NOISE ENVIRONMENT IN THE SLS STORAGE RING

V. Schlott, M. Böge, T. Schilcher

Residual disturbances to the electron beam orbit in the SLS storage ring have been correlated with data from vibration measurements. The resulting identification of noise sources allows the final definition of the parameter space for an active electron beam position stabilization, which will be realized through a fast closed orbit feedback (FOFB).

INTRODUCTION

After successful commissioning of the SLS and the achievement of most of the crucial beam parameters according to specification [1], the recognition of noise sources around the storage ring and the subsequent active electron beam stabilization will play one of the major roles for the provision of satisfactory beam quality to the users. Medium and long term drifts of storage ring and beamline components have been minimized through the application of the so called top-up operation mode of the SLS, where the storage ring beam current is kept constant to a level of about 10^{-3} in reference to a pre-defined value (typically 300 mA throughout the year 2002). Consequently, the heat load on all components remains constant and electron as well as photon beam stability on a micron level has been provided over weeks by applying only minor electron beam orbit corrections at a 1 Hz repetition rate through the SLS slow orbit feedback system (SOFB) [2]. Still, substantial electron beam motions in a frequency range between 3 Hz and 100 Hz have been observed with the digital beam position monitor (DBPM) system [3]. These measurements indicate residual, integrated beam motions of 1.2 μm rms horizontally and 0.9 μm rms vertically [4] throughout this frequency band. While additional disturbances of the photon beam through beamline components such as mirrors, gratings, slits and others are treated as a separate issue [5], this report concentrates on noise, which is generated by the electron beam. In this respect measurements of vibration spectra, which were taken at different locations in the SLS storage ring, are correlated with electron beam data. Noise sources are identified and strategies to suppress the disturbing beam motions are presented.

NOISE FLOOR AT THE SLS STORAGE RING

In synchrotron radiation facilities, the noise floor in a frequency range between 1 Hz and 100 Hz is usually dominated by ground vibrations, environmental influences, cooling water, booster operation, power supplies, insertion device motion, rotating machinery and other similar sources. Just recently, in November 2002, a vibration measurement campaign was carried out to map the noise environment in sector 08 of the storage ring and along the 09L SIS beamline [6]. The spectral power densities (PSD) and the resulting cumulative spectral densities (CSD) for both, the horizontal and the vertical directions are shown in Fig. 1 and 2, visualizing the motion of the storage ring floor, the girders and the quadrupoles for frequencies up to 100 Hz. The spectra of all three components are dominated by a peak at 12 Hz, which is caused by the compressor of the SULTAN test facility on the west side of PSI. While the floor spectrum shows only two further peaks at 25 Hz and 50 Hz, which are most probably related to EDH membrane pumps, situated along the SIS beamline [5], the storage ring girders and quadrupoles cause some considerable vibration peaks between 20 Hz and 50 Hz. They correspond to the eigenfrequencies of the magnet support structures, which have been optimized by FEM-based mechanical design for highest possible values [7]. Simultaneously, quite moderate amplification factors (ratio of girder motion to ground motion) of less than 20 in the horizontal and well below 10 in the vertical have been measured over a frequency range from DC to 100 Hz [6]. Another noise peak occurs at around 80 Hz and is most likely due to cooling water circulation.

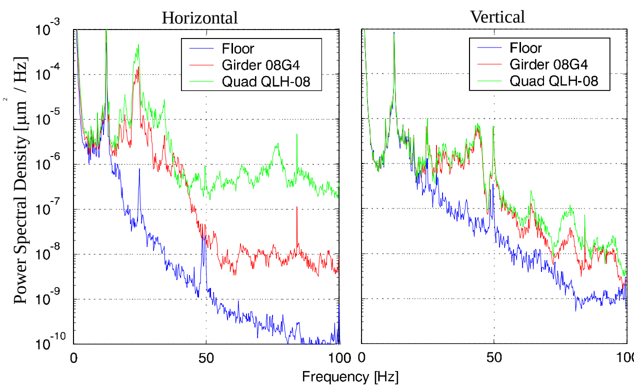

Fig. 1: Horizontal (left) and vertical (right) PSD of the SLS storage ring floor, girder 08G4 and respective quadrupoles close to the 09L SIS beamline.

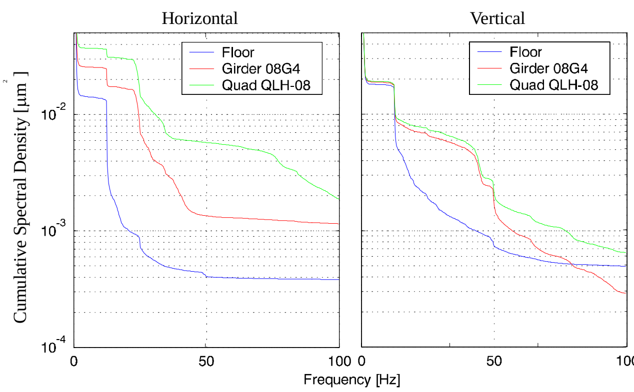

Fig. 2: CSD of the data shown in Fig. 1. Since the spectral contributions add up quadratically, the real motion of components can be extracted by subtracting the respective contributions of the CSD and subsequently taking the square-root of the result.

