ACCELERATOR ACTIVITIES AT ELETTRA

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Abstract

An overview is given of accelerator activities at the third generation light source ELETTRA. In routine operation since late 1993, the performance of the 2.0 to 2.4 GeV storage ring has steadily been enhanced. Activities focus on improving the fundamental criteria of a synchrotron radiation facility: brightness, lifetime, stability and reliability. A progress report is given of major ongoing activities: a passive superconducting 3rd harmonic cavity for lifetime improvement, fast and slow feedback systems for beam stability, new insertion devices and the storage ring FEL for greater brightness, improved diagnostics, upgrades to the RF system and vacuum chamber and a full energy injector.

1 OPERATIONS

ELETTRA typically operates for 6500 hours per year of which 5000 are dedicated to User experiments. 2002 will have a reduced number of User hours (4700) to allow the installation of numerous upgrades, but maintain the same number of machine dedicated time for new system commissioning. The overall uptime of the facility, as in previous years, is high (96% in 2001 excluding external disturbances). At present there are twelve operational beamlines, five in commissioning and five in construction or design. Fourteen of the beamlines use insertion devices and the rest bending magnets.

The alignment of the storage ring magnets was started the last year. After finishing the installation of the necessary stable bases and target holders in the first half of 2001 a laser tracking system was used for the complete survey of the magnet positions and the alignment of about one fourth of the storage ring containing the most miss-aligned elements. The laser tracker proved to be an efficient device and allows to take advantage of relatively short shutdown periods to perform re-alignment of magnets.

2 ACCELERATOR DEVELOPMENTS

2.1 Feedback and Feedforward Systems

Last year the Transverse Multi-Bunch Feedback (TMBF) was commissioned and put into regular operation during User shifts at 2.4 GeV [1]. The enhancement in beam quality is seen in the undulator spectra where higher harmonics are 30 to 50% brighter. The TMBF is a bunch-by-bunch system where the positions of each bunch are individually detected and corrected so that any potentially excited transverse coupled-bunch mode of the stored beam can be damped. The additional requirements for flexibility and availability of diagnostic tools have led to the development of a novel digitally based scheme where the position data from the 432 2-ns spaced bunches are processed by 24 Digital Signal Processors (DSP). The DSPs concurrently execute the feedback digital filters associated to each bunch and run data acquisition and diagnostics tasks. Bunch-by-bunch data are stored in up to 96 Mbytes of memory allowing high-resolution measurements, which can also be used to change the feedback filter coefficients on the fly.

Commissioning activities focused on finding the best technique to make feedback operation effective and transparent even in presence of the considerable betatron tune variations that can be observed when opening/closing some insertion devices and during the energy ramping from 0.9 to 2.0 or 2.4 GeV. A new family of 5-tap FIR (Finite Impulse Response) digital filters featuring compensation of the tune variations was developed and is implemented. The possibility of using an adaptive tune tracking technique was also demonstrated. It consists of periodically measuring the tune by creating short anti-damping/damping transients on one or a few bunches, which are transparent to User experimental activities, calculating the feedback digital filter coefficients according to the updated tune value and downloading these coefficients into the running DSPs. A further objective of TMBF commissioning was the overall identification of machine operational conditions that simultaneously guarantee reliable energy ramping without beam loss together with an improved beam for Users featuring damped transverse and longitudinal coupled-bunch oscillations. A suitable set up was found at 140 mA, 2.4 GeV where longitudinal instabilities are damped by an appropriate setting of the cavity temperatures and Higher Order Mode shifters, horizontal and vertical instabilities are damped by a slightly changed optic and the TMBF respectively.

The future installation of a complementary Longitudinal Multi-Bunch Feedback (LMBF) will make the scenario for the different machine operating conditions simpler. The LMBF uses the already developed digital processing hardware of the TMBF running the appropriate software. The kicker, designed by the Swiss Light Source (SLS) in the frame of an effective collaboration, will be installed within the first half of 2002 and first tests performed in the second half.

