ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-MOPRO076

ELETTRA STATUS AND 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 the latest studies and upgrades.

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 add to the smooth and reliable operation of Elettra. Those include adding more correctors for better reproducibility of the dipole source point [3], upgrading the intensity to 200 mA at 2.4 GeV, upgrading the controls of the power supplies [4], a real-time emittance measuring system, beam dump fast diagnostics, interlocks upgrade, digital low level rf and rf upgrade. Studies were also made aiming to partially increase the upper energy, to control the coupling [5] and to modify the optics in order to double the machine brilliance.

ELETTRA STATUS

Elettra operates 24 hours/day, seven days a week delivering 5000 hours/year of synchrotron light from IR to soft x-rays to 26 beam lines of which 9 are served from dipoles while 2 more are in construction to use light from a superconducting [6] 49 pole 64 mm period 3.5 T wiggler. The other types of insertion devices used are 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 has improved much over the last 10 years.

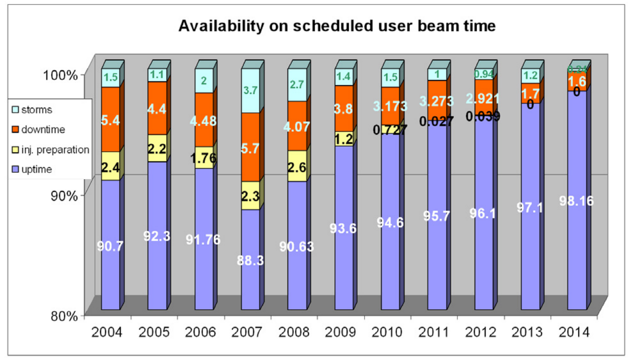

Figure 1: Availability of Elettra. The downtime is shown with red, with yellow the time lost for refilling and with light turquoise the time lost due to electricity surges.

Another important number indicative of the reliability of a light source is the mean time between failures (MTBF). Also in this case (Figure 2) a clear improvement can be observed after 2007. An increase of the maximum time between failures is also observed, currently is about 300 hours with peaks at 424 hours.

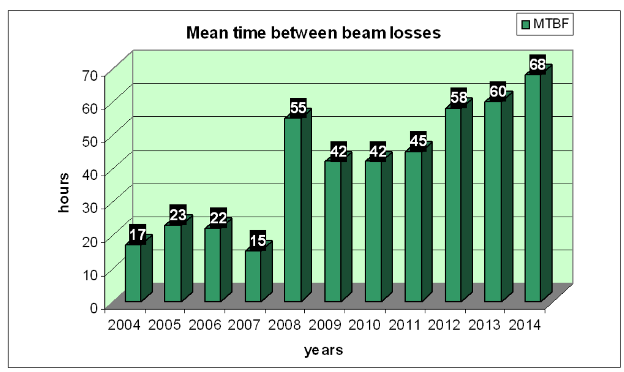

Figure 2: Mean time between beam failures.

The top-up was mainly invented for keeping source and experiments thermally stable including the electronics. At the same time as shown above proved to be beneficial for the availability but also in it proved to be a very stable mode of operations. In the next Figure (Figure 3), the top-up availability to the total user time is shown and is 97-98%. The remaining 2-3% indicates functioning in the decay mode due to some failure, usually of the booster power supplies, controls and rf-system and of injector's cooling system. It is worth noting that the injectors themselves do 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).

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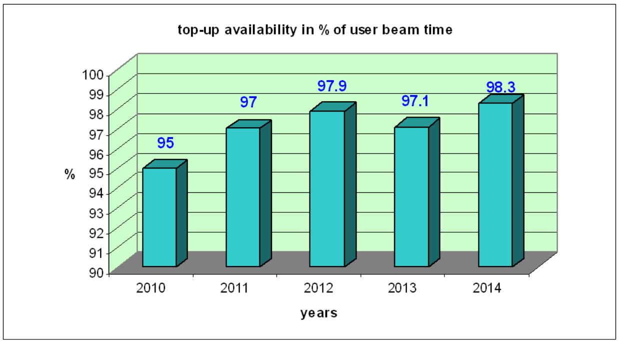

Figure 3: Top-up availability.

