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First operation of SOLEIL, a third generation synchrotron radiation source in France and prospects for ARC-EN-CIEL, a LINAC based fourth generation source

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Abstract

The first results of commissioning for the French Synchrotron Radiation Facility SOLEIL at 2.75 GeV are presented. Perspectives for the fourth generation light source based on the ARC-EN-CIEL project are described.

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Keywords: Storage ring; Synchrotron radiation; Free electron laser

1. Introduction

France has a long tradition on synchrotron radiation, in the UV–soft X-ray on ACO (1973–1989), Super-ACO (1987–2003) and hard X-ray second generation light source such as DCI (1975–2003) rings at Orsay, and on the third generation hard X-ray source European Synchrotron Radiation Light Source (ESRF) (from 1992) at Grenoble. The new facility SOLEIL, aiming at providing synchrotron radiation for the French user community to complement ESRF and replace Super-ACO and DCI, consists of an injector (100 MeV LINAC and 3 Hz full energy booster synchrotron) and a 2.75 GeV storage ring of 357 m circumference. Designed as a low emittance (3.7 nm rad) synchrotron radiation source with a modified Chassman Green optics, it accommodates a total of 162 m of straight sections (4×12 m, 12×7 m, 8×3.6 m) [1], for up to 21 insertion devices (ID). High average brilliance radiation extends from the IR–UV–VUV up to the hard X-ray domain (20 keV), ranging from 10^{16} (respectively, 10^{18}–10^{20}) ph/s/0.1% BW/mm^2/mrad^2 for the bending magnets sources (respectively, ID). Electrons first circulated in a few turns (May 14th, 2006), were then stored and accumulated in early June 2006. Nowadays, a current of 300 mA has been stored. First beamlines have been opened: DIFFABS (bending magnet beamline for absorption,

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Table 1
SOLEIL characteristics

Nominal energy (GeV)	2.75
Circumference (m)	254.097
Revolution period (μs)	1.18
Number of cells/super-periods	16/4
Betatron tunes ν_x; ν_z	18.2; 10.3
Momentum compaction (α_1, α_2)	$4.38\times10^{-4}/4.49\times10^{-3}$
Relative energy spread	1.016×10^{-3}
Damping time (longitudinal, transverse) (ms)	3.27/6.56
Emittance (nm rad)	3.74
Total radiation power loss for 500 mA (kW)	575
Bunch length (ps)	13.8
Linac pulse/train duration (ns)	300/1.13 (MR) 1.3 (TS)
Linac total charge (nC)	9.3 (MR), 0.52/p (TS)
Linac energy spread (%)	±0.5 (MR) ±0.58 (TS)
Linac emittance (π mm mrad) horizontal/vertical	47 (±10)/52 (±10) (MR) 64±10/67±10 (TS)

MR: mulitbunch regime; TS: temporal structure (single pulse mode).

September 13), TEMPO (first undulator beamline, September 21st), ODE (bending magnet beamline for dispersive EXAFS, October). SOLEIL characteristics are given in Table 1.

After a long tradition in free-electron laser (FEL), both on storage ring based FELs (ACO, Super-ACO) and on infra-red LINAC based FELs (CLIO, ELSA), the fourth generation light source activity in France is based on the ARC-EN-CIEL proposal. After considering the installation of an FEL in the VUV on SOLEIL in the oscillator or coherent harmonic generation configurations, it was decided to propose an independent LINAC based dedicated facility providing coherent radiation down to 1 nm, for easier access of the users. ARC-EN-CIEL [2] aims at developing a strong synergy between the FEL and the laser communities. The innovative choice of seeding the FEL with high order harmonic produced in gas, at a high repetition rate leads to a significant shortening of the wavelength of the seed, in addition to the advantages of seeding with respect to SASE (pulse to pulse intensity stability, reduction of jitter, compactness, enhanced longitudinal coherence). Indeed, more than 70% of the users intend to perform pump-probe experiments and a high stability is requested, as discussed in the frame of the user workshop "Applications of VUV X fs tuneable sources combining accelerators and laser: "slicing" at SOLEIL and the ARC-EN-CIEL project" (February 3–4, 2004, Orsay). Besides, propositions of plasma acceleration and Thomson scattering emerged from the laser–electron beam combination. A high repetition rate (1–10 kHz) from a superconducting LINAC as forseen by the users, permits also efficient injection of the high harmonics produced in gas, and high electron beam stability. The possible implementation of the first phases in the former tunnel of the Accélérateur Linéaire de Saclay, next to SOLEIL, would make a very attractive accelerator based light source complex.

2. The third generation light source SOLEIL

2.1. The injector

The SOLEIL 100 MeV 352 MHz LINAC (THALES) produced its first beam on July 2nd. After various adjustments, the first turns and rapidly up to 2 million runs were performed in the booster, with magnets arranged in a FODO lattice, on July 23rd. The beam has been stored with an injection occurring at 3 Hz (every 340 ms) (October 8th, 2005), ramped in energy ramping at 2.75 GeV (October 13th, 2005) and extracted from the booster (May 8th, 2006).

2.2. The ring

The dipoles (TESLA), quadrupoles (DANFYSIK), and sectupoles (SIGMAPHI) were characterized in terms of magnetic axis and field properties. The quadrupole measurements led to mean (respectively RMS) position of 1.5 (respectively 8.4) μm in horizontal H, 2.6 (7.5) μm in vertical V, and 8 (40) μrad in tilt. The 124 sextupoles led to mean (respectively average) position of −3 (15) μm in H, 2 (10) μm in V and l0 (1 0 0) μrad in tilt. Main power supplies are from Hazemeyer, correctors' ones from Bruker.

The vacuum system comports the 2.5 m long dipole vacuum chambers (SDMS), aluminium with NEG coating chambers (SDMS, SAES) for all straight sections and quadrupoles. Ten 10 mm inner aperture ID vacuum vessels have been installed in the medium straight section from the beginning.

The superconducting technology RF cavities aiming at a good longitudinal stability consists of two cryomodules with two cavities leading to a maximum power of 600 kW. The first cryomodule (ACCEL) provides 150 kW/coupler and 1.5 MV/cavity at 352 MHz for 300 mA operation, while 500 mA are expected in 2007 with the second cryomodule. Each cavity is powered by a 190 kW solid state amplifier developed at SOLEIL consisting in a combination of four 50 kW "towers", combining the RF power amplified by all the 320 W elementary modules.

Various diagnostics were installed on the ring, such as a visible light monitor, a pinhole camera to measure the emittances, H and V scrapers, current monitors, beam loss monitors, and a streak camera. In all 120 temperature stabilized beam position monitors (BPM) are distributed along the ring and with the LIBERA electronic modules (I-Tec) for the control of the electron orbits with a submicron resolution. Turn by turn reading of the BPM was used efficiently during initial commissioning.

Pulsed magnetic equipments (septum magnets, kickers) are designed in house. Special care was devoted to the magnetic shield of the eddy current septum magnet for top-up injection: the stray field seen by the stored beam is reduced to 10 ppm of the main field.

The SOLEIL control system is based on TANGO, with hardware components such as Programmable Logic