ELETTRA Commissioning and Operation

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Abstract

A summary of the commissioning results and a description of the present operational performance of the ELETTRA synchrotron radiation facility is presented.

1. INTRODUCTION

The Italian synchrotron radiation facility ELETTRA a 1.5 to 2.0 GeV light source based in Trieste is in its commissioning phase [1]. The first steps towards the commissioning of the facility started in June 1993, when the linac to storage ring transfer line was commissioned. Commissioning of the storage ring started four months later at the beginning of October 1993. Rapid progress was made and twelve days after the start of commissioning 216 mA were stored in the machine. At present the facility is regularly producing light for experiments and the commissioning of the beamlines.

The facility uses an electron linac as its injection system. The linac is being commissioned in conjunction with the storage ring, and has not reached its final energy of 1.5 GeV. This has had a large impact in the approach adopted for the commissioning of the ring. The highest attained injection energy is 1.25 GeV, however, commissioning at present uses a 1.1 GeV injection energy. In answer to the needs of users the implementation of a energy ramping scheme in the storage ring was made in January this year. This proved to be very successful with no deleterious effects on the beam quality and machine operation. At the request of the user community operation of the facility for experiments is made in the energy range 1.5 to 2.0 GeV. The commissioning-operation timetable takes into account the need to commission the linac, and allows machine upgrades and maintenance. Generally the ring operates for a three week period followed by a two week shutdown. All technical and scientific personnel of the accelerator division are involved in the commissioning and operating shifts, which works on a 24 hour three shift per day basis. By July 1994 55% of machine time will be dedicated to the users.

The current status of the machine is shown in table 1, where a confrontation is made with the design goals (where applicable).

Table 1: Comparison of the main design targets with those obtained.

	Design Value	Present Value
Energy (GeV)	1.5-2.0	1.0-2.3
Multibunch (MB) Current (mA)	400 (@ 1.5 GeV) & 200 (@ 2.0 GeV)	>530 (@ 1.1 GeV) & 265 (@ 2.0 GeV)
Single Bunch (SB) Current (mA)	8	>50
Filling time to 400(MB)/8(SB) mA (sec)	116 & 42	<80 & 8
Tunes Qx,y	14.3, 8.2	14.3, 8.2
Emittance (nm-rad)	7.2	~8.3
Coupling $\varepsilon_y/\varepsilon_x$	to be kept below ~10%	0.6%
|Z/n| (Ohms)	to be kept below 2	0.75

2. COMMISSIONING

The transfer line, built for the transport of positrons, was easily commissioned within a few weeks. The transfer line, due to its achromatic arcs, has a very generous energy acceptance of 10%. The commissioning was done in two stages in June and July 1993. The first half of the line contains diagnostic tools which are routinely used by the linac to test its performance limits: current, energy, energy spread and emittance. Transfer line transmission is 100% and capture into the storage ring exceeds 90%. In multi-bunch mode, injection rates greater than 10 mA/sec are easily achieved. The injection system, made up of two septa in a common tank and four fast kicker magnets, have performed without fault since the start of commissioning, only compensation of a slight thermal drift on the septa has been done.

A low emittance machine such as ELETTRA needs very tight alignment of the main magnets. The goal of less than 100 microns in the rms accuracy of transverse positioning of the magnets has been achieved. The circumference of the machine has been kept to within 2 mm. Transverse and vertical deformations after four months of machine operation show that the foundation is very stable: the transverse deformations are within +200 to -400 microns, whilst the vertical deformation is contained within ±200 microns [2]. These changes can be attributed to seasonal ground variations. No orbit correction was needed to store the first beam.

The closed orbit is monitored using 96 beam position monitors, eight per achromat, and corrected using 82 lumped steerer magnets. Various orbit correction schemes are available [3] and include MICADO, simplex and repeated use of interleaving local bumps. Orbit corrections to 0.15 mm rms in both planes are routinely obtained, see figure 1. Many of the machine parameters sensitively depend on the closed orbit because of the strong focusing and also because of the consequent high sextupole strengths, e.g., an rms change in the vertical closed orbit of -0.12 mm, gives $\Delta Q_{x,y}$ of (0.013,0.018). The measured optical asymmetry is approximately 10% in the vertical plane and 15% in the horizontal.

