ELETTRA STATUS AND FUTURE PROSPECTS

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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 possible future upgrades and a vision to its 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 20 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, 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 to the smooth and reliable operation of Elettra as reported previously [3]. At the same time studies based on various upgrade scenarios that define the upgrade Phase I are performed. This phase includes plans for upgrading the energy from 2.4 to 2.5 GeV, the possibility of decreasing the emittance [3] (in the present paper the superconducting wiggler currently in operation is taken into consideration), coupling control [4] and mainly rearranging the space for a larger short straight section to be used for additional longer insertion devices.

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 while 2 are in construction/conditioning using light from a superconducting [5] 49 pole 64 mm period 3.5 T wiggler. Many types of insertion devices used such as planar, Figure 8, APPLE II, electromagnetic while one beam line uses a canted set of APPLE II type undulators. The machine consists of a 100 MeV linac a 2.5 GeV booster and a 2/2.4 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 multibunch with a dark gap of 42 ns and hybrid (at 20% of the total user beam time) with a single bunch in the middle of the dark gap. The operating intensities are 310 mA at 2 GeV and 160 mA at 2.4 GeV with a 5 mA single bunch added when in hybrid mode.

In Figure 1, the net availability (blue) is shown during the 3 phases of operations of Elettra; 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 that the availability is continuously improving.

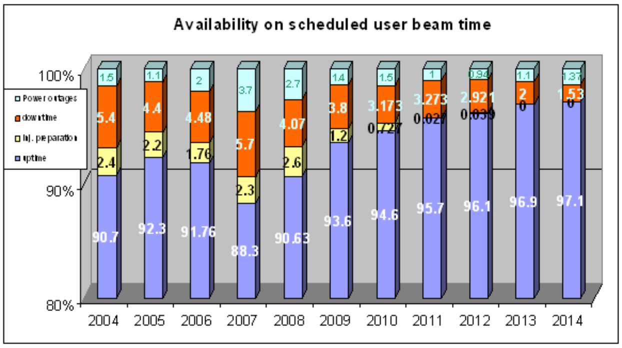

Figure 1: Availability of Elettra. The downtime is shown with red, with yellow the time lost for refilling and with light turquoise the time lost due to external electric power surges.

The downtime distribution amongst the subsystems of Elettra is shown in the next figure 2. As one can observe almost one third of the downtime is due to external electric power surges.

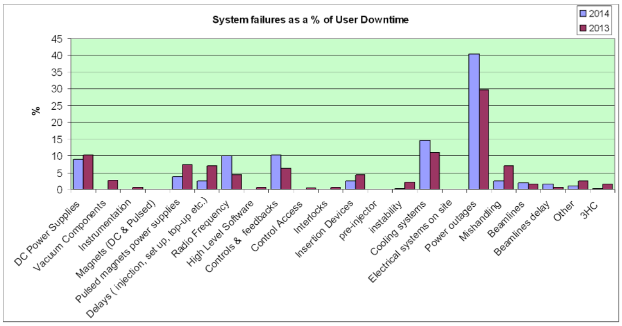

Figure 2: System failures as percent of user downtime for 2014 and 2013.

Another important number indicative of the reliability of a light source is the mean time between failures (MTBF).

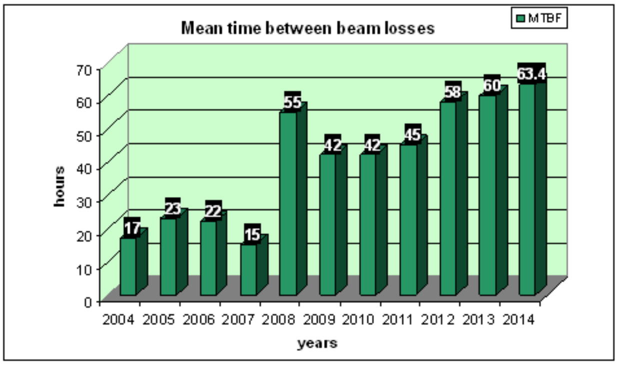

Figure 3: Mean time between beam failures.

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Also in that case (Figure 3) a clear improvement after 2007 is observed. An increase of the maximum time between failures is also observed, currently is about 300 hours with peaks at 424 hours.

The top-up was mainly invented for keeping source and experiments thermally stable including the electronics. At the same time proved to be very beneficial for the availability but also in it proved to be a very stable mode of operations. In the next Figure 4, the top-up availability to the total user scheduled time shown is 97 to 99 %. The remaining 1-3% indicates functioning in the decay mode due to some failure, usually of the booster power supplies, controls, radiofrequency and the cooling system of the injector. Note that the injectors themselves did not give any real downtime, however it is considered downtime when in decay mode and below a certain threshold of intensity (270 mA at 2 GeV and 130 mA at 2.4 GeV).

