IMPACT OF NOISE FLOOR AND STRUCTURE VIBRATIONS ON THE PHOTON BEAM STABILITY AT THE SIS BEAMLINE

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The impact of the noise floor and structure vibrations on the photon beam stability at Surfaces Interfaces Spectroscopy beamline (further SIS) has been investigated within the scope of understanding fundamental limits of the beam stability for the experiments. In order to understand the sources of the photon beam instabilities the signal noise of the SR in the beamline front-end is compared with the signal near the end of the optical path. It is shown, that the main vibration source at the beamline focal point are the membrane pumps. Diagnostics to monitor the beamline 'health' in terms of beam noise at SLS beamlines is proposed.

INTRODUCTION

Due to the small emittance of the 3rd generation SR sources, the signal stability at the beamline focal point is very sensitive to noise, especially in the vertical direction. For the SIS beamline vertical beam noise influences the energy resolution, while the horizontal one impacts on the beam flux. Generally speaking, the final noise at the beamline focal point is a superposition of the ground noise which induces mechanical noise on storage ring structures. This, in turn, induces noise in the storage ring beam orbit which impacts on the SR beam position at the beamline source point along with machine operation instabilities [1]. The flux or beam position instability at the SIS refocusing mirror (RMU) is again a superposition of mechanical noise at the beamline optical components and the photon beam itself.

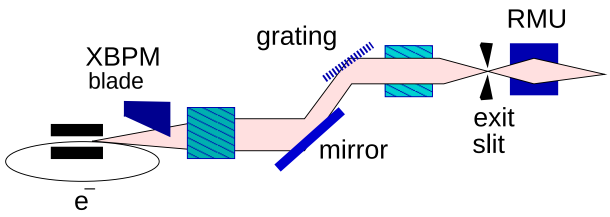

Fig. 1: Schematic layout of the experimental setup to quantify low frequency beam vibrations at the SIS beamline. While X-ray beam position monitor blades (XBPM) characterise the noise in the SR source, the RMU is used to characterize the total beam noise.

Putting all these factors together, understanding the beam noise source footprints on a beamline is a challenging task. The scope of this note is to understand what noise contributions are coming from the storage ring and what are induced at the beamline.

ANALYSIS TOOL: CUMULATIVE PSD

Using direct algorithms such as Fourier techniques for the analysis of the noise signal is in general not a suitable approach. The direct Fourier transform $X(j\omega) = \int x(t)e^{-j\omega\, t}dt$ can also be interpreted as the mean value of $x(t)e^{-i\omega\, t}$, which for a purely random signal would amount to zero, even if the signal shows some strong characteristic frequencies. With finite length samples, these frequencies may show up as strong peaks, but nonetheless with random amplitudes not suitable for quantitative analysis. A systematic way of analysing these signals uses the autocovariance function, which gives the non normalized correlation of a random signal at different times t and $t+\tau$: $acov(x,\tau) = \int \; x(t)x(t+\tau)\; dt$. For white noise the $acov(x,\tau) = 0$ for $\tau \neq 0$, and coloured noise will come up. An attractive feature of the autocovariance is its Fourier transform, which for discrete sampled signals x_n equals the $\sum_{k=0}^{N-1}|X_k|^2$ (X_k are the frequency components of the discrete Fourier transform). Parseval's theorem states, that $\sum_{k=1}^{N-1}|X_k|^2 \equiv \sigma_x^2$, which is the total signal variance. This is the basis definition for power spectral density (PSD). In the context of vibrations studies one wants to know the mean square amplitude of the sine components characteristic to some coloured noise. The plots presented in this note are square root (!) of cumulative PSD sums vs. frequency bins. Well visible jumps in such cumulative spectral density plots correspond to rms of some coloured noise emerging from the white noise.

THE X-ray BEAM POSITION MONITOR

The X-ray beam position monitors are used for monitoring the position of the SR beam. The four blades provide horizontal and vertical photocurrent assymetries by means of which the central position cone of the SR radiation is calculated.

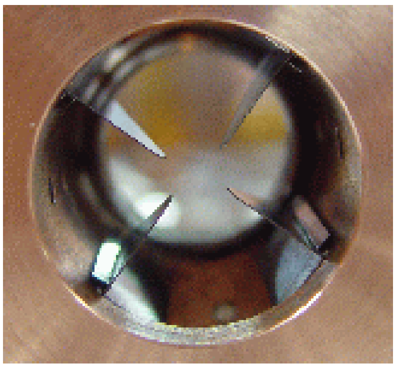

Fig. 2: Four blades of the X-ray beam position monitor located in the front-end part of the SIS beamline.

In this note, however, we examine the photoemission current noise on just **one blade**. The point is to check how this signal correlates with the orbit jitter sensed by the RF beam position monitors in the section 08 of the storage ring - the one in front of the SIS beamline. One important aspect of the XBPM design [2] is its stiffness against low frequency resonances induced by the floor noise, otherwise it would be difficult to separate beam motion from the XBPM device itself. As seen in Fig. 3, the spectra of the RF beam position monitors and X-ray monitor are almost identical in the 0÷50 Hz bandwidth, demonstrating this important aspect.