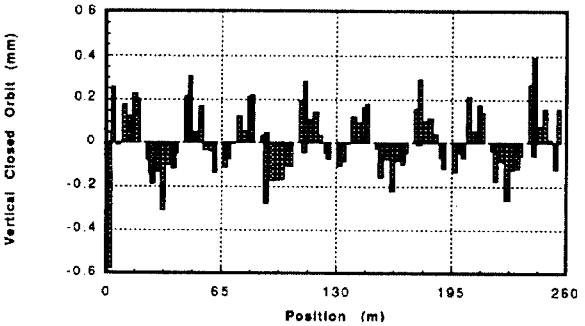

Figure 1. Vertical closed orbit.

The dependence of the dispersion on the quality of the closed orbit follows a similar pattern to that of the tune. A closed orbit with an rms of 2 mm yields a measured horizontal dispersion of up to 70 cm (nominal value: 40 cm). The measured dispersion for a well corrected orbit is shown in figure 2 for the vertical plane. The difference between the model and measured dispersion shows discrepancies of around 5 cm in the horizontal plane and up to 4 cm in the vertical plane. Measurements of the vertical to horizontal coupling due to skew quadrupole effects show a coupling which is less than 0.6%.

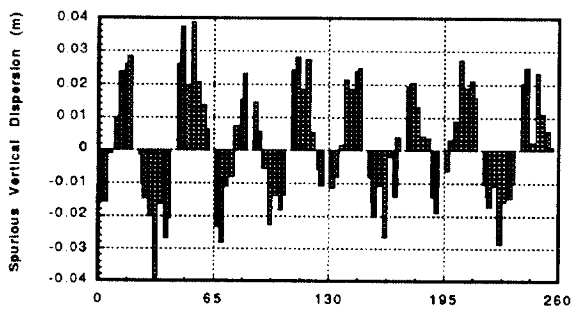

Figure 2. Spurious vertical dispersion.

The cavities are placed in a region with non-zero dispersion, increasing the number of straight sections which can be used for insertion devices. As predicted by simulations, no synchro-betatron resonance satellites have been seen.

One of the major concerns in the construction of any storage ring is the effective impedance presented to the beam by the vacuum chamber. The rf cavities which are the greatest impedance source of the ring, are characterised by their higher order modes (HOM) [5]. Temperature regulation of the cavities move the HOM's to frequencies which are less damaging. All the modes of the cavities have been mapped, and by a proper choice of temperature can be avoided. Three rf cavities have maintained a 265 mA beam at 2.0 GeV. With four cavities>350 mA will be routinely stored at 2.0 GeV. Longitudinal multibunch instabilities are present in ELETTRA even down to the lowest currents [4]. Transverse multibunch instabilities (TMBI) have also been observed. Both these instabilities are avoided by a proper choice of cavity temperature. The TMBI showed no particular threshold but rather gave unstable beam conditions by which sudden beam losses of some tens of percent occurred. Single bunch thresholds, current and bunch length are determined by the broad band impedance. This has been estimated from bunch length measurements as a function of beam current and rf voltage to be $|Z/n| \sim 0.75\ \Omega$. No appreciable horizontal tune shift has been measured. Mode coupling has been predicted for the measured machine parameters to occur at ~40 mA. Results show no strong evidence of mode coupling near this value.

The lifetime conditions of the machine have been complicated by the need to commission at a low beam energy, and the opening of the chamber for the installation of low gap insertion device vacuum vessels. Although, ramping to 2.0 GeV is used in machine operation, this is an inconvenience for machine studies. The consequence of this being a reduced lifetime at 2.0 GeV operation in comparison to 1.1 GeV, for currents exceeding a few tens of mA: at 100 mA the lifetimes are 26 and 10 hours at 1.1 and 2.0 GeV respectively [5]. The total machine dose is >60mA, however, most of this was registered at 1.1 GeV, at which energy the conditioning is less efficient. To reach the design lifetime goals, a further 40 Ahrs under the same operating conditions is needed. The effect of elastic scattering which is dominant for low gap vacuum vessels has been measured and reveals the possibility to use chambers with a 6 mm full gap, which at 2.0 GeV and 1 nTorr pressure gives 10 hours lifetime. Furthermore dynamic aperture studies of the effect of insertion devices have shown that simulations are slightly pessimistic. The closure of all insertion devices (see below) reduced the vertical dynamic aperture from 8 to 7 mm at 1.1 GeV, and no effects were seen at 2.0 GeV [6].

Sources for instabilities have been identified. The two main sources are the HOM's of the cavities and ions trapped by the beam. Ion problems are seen as a beam blow-up and a source for low frequency beam oscillations [7]. A 75% or less filling of the ring eliminates ion-trapping effects. Future improvements in the spurious dispersion will also ameliorate the working conditions. At present no problems associated with ground vibrations have been observed.

