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STATUS OF ELETTRA AND FUTURE UPGRADES

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Abstract

The operational status of the Italian 2.4/2.0 GeV third generation light source Elettra is presented together with upgrades especially concerning the next low emittance light source Elettra 2.0.

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 25 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 a low emittance successor of Elettra was studied [7, 8] with a bare emittance of 250 pm-rad.

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 two more beam lines.

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 (this year at 32% 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, red 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. A large portion of the downtime is due to external causes like electric power surges, cooling and lately from RF.

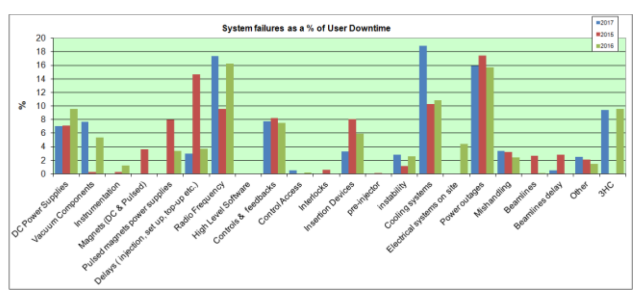

Figure 2: System failures as percentage of user downtime for 2015, 2016 and 2017.

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 above 97% whereas its value for 2017 was 99.4%.

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The remaining percentage indicates functioning in decay mode due to some failure while it 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).

RECENT UPGRADES

Over the last few years many improvements aiming also to the next machine, were made. In the following a selection is presented.

Air-conditioning Control System Upgrade

At the end of 2015 the old system was replaced by a new one and after few months was fully functioning at specifications. Some more effort in control fine tuning resulted in tunnel temperature stability better than ±0.5^0 C. As can be seen in Figure 3, the 24 hour stability is less than 0.4^0 C ptp.

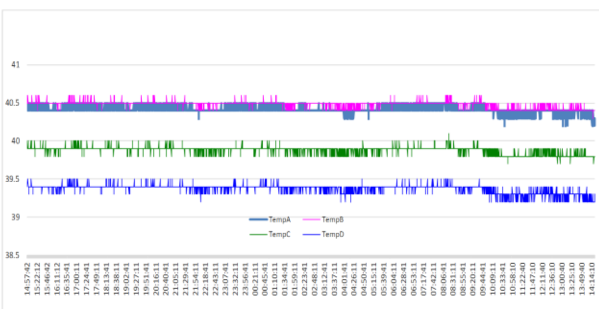

Figure 3: Tunnel temperature at three different points for a twenty four hour interval.

Booster Solid State Amplifier

Elettra uses four radio frequency (rf) 500 MHz stations for the storage ring and one for the booster. The three storage ring and the one booster stations use 60 kW CW klystrons while the fourth station uses the combination of 2 80 kW IOTs. Due to 60 kW K3672 BCD klystron production discontinuity and the ageing of amplifiers (more than 140000 hours of operation) has been decided to replace them with solid state amplifiers (SSA). Already the booster rf station has been replaced in 2017 with 18 kW SSA and no faults occurred since then. The other stations will be all replaced within the next 3 years.

E^{2}BPM

The Elettra Electron Beam Position Monitor system (E^{2}BPM) project started in 2015 with scope to produce a new, better and cheaper electron beam position monitor system. The project was based on a novel electron BPM front end with submicron resolution based on pilot tone compensation [11] i.e. direct measurement of the measurement quality therefore continuous calibration of the system by using a pilot tone for both beam current dependency and thermal drift compensation, completely eliminating the need for thermoregulation.

A prototype of the new E²BPM has been successfully tested and used in Elettra within the control system and Global Orbit Feedback (GOF) replacing one current BPM detector during user shifts. The measured “on field” performances for E²BPM with 20 mm gap chamber are based on “pilot tone” compensation. The resolution is 200 nm and the eight hrs stability < 300 nm as can easily be seen from the next Figure 4.

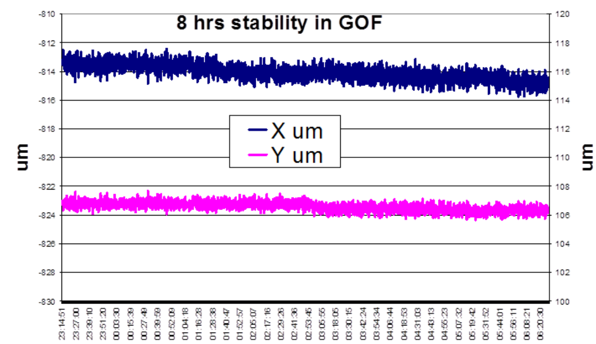

Figure 4: Eight hour stability of the new monitor detector during user run.

ELETTRA 2.0

After 25 years of serving the user community with excellent results, a major upgrade towards what it is called the “ultimate” light source is planned for Elettra in order to remain competitive for synchrotron research and enable new science and new technology developments.