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) as shown in Figure 4.

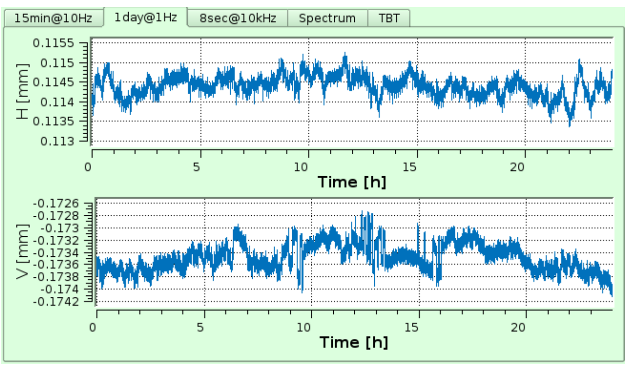

Figure 4: Short term orbit stability.

SMALL UPGRADES AND DEVELOPMENT STUDIES

Over the last 2 years many small upgrades were made aiming to update the machine and increase its stability, flexibility, limits and operability; only a selection of these works is presented here due to space limitation.

Additional Correctors

Elettra originally was not supposed to have beam lines from dipoles and the configuration of the corrector magnets could not produce a closed bump controlling both position and angle for a dipole source point (only 3 correctors available around the source point instead of 4). Later Elettra obtained 9 beam lines served from 6 dipoles and the reproducibility of the source point became a problem since either position or angle could be set, resulting in user time loss when trying to set the beam at the requested position; to complicate matters the available space for an additional corrector is only 140 mm and occupied by a NEG pump. Nevertheless additional combined air cooled correctors were home designed, produced by KYMA and three are already installed [3] while three more are expected to be installed within the next year(s). Dipole beam lines already equipped with the additional corrector reported an excellent reproducibility.

Intensity Upgrade

Originally the designed operating intensity of Elettra was 200 mA at 2 GeV which was also the maximum operating energy. Already above 250 mA thermal load increase is observed and above 330 mA damage can occur due to expansion and/or excessive heating of the vacuum chamber beam position monitor (bpm) seals resulting in vacuum breaks. The intensity allowed at 2.4 GeV for equivalent thermal load was 100 mA but experiments were pressing for more flux at that energy. To solve the problem local cooling by means of remote controlled fans was installed on each bpm position and the intensity reached 200 mA at 2.4 GeV. Currently Elettra operates at 310 (160) mA at 2 (2.4) GeV due to thermal load limits imposed by the beam lines.

Beam Dump Fast Diagnostics

Fast understanding and fixing the cause of a beam dump can help in increasing the availability. While before full energy injection and top-up the level of unresolved causes was rather low afterwards new effects were added sometimes very subtle to understand (like spurious kicks from a kicker during top-up injection) and special care was taken to resolve involving also special instrumentation which however was manually operated.

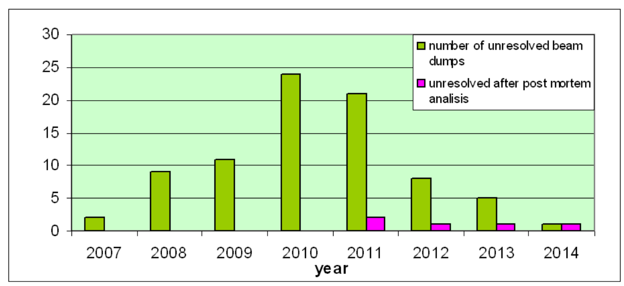

Figure 5: Number of unresolved beam loses.

Applying post mortem analysis (from 2011) based on beam dump signatures willingly provoked for comparison, reduced the number of unresolved cases to practically zero (Figure 5). Now unresolved beam losses are mainly due to negligence in saving the relevant data. To eliminate also this aspect as well as not loosing time for post mortem analysis, a special electronic board was constructed (Figure 6) that in real time analyses and indicates the cause of the beam dump.

