STATUS AND DEVELOPMENT OF ELETTRA

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Abstract

An overview is presented of the current operational performance and the status of ongoing and future development of ELETTRA.

1 PRESENT OPERATIONS

1.1 Operating Statistics

The ELETTRA third generation light source has completed 6 and 1/2 years of operation since the start of commissioning in October 1993.

ELETTRA operated for 6192 hours in 1999, with 5088 hours (82 %) dedicated to SR users. Machine up-time for user beam time less injection time (a standard 1/2 hour per re-fill) was 89.8 %. The major cause of down-time (22 %) was due to electrical mains disturbances. When this is subtracted the efficiency is 92.0 %, slightly less than in previous years due to a single failure of the 20 kV transformer on the dipole power supply circuit. Average operating statistics over the last 5 years of regular operation show 91.3 % efficiency (93 % excluding mains disturbances).

In 2000 ELETTRA is scheduled to operate for a total of 6504 hours, 5040 hours (77.5 %) for users. The increased total number of hours, with the same number of user hours, reflects the need for more accelerator physics time to commission a number of new developments, described below. In the first 5 months the efficiency so far has been 90.4 % (91.3 % excluding mains disturbances).

Normal injection energy is 1.0 GeV, however injection has been performed throughout last year at 0.9 GeV without difficulty to permit linac control upgrades. While the normal operating energy for users remains 2 GeV a significant fraction of the time, 22 % in both 1999 and 2000 is dedicated to operation at 2.4 GeV. Despite the lower beam current (120 mA instead of 320 mA, limited by vacuum chamber heating) the increased lifetime, better beam stability and increased performance at higher photon energies is attractive to users.

Under standard conditions injection is performed once per day, the initial current of 320 mA decaying to 100 mA after 23.5 hours. Several periods with 2 injections per day have been required however during conditioning of new vacuum chambers (see below).

1.2 Understanding Beam Losses

A particular effort has been made recently to understand the cause of “spurious beam dumps” i.e. beam losses not associated with a hardware fault, which typically amounted to about 40 events per year, about a third of which could be associated with evident storms or mains interruptions. All of these losses were associated with the fast interlock system which intervenes to protect the vacuum chamber against mis-steered ID radiation beams, based on electron BPM readings. Two systems were set up to monitor the stability of various magnet power supplies mains circuits and to monitor the interlock system by registering the last 1 sec. of BPM data. The result of this analysis is that 70 % of these losses (up to 14 % of all beam losses) can be associated with disturbances of the mains (including both mains dips and micro-interruptions). The remaining 30 % (about 12 per year) can be divided equally between those in which the interlock kills the beam because a real beam movement has occurred, and those in which the beam is lost prior to the interlock action. Studies are continuing to identify the causes of these beam losses as well as to determine which are the most sensitive elements to mains disturbances.

2 ONGOING DEVELOPMENTS

2.1 Electromagnetic Elliptical Wiggler (EEW)

Further progress has been made with the correction of the orbit distortion introduced by the EEW. A slow feed-forward correction loop, acting on special correction coils on either side of the device, has allowed users to have direct control of EEW currents during d.c. operation since Dec. ‘98. The a.c. mode however introduces a regular disturbance that was not initially acceptable to users on other SR beamlines. To improve the correction it was found necessary to take into account the magnetic hysteresis by creating two calibration curves, for increasing and decreasing currents. The change in global orbit was corrected at each current step to a level of 1 μm rms, i.e. at the limit of sensitivity of the BPM system. After averaging a number of such calibration curves acceptable performance was obtained. At the same time a new system architecture has also been set up which uses the same DSP for both principal waveform generation and orbit correction. The EEW can now be operated during user shifts in a.c. mode for fixed wiggler mode settings

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(+160 A vertical field, ± 260 A horizontal field) with a slow trapezoidal waveform (1 s ramp, 5 s flat-top). Work will continue to explore the limits in frequency of the existing calibration for both trapezoidal and sinusoidal excitation.

2.2 Insertion Devices

A large effort is presently underway to increase the number of active beamlines, from 10 at present to 23, in the next 1-2 years. In the last two years 5 elliptical undulator modules (each 2.0-2.2 m long), 4 new aluminium ID vessels, 4 new bending magnet (BM) vessels as well as 6 ID and BM beamline front-ends have been installed.

Three ID straight sections will each contain two APPLE-type undulator modules with periods ranging from 4.8 cm to 12.5 cm, one of which is a novel quasi-periodic design. The five devices installed so far have all reached very good performance: rms phase errors of < 3.5 deg. (apart from the first device, 4.5 deg.) and field integrals < 2.5 Gm and 3 Gm^2, at any gap and phase [1]. Commissioning of the devices in the ring is in progress [2], including extension of the usual feed-forward closed orbit correction system to include both gap and phase.

Further to these devices the final two ID straight sections have also been dedicated; a 3.5 T superconducting multipole wiggler has been chosen for one, while a figure-8 undulator is under consideration for the other.

Having now defined all eleven ID straights, attention is turning to the use of short straights in the dispersive regions of the DBA lattice. Presently there are four possibilities for use of the longer downstream straights permitting an ID length of 1 m; in addition a further two shorter straights could be used for IDs of about 0.75 m in length. Despite the shortness such sources are still much more powerful than bending magnet sources. A prototype support structure is presently under design and construction, with installation planned for Spring 2001.