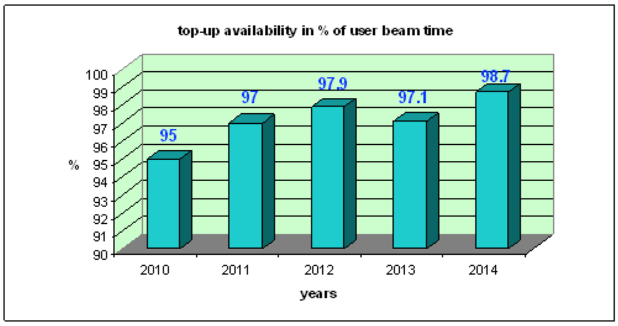

Figure 4: Top-up availability.

The top-up contributes also to very good long and short term orbit stability. Currently the long term (2 to 5 days) is at ± 5µm maximum while the short term (24 hours) at 2% of the beam size (1.7 horizontally and 1.2 µm vertically).

NEAR FUTURE PROSPECTS

Over the last few years except many small upgrades that were made aiming to update the machine and increase its stability, flexibility, limits and operability; studies were performed to evaluate possibilities of some machine upgrades as Phase I, some described previously [3].

Energy Upgrade

The magnets and power supplies of Elettra have a big margin and although initially the machine was designed to operate at 1.5 and in a second stage at 2 GeV it operated from the very beginning at 2 and since 1999 also at 2.4 GeV without any additional change. Users that currently use the 2.4 GeV beam time (25% of the total) have shown an interest to get at higher energy. Although quadrupoles and sextupoles can go higher the main question concerned the dipoles. The bending magnet at 2.4 GeV (1.4 T) is having a 9% saturation and in the laboratory tests it could go up to 1.7 T (2.7 GeV) however with large measured saturation (27%) and therefore prohibitive for the beam. Additionally above 2.5 GeV (1.5 T) magnet heating problems were observed thus any energy upgrade has to limit to 2.5 GeV. Still users show interest even for this small upgrade that currently reached 2.4695 GeV, the limitation is due to the dipole power supply.

Brilliance Increase

The emittance of Elettra (7 nm-rad) is one of the closest to the theoretical limit for a double bend achromat. This emittance can be further reduced if one abandons the achromat condition introducing thus dispersion in the straight sections. For Elettra an alternative theoretical optics is found (Figure 5) using OPA [6], with an emittance of 2.6 nm-rad, a 30-60% reduction in spot size and an average factor of two in brilliance increase.
The machine tunes become 15.3 and 8.2 whereas the dynamic aperture is reduced by 50%, still enough for beam injection. The dispersion although distributed is now about 50% less than the actual maximum.

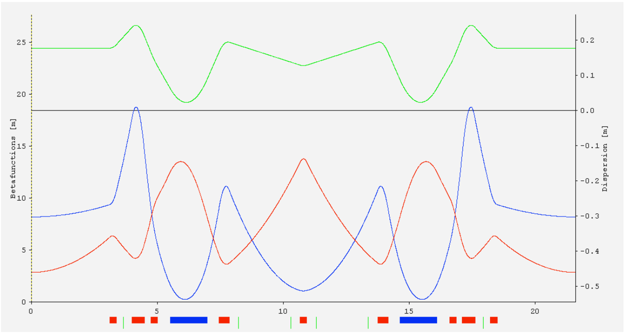

Figure 5: Elettra optics for reduced emittance.

However since the dispersion is distributed one has also to examine the effective emittance and at the same time the influence of the 3.5 T superconducting wiggler currently is operation.

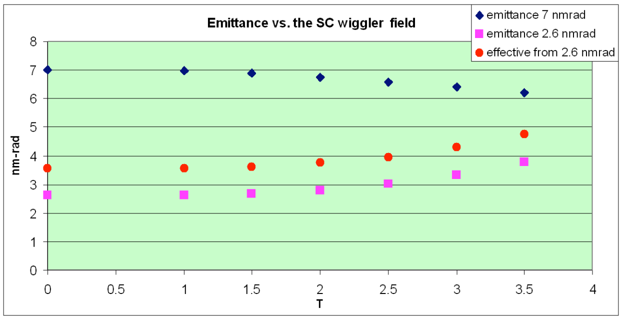

Figure 6: Emittance vs. the super - conducting wiggler field (T).