The system monitors a range of operating and beam parameters such as: Beam current, direct and reflected power for each rf-cavity, impulse number of each kicker, interlock and power supply signals. The peculiarity of the system is that all the available channels are synchronous sampled at the revolution frequency and also the trigger event that stores the acquired data can be transmitted between units, an important aspect for modularity and expandability of the system.

Each unit is equipped with five analogue and one 16-bit digital acquisition channel. The inputs of the analogue channels, after conditioned by a stage amplifier-attenuator and in case of an rf inputs a demodulated baseband, are

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stored in a 2 Mega Sample memory. This allows to quickly identify the fast beam losses ≤ 1µs i.e. one beam revolution to those that are slower > 20ms. The system detects changes in amplitude and/or state in any of the channels and generates a trigger event that stores in a two second sample the history before and after the event; then a CPU PC104 Linux sends the acquired samples to the control system.

The board was also tested with a modified firmware for tune measurement by connecting it to the buttons of a bpm with excellent results. Thus with a limited FPGA firmware change, the board can be easily converted into a low cost bpm detector.

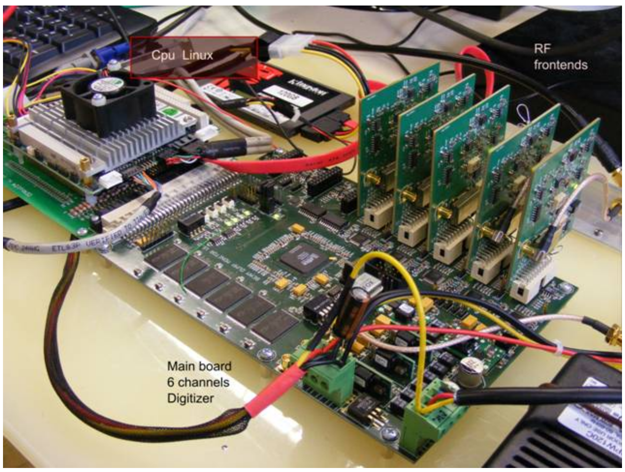

Figure 6: Fast beam dump detector also functioning as a low cost bpm detector.

Coupling Control

Elettra lacks skew quadrupoles and therefore coupling is controlled by the vertical orbit. Currently the machine operates for users at 1% coupling (measured) while in the past during machine development reached 0.3% but not in an operationally easy way. To fully control coupling 12 skew quadrupoles in two families are considered [5] and with modest strengths the coupling can become as low as 0.1% reducing thus further the vertical beam size.

Brilliance Increase

The emittance of Elettra (7nm-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 optics is found (Figure 7) [7], with an emittance of 2.8 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. Experiments however asked for caution in case of operating with this optics due to possible increase of the thermal load on the beam lines. Simulations have shown that the heating should be well tolerated [8].

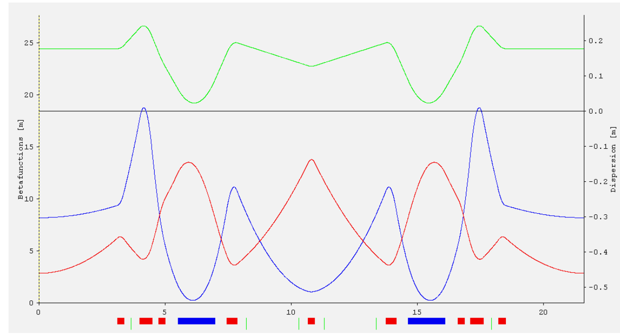

Figure 7: Elettra optics for reduced emittance.

CONCLUSIONS

Elettra in 2014 completes 20 years of non interrupted service delivering 5000 hours/year of synchrotron light in the range of IR to soft x-rays to more that 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 fully reflecting the big improvements of the facility.

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