Two low-gap BPM's have been installed either side of undulator U5.6 in a long straight section [2]. These BPM's are based on a new mechanical design of the sensor that takes full advantage of the 14 mm low gap ID chamber and on detector electronics adopting modern digital demodulation techniques. The low-gap BPM's have been integrated in a Local Orbit Feedback (LOF) system prototype that utilises a standard PID controller to reduce the low frequency components of the beam noise spectrum, while dedicated selective narrow-band filters concurrently suppress the periodic components, i.e. 50 Hz and its harmonics. The LOF loop has been closed at a rate of 8 kHz in both vertical and horizontal planes and stabilises the position signal in the 0-80 Hz range to 0.2 μm.

The high accuracy and resolution of the low gap BPM's have been used to compensate the magnetic field errors of the fast switching electromagnetic elliptical wiggler (EEW). The wideband signals of these BPM's are iteratively analysed and digitally processed and a feedforward table is generated. The table is used to compensate to the beam noise level the dynamic effects of the EEW at any operating frequency up to 90 Hz and above [3].

2.2 Superconducting 3rd Harmonic Cavity

The reduction in lifetime that will result from a beam with no coupled-bunch instabilities will be compensated by an idle super-conducting 3rd harmonic cavity [4] that is has been developed in collaboration with CEA-DAPNIA (Saclay, France) and SLS. The cavity, a scaled version of the SOLEIL 350 MHz cavity, will have a nominal field of 4 MV/m at 1499 Mhz and is expected to more than double the overall lifetime. The cavity constructed at CERN has undergone pre-testing in the final cryostat at SACLAY. Delivery and installation in the ring will be made during summer this year. The cryostat will be cooled by a He cryogenic plant working in closed circuit mode, rated at 65W. The He compressor and cleaning system will be located outside the experimental building whilst the refrigerator and a 500 litre liquid He dewar, will be placed in the storage ring service area.

2.3 RF Upgrade

An Upgrade of the storage ring RF system is underway to provide more margin in view of future insertion device installations. The multi-phase upgrade involves the replacement of two of the four existing 60 kW plants by 180 kW plants. The removed amplifiers will be reused for the booster synchrotron. A set of Inductive Output Tubes (IOT's) will be adopted as the RF amplifiers [5] rather than conventional high power klystrons. IOT's have the advantage of higher efficiency, smaller size, ease of operation and installation and a large purchase market. 50 or 80 kW tubes will be combined by switchless combiners. Calls for tender for the amplifiers are being issued. The associated ELETTRA type cavities will also be upgraded to more recent versions that are being used at ANKA, the SLS and in the future INDUS-II. Installation of one plant and associated equipment is planned for the end of 2003.

2.4 Full Energy Injector

The full energy injector is at an advanced stage and is based on a 100 MeV linac pre-injector and a 2.5 GeV booster synchrotron. The construction phase started last year and activities have focused on the study of the overall infrastructures and of key components. The booster a two fold FODO structure with missing magnets, will be placed in the inner side of the storage ring building. The lattice has recently been optimised for a lower emittance and increased efficiency whilst maintaining the previous geometry and number of dipoles and quadrupoles [6]. The synchrotron will have a repetition frequency of up to 3Hz, has a 1 mm thick stainless steel vacuum chamber and uses sextupoles to maximise the dynamic aperture. The RF system will use one of the storage ring amplifiers that will be available after the RF upgrade. The amplifier will power a DORIS type five cell cavity that has already been purchased. The pre-injector is being constructed in-house and will utilise sections of the decommissioned LIL injector. Assembly of the gun system and modulator are progressing and completion of the pre-injector is planned for the first half of 2004. Construction of the booster to storage ring tunnel will initiate early summer 2002 and main buildings will be ready to house the pre-injector late next year. Orders to industry for magnets, main power supplies and injection and extraction septa will be issued this year. First beam will be extracted in the second half of 2004.

2.5 NEG Coated Vacuum Chambers

At the start of the year a pump free NEG coated extruded aluminium vacuum chamber for an insertion device (Figure-8) was installed. Conditioning time was comparable to a stainless steel chamber in addition to very low gas Bremsstrahlung radiation [7] that was reduced by almost two orders of magnitude compared to a similar chamber without the coating.

