SLS WORKSHOP ON BEAM STABILITY

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After three years of user operation an internal workshop on beam stability was held at SLS in September 2004. It was intended to review the performance and limitations of the actual HW installations and the applied orbit correction schemes from the perspective of present and future user and operational requirements. A short summary on the main aspects of beam stability is presented in this report resulting in a critical analysis of the present situation and providing updated specifications for fast orbit feedback (FOFB) sub-systems and correction strategies.

ORIGINAL SPECIFICATIONS

The original specifications on beam stability at SLS have been defined by the Phase-I beamlines, which are designed to provide energy resolutions on the order of 10^{-4} and photon spot sizes of about 100 μm at the locations of their experiments. These photon beam parameters directly translate into limits for tolerable electron beam motion at the source points, resulting in requirements of about 1 μrad for the angular stability and σ/10 for the pointing stability of the electron beam [1]. In case of the SLS low-β insertion device (ID) straight sections this corresponds to about 1 μm rms beam motion for 1% emittance coupling. Critical time scales for data acquisition during which these stability criteria have to be fulfilled, reach from some tens of milliseconds to about one day with highest possible availability of the photon beam, which is considered to be > 95% of the usable SLS beam time.

PRESENT STATUS AND FOFB PERFORMANCE

A (fast) orbit feedback system (FOFB) has been designed for actively stabilizing the SLS electron beam in a frequency range from about 10^{-5} Hz (days) to 100 Hz. It represents a highly sophisticated system, consisting of a large number of components such as:

- 72 RF beam position monitors including their digital electronics for measurement and processing of horizontal and vertical electron beam positions.
- 24 fast network modules for real time data exchange.
- 144 corrector power supplies and their digital controllers for applying correction kicks to the electron beam.
- 12 event receivers as part of the SLS timing system to synchronize the FB action.
- The SLS network and the control system with vxWorks, EPICS, Linux and Oracle database.
- Finally, several beam dynamics services, which are running numerous high level feedback applications, allowing data analyses and providing the operator interfaces.

In order to achieve high availability of the FOFB in standard SLS user operation, the requirements for reliability and maintainability for each sub-system represent a major challenge and even the user interfaces and operator controls have to reach a fairly high standard. The FOFB commissioning phase during the year 2003 concentrated on these safety and reliability aspects, so that it was possible to put the FOFB into SLS user operation at the end of 2003. As a result, the electron beam motion is effectively damped up to a frequency of 100 Hz. In the frequency range between 1 Hz and 100 Hz the integrated vertical (horizontal) beam stability results in 0.25 (0.36) μm rms at the location of the low-β ID straights. Moreover, ID gap changes can be completely handed over to user control and remain transparent to the rest of the storage ring. The overall FOFB performance exceeds the original specifications by a factor of 4. The long term stability (1 Hz up to days) at SLS complies with the original stability requirements of 1 μm rms at the ID source points. It has to be noticed, that these fairly low values can only be reached through top-up operation of the storage ring. The application of an additional filling pattern and some local high level photon beam feedbacks compensate for systematic effects of the DBPM electronics and lead to μm-level photon beam stability. The FOFB performance has been confirmed by independent measurements with “out of FOFB loop” sensors in the storage ring - such as additional RF BPMs and/or photon BPMs and is supported by “every day” user experience. More detailed information about the SLS beam stability and the FOFB performance can be found in [2].

OPERATIONS / OPERATORS POINT OF VIEW

The SLS operators generally confirm the excellent short and medium term performance of the FOFB and appreciate the high reproducibility of the “golden orbit” even after shut-downs (periods of weeks), however their greatest concern is the handling of the FOFB and its beam dynamics applications as well as the reliability and maintainability of each of the FOFB sub-systems.

Concerning the user-friendliness of the FOFB, considerable steps have been made during the year 2004 to simplify the high level FOFB control. Unfortunately, it has to be stated that a highly complex system like the FOFB with its many options and the possibility to adjust any desired orbit cannot be expected to be easy to use but it needs rather conscious and elaborate handling to avoid undesired action or even beam losses. More specifically, in case of FOFB failures, extended knowledge about the FOFB architecture and the functioning of its sub-systems is required. Thus, adequate time and effort have to be put into the training of the operators.

The reliability of the FOFB has still been improved during 2004 by introducing software safety packages, which avoid beam losses in case of FOFB sub-system failures. Thus, the FOFB failure rate could be reduced since September to the desired rate of less than one failure per month. The immediate repair of faulty FOFB components (e.g. broken DBPM hardware) within less than one hour still remains a logistic challenge to the persons in charge of sub-systems. This issue is mainly addressed by stocking an adequate number of spare parts and by a 24h stand-by service.

