PROGRESS REPORT ON THE CONSTRUCTION OF SOLEIL

JM Filhol, on behalf of the SOLEIL project team, Synchrotron SOLEIL, Gif-sur-Yvette, FRANCE

Abstract

The construction of SOLEIL, the French new SR facility, was launched in Jan 2002. All the major components have been ordered and some have already been delivered. Some innovative development have been initiated specifically for SOLEIL and are described hereafter. In order to provide the best performances, significant attention was paid at each design stage (optics, magnets, BPM, vacuum and RF systems,..), involving a large effort of simulation, using 6D tracking codes, or evaluating in detail the contribution of each component to the machine impedance.

INTRODUCTION

The main characteristics of the SOLEIL project and accelerator systems were described in [1] and [2]. The construction of the building has started in Aug 2003 and will enable a progressive beneficial occupancy from summer 2004 onwards. It is foreseen to achieve the commissioning of the 100 MeV Linac by the end of 2004, of the 3 Hz Booster in spring 2005 and of the 2.75 GeV Storage Ring by the end of 2005. 12 beamlines shall enter into operation in 2006 among which 6 require insertions devices, described in [3]. Here follows a progress report on the main sub systems.

100 MEV LINAC

The 100 MeV LINAC is being constructed by THALES and will be delivered as a "turn-key" equipment before the end of this year. It will integrate 2 "LIL" accelerating sections donated by CERN. As of June 2004, all the main parts of the LINAC are completed. The two klystron modulators have been tested at nominal power. All the magnetic lenses, steerer and quadrupole magnets, and beam diagnostics are built. The bunching accelerating section is under HF tests. The electron gun is equipped with a fast cleaner that allows to eliminate electrons outside the 2 ns short pulse. The injector part i.e. gun, cleaner, pre-bunching cavity and magnetic lens, will be tested with beam in July at THALES premises. The system will be delivered with its own local control system, using Labview applications, and will be linked later to the TANGO control system of SOLEIL. The installation of the LINAC and of the transfer Line from LINAC to Booster will start in September, with the aim of having completed the commissioning around the year end.

BOOSTER PROGRESS REPORT

All the 36 dipole magnets were delivered by SIGMAPHI by the end of 2003. Mappings were performed on 2 magnets and are in good accordance with the modelling. A campaign of systematic relative comparison of the integrated field of all the magnets is undergoing, using a travelling coil bench. Over the first 20 magnets measured, the spread at max field (0.74 T) is within ±0.15 % that is a factor of 2 below the tolerance (±0.3%). At injection field (0.027 T), the measured spread is enlarged up to ±0.5 % due to remanent field. It is planned to sort the magnets before installation so as to minimise the induced closed orbit errors, as no correction is foreseen at high field.

The 44 quadrupoles are under construction at Budker Institute and will be delivered in two batches by mid July and mid August 2004. A prototype has already been assembled and field mapping gave good results on the relative transverse gradient variation.

The 28 sextupole magnets have been built by SEF and delivered. The 44 steerer dipole magnets have also been built by SEF and will arrive in July 2004.

All the girders and supports have also been ordered. A prototype has already been delivered and tested with the magnets. They will all be delivered by September 2004.

All vacuum chambers are being manufactured by RIAL. They will be delivered in few batches, the last one being expected in October 2004. A prototype of a long dipole-sextupole-quadrupole chamber was already delivered and fitted inside the magnets.

The injection and extraction septum and kicker magnets, have been ordered. The pulsers are being built in-house.

A 35 kW-352 MHz solid state amplifier will power a 5-cell copper cavity of the LEP type, donated by CERN. The complete booster plant, amplifier and cavity, was successfully tested up to 30 kW in June 2004 [4].

The 3 Hz dipole and quadrupole power supplies (PS) are being built by BRUKER. The detail design, derived from that of the SLS booster has been approved in June. The delivery on the site is scheduled for February 2005. The steerers PS were also ordered at BRUKER, and were delivered at the end of May. The 2 sextupoles PS are being built in-house.

The BPMs will be equipped with the same electronics developed for the storage ring. The other diagnostics (beam viewers, light and currents monitors, tune monitors,..) will be available in time for installation.

The booster installation is planned from October to December 2004 and the equipment tests will follow from January to mid March 2005, before starting the commissioning with beam.

STORAGE RING MAGNETS

Storage Ring Dipoles

All the 37 dipole magnets (32 for the SR + 1 ref.+ 4 for the Booster to SR transfer line) have been delivered by TESLA beginning of 2004. Magnetic measurements are under progress using an Hall probes bench, to perform mapping in Cartesian coordinates, and another bench with a stretched wire to perform integrated field comparison.