2.3 Aluminium Vacuum Chambers

In order to permit the installation of elliptical undulators, with a larger vertical radiation opening angle compared to planar devices, particularly those with large K values designed for low photon energies, it has been necessary to improve the cooling in the region of the radiation slot in the downstream bending magnets. New chambers have therefore been constructed made of aluminium alloy with integral cooling channels [3]. Four such chambers have been installed, two with an enlarged slot height of 20 mm (instead of the usual 10 mm) in the region of the light exit to ease operation of the free-electron laser (see below). In addition, four new ID vacuum chambers have been built and installed based on extruded aluminium, each 4.7 m in length, with internal/external vertical dimension of 14/17 mm [3]. Based on previous positive experience with ID vessels with no lateral pumping, these new chambers were also based on that concept.

Conditioning of these chambers has been more slow than for previous stainless steel vessels, particularly for the ID vessels, which have required approximately 100 Ah of beam dose to recover the beam lifetime. Gas bremsstrahlung levels however remain significantly higher than for other ID vessels, including the one with no lateral pumping; a change in approach will therefore be required for any future low-gap vessels.

2.4 Low-gap Electron BPMs

In an effort to improve beam orbit stability, both locally at the ID source points, as well as globally, a new low-gap BPM system is being developed, to provide stable sub-µm resolution position signals based on the following key elements [4]:

- higher sensitivity BPM geometry based on the narrow gap (14 mm) ID vacuum chamber cross-section
- a novel digital detector, developed jointly with the SLS Project (PSI, Switzerland), consisting of a 4-channel RF front-end, 4 channel digital receiver and DSP module, providing optimised resolution/bandwidth for different detector modes: closed orbit, feedback, turn-by-turn and single pass
- a stable support system for the BPM block, which is isolated from the rest of the vacuum system by means of bellows on either side
- monitoring of the residual motion of the BPM to sub-µm accuracy by means of capacitive sensors with respect to a separate highly stable (1.9 µm/°C expansion) reference column based on carbon epoxy laminate.

Measurements in July ’99 with a prototype RF front-end and digital receiver confirmed the position resolution of 1.6 µm rms in closed-orbit mode (1 kHz bandwidth). Two prototype low-gap BPMs as well as the position monitoring system were installed in January 2000. Subsequent tests have confirmed the sub-µm resolution of the position monitoring system, as well as a factor of 2.6 improvement in sensitivity, $\Delta x/(\Delta V/\Sigma V)$, of the new BPM geometry. Final system tests will begin in July.

2.5 Photon BPMs

A new type of photon BPM is also being developed for undulator beamlines [5] as a second, independent, position monitor and one that could also be used in a feedback loop for particularly sensitive beamlines. The new monitor design incorporates a custom designed electrostatic hemispherical analyser and lens system in order to perform an energy analysis of the emitted photo-electrons, thereby drastically reducing the contamination introduced by the upstream and downstream bending magnets. A prototype consisting of two blades and monitors has been constructed and installed on a beamline for tests. Results show that when the analyser is tuned to the correct energy corresponding to the undulator and the blade photoemission spectra, the sensitivity to bending magnet radiation is reduced from 15 % in the original device to less than 0.1 %, while still maintaining the same micron level sensitivity [6]. The future goal is now to design a simpler final 4-blade device, and to install two such monitors on an undulator beamline.

2.6 Transverse Multibunch Feedback

Normal operation of ELETTRA is with a controlled amount of longitudinal excitation introduced by adjustment of r.f. cavity temperatures, in order to stabilise the beam against transverse instabilities, as well as to increase the lifetime. To permit stable longitudinal conditions to be obtained therefore requires overcoming transverse multibunch instabilities and to this end a digital transverse feedback system is being developed, in collaboration with the SLS Project [7]. Horizontal and vertical kickers, constructed at PSI, and the new BPM r.f. front-ends were installed in April this year and first tests have been carried out [8]. The timing system, remote control electronics and software are under development. Following delivery of r.f. amplifiers and the first DSP boards, first complete system tests in one plane will begin in the second half of July.

2.7 Superconducting 3^rd^ Harmonic Cavity

In order to offset the reduction in beam lifetime that will result when the ELETTRA beam is fully stabilised, an idle superconducting 3rd harmonic cavity is being developed, in collaboration with CEA-DAPNIA (Saclay, France) and SLS [9]. The first phase of the project, involving the cavity design, construction and characterisation of a Cu model and preliminary cryomodule design is nearing completion. Copper model tests began in May. Plans for the second phase, which foresees installation of the final system in March 2002, are presently under discussion.

2.8 Free-Electron Laser

A storage ring free-electron laser is being developed by a European collaboration as a future facility for users in the UV/VUV range (350-190 nm) [10]. The project makes use of two 10 cm period elliptical undulators arranged in an optical klystron configuration. First lasing was obtained at 350 nm on February 29th this year; 220 nm was achieved on May 27th. As well as studies of FEL operation and its effect on the electron beam, future plans are to proceed to shorter wavelength and to prepare for pilot experiments.

3 PROPOSED MACHINE DEVELOPMENT PROJECTS

3.1 Longitudinal Multibunch Feedback

The development of a longitudinal multibunch feedback system is proposed in order to guarantee longitudinal stability under all machine operating conditions. The system will capitalise on the modular design already developed for the digital processing of the transverse feedback and will adopt the same ADC, DAC and DSP board types running different filter software. Work on the longitudinal system, in collaboration with SLS, is planned to start after this Summer.

3.2 New Injector

A major handicap to the efficiency, stability and future potential of ELETTRA is the lack of a full-energy injector. During the last year a significant effort has been dedicated to the completion of a design study for a full-energy injector based on a 100 MeV linac and 2.5 GeV booster synchrotron [11]. The booster would be located in the presently open area on the inside of the ring and could be constructed and tested without interference to storage ring operation. A relatively short shut-down of 3 months would be required for connection to the storage ring and for commissioning. Following a major project review in May, a final optimisation of the design is presently underway. The go-ahead for construction could be obtained before the end of this year.

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