ELETTRA STATUS PRESENT UPGRADES AND PLANS

E. Karantzoulis†, A. Carniel, M. Cautero, B. Diviacco, S. Krecic, R.Visintini
Elettra – Sincrotrone Trieste, Italy

Abstract

The operational status of the Italian 2.4/2.0 GeV third generation light source Elettra is presented together with an account of some present upgrades and plans for the near future.

INTRODUCTION

Located on the outskirts of Trieste, Elettra operates for users since 1994 being the first third generation light source for soft X-rays in Europe. During those 23 years many improvements were made in order to keep the machine updated and therefore competitive with the other more recent and modern light sources already designed to operate in top-up. Following the successful set in operation of the full energy injector in 2008, after 14 years of energy ramping, Elettra established top-up operations [1] in spring 2010, although not originally designed for it. Operating in top-up proved to be and still is very beneficial for the machine [2]. Except the above-mentioned big upgrades other minor ones added aiming to the smooth and reliable operation of Elettra as reported previously [3-5]. At the same time studies based on various upgrade scenarios that define the upgrade Phase I were made. That phase included the possibility of decreasing the emittance [3], controlling coupling [6], rearranging the space for a larger short straight section to be used for additional longer insertion devices and plans for upgrading the energy from 2.4 to 2.5 GeV [5]. Looking into the future an ultra-low emittance successor of Elettra was studied [7, 8] with a bare emittance of 250 pm-rad i.e. 28 times smaller than that of the actual machine.

ELETTRA STATUS

Elettra operates 24 hours/day, seven days a week delivering more than 5000 hours/year of synchrotron light from IR to soft x-rays to 28 beam lines of which 10 are served from dipoles. Two beam-lines use light from a superconducting 49-pole, 64-mm period, 3.5-T wiggler.

Many types of insertion devices are installed such as planar, Figure-8, APPLE II, electromagnetic, superconducting while one beam line uses a canted set of APPLE II type undulators. All twelve long straights are occupied and dispersive short straights are used for insertion devices. Thus a short undulator serves the TwinMic beam-line while there are plans for another XAFS beam line served by a short 2-T wiggler.

The machine consists of a 100-MeV linac, a 2.5-GeV booster and a 2.0/2.4-GeV storage ring. At about 75% of user dedicated time Elettra operates at 2 GeV while for the remaining 25% at 2.4 GeV, being the only facility to operate at two energies (both in top-up). The main operating modes are multi-bunch with a dark gap of 42 ns and hybrid (at 10% of the total user beam time) i.e. multi-bunch with one (for time resolved experiments) or two single bunches (distant 40 ns in a dark gap of 120 ns for pump and probe experiments). The operating intensities are 310 mA at 2 GeV and 160 mA at 2.4 GeV with 5 mA single bunch(es) is (are) added when in hybrid mode.

In Figure 1, the total availability (green bars) is shown during the three phases of operation; in fact before 2008 the storage ring ramped in energy, whereas after 2008 operates with a full energy injector and since 2010 in top-up. The numbers clearly show a continuous improvement of availability.

Another important number indicative of the reliability of a light source is the Mean Time between Failures (MTBF, Figure 1, yellow bars). Also in that case a clear improvement after 2007 is observed. An increase of the maximum time between failures is also observed, currently about 300 hours with peaks at 424 hours.

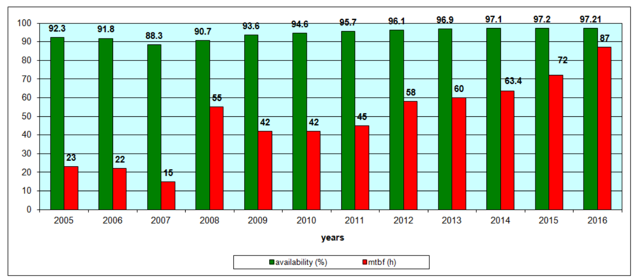

Figure 1: Combined graph of Electra availability (in %, green bars) and MTBF (in hours, red bars).

The downtime distribution amongst the subsystems of Elettra is shown in Figure 2. It is clear that a large portion of the downtime is due to external causes like electric power surges.

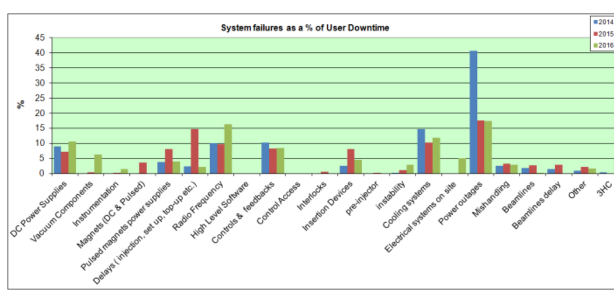

Figure 2: System failures as percentage of user downtime for 2014, 2015 and 2016.