Four dipoles (including the prototype) have been measured with BCH15 at the nominal field of 1.71T. The measured magnetic length of 1055.5mm is larger than the expected one (1052.43mm). The transverse homogeneity of the integrated field was deduced from the mapping, taking into account the real curved trajectory (Fig. 1). Harmonic components deduced from polynomial analysis in the good field region (±20mm) are very close to the expected ones.

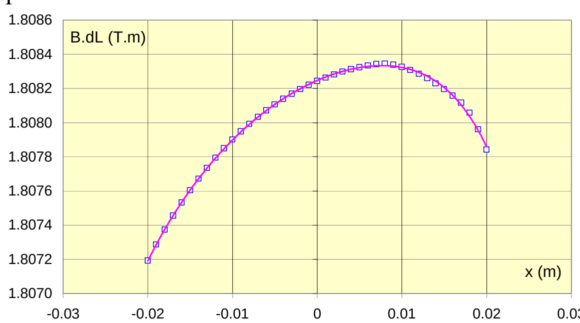

Figure 1: Transverse Field Homogeneity in SR Dipoles.

Measurements are now focusing on the comparison of series dipoles. Up to now, 10 dipoles have been measured and the maximum difference between magnets, is $\Delta BL/BL < 2.2 10^{-3}$, which is in line with the 1.10^{-3} r.m.s. value distribution expected over the 32 dipoles.

Storage Ring Quadrupoles

The 160 quadrupole magnets are being built by DANFYSIK. Two prototype magnets were delivered in June and are being measured at SOLEIL on a rotating coil bench that provides accurate harmonic analysis. All quadrupoles will be measured on that bench so as to determine and finely adjust the position of the magnetic axis with respect to the supporting girder (± 50 µm).

Storage Ring Sextupoles

The 120 sextupole magnets are being built by SIGMAPHI. The first prototypes have been assembled and are being measured at SIGMAPHI.

STORAGE RING GIRDERS

56 girders will support the 160 quadrupoles and the 120 sextupoles. The 32 dipoles will be sitting on the extremities of 2 adjacent girders. The SR girders have 4 different lengths, from 2.47m to 4.80m, depending on their position in the lattice and the number of magnets they bear. They consist in a welded steel structure of trapezoid section, linked to the ground by 2 stands. These stands include 3 jacks with roller bearings, thus allowing vertical and horizontal movements of the girder in order to set the magnet group axis on the reference beam axis. After setting, the girder is strongly fastened to the stands by a double clamping system. This achieves a high stiffness link between girder and ground, resulting in low amplification factors of the vibrations and high eigen frequencies (lowest mode @46Hz). The girder movements will be monitored during the setting operations by electronic sensors, and the vertical position long term drifts will be monitored during machine operation by an hydrostatic levelling system (HLS) .

STORAGE RING RF SYSTEM

In the storage ring, two cryomodules [5], each containing a pair of superconducting cavities will provide the maximum power of 600 kW, required at full beam intensity and with all the insertion devices. Each of the four cavities will be powered with a 190 kW-352 MHz solid state amplifier consisting in a combination of 315 W elementary modules (about 750 modules per amplifier) [4]. The 3000 amplifier modules, based on a technology developed in house, with MOSFET transistor, integrated circulator and individual power supply, are being fabricated by BBEF.

The storage ring RF system will be implemented in two stages : Cryomodule n°1 with two 190 kW amplifiers for the commissioning start in May 2005, that will enable operation up to 300 mA, and the complement of the system, about one year later. The cryomodule prototype that was successfully tested on the ESRF ring in 2002, is being refurbished and will become cryomodule n°1. The second cryomodule will be ordered soon to industry.

STORAGE RING POWER SUPPLIES

The manufacture of the 160 quadrupole individual PS is being made by HAZEMEYER. The digital regulation loop (specific development) was validated in February and the reception of the prototype was made in June with a delivery at the end of July of the first 5 units. HAZEMEYER is also building the dipole and 11 sextupole family PS, on the same basic design. The 150 power supplies for the correctors are being made by BRUKER with the first 8 units to be delivered in July.