In figure 6 the wiggler magnetic field influence on the emittance for the actual lattice (7 nm-rad) and the modified one (2.6 nm-rad) is shown. As can be seen with the wiggler at full field the effective emittance is only 20% less than the nominal one indicating that the emittance reduction must be based on the effective. Finally there is a net gain of a factor of 2 if the magnetic field is at zero.

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Magnet Splitting for Space Unification

All straight section of Elettra are fully occupied and still there is demand for new insertion device based beam lines thus having more space available is highly desirable. From figure 5 (where the position of the magnets are the nominal ones) one sees that Elettra is having 3 straight sections per achromat: a large straight section of about 5 m and two shorter ones in the arcs of 1 and 1.3 m separated by a defocusing quadrupole. Those sections are used for instrumentation and for the rf-cavities while in one 1.3 m long section a 1 meter short undulator is installed serving the TweenMic beam line. This fragmented space can be unified by replacing the defocusing quadrupole by 2 other ones of reduced dimensions and shifted from the centre as can be seen in the next figure 7.

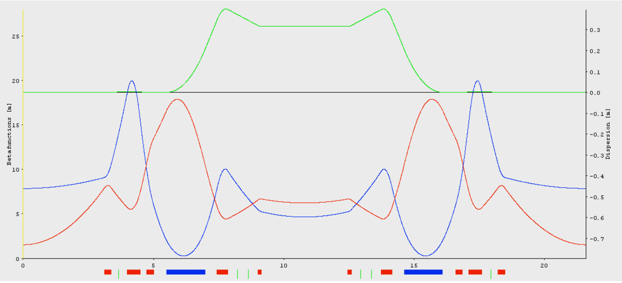

Figure 7: The central defocusing quadrupole is replaced by two others shifted towards the dipoles.

The emittance is as the nominal i.e. 7 nm-rad with the same working point (14.3,8.2) and almost same natural chromaticities (-39.7,-18) current optics is having (-41,-13).

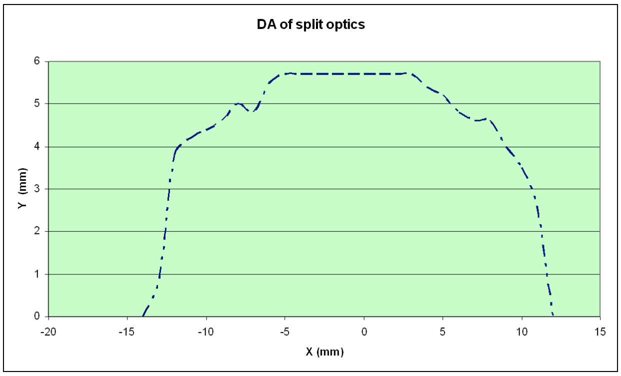

Figure 8: Dynamic aperture with errors.

The dynamic aperture shown in figure 8 is already acceptable and further sextupole optimisation will render it larger.

This rearrangement gives a unified free space of 2.5 meters for installation of longer insertion devices. The fact that the insertion device will be in a dispersive region is not a problem as long as the undulator field remains low i.e. ≤ 1 T as is usually the case. The experience with the already installed short undulator for TweenMic confirms that statement.

CONCLUSIONS

Elettra in 2014 completed 20 years of non interrupted service and delivered more than 97000 hours of synchrotron radiation in the range of IR to soft x-rays to more than 1000 users of the scientific community. At the beginning and for 14 years the injection and operation energies did not match a really difficult task also because after 1999 Elettra was operating at both 2 and 2.4 GeV. Then in 2010 top-up operation was established rendering Elettra competitive with the more recent and modern synchrotron light sources. Many small projects and studies followed aiming to further improve the facility. The overall benefit on availability, stability, reproducibility, flexibility and versatility is evident. In the last two years a 12% increase in the experimental proposals is registered partly also due to the big improvements of the facility which anyway was having an overbooking factor of more than three.

In the last few years studies are ongoing in order to examine the near and far future of Elettra, described as phase I and II. Phase I includes all improvements on the current machine such as coupling control, unification of the free space for additional insertion devices and if possible upgrade the high energy part of operations from 2.4 to 2.5 GeV. The emittance reduction idea can be realized without any additional costs and although less attractive due to the superconducting wiggler is still possible upon acting on the effective emittance.

For the phase II [7] a new machine with an emittance of <0.3 nm-rad is in the conceptual design phase. This next generation light source will replace the actual Elettra in the same tunnel and should respect all the positions of the photon source points from insertion devices (possibly saving also the beam lines served form a bending magnet).

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