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DESIGN AND STATUS OF FAST ORBIT FEEDBACK SYSTEM AT SOLARIS

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Abstract

SOLARIS storage ring has been built with basic set of diagnostic and feedback systems. FOFB system, as much more advanced and not as critical for startup was envisioned as later addition to the design. Now, we are in the process of implementing this addition. The system's workhorse is Instrumentation Technologies Libera Brilliance+ with its Fast Acquisition data path and customizable FPGA modules. Feedback algorithm running in hardware provides fast calculations and direct communication with fast power supplies. The hardware installation is almost finished with configuration and software works running in parallel. First measurements of response matrix and proof-of-concept tests were performed.

DESIGN OF SOLARIS DOUBLE-BEND ACHROMAT (DBA) MAGNET CELLS

The SOLARIS storage ring consists of 12 double bend achromat (DBA) cells (Fog. 1). Conceptually, the magnet design is identical to MAX IV 1.5 GeV storage ring. All magnet elements are machined out of one solid block of iron, about 4.5 m long. The magnet design is optimized for 1.5 GeV beam energy, but since SOLARIS injector currently operates at 0.5 GeV it has been evaluated for that energy as well [1].

DESIGN OF SOLARIS ORBIT FEEDBACK SYSTEMS

Slow Orbit Feedback (SOFB)

The Slow Orbit Feedback system is used for initial beam positioning and maintaining a stable orbit. This system uses 36 beam position monitors (BPMs) (3 per DBA cell) and 72 corrector magnets (3 per plane per DBA cell) [2]. The SOFB correctors are much stronger than the FOFB ones, with current range of ± 11.5 A. This allows for correction of larger beam displacement, but comes at the cost of increased current rise time and thus reduced correction frequency. During standard user operation the SOFB system runs with a frequency of 0.25 Hz or 0.33 Hz, with theoretical maximum of 1 Hz. Software-wise, there are currently two applications used interchangeably: the Matlab MML-based solution [3] and a TangoFeedback based application integrated into the control system [4].

Fast Orbit Feedback (FOFB)

The Fast Orbit Feedback application is a system used for the stabilization of the electron beam and is thought to achieve a stable photon beam for users. It consists of several subsystems that together actively monitor and stabilize the beam position. The main reference is an ideal orbit (so-called golden orbit) which is implemented into the control system and used as a reference for all calculations. The orbit position is established in real-time via BPMs. The BPMs used by the FOFB system are the same ones used by SOFB. The orbit correction uses 24 dual-plane corrector magnets for fast positioning around the storage ring. Once the deviation of the electron beam from its golden orbit is detected, the control signal calculated from the orbit correction bumps magnets towards the setpoint. Each value is unique for each of the magnets and depends on its location around the storage ring and displacement measured at that point. The heart of the system is Libera Brilliance+ (LB+) instruments used for the calculation of the electron position. The closed-loop control follows in several stages: beam position measurements, orbit data concentration from several LB+ instruments into the single orbit data packet, interlock status check, orbit correction calculation, and streaming of the magnet data to the serial output module of LB+.

FOFB COMPONENTS OVERVIEW

BPM Pickups

The SOLARIS storage ring uses 36 quarter wave diagonal button pickups, 3 per DBA cell. There are two types of sensor heads arrangement: type I used at both ends of DBA cell is aligned directly along diagonal coordinates, and type II used at the centre of DBA with heads aligned along vertical axis [3].

Libera Brilliance+ Instruments

Libera Brilliance+ is a high precision beam position measurement device from Instrumentation Technologies. Single instrument can support up to 4 BPM modules and provides different data paths for different purposes, all of which can be accessed simultaneously. Out-of-the-box support for MRF's digital timing protocol greatly simplifies control, triggering and synchronization. The optional GDX and SER modules provide a framework for orbit feedback applications running entirely inside the device.

Itest Fast Power Supplies

Itest BE5495 power supplies are magnet power supply modules specifically designed for Fast Orbit Feedback applications. The available current range is ± 2 A with 10 kHz setpoint change frequency. The modules support communication over Ethernet and RS485 serial link, and are mounted in Itest BN210 chassis.