STORAGE RING VACUUM SYSTEM

The stainless steel vacuum chambers of the dipoles are being built by SDMS, who are also building the extruded aluminium vacuum chambers for the quadrupoles and sextupoles. The extruded sections were produced by PANDOLFO and delivered to SDMS at the end of May. SAES GETTER will perform the NEG coating on these vessels according to the method developed at CERN. The design of the bi-metal CONFLAT flanges was optimised by adding an HF short-circuit that reduces significantly their contribution to the machine impedance [6] and the order was placed to ATLAS. The crotch absorbers and the BPM/bellows assemblies were ordered recently. A frame contract was signed with VARIAN for the supply of the ion pumps and their controllers, and with MKS for the residual gas analysers. All these equipment will be delivered in time, the main chambers being however on the critical path.

DIGITAL BPM ELECTRONICS

SOLEIL small beam (down to 5 µm rms vertically) is expected to be stabilized within 0.2 µm rms with a closed orbit correction based on 120 Beam Position Monitors (BPM) and 56 correctors in each plane. A Fast global Orbit Feedback system (FOFB) will also be implemented using the same BPM and additional air coil correctors. A dedicated electronics called LIBERA provides a new an innovative feature for the BPM : the four electrodes signals are multiplexed to four RF channels in order to reach the micron level stability, without current and bunch pattern dependence. After amplification, the RF signals are down converted by undersampling. A powerful FPGA computes the four signal amplitudes, then the X and Z beam positions. This multiplexing is not required for the 2 other operating modes, the first-turn mode required for commissioning and the turn-by-turn mode to be used for machine studies. Each BPM also provides a position interlock signal.

First results on the prototype show stability, current, and bunch pattern dependence in the micron range; the measured resolution corresponds to about 25µm for a low current beam in first turn mode; to about 5µm in turn-by-turn mode for a 10 mA stored beam, and to 0.2µm in a 700 Hz bandwidth for stored beams above 20 mA.

The fast orbit feedback calculations are directly implemented in the BPM FPGAs. Four out of the 8 fast I/O links are used as a fast dedicated network with a high reliability. A built-in FPGA serial link sends the calculated correction to the power supply of the air-core dipole magnet. In fast orbit feedback mode the 120 beam positions can be made available to each BPM at an 8 kHz rate. The system is flexible regarding the number of BPMs and correctors to use, as well as regarding the digital filtering and cut-off frequency. It will allow to optimise the fast orbit feedback efficiency.

This project has been a good example of collaboration between industry and several institutes: Instrumentation Technologies (IT) develops the BPM electronics; SOLEIL specified the system and proposed a multiplexed scheme later improved by IT; SOLEIL and ESRF proposed the FOFB architecture; SLS, Diamond, and ELETTRA also contributed.

BEAMLINE FRONT-ENDS

The design of the functional elements of the front-ends is completed. Several test samples were made to qualified the brazing of the parts made with glidcop that are integrated in the fixed and movable absorbers. The procurement of the components for the realization of the first 12 front-ends was launched.

STORAGE RING INSTALLATION

The installation of the storage ring will start at the beginning of November. A detailed program of the various tasks to be realized and of their sequencing has been set-up. All the specific handling tools have been ordered and technical assistance contracts are being placed for piping and cabling works. We plan to complete the installation within 6 months; that will enable to start the commissioning with beam before summer 2005.

THE MACHINE CONTROL SYSTEM

At the field level, the machine control system will be composed of three kinds of hardware components. The first ones, Programmable Logic Controllers, S7-314C-2DP and S7-315-2DP from SIEMENS, will manage slow and asynchronous processes. Inputs and outputs will be connected directly or via Profibus as fieldbus. The second ones are CompactPCI crates for fast acquisition and asynchronous processes. They will be equipped with the ICP-P4 processor from INOVA, Linux or Windows based, and with standardized input/output boards from ADLINK and National Instruments. Standalone motion controllers, based on DMC2182 from GALIL, will manage stepper motors as well as DC or piezo ones. Frame contracts have been set up for the supply of all these components.

These components will be connected to the higher level - operator consoles, process and archiving servers - via a switched Ethernet network, dedicated to the machine control system. To guarantee its availability, a redundant backbone will be installed. The central switch and local ones will be interconnected at 1Gb/s, and will be able to be operated later, if necessary, up to 10Gb/s. A call for tender is on progress to select the provider.

On the software side, TANGO has been selected as control-oriented CORBA framework. TANGO is an evolution of TACO, the ESRF original control system. A cooperation agreement has been set up in June 2002 to develop its functionalities, and ELETTRA recently joined it. Today, all the necessary basic functionalities, «generic» high level applications (to configure the system, to monitor values, …) and bindings to development tools like Matlab, Labview and Python, are available. Recently, GlobalScreen the software tool from ORDINAL was chosen to provide Supervision Control and Data Acquisition and is being interfaced to TANGO.

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