The top-up was mainly invented for keeping source and experiments thermally/electronically stable. At the same time proved to be very beneficial for the availability being at the same time a very stable mode of operations. The top-up availability to the total user scheduled time since 2010 is between 97% and 99%. The remaining 1-3%

†emanuel.karantzoulis@elettra.eu (2017)

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indicates functioning in decay mode due to some failure that is considered downtime when below a certain threshold of intensity (270 mA at 2.0 GeV and 130 mA at 2.4 GeV).

Top-up contributes also to very good short and long term orbit stability. When the air temperature stays constant within ±1 ^{0}C , the long term (2 to 5 days) orbit stability is at ±5 µm maximum while the short term (24 hours) at less than 10% of the beam size (1.7 µm horizontally and 1.2 µm vertically).

PRESENT UPGRADES

Over the last few years many improvements were made aiming to update the machine and increase its stability, flexibility and operability. In the following a selection is presented.

Air-conditioning Control System Upgrade

After 22 years of continuous operation, control of the air-conditioning system serving the machine and the experimental hall was not functioning properly and spare parts were not easy to find. At the end of 2015 the old system was replaced by a new one and after few months was a fully calibrated and working at specification. Air temperature in the tunnel is now kept stable at ±0.5 ^{0}C while in all other spaces at ±1 ^{0}C. This can be seen in Figure 3, where the photon beam stability is shown for a period of 4 days. As comparison, the photon beam stability while the control system was off and in presence of a big external temperature gradient between day and night is also shown (blue line).

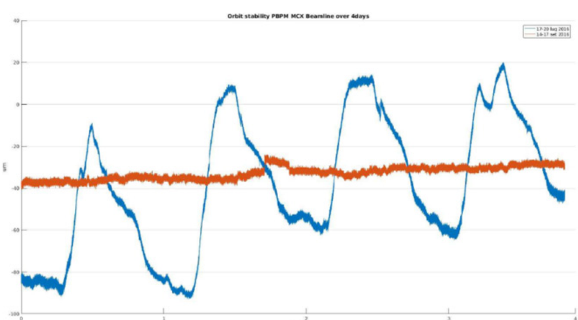

Figure 3: Photon beam stability at the MCX beam line for a period of 4 days with the air-conditioning control system on (red line) and off (blue line)

Big Power Supplies Remote Control Upgrade

The VME-based control system of the magnet power supplies (PS) of the storage ring was in operation since 1992 and the hardware became obsolete. There was also an increase in the frequency of damages on some of the cards in the PS low-level electronics. The management of the spares was becoming difficult and critical, with a high degree of risk for the global Elettra reliability and the upgrade of the existing controllers (EIUs) was considered essential. Modern micro-controllers, in particular the BeagleBone (BB), offer the opportunity to adopt powerful, compact hardware (including native Ethernet connectivity) along with versatile software tools. In order to replace the EIU features, a carrier board (BBC) to host the BB was needed. A BBC prototype was developed and positively tested as a starting point. Along with the BBC, new low-level electronic cards have been designed to replace some of the original cards from the PSs [9, 10]. The replacement of the EIUs and the low-level cards required some significant modifications on the 42 "Big" power supplies of the storage ring. The remote functionalities are kept and extended as the complete state of the machine is now replicated in CR, and no operator is needed locally to detect any malfunction. Local operability takes place via a touch screen display, which enables the technician to operate the power supply. The new control board offers a DAC set point variation of 45 µV (±2.25 ppm) over 12-hour operation, while the ADC variation was ±7.5 ppm over the same time. There has been no downtime directly correlated to a failure of the new system in more than one year.

Adjustable Phase Undulator

Until 2016, all Elettra permanent magnet devices have been of the Adjustable Gap Undulator type (AGU), in which the desired emission wavelength is selected by changing the distance between the upper and lower magnetic arrays. In contrast, the Adjustable Phase Undulator (APU) is a fixed-gap device whose field strength is varied by shifting longitudinally the upper array relative to the lower one.

