ELETTRA PRESENT AND FUTURE UPGRADES

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Abstract

During the last year, the third generation synchrotron light source ELETTRA could fully benefit of several upgrades that have been implemented in the frame of a project to enhance the quality of the light source. The super conducting third harmonic cavity, the feedbacks, the realignment of the whole ring and other improved devices have allowed to further, significantly optimize the beam stability and lifetime, as well as the operability and uptime of the facility. At the same time two large-scale projects are underway that will change the perspectives of the whole ELETTRA laboratory, namely the full energy booster injector and the single pass X-ray FEL FERMI@Elettra, based on the existing linac. Their status will be presented here together with the overview of the existing light source.

OPERATIONS

During 2004 ELETTRA operated for 6216 hours, of which 4664 dedicated to user experiments, with a user uptime of 94.5% (excluding beam losses due to storms). 6168 hours are foreseen in 2005, of which 4832 dedicated to user experiments. Nineteen beam lines are fully operational, two in commissioning phase. Fourteen of the beam lines use Insertion Devices (IDs). The machine is operated at 2 GeV for 73.6% of its user time whereas the 25.4% is at 2.4 GeV. The few bunch operational mode has also been requested in 2004 for about 5% of the user dedicated time. A similar quota has been requested in 2005. The few bunch operational mode consists of four equidistant bunches at 2 GeV with a total initial current of 40 mA and two hours lifetime. In this mode of operation the ring is refilled every eight hours.

With the third harmonic cavity fully operational, the beam lifetime at the injection current of 330 mA (2 GeV) was lengthened by a factor of three. This allowed to increase the interval between two subsequent refills from 24 to 36 hours. The Landau damping induced by the cavity results in a totally longitudinally stable beam. By adding the effect of the horizontal and vertical transverse feedback systems, an electron beam completely free of multi-bunch instabilities is obtained, which has significantly improved the brightness of the photon beam delivered to the users.

A complete realignment of the machine was performed in 2004. The outcome showed an overall improvement on operability due to minimization of the linear coupling and an estimated increase in brilliance by 50%.

In the framework of the EUROTeV/GANMVL European Project on remote operations, ELETTRA has been remotely refilled for user operations from the DESY laboratory in Hamburg and accelerator physics measurements have been performed from the ESRF in Grenoble.

MACHINE UPGRADES

In parallel to improved operations, the continuous development of the machine and the refinement of the quality of the delivered beam are supported by major upgrades and by specific projects. The RF upgrade and the orbit feedback systems are the most significant.

RF Upgrade

A project of upgrade of the existing storage ring RF system has been started in order to provide the necessary safety margins, when all IDs are operational (with a slight increase in the Touschek lifetime), and in view of a possible increase of the beam current and energy.

The design strategy has taken into account the need of minimising the interference with the operation of the machine and the requirement of keeping the space for the RF in the machine unchanged. The upgrade project is also consistent with other facility upgrades, such as the new full energy injector. This has lead to a gradual upgrade strategy based on three stages.

During the first phase (Phase A) one of the existing 60 kW plants is upgraded to 150 kW. Phase B consists of replicating such improvement on a second plant. As an alternative to performing the same upgrade on the remaining two plants, the possibility of using super conducting cavities has been considered for Phase C.

Phase A is in progress. It basically requires the replacement of the 60 kW amplifier with a 150 kW one and the substitution of one cavity with a similar ELETTRA type one featuring enhanced cooling system. This last activity has already been performed.

For the 150 kW amplifier, since the RF frequency of 500 MHz is well within the UHF range, one can take advantage of the solutions adopted in professional broadcasting systems. Therefore the 150 kW amplifier will be made by combining two 80 kW Inductive Output Tubes (IOTs). This will be a novel solution for a light source, and is being adopted for new machines under construction. IOTs are widely used in UHF TV applications due to their general higher efficiency and moderate loss of efficiency at reduced power levels. In the TV field they have almost completely replaced klystrons as the preferred electron tube for the final amplifying stage. Compared to klystrons, IOTs offer additional advantages in terms of electrical power and cooling requirements, physical dimensions, maintenance and replacement. The main drawback is related to the lower gain, which has to be compensated by a higher power solid-state preamplifier.

