feedback.

![Figure 4](image1.png) **Figure 4.** Vertical field of EMPHU is 0.15 G.m after main coil current switches from +350 A to -350 A.

![Figure 5](image2.png) **Figure 5.** Horizontal position of the electron beam on exiting EMPHU, with a gap of 14.7 mm and when main coil current switches from +350 A to -350 A.

Before using EMPHU for experiments the undulator must be commissioned and fully validated on the machine. This is to be scheduled during the first half of 2012.

5. **Conclusion**

These major upgrades made on insertion devices are part of overall work conducted on the machine and beam lines in order to improve their performance and reliability. For beamlines, improving rapid switching of the polarization opens the possibility of new dichroism experiments. For the control system, the SPI BOARDS PACKAGE platform reaches our expectation of being modular and flexible for various applications. Moreover, it permits us to implement new processes quickly.

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