3 PHOTON SOURCE ACTIVITIES

3.1 Superconducting wiggler

The superconducting wiggler [8], (construction at the Budker Institute of Nuclear Physics), will provide photons in the 10-25 keV range with a factor of 3 (14) improved flux at 12.5 keV (25 keV) compared to the already installed 57-pole W14.0 wiggler. A further significant improvement will be gained from the smaller source size resulting from the shorter wiggler length (1.4 m instead of 4.5 m). The device has recently undergone the factory acceptance tests and has reached the nominal field of 3.5 T. Installation in the ring is planned for early autumn 2002, it will be placed in a long straight section together with the superconducting third harmonic cavity.

3.2 Figure-8 undulator

A high flux of linearly polarized photons in the 5 to 10 eV range is requested by the IUVS beamline. To overcome the problems of very high on-axis power density that a conventional undulator would generate at such low photon energy a Figure-8 structure has been adopted [9]. The results of Helmholtz-Coil measurements on a random sample of magnetic blocks in order to cross-check the manufacturer's magnetic data showed good correlation between the two sets of measurements. Based on this data, a sorting algorithm has been developed in order to limit the amount of random field and trajectory errors in the assembled device. Measurement errors and volume inhomogeneity in the magnetic material will, however, ultimately limit the obtainable field quality. Therefore the design of the mechanical arrays has foreseen the possibility of two compensation techniques for post-assembly correction. The first is based on the displacement of selected blocks from their nominal position ('virtual shimming'), already successfully applied to the APPLE-type elliptical undulators. The second will use small ferromagnetic screws located between the magnetic blocks the vertical position of which effect the field distribution. Construction of the device is underway and installation of the first of two sections will be done in the summer shutdown.

3.3 Short Insertion Devices

With the eleven long straights filled with IDs in the near future, the possibility of installing short IDs in the dispersive regions has been tested. A 1 m long prototype device [10], which can provide about 20 times more flux and 200-300 times more brightness than a bending magnet source, has been installed in June 2001. Effects of the device on beam dynamics and closed orbit are negligible.

3.4 Storage Ring Free Electron Laser

The European storage ring Free-Electron Laser project at ELETTRA made further significant progress in the last year. In February 2001 lasing was achieved at slightly less than 190 nm using specially developed oxide multilayer-coated mirrors. This represents the current shortest wavelength reached by any FEL oscillator. With the goal of increasing the FEL beam extracted power, lasing experiments were recently carried out at a higher energy of the stored electron beam. A new phase of the FEL project called EUFELE (European Free-Electron Laser at ELETTRA as a VUV Research Facility) started in December 2001 under a second EC contract. The main objectives of the three-year EUFELE project are, to improve the macro temporal stability of the FEL beam both to permit two-colour (“pump-probe”) experiments as well as improving single beam experiments, to extend the operation to shorter wavelength and to develop the necessary experimental instrumentation.Measurement of the detuning curve using the RF modulation technique has been performed showing the different dynamical regimes that can be expected from the laser when changing conditions of synchronization [11]. The Q-switched mode of operation also gave promising results providing a macro-temporal structure regularly pulsed at the RF-sweeping frequency of 2 Hz.

4 FUTURE DEVELOPMENTS

To further increase the brightness, coherence and temporal structure of photon beams a FEL based on the existing linac has been proposed: FERMI@ELETTRA. This new development, by Sincrotrone Trieste, the INFM and other institutes, answers a recent call for proposals made by the Italian government for a “multipurpose, pulsed laser X-ray source”. The project is articulated along three lines of development allowing gradual improvements and consolidation of maturing technologies, in addition to taking advantage of the full availability of the linac after installation of the booster. The proposal will, furthermore, utilise schemes to seed the FEL whenever possible for the production of controlled narrow bandwidth radiation. The first phase will use the existing linac at 1.0 GeV with a new photoinjector and bunch compressor to generate high quality beams for the production of 40 nm polarised radiation (and if sufficient request 100 nm). The second phase requires increased electron beam quality for a second beamline at 10 nm. The third phase (done partially in parallel with the second) requires extending the operational energy the linac to 3.0 GeV and an increased improvement of beam quality for the production of 1.2 - 1.5 nm radiation.

5 REFERENCES

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