Each of the two IOTs will be able to work in standalone mode, thus increasing operational flexibility. The combining system will consist of a switch less combiner. This device is made up of two hybrids and a variable phase shifter. It features only 3 dB loss in case one tube is out of service and allows for hot adjustments of the system. The maintenance of one tube, for example, could take place with no interference to the operation of the associated one. These types of combiners have been used for years and their principle of operation is now completely understood.

The power amplifier will be purchased as a turnkey system from industry. The call for tender is now in progress. Installation of the new amplifier in the service area is planned in the second quarter of 2006. The connection to the cavity and operation in the storage ring is foreseen by the end of year 2006.

Orbit Feedback Systems

After the cure of coupled bunch instabilities, which, as described above, lead to an improvement of the photon beam brightness, efforts are focussing on orbit stability issues. Fast local feedback systems using dedicated Beam Position Monitors (BPM) and digital detector electronics have been developed and installed in two straight sections to improve the stability of the electron beam at the ID source points [1]. Stability in the sub-micron range over frequencies up to 250 Hz has been achieved by combining a PID regulator with a series of specific notch filters centred on the periodic components of the noise spectrum.

Although several local feedback systems may be installed they would only correct the orbit at ID but not at bending magnet source points; moreover cross talk between local control loops could become an issue with many local feedbacks installed. A global orbit feedback system has therefore been designed that will take advantage of all of the existing rhomboidal BPMs and corrector magnets of the storage ring. The existing BPM system will be upgraded with digital detector electronics providing position measurements with sub-micron resolution and fast data rate. A distributed processing system based on twelve stations equipped with standard VME CPU boards will share beam position data by means of a commercial real-time fiber optic network and set the calculated correction values on the steerer power supplies through dedicated analog links.

FULL ENERGY INJECTOR

The construction of the ELETTRA full energy injector can be divided in two phases. A first phase, which includes the machine design, started in 2000 and lasted about three years, within limited budget resources. In the second part of 2004 a general design review was initiated in view of full funding in 2005. The second construction phase formally began on the 1st of March 2005 with the release of the tender for the booster and transfer line magnets. The bids are presently being evaluated.

The full energy injector consists of a 100 MeV pre-injector plus a 2.5 GeV booster synchrotron. Maximum booster energy ramping frequency is 3.125 Hz. Figure 1 shows the two possible booster optics, the 226 nmrad Normal Emittance Optics (NEO) and the 166 nmrad Low Emittance Optics (LEO) in view of top-up operation. The good field region in the dipole magnets is HxV=48x18 mm^2. This results in a reduced magnetic gap from 30 down to 22 mm. The narrower gap allows for decreasing the number of power supplies from 4 to 2, while still keeping the voltage of each of them within the low voltage limit. This has a positive effect on the magnetic field quality and uniformity and limits the total electric power needed to continuously run the booster.

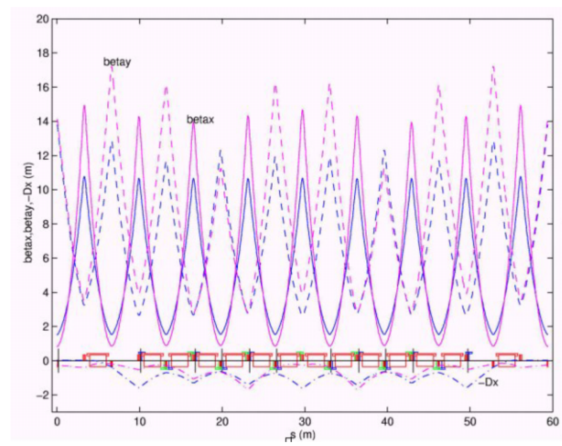

Figure 1: Half booster lattice: NEO optics in blue and LEO in pink.

A first analysis of a possible top-up scheme has been carried out. We expect to keep the beam current in the storage ring constant within a dead band of typically ±1.0 mA, over 330 mA nominal stored current. The required injected electron charge is expected to be about 0.1 nC in a single bunch. Depending on the storage ring beam lifetime and the chosen dead band, the time between subsequent injections is between 5 and 10 minutes.