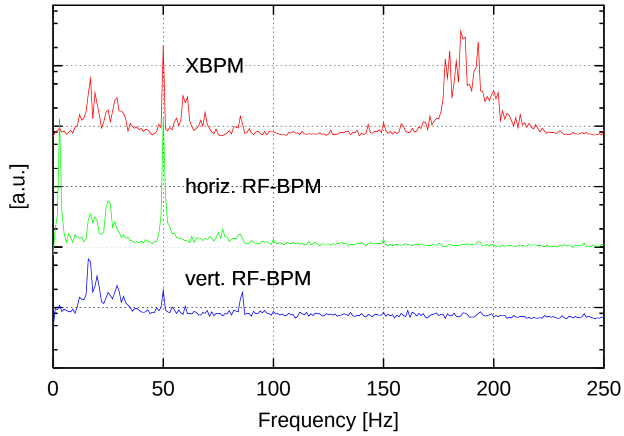

Fig. 3: Spectral comparision of XBPM beam intensity horizontal and vertical electron beam position of the SLS RF monitors in section 08.

The spectral sensitivity of the XBPM is surprising. It sees also low frequency eigenmodes of the storage ring structures in the 15÷30 Hz range and 80 Hz from the storage ring cooling system [3]. The resonances near 200 Hz on Fig. 3 (and near 400 Hz on Fig. 7) are coming from the insertion device being set to low energies (20÷90 eV). The same figure shows, that the electron beam is not influenced by these resonances. This anomaly is coming from the insertion device power supplies [1].

LOCALISING THE VIBRATION SOURCES

For the SIS beamline surroundings the cumulative spectral density taken from the geophones is seen on Fig. 4. They have been measured at four equidistant points between the storage ring wall and the SLS building main entrance. The 16 Hz line originates probably in the Ecodry (Leybold) pump station located 7 metres from the beamline, 25÷50÷100 Hz lines are EDH membrane pumps situated along the beamline. In total the floor noise amplitude is ≈10 nm, which agrees with earlier floor noise measurements at SLS [4].

In order to characterise noise floor directly at the beamline, the geophones were placed on the floor next the monochromator concrete block, on the monochromator frame, on the exit slit and refocusing mirror unit (RMU).

[1]turning off the ID212 power supplies make the resonances disappear completely

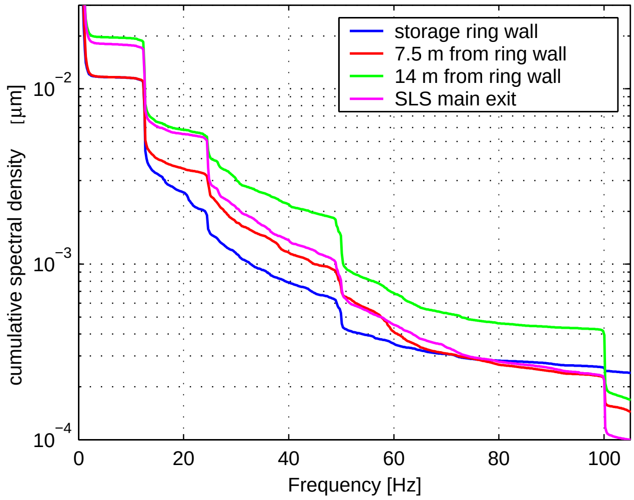

Fig. 4: Cumulative spectral density of the floor near the SIS beamline between the ring wall and SLS main exit.

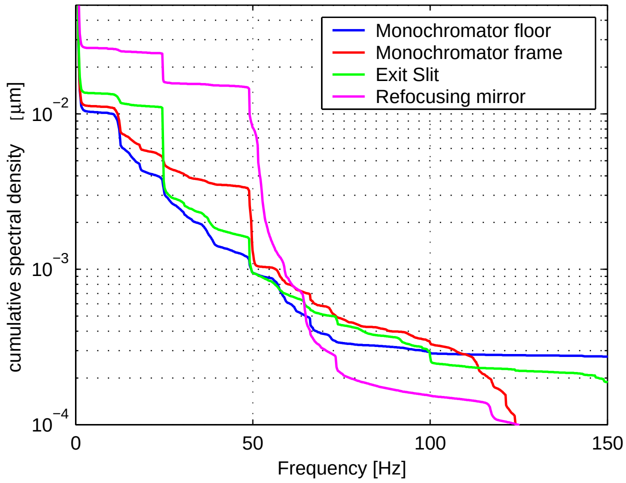

Fig. 5: Cumulative spectral density measured with geophones at four locations of the SIS beamline.