Already since 2014 discussions with users and partners started in order to define the requirements of the machine described in a series of papers [7-10]. Lately in a workshop held at ICTP, Trieste in December 2017 users and partners discussed also other possibilities except the high brilliance such as the inclusion of super-bends , in-vacuum undulators, more space for insertion devices, possibility to operate at 2 energies and last but not least possibility of short pulses.

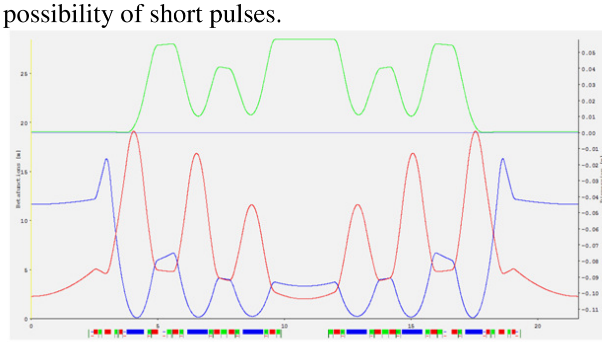

Figure 5: The S6BA lattice basic version.

The up to now best candidate for Electra 2.0 is a six bend achromat lattice named S6BA (Figure 5) and modified to meet the most requests. The S6BA is the current official version that is also presented in the conceptual design report (CDR) already publicly available since 2017 [12].

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The symmetric six bend achromat (S6BA) lattice consists of 6 quad-dipole-quad cells per achromat creating an invariant optic under relative position shifts between them. Thus relative long straight section can be created in the arcs without appreciable change of the optics functions increasing thus the space available for insertion devices.

The S6BA optics (basic version), shown in Figure 5 has an emittance of 0.25 nm-rad with working point (33.3, 9.2) and natural chromaticities (-75,-51). The corresponding horizontal beam size at the straight sections is 40 μm in the horizontal and 3 μm in the vertical at 1% coupling (however higher coupling i.e. towards round beams to avoid resistive wall effects is preferable) and the divergence is 6 μrad. The dipoles will be combined having a dipole field of 0.8 T (compared with 1.2 T at 2 GeV of the actual Elettra) and their maximum gradient is ≤15 T/m (compared with 2.8 T/m in Elettra). The quadrupoles have a maximum gradient of ≤50 T/m (compared with 15 T/m in Electra).

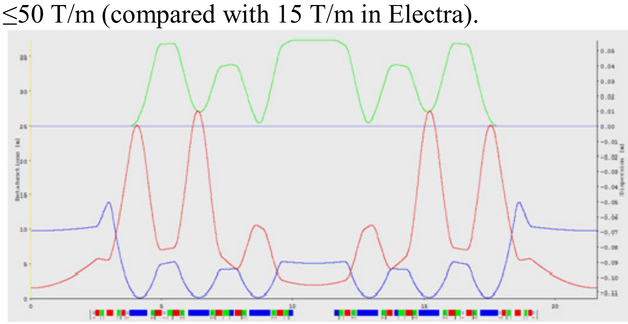

Figure 6: The S6BA lattice with anti-bends and two longitudinally focusing dipoles.

The dispersion in the arcs is low (58 mm compared with 400 mm in the actual Elettra) meaning that also the short straight sections (1.8 m long) situated in the middle of the arc can be used for insertion devices or other equipment. The rf cavities will be installed in the arcs as in the actual machine.

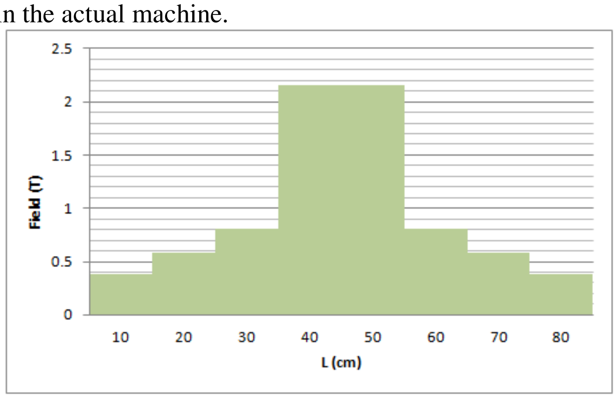

Figure 7: High field magnet profile.

Since the dipole fields of the lattice are about 30% reduced from the ones of the actual machine, may not be adequate for the dipole based beam lines with the exception of the infrared beam line. To solve the problem various solutions were considered: one would be to install a short wiggler in the short straight section another to install a super-bend. Both solutions may contribute to an emittance increase of the bare lattice depending upon their field and number. A third solution uses longitudinal gradient dipoles and anti-bends. In that case (Fig. 6) the dipoles that will serve a beam line can have a peak field of 2.2 T and the emittance is reduced to 0.19 nm-rad while the available free space in the arc is reduced to 1.55 m, still acceptable. In that version of S6BA four anti-bends are used to reduce the dispersion on the 3rd and 4th bending magnet that now has the following profile (fig. 7)

The S6BA lattice basic version could also work at 2.4 GeV with some further reduction of the free space in the arc. Discussions with users and partners continue and other possible lattices such as S4BA are examined [10].

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