PRELIMINARY TESTS OF A NEW KIND OF BPM SYSTEM FOR SOLEIL

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Abstract

SOLEIL is a third generation light source in construction near Paris. Its small emittance requires improving the resolution of existing BPM systems to submicron level up to 100 Hz and stability to the micron level. The same BPM system has also to perform turn-byturn acquisitions at high rate (846 kHz) with a resolution of a few microns for machine physics studies. SOLEIL entrusted the design of a new digital BPM system to a Slovenian company, Instrumentation voung Technologies. SOLEIL defined technical specifications that seemed attainable and proposed a way of improving beam position measurement stability when the current or the bunch pattern of the beam changes. This paper presents the preliminary tests performed in the laboratory with signal generators simulating the electron beam as well as those done with real beam at ESRF in order to evaluate the SOLEIL BPM Electronics.

INTRODUCTION

SOLEIL, a third generation light source being built near Paris (France), will provide users with 24 beam lines [1]. Its small emittance leads to small beam sizes, especially in the vertical direction with 8 μ m (at 1% coupling) at the insertion device source points.

The Beam Position Monitor (BPM) system comprises 120 monitors located around the storage ring next to quadrupoles. The system fulfils several important tasks:

- Slow acquisition: the closed orbit is measured at about 10 Hz acquisition rate for stabilizing it with a slow global orbit feedback via the control system and the dipole corrector coils located in the sextupole magnets. The important performances are current and bunch pattern dependences in order to always deliver photon beams at the same spot to the users for all beam currents and bunch patterns they work with.
- Fast acquisition: the closed orbit is measured at a high acquisition rate (> 4 kHz). In addition to the performances previously mentioned a good resolution (rms position fluctuation) is necessary. This mode is used for the fast orbit feedback [3].
- Turn-by-turn: for machine physics applications (machine model, non linear beam dynamic studies) and for tune measurements. High resolution ($\leq 3 \mu m$) beam positions are measured at the revolution frequency (846 KHz).
- First turns: this is mainly for the commissioning. The system must accommodate low currents on a single beam passage.

- Interlock: when the beam goes outside a predefined position range at any selected BPM, the BPM electronics gives an interlock signal which is used to prevent possible damage to the machine.
- Post mortem: records the last few thousand turns of beam position data in case of a sudden beam loss.

BPM ELECTRONICS

Each BPM has four button electrodes delivering narrow pulses to an electronic processing unit located outside the machine tunnel, via four coaxial cables. The spectrum line at the RF frequency (352 MHz) is the useful part of the signal processed by the electronics. The BPM electronics requirements for the Storage Ring are shown in table 1.

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Table 1. Storage King BPM electronics redill	irements

	Slow acquisit.	Fast acquisit.	First turns	Turn-by- turn
Absolute accuracy	\leq 20 μm	\leq 20 μm	≤ 500 μm	\leq 200 μm
Resolution rms	\leq 0.2 μm	\leq 0.2 μm	≤ 500 μm	\leq 3 μ m
Measurement rate	10 Hz	≥4000 Hz	847 kHz	847 kHz
Dynamic range	$\begin{array}{c} 20-600\\ mA \end{array}$	20-600 mA	0.4 - 4 mA	4 - 600 mA
Current dependence	$\leq 1 \ \mu m$	$\leq 1 \ \mu m$	≤ 500 μm	×
Bunch pattern depend.	$\leq 1 \ \mu m$	$\leq 1 \ \mu m$	≤ 500 μm	\leq 500 μm
8-h drift	$\leq 1 \ \mu m$	$\leq 1 \ \mu m$	≤ 500 μm	×
1-month drift	\leq 3 μ m	\leq 3 μ m	$\leq 500 \ \mu m$	×

The same electronics equips the Booster and the measurement rate reaches 1.9 MHz. Booster resolution and stability requirements are relaxed. A Booster specific mode provides beam positions over the acceleration cycle with a choice of data averaging; it is called Booster Normal mode.

Instrumentation Technologies, a Slovenian company, has been chosen to design and build the electronics. There is one 1U-19" chassis (figure 1) per monitor. It takes its power from the 220 V 50 Hz mains and provides the X and Z positions directly to the control system via an Ethernet port. It also provides the four electrode signals, their sum, and a signal for checking the BPM.



Figure 1: Front and back panels of a Libera chassis

A description of the resulting electronics called "Libera" is found in reference [2]. The processing board includes a powerful FPGA with two imbedded PowerPCTM. The FPGA firmware, split in two, can be loaded via Ethernet. One part is for Storage Ring operation, the other for the Booster.