A prototype APU was recently designed and built, whose parameters and brilliance are shown in Figure 4:

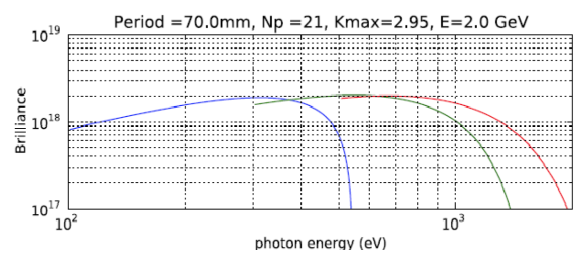

Figure 4: Brilliance in photons/sec/mm^2/mrad^2/0.1bw and some parameters of APU undulator

The magnetic material is NdFeB, its fixed gap is at 32 mm with a magnet width of 50 mm, length of 1.5 m and maximum field at 0.45 T. The peak field agrees well with model calculations. Trajectory straightness and phase errors were corrected using iron screws placed on the side of the magnets. Multipole errors were also reduced using small permanent magnets attached at both ends of the undulator, the so-called "magic fingers".

The undulator was installed in Elettra replacing an old (operated since 1994) undulator in the beam line ALOISA. The commissioning of the new device has been extremely fast. No effect on the stored beam lifetime or on the injection rate during top-up was observed. A minimal closed orbit distortion was observed only in the horizontal plane, reaching up to a negligible 3 µm rms. As seen in Figure 5, the measured perturbation is well correlated with magnetic field integral predicted for an ideal device.

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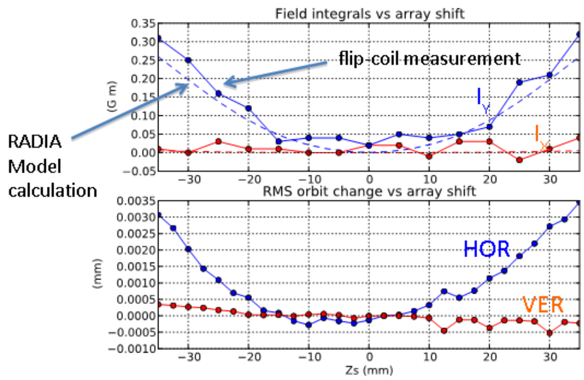

Figure 5: Calculated and measured perturbation on the electron beam orbit. The field is zero for Zs zero.

Based on this successful installation, future upgrades of the other undulators may adopt the same solution and be converted from AGUs to APUs, with significant benefits in terms of cost and reliability. Given the importance of these aspects, an R&D program is now starting aiming to develop a compact fixed-gap, elliptically polarized device, to be tested again for compatibility with the storage ring operation.

PLANS

Future plans have been presented yet before [3-6], including the possibility of decreasing the emittance, controlling coupling, rearranging the space in the arc for a larger short straight section to be used for longer insertion devices and upgrading the energy from 2.4 to 2.5 GeV. With the possibility of actualization of Elettra 2.0 [11] those plans may not be realized however even if the new project will start next year, the present machine will work for users for more than 3 years and upgrade plans for the beam lines and/or new undulators will always be actual, especially for devices foreseen to be used in the new machine.

MOST Beam Line Undulator

All straight sections of Elettra are occupied but still there is demand for new insertion device based beam lines. An upgrade plan is presently being developed which will merge the experiments running on the existing GasPhase and CiPo beam-lines. Two new variable polarization undulators will be developed for this purpose, one for the lower (10÷200 eV) and one for the higher photon energies (80÷2000 eV), while the old electromagnetic elliptical wiggler serving CiPo will be dismissed. Replacement of the existing straight section vacuum chamber is required due to the smaller vertical gap of the new magnets. Modifications to the front-end components, which have to sustain the increased power load of the new sources, are presently under study. The low energy undulator will have a period of 125 mm and its minimum gap of 20 mm corresponds to photon energy of 10 eV. In the next Figure 6 the brilliance and the flux of this device is shown for the three first harmonics in the planar mode, and the first harmonic in the circular polarization mode.

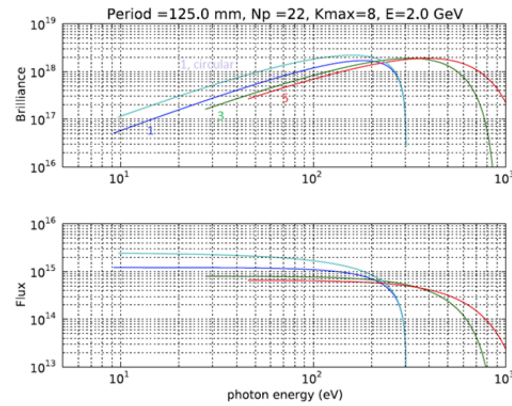

Figure 6: Characteristics, brilliance and flux of the low energy undulator for MOST.

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