THE USERS POINT OF VIEW

In general, the Phase-I beamlines of the SLS are pleased with the present short and long term beam stability and the reproducibility of the "golden orbit". This circumstance helps improving the sophistication of their experiments and reflects directly onto the quality of their data. The Phase-II beamlines at the SLS, however, aim for micro-foci between 10 μm and 20 nm and higher photon energy resolution ($\Delta E/E < 10^{-4}$) at their end stations. Thus, tighter requirements for the beam stability compared to the Phase-I beamlines are put on the electron beam meaning that the presently achieved FOFB performance will become insufficient in the future, as soon as they are able to reach their ultimate experimental plans. First experience from the μ-focus beamline LUCIA supports this statement, since most of their experiments cannot be conducted without an operational FOFB and its short term performance. The reproducibility of absolute electron / photon beam positions (e.g. after shut-downs) however, needs to be improved in the future. Likewise, top-up injections are not completely transparent to the μ-focus users due to non-closure of the injection bumps and the inability of some experiments to gate their data acquisition systems.

FOFB AND SUB-SYSTEMS LIMITATIONS

The core piece of the FOFB is the digital beam position monitor (DBPM) system [3]. It has been the first BPM electronics to follow a highly flexible approach, allowing the operator to freely select the mode of operation (from high bandwidth, medium resolution turn-by-turn mode to medium bandwidth, high resolution FB-mode) by software. While the DBPM concept has proven to be still valid and has been copied by new electronics developments, it has to be kept in mind that most of the hardware components of the SLS system are already 7 to 10 years old and thus outdated and/or commercially not available anymore. Although the DBPM hardware and software is well debugged and most systematic effects are examined and eliminated, the possibilities to upgrade and improve the present performance and to extend the FOFB system as required e.g. for the SLS femto-second pulse slicing project are quite limited.

In general, photon beam position monitors (PBPM) provide superior resolution compared to RF BPMs due to their long lever arm. However, the interpretation of their signals is not always straightforward. In case of undulator beamlines, extensive calibration procedures are mandatory for PBPM integration into the orbit feedback. At SLS, PBPM signals are only used at the 04S and 06S beamlines to monitor and compensate for systematic effects of the DBPM electronics. As a result, sub-μm short and long term photon beam stability can be delivered even at the locations of the beamlines first optical elements.

CONCLUSIONS AND OUTLOOK

The SLS internal workshop on beam stability has reviewed the present situation in perspective of the original requirements and has started a discussion and exchange between users, operators and accelerator groups. The presently achieved μm-level short and long term beam stability at SLS is sufficient for the Phase-I beamlines. The Phase-II beamlines, however, which are intending to provide μ-foci and highest photon energy resolution to their users, may demand even higher beam stability in the near future. In addition, new experiments like the femto-second pulse slicing project and the superbend beamlines will require the integration of additional RF and/or photon BPMs into the FOFB architecture. Corresponding performance upgrades and extensions of the FOFB are quite limited due to some aged and not anymore available hardware components. Design considerations towards new BPM electronics with improved performance should thus be made in due time. Active photon BPM integration in the FOFB will be required to achieve improved resolution for beam position measurements providing even better beam stability and absolute reproducibility of photon beam positions. A corresponding PBPM electronics upgrade will be realized in 2005, but PBPM calibration for higher signal integrity needs definitely more priority and manpower in the future. In this context, it also needs to be mentioned, that the (bit-) resolution of the SLS corrector power supplies have to match an improved performance of possibly upgraded measuring systems in order to achieve higher beam stability.

REFERENCES

[1] V. Schlott, *Global Position Feedback in SR Sources*, Proc. EPAC'02, Paris, France, pp.104 http://accelconf.web.cern.ch/accelconf/e02/PAPERS/THXGB001.pdf

[2] T. Schilcher et al., *Commissioning and Operation of the SLS Fast Orbit Feedback*, Proc. EPAC 2004, Luzern, Switzerland, pp. 2523. http://accelconf.web.cern.ch/accelconf/e04/PAPERS/THPLT024.PDF

[3] V. Schlott et al., *Performance of the Digital BPM System fort he Swiss Light Source*, Proc. DIPAC 2001, Grenoble, France, pp. 69. http://accelconf.web.cern.ch/accelconf/d01/papers/CT03.pdf