Part of the booster components have been procured and are already in house. This is the case for the radio frequency cavity and for all the septa magnets, including the upgraded storage ring injection septa that are needed to inject at full energy and in top-up. Installation is scheduled during the summer 2005 shutdown. The pre-injector linac accelerating sections, donated by CERN, are also in house. The high voltage modulator for the klystron has been assembled and tested. Parts of the booster control and diagnostic system have been tested.

A review of the budget for the building and for the technical plants has shown a cost increase over the years during which the project has been in stand-by. A general revision, oriented to budget saving, has been thus decided. The wall between booster and technical gallery has been eliminated, as shown in figure 2, allowing for a smaller building and simpler technical plants.

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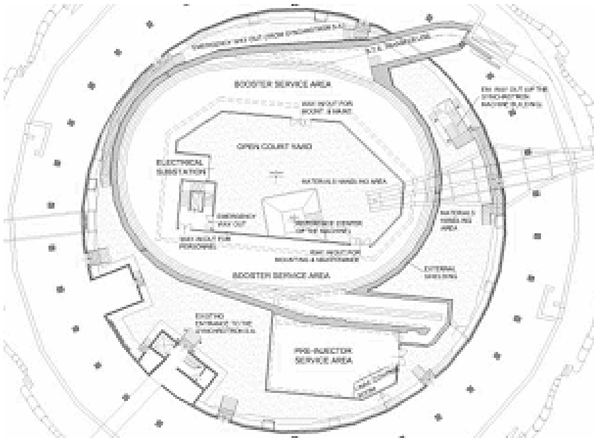

Figure 2: Booster building reviewed concept.

FERMI@ELETTRA

FERMI@Elettra is the new photon source based on a single-pass Free-Electron Laser (FEL) that will be built and will remarkably enhance the capabilities of the ELETTRA laboratory. It will be one of the first FEL user facilities in the world operating at wavelengths in the UV to soft X-ray range and will provide ultra-high brightness photon beams between 100 and 10 nm. FERMI@Elettra will be developed in two phases, operating from 100 to 40 and from 40 to 10 nm respectively. The facility will make full use of the existing ELETTRA linac that will be appropriately upgraded for FEL operation in order to generate high peak-current and low-emittance electron bunches at the entrance of the undulator chain. A new SLAC/BNL/UCLA-type photo-injector will be adopted, which will be eventually operated at 50 Hz. A state-of-the-art timing and synchronisation system based on laser technology will provide synchronisation between subsystems down to few tens of fs.

Two different undulator chains, FEL1 and FEL2 respectively, will cover the range 100-40 and 40-10 nm providing tuneable and polarized radiation. The FELs will be of the harmonic generation type driven by seed lasers. In the case of FEL2 a cascade of such FELs will be adopted. In this scheme [2] the transverse and longitudinal coherence properties of the output radiation follow those of the seeding beam. The harmonic cascade FEL process is started by a temporally and transversely coherent input signal from a conventional laser in the ultraviolet region (e.g. 200-300 nm). This input is then effectively frequency-up shifted via resonant electron-radiation FEL interaction in a series of magnetic undulators to produce short wavelength radiation with excellent transverse and temporal coherence (see Fig. 3). The final sections of the FELs will adopt APPLE type undulators for full polarisation control.

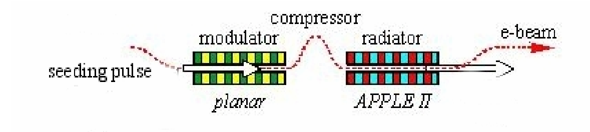

Figure 3: Set-up of FEL1 based on a single-stage harmonic generation scheme. A two-stage cascaded harmonic generation configuration is foreseen for FEL2.

The design and commissioning of the new machine will also profit from the experience gained during the past years in the development of the ELETTRA storage-ring FEL [3]. This facility (supported by EUFELE, a European Commission funded project) provides FEL light in the spectral range from the visible down to 177 nm, which is the shortest wavelength ever obtained by a FEL in an oscillator configuration. If operated in a seeded mode, after removing the optical cavity, the ELETTRA storage-ring FEL is the ideal test facility in view of the first phase of FERMI@Elettra. This configuration will be tested in the framework of EUROFEL, a large-scale project funded by the European Commission, which supports design studies for the major new generation FEL sources in Europe.

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