IMPACT OF NOISE FLOOR ON ELECTRON BEAM

The direct impact of the noise floor on the electron beam orbit depends strongly on the storage ring optics respectively the horizontal and vertical betatron wavelengths around the machine. The resulting amplification factors, which are defined as the ratio of rms electron beam motion to ground wave amplitudes for components mounted on girders, have been evaluated under the assumption of the above mentioned mechanical amplification factors of < 10 for the SLS storage ring girders [8]. In the horizontal direction, where the beam performs 20.42 betatron oscillations, the influence of vibrations up to about 30 Hz is rather moderate (5 to 10), while higher frequency noise is quite strongly amplified (between 30 and 40). In the vertical, where the number of betatron oscillations is lower (8.17), the amplification factors are quite moderate (~ 5) over a much broader band from about 15 Hz to 100 Hz. The amplification of low frequency vibrations (< 15 Hz) is almost negligible in both directions.

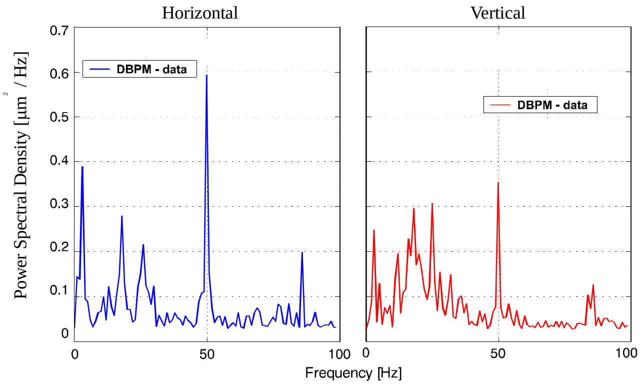

Fig. 3: Horizontal (left) and vertical (right) PSD of the electron beam in the SLS storage ring, measured in the feedback mode of the DBPM system

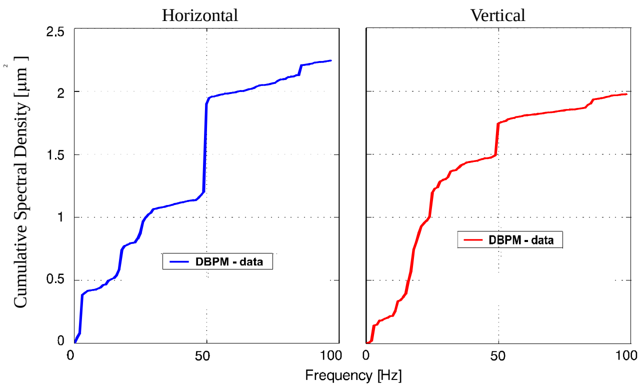

Fig. 4: Horizontal (left) and vertical (right) CSD of the electron beam in the SLS storage ring, measured in the feedback mode of the DBPM system

Fig. 3 and 4 are showing the PSDs and CSDs of the electron beam in the storage ring for the horizontal and vertical directions. They have been measured in the feedback mode of the SLS digital beam position monitor (DBPM) system, which is providing sub-micron spatial resolution at 2 kHz bandwidth. Several lines can clearly be identified in the PSDs.

- The 3.125 Hz of the booster ramping cycle shows up in both planes (h, v).
- A number of peaks at 18 Hz (h, v), 25–27 Hz (h, v), 32 Hz (v) and 50.5 Hz (h, v) correspond to the eigenfrequency band of the SLS girders.
- A peak at 85 Hz is most probably related to cooling water circulation in the storage ring magnets.

The relative amplitudes are in good agreement with the theoretical expectations, while the absolute values are fairly overestimated due to the rather pessimistic assumptions in [8]. The dominant mechanical vibration peak of girders and quadrupoles at 12 Hz is hardly transmitted to the electron beam, since the amplification factors for low frequency noise are negligible as predicted in [8].

CONCLUSIONS AND OUTLOOK

Most of the electron beam disturbances between 1 Hz and 100 Hz in the storage ring could be correlated to mechanical noise sources at the SLS site. The residual integrated beam motions in this frequency range has been measured to be 1.2 μm rms horizontally and 0.9 μm rms vertically, taking the noise contribution of the DBPM system in the feedback mode already into account. Attenuations of 50 dB (factor of 300) at 1 Hz and 10 dB (factor of 3) at 100 Hz [9] provided by the fast orbit feedback (FOFB) system will be sufficient for the anticipated sub-micron closed orbit stability in the SLS storage ring.

REFERENCES

[1] M. Böge, *First Operation of the Swiss Light Source*, Proc. EPAC'2002, Paris, June 2002.

[2] M. Böge et al., *Stability Aspect and Top-Up*, PSI Scientific Report 2002, VI.

[3] V. Schlott et al., *Commissioning of the SLS Digital BPM System*, Proc. PAC'2001, Chicago, June 2001. See also: http://accelconf.web.cern.ch/AccelConf/p01/PAPERS/WPAH134.PDF

[4] T. Schilcher, *Fast Orbit Feedback at SLS*, Proc. 2nd Workshop on Beam Orbit Stabilization, Hyogo, December 2002.

[5] J. Krempaský, *Impact of Noise Floor and Structure Vibrations on the Photon Beam Stability at the SIS Beamline*, PSI Scientific Report 2002, VI.

[6] S. Redaelli, PHD-Thesis, in preparation.

[7] P. Wiegand, *SLS SR Girder: Vibration and Modal Analysis Tests*, SLS-TME-TA-2000-0153.

[8] M. Böge et al., *Studies on Imperfections in the SLS Storage Ring*, Proc. PAC'1999, New York, April 1999.

[9] V. Schlott, *Global Position Feedback in SR Sources*, Proc. EPAC'2002, Paris, June 2002.