As seen in Fig. 5, while in the spectrum at the feet of the monochromator concrete block no significant 50 Hz line is visible, the monochromator frame vibrates at this frequency with ≈3 nm rms amplitude. This probably means, that the 50 Hz noise is transduced through the beamline structures. The monochromator has a water cooled mirror and three gratings. The 50 Hz line is clearly visible on the mirror angular spectrum (see Fig. 6), the grating being much smaller, much lighter and much more stiff, has negligible 50 Hz, but is resonant near 90 Hz. The total rms amplitude of the mirror is ≈0.9 μradians, the one of the grating is negligible. No significant changes in the cumulative spectral density on Fig. 6 were seen turning on and off the water cooling.

The total beam flux being proportional to the photoemission current on the refocusing mirror unit, has been measured in zero order mode, exit slit fully open and with the first insertion device at 90 eV. The spectrum on Fig. 7 clearly shows 50 Hz resonances. This is probably due to signal sum of all uncorrelated 50 Hz motions,

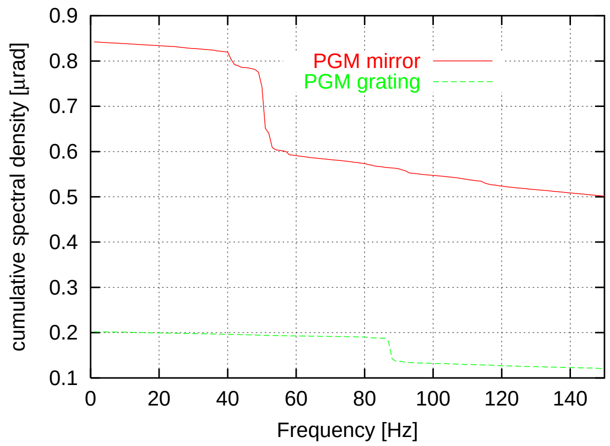

Fig. 6: Cumulative spectral density of the monochromator mirror and grating.

including the beam position at the SR source point [3], also witnessed by the spectrum of XBPM seen on the same figure. The fluctuations of the beam flux have been estimated to 0.02% of the photocurrent rms.

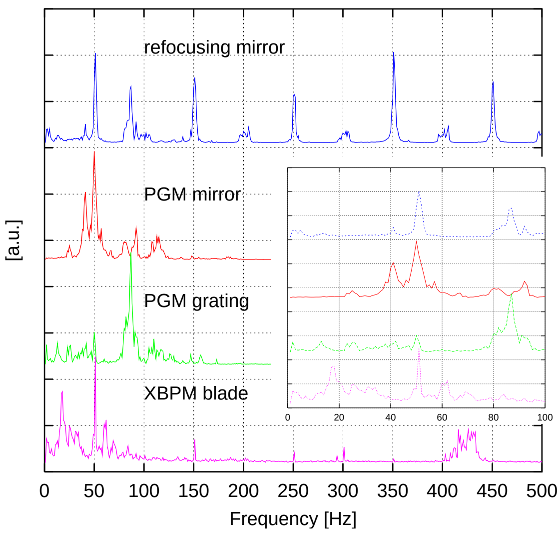

Fig. 7: Spectral comparison of selected beamline optical components. The figure inset clearly shows the noise footprints from the monochromator mirror and grating on the upper plot from the RMU. The influence of the SR sensed by the XBPM is negligible.

DATA ACQUISITION

The frequency bandwidth limit for the floor noise vibration studies in this note is limited by the geophone (GeoSig GSV-310) giving Nyquist frequency of ≈150 Hz, which is sufficient for low frequency noise studies. The geophones were the only dedicated experimental setup for data acquisition in this note. All other devices are controlled via standard beamline EPICS systems. This is good for on-line photon beam noise diagnostics especially in the case of the RMU photocurrent which is proportional to the total beam flux. It should be emphasised, that the frequency bandwidth of 1kHz for the angular in-vacuum optical encoders (Heidenhain IK320) is a realistic sampling rate for our standard EPICS systems. A separate VME scaler used to measure the 1000 sample acquisition time gave a stable 1.020 second acquisition time. The photocurrents from the XBPM and refocusing mirror are internally buffered in the IP modules ADC8401 located on the Hytec8002 IPAC carrier boards [5] and read out as standard EPICS waveforms containing 1000 samples each second.

CONCLUSIONS

The floor noise and structure vibrations on the SIS beamline components combined with the SR photoemission signal spectral analysis on the XBPM was studied in order to understand and separate the photon beam noise contributions coming from the storage ring and the one induced at the beamline. The XBPM spectral density is in good agreement with the storage ring RF monitors proving its mechanical stiffness which is important for reliable monitoring of the SR. It turns out to be also a very helpful device for commissioning the insertion devices. At the final beamline optical element no significant noise footprints coming from the SR were detected. The most significant vibrations originate in the membrane pumps situated directly at the beamline. For the beamline energy resolution the most critical element seems to be the monochromator mirror. It vibrates with $\sigma_\theta \approx 0.9$ μradians, which is almost twice the slope error of the mirror (≈ 0.5 μradians).

ACKNOWLEDGEMENTS

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