LABORATORY TESTS

Goal

We check the performances of the Libera chassis in the laboratory at their arrival at SOLEIL. The measurements were carried out on 25 Liberas randomly picked from 152 units. Four kinds of measurements were performed:

- Absolute accuracy: measurements of a centered beam (simulated with same signal levels on the 4 inputs)
- Beam Current Dependence (BCD): measurements of an off-centered beam (simulated with unbalanced signal levels on the inputs). The input level covers the -2 to -72 dBm range in 4 dB steps.
- Measurements of an off-centered beam in "First-Turns" mode for the Storage Ring measured in the -44 to -86 dBm range.
- Raw (non averaged) measurements with offcentered beam in the "First Turns" mode for the Booster measured in the -20 to -80 dBm range.



Figure 2: Measurement set-up

Measurement Results

The results are consistent with the end-ofmanufacturing tests performed by Instrumentation Technologies:

- Resolution in First Turns mode is better than the 0.5 mm resolution specification, down to 80 dBm for the SR (~15 μA) and -78 dBm for the Booster (~0.2 mA considering injection bunch length).
- Absolute accuracy is outside the specifications, especially for the vertical position. It is planned to apply a fixed offset correction specific to each Libera.
- Beam Current Dependence (figure 4) and Bunch Pattern Dependence should easily be brought within specifications using correction tables.



Figure 3: Beam Current Dependence for a simulated beam off-centered by 1.4 mm in X and Z.

Resolution

The resolution of the SOLEIL Liberas has been improved in three steps in order to lower it to an acceptable level. Resolution is an issue for fast orbit feedback. The BPMs must not induce excessive noise on the beam. It is also an issue at revolution frequency for machine physics studies. IT measured the performance of the first few units recently upgraded (figure 4). The acquisition in turn-by-turn mode (846 kHz) is within 3 μ m down to 20 mA. Some units are slightly outside the very tight requirement of 0.2 μ m rms @ 100 Hz acquisition rate for a -32 dBm input level. However, the whole production of 152 chassis should be within 0.3 μ m.



Figure 4: Resolution @ 100 Hz repetition rate

TESTS ON ESRF BOOSTER

Goal

We need to check the behavior of Libera hardware, FPGA firmware, and generic server software with its SOLEIL Device Server on a real machine in order to identify any problems and fix them before the Booster commissioning. A similar test on the Storage Ring will be done when the corresponding FPGA firmware is ready.

Test Setup Characteristics

ESRF and SOLEIL RF frequencies are both 352 MHz. Libera features a VCXO for Booster BPM sampling frequency at 107.19 MHz that combined with the processing, results in one measurement every SOLEIL Booster revolution period of 522 ns. ESRF Booster revolution period being 1000 ns, there is almost two measurements per revolution period for our Libera monitoring the ESRF Booster. A BPM with four striplines is available for the test. Its geometry is different (electrodes on the X and Z axis) from that of SOLEIL Booster BPM (electrodes on the diagonals). The X and Z computation, done in the Tango Device Server, is modified accordingly for the test. A trigger, 190 µs ahead of the injection, can be delayed at will via a pulse generator and applied to the Libera. A laptop computer running the Tango Device Server and another laptop running SOLEIL Tango control system are connected to a same local Ethernet switch as the Libera.

Tests in "turn-by-turn" mode

We record 40 000 position measurements (~20 ms) at a 522 ns repetition period during the acceleration cycle. The signal levels were adjusted from - 44 to -74 dBm with attenuators. It corresponds to currents from 5 to 0.15 mA, the useful SOLEIL Booster dynamic range. The beam trajectory for the first turns after injection are shown in figure 5.

CONCLUSION

The laboratory tests and ESRF tests of the SOLEIL BPM electronics (Libera) gave encouraging results. We think all performances should eventually reach our very tight requirements.

The current dependence should be suppressed and fit the specifications by using correction tables.

The fast feedback mode resolution has being improved via hardware upgrades implemented by IT and we expect all units to be within 0.3 µm.

The tests done on the ESRF Booster showed the Libera operates well with Tango, the SOLEIL control system, and a first version of the BPM Device Server.



Figure 5: ESRF Booster horizontal position and BPM sum signal for 100 acquisitions.

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REFERENCES

- M-P. Level et al, "Progress Report on the Construction of SOLEIL", PAC'03, Portland (OR), May 2003, p. 229.
- [2] A. Kosicek, "Libera Electron Beam Position Processor", PAC'05, Knoxville, May 2005, to be published.
- [3] N. Hubert et al, "Design of a Fast Orbit Feedback for SOLEIL. This conference.