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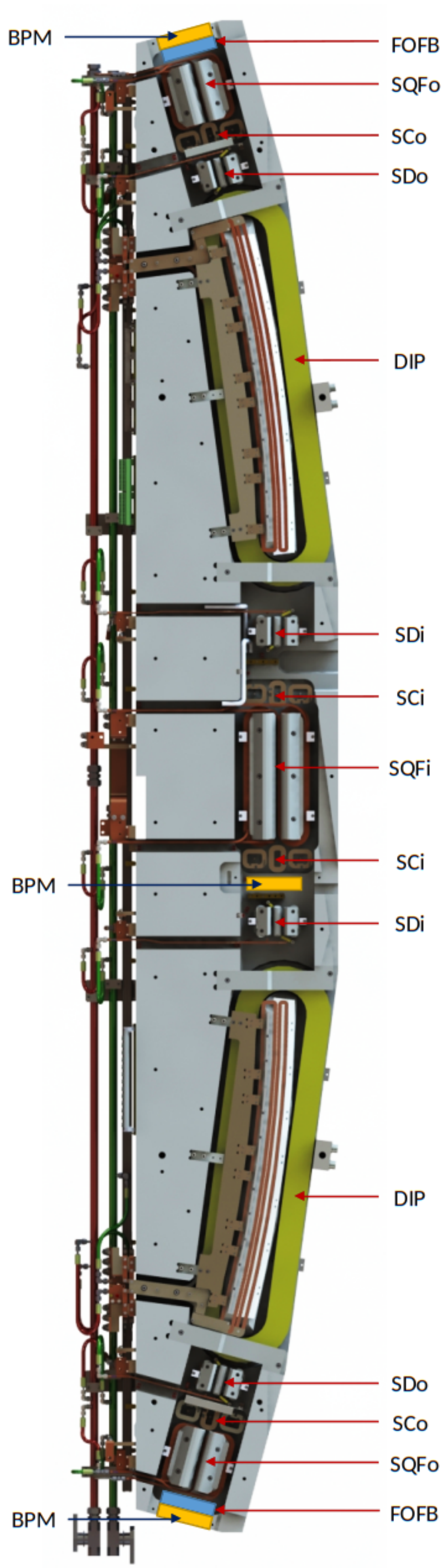

Figure 1: Layout of magnets and BPMs inside DBA cell.

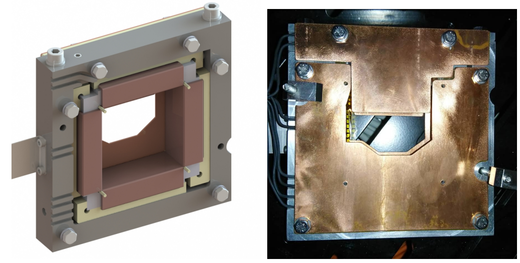

Figure 2: Fast corrector magnet.

Fast Corrector Magnets

The fast corrector magnets are small ferrite core/copper coil quadrupole magnets based on design by MAXIV Laboratory and manufactured by Scanditronix (Fog. 2). The correctors are wired as two separate magnets for correcting the orbit in X and Y planes. Each DBA cell has two fast correctors mounted at both ends, in places where stainless steel vacuum chamber was mandated by design.

Fast Acquisition Archiver

For FOFB diagnostics and fast phenomena observation the Diamond Fast Acquisition (FA) Archiver is used, which continuously captures the accumulated Fast Acquisition orbit data [5]. The archive currently uses a dedicated 320 GB hard disk and spans about 26 h of data. Instead of dedicated sniffer hardware, a HP 560SFP+ 10 Gbit network interface card is used, which features two SFP ports. This will allow archiving of fast corrector magnet data as well in the future.

LOW LEVEL SYSTEM DESIGN

On the low level, the FOFB system uses an algorithm developed by Instrumentation Technologies together with MAX IV Laboratory [6]. The algorithm consists of data aggregation from multiple BPM boards, matrices multiplication and PI controller. Finally, resulting corrector setpoints are pushed out via optical link or serial connections directly to power supplies. The global orbit data is combined with desired golden orbit and multiplied by SVD-decomposed corrector response matrix. For operation, only hardware links such as optical links, LVDS and serial connections are used. This, combined with the fact that the calculations are done exclusively in FPGA chips ensures no network related delays and makes the feedback loop independent of the control system. The system is controlled via timing system events.

