Accelerator Physics Alignment and Stability Requirements for the SLS 2.0 Girders and Magnets

(Michael Böge, PSI)

From the SLS 2.0 accelerator physics point of view, the arrangement of four vertically movable girders per arc with a fixed support for the central dipole provides the desired flexibility for remote realignment of girders (± 500 µm pitch, heave and roll with ± 10 µm positioning resolution) after commissioning. It also allows the exchange of a central permanent magnet dipole with a high field super-conducting “superbend” on beamline request. At SLS, the remote realignment of girders based on stored beam orbit data allowed the minimization of localized (girder) alignment errors, resulting in strongly reduced rms kicks (from ~ 150 µrad to ~ 50 µrad). The resulting “free overall corrector strengths” has been used for additional orbit (photon beam) adjustments upon beamline requests. This strategy (vertical re-alignment of girders with stored beam) is one of the essential ingredients for a rapid SLS 2.0 commissioning.

The following alignment tolerances (2-sigma cut of Gaussian distributions) have been defined by SLS 2.0 beam dynamics:

- Absolute girder alignment: 60 µm (RMS)
- Girder-to-girder alignment: 20 µm (RMS)
- Magnet-to-magnet alignment: 30 µm (RMS)

The small (< 60 µm) girder-to-girder alignment errors establish a virtual train link between girders resulting in a minimization of short-range distortions around the storage ring. A total of 108 beam position monitors (BPM) and horizontal and vertical correctors (CHV) – 9 BPM/CHV per arc – are placed adjacent to sextupoles. They are assumed as correlated components with a relative alignment error of 5 µm (RMS) after beam-based alignment. BPMs in the straight sections without adjacent sextupoles are requested to have a 30 µm (RMS) alignment error. For global orbit correction, there will be 9 horizontal and vertical correctors (CHV) adjacent to BPMs in the 12 arcs of the SLS 2.0 storage ring with a maximum correction strength of ± 400 µrad. Each of the 12 straight sections will be equipped with two BPM/CHV for orbit adjustment through the insertion devices and for ID protection (ID interlock). The injection straight will have an additional BPM/CHV.

The eigenfrequencies of the SLS 2.0 girders are requested to be above 50 Hz, such that ground vibrations, which have been measured to be predominately below 10 Hz for the SLS site, are not transferred or amplified onto the electron beam orbit. The SLS 2.0 fast orbit feedback will provide an extended correction bandwidth up to a few hundred Hz, which allows to damp low frequency beam distortions (< 50 Hz) very efficiently.

SLS 2.0 Girder Design

(Maximilian Wurm, PSI)

For the SLS 2.0 upgrade, a girder layout was chosen that provides a good mix of adjustability and handling. Longer girders are favorable for short “dark periods” and efficient installation, since pre-assembly and (pre-) alignment, can be off-site. The choice for shorter girders (3850 mm and 4350 mm lengths) and four girders per sector (arc) with a stand-alone plinth for the central dipole, which may be exchanged by user request to a superconducting “superbend”, was mainly motivated by the consideration that a higher stiffness (higher eigenfrequencies) of the girders can be achieved more easily. In addition, this configuration also allows to re-align (and possibly selectively misalign) girders with the mover system, which is of special interest for rapid commissioning and beam dynamics studies of the SLS 2.0 accelerator physics group (see contribution from Michael Böge). Thus, the SLS 2.0 storage ring will consist of 48 girders of two types (24 pieces each) and 12 one-magnet (central dipole) plinths, one in the center of each arc.

A prototype girder made from steel with mineral cast filling, which may provide the required stiffness with eignfrequencies > 50 Hz, will be purchased within the next six months (to be delivered to PSI until end of 2020). Vibration measurements will be performed with this prototype girder to make a comparison with the eigenfrequency calculations. The girder mover concept and its impact on the eigenfrequencies will be tested for three different version: a) a fixed support without online adjustment possibilities (to normalize the model), b) a camshaft mover systems as it has been used at SLS and SwissFEL and c) the new (favorable) concept for the SLS 2.0 girder with flexors providing a region of movement of ± 0.5 mm and ± 0.5 mrad roll. The flexor concept follows the requirement of a stiffer (as still as possible) girder assembly with fixed connections from the girder to the ground. This concept promises to be (in theory) better than other adjustments (e.g. with movers or wedges), which are only friction based connections. This assumption will also be tested (and hopefully verified) on the prototype girder.

The overall time schedule for the girders foresees:

- delivery of the prototype girder (based on the present concept with flexors for remote adjustment) until end of 2020
- prototype tests and (eigenfrequencies as well as flexors) validation by mid of 2021
- series production from fall of 2021 until fall of 2022
- start of preassembly and pre-alignment of components (on girders) end of 2022
- start of installation in SLS 2.0 April to mid of 2023 (depending on possible “Corona-delays”

20 Year of Experience with the Hydrostatic Levelling System at SLS

(Edi Meier, Edi Meier & Partner AG, Winterthur, Switzerland)

Twenty years ago, the SLS HLS (hydrostatic levelling system) was installed and is since then continuously monitoring the vertical positioning of the SLS storage ring girders at an sampling (update) rate of 2 seconds. The HLS consists of 450 m of stainless steel tubes, horizontally guides along the outside of the SLS girders and a total of 192 sensors, four of the installed on 0.01 mm precisely machines platforms at each of the 48 SLS girders. The HLS can measure heave, roll and pitch of each individual girder. The relative measurement of the water level in each of the HLS sensors is achieved through a water-level dependent change of capacity (HLS sensor is a capacitive pick-up). Temperature (with a temperature sensor outside of the HLS “water pot”) as well as water level have to be controlled for a precision measurement. The HLS software (application) and examples high precision measurements with sub-µm resolution from SLS and the “Rock Laboratory” in the Kanton Jura, Switzerland have been shown. Likewise, measurements of earthquakes and ground motion induced by Atlantic waves were shown, demonstrating the functionality and applicability of the system. Nanometer resolution can be achieved with a 24-bit ADC (upgrade option for SLS 2.0).