3. OPERATIONS

The choice of control system architecture [8] using local process computers to do the main machine computing proved very versatile, permitting a transparent expansion of the control of the machine. At the start of commissioning twenty-one main programs were tested and ready for use. The programs ranged from orbit correction, main optical parameter measurements to machine file scaling utilities [9]. These programs took eight man-years to write and two man-years to define the data structures and architecture. The software was heavily tested on simulations of the machine before actual use and consented quick commissioning of the software itself with consequent rapid machine commissioning. All high level software utilise the same data structure. This was found to be essential and allowed extremely rapid evolution of the control of the facility. Nearly all of the high level software uses graphical user interfaces, allowing ease of use to non-experts.

The timing system allows any desired filling to be performed, either in single bunch of multi-bunch. Switching from multi-bunch to single bunch injection is rapidly performed in a matter of minutes. The injection rate in single bunch is sufficiently high to permit arbitrary filling patterns. Operation for beamline experiments uses a partial filling of ~75%.

The present maximum injection energy of the linac is insufficient for machine operation for the users. An energy ramping procedure of the storage ring magnets surmounts this problem [10]. Main magnets, steerer and cavity gap voltages can be ramped to 2.3 GeV. The maximum ramp speed from 1.1 to 2.0 GeV is 3.5 minutes with practically no beam loss. Ramping to 2.0 GeV initially required the use of a tune feedback system to compensate saturation effects and a residual gradient error of the bending magnets, but can at present be made through file ramping were the final energy is reached by energy ramping to several intermediate machine files. The reproducibility of the ramping procedure is very good. File ramping has the advantage that optical distortions are less during the ramp. Ramping to 2.0 GeV and above creates a closed orbit distortion. This can be eliminated by including the steerer magnets in the file ramps.

At present three main beam lines are active, of which one has a branch line. All four beam lines take light from insertion devices [11]. The devices presently installed are two full undulators with periods 12.5 and 5.6 cm, each made up of three 1.5 m long sections, and one 1.5 m wiggler section with period length 14 cm. Both types of insertion devices have correction schemes for the correction of closed orbit distortions during gap closure. Protection of the vacuum chamber against accidental irradiation is performed by an interlock system installed in all straight sections.

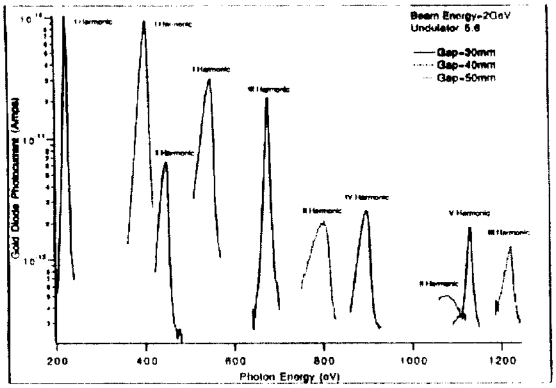

Figure 3. Spectral measurements for U5.6 (10 mA).

Spectra taken from U5.6 shown are shown in figure 3. The preliminary measurements, with the given beam conditions, confirm the proper functioning of the device.

Minimum gap closure of the insertion devices U5.6, U12.5 and W14.0 gave tune shifts as predicted by theory: 0.008, 0.011 and 0.015 respectively at 1.1 GeV. Programs for the dynamic correction of optical distortions using the straight section triplets during gap closure are ready for use.

A dedicated program for the production of closed orbit bumps at the source points corrects the beam for experimental use. Studies have shown that a certain amount of leakage of the bumps ensues after a position or angle change is made. The closed orbit is corrected to zero position and slope at the photon source points before use is made of the light. The careful alignment of the beamlines to the source points has so far obviated the need for orbit corrections after this procedure is performed. Local orbit feedback will be soon installed in all active straight sections, effectively de-coupling beamlines. Orbit stability is very good: an rms closed orbit variation of 6 μm in the vertical plane and 17 in the horizontal over a ten hour period at 10 mA and 2.0 GeV.

To improve the performance of the machine extensive component monitoring is performed. Monitoring is made of all main machine components and closed orbit once a minute. The monitoring is done in an intelligent way, recording unintentional changes only, allowing monitoring on a continual basis, even through machine physics shifts which are associated with many changes of machine parameters. Once suspicion arises as to the proper functioning of a component subsequent monitoring can be done on a faster basis.

4. CONCLUSIONS

The commissioning of ELETTRA is proceeding extremely well with rapid progress towards a stable configuration for routine operation. The good performance and handling of the facility will allow a rapid increase of the amount of beam time dedicated to the users.

5. REFERENCES

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