CONTROL SOFTWARE

Despite on-hardware design of the FOFB system, several control application are needed for controlling the feedback state and configuration of parameters.

Response Matrix Measurement

An application for measurement of corrector response matrix has been developed (Fog. 3). It allows measurements

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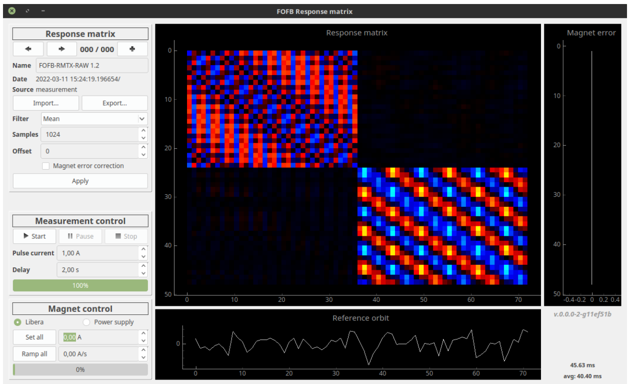

Figure 3: Response matrix measurement application.

in different configurations controlling the power supplies either via Libera instruments or directly via the control system. For each corrector, an entire fast acquisition buffer of each BPM is retrieved. At the response matrix calculation stage, an operator can either use single samples from these buffers or calculate over mean or median value of multiple samples. With magnet control via control system, magnet error, as indicated by the power supply, can be taken into account as well. The output of the application can be saved as raw measurement data or calculated response matrix. The response matrix can be reformatted for the Libera instrument and loaded into its registers. Feeding response matrix data into Liberas is a work in progress feature.

Control Application

A simple application for controlling the feedback loop has been developed (Fog. 4). Currently, it can be used to send FOFB commands via timing system and to check Libera Grouping status and status and configuration of magnet outputs. It can also be used for manual control of the corrector magnets. The detailed FOFB loop status, interlock and saturation registers display and parameter manipulation are work in progress features.

PROJECT STATUS

Currently, all hardware installations have been finished. Hardware connections were verified and tested. First proof-of-concept measurements and test runs were performed (Fog. 5). The core of the work focuses now on experimentally determining parameter values, control software development and solving problems as they arise. The machine studies time is shared with other new developments [7], but we expect to have first FOFB-enabled operations this year.

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Figure 4: FOFB control application.

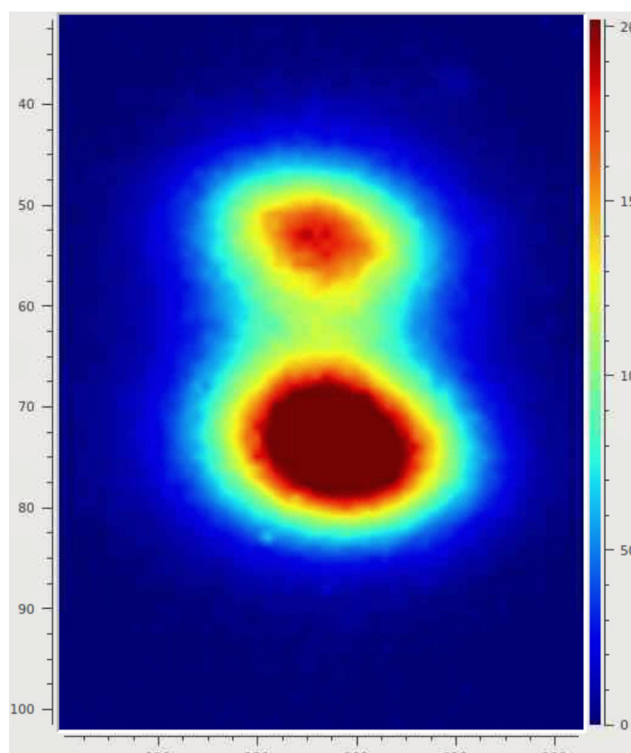

Figure 5: FOFB test run; rapid switching between two stable positions. Beam image from Pinhole diagnostic beamline.

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