PRESENT PERFORMANCE AND FUTURE OBJECTIVES AT ELETTRA

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Abstract

The present performance of ELETTRA including recent improvements is summarised. The future objectives and the developments projects that are underway to reach them are discussed.

1 INTRODUCTION

The ELETTRA 2 GeV third generation light source is nearing 5 years since the start of commissioning (October '93). ELETTRA currently operates for a relatively large number of hours per year, and with good efficiency. In 1997 the machine operated for a total of 6168 hours, 82 % of which were dedicated to user operations, with an achieved efficiency of 91 %. In 1998 the machine will be operated for 6528 h, 81 % for users. At the present time there are 6 operational insertion devices and one bending magnet port feeding a total of 11 beamlines, of which 10 are open to external use and 1 is in the commissioning phase.

Far from entering a static operations phase, a great deal of investment is being placed in the future growth and improvement of the facility. In the last year the construction of a number of major new beamlines and insertion devices has been approved and several more are under active consideration. In parallel with this activity a number of important machine development projects are underway which are designed to further improve the performance and competitiveness of ELETTRA. A major upgrade of the injection system is also under consideration. In the present article we firstly summarise some recent machine developments, and then present further details of the development programme.

2 RECENT DEVELOPMENTS

2.1 Current and Energy [1]

The substitution last summer of critical beam position monitor gaskets immediately downstream of the bending magnets with a composite steel/copper type having a greater resistance to transverse forces has permitted an increase in beam current from the previous 250 mA to a typical 320 mA.

We have also recently been re-examining the possibility of operating the machine at higher energy. The limit is set by bending magnet power supplies. Tests have been performed at 2.4 GeV with a conservative current of 130 mA, which has the same synchrotron radiation power density (~ E^5) as 320 mA at 2 GeV. Measurements show that the beam is more stable under these conditions and has a significantly greater lifetime, 52 h at 2.4 GeV, 100 mA compared to 32 h at 2 GeV with the same current. The interest in such an operation is sufficiently great that a 7 day period will be scheduled in August for continuous 2.4 GeV operation. If there are no limits due to the increased thermal load, a maximum current of 180 mA will be able to be supported at 2.4 GeV with the present r.f. system.

2.2 Few-bunch Mode

Apart from Accelerator Physics studies, until recently there has been little interest in using ELETTRA in anything other than the standard 90 % filling mode. Some interest has now been expressed in using 6- and 12-bunch modes in order to carry time-resolved studies and so a number of exploratory tests have been carried out [1]. Currents of 10 to 20 mA have easily been able to be accumulated in 6 and 12 bunch modes.

2.3 Electromagnetic Elliptical Wiggler

A novel electromagnetic elliptical wiggler (EEW) was installed at the beginning of January '98 as a source of circularly polarised radiation for a new beamline [2]. The main feature of this device is the possibility of switching the helicity of the radiation in either a trapezoidal (0.1-1 Hz) or sinusoidal mode (10-100 Hz). The main influence on the beam that has been observed during the commissioning of the device is a change in closed orbit [3]. A correction system consisting of air-cored coils and arbitrarily programmable power supplies will soon be operational in the d.c. mode, and thereafter in the a.c. modes.

3 MACHINE DEVELOPMENT PROJECTS

3.1 Longitudinal and Transverse Coupled Bunch Instabilities

Longitudinal instabilities are successfully controlled in ELETTRA by means of a precise adjustment and regulation of r.f. cavity temperatures [4]. A detailed study has been carried out of the dependence of higher order mode (HOM) frequency with cavity temperature, enabling temperature tuning intervals to be determined for each cavity which avoid interaction of the HOM's with the beam. To provide an extra degree of freedom, variable plungers (HOM frequency shifters) have also been installed in two cavities [5]. At the present time the cavity settings are adjusted so as to leave a residual longitudinal excitation, in order to provide an increase in beam lifetime [6] as well as to overcome transverse effects which arise when the beam is completely stable longitudinally.

Since longitudinal stability is desirable in order not to deteriorate the undulator radiation spectra, particularly in the future when the use of higher harmonic numbers are foreseen, another method will be needed to guarantee transverse stability. For this reason a wide-band bunch-by-bunch transverse feedback system is under development. After a fast (500 Msample/s) analog-to-digital conversion, the input data flux is de-multiplexed and processed by digital electronics. The correction data is digitally delayed, multiplexed, passed to a 500 Msample/s digital-to-analog converter and eventually applied to the RF power amplifier-plus-kicker. Programmable DSP based electronics is being considered for the processing block. It will provide the best flexibility (e.g. account for changes in machine operating conditions, allow the implementation of different software filters and permit controlled behaviour in case of system saturation) and will allow the installation of different beam (e.g. tune measurement, growth/damping measurements, mode detection) and system diagnostics tools (e.g. measurement of system gain margins, operation monitoring of system components). System simulations using different filter types are being run in order to prove the feasibility of a "1BPM+1kicker" scheme. The BPM-kicker betatron phase constraint should be dealt with by the digital filter, so that the choice of the BPM/kicker positions may be driven only by the requirements of engineering, space and ease of installation. The very same digital processing hardware could also be used on different machines and/or for longitudinal coupled-bunch systems.

3.2 Beam Lifetime

The lifetime in ELETTRA is very strongly influenced by the Touschek effect [6]. When complete beam stability is achieved a deterioration of the lifetime can therefore be expected. A Third Harmonic cavity is being designed in order to improve the lifetime, without compromising the transverse emittance or energy spread. A comparative study of the technology to use (normal or super-conducting) will be concluded during the summer. Within this context a feasibility study has been performed with an analysis of the geometry suitable for a super conducting single mode cavity.

3.3 Closed Orbit Stability

A lot of effort has gone on over the past few years to develop a local feedback system in order to stabilise the beam on each individual beamline. The final result was successful in that the system could stabilise the measured beam positions at the two photon beam position monitors (pBPM's) to less than 1 micron up to high frequency, and also operate on two beamlines simultaneously [7]. The difficulty with this approach is however the contamination of the insertion device radiation with that of the bending magnets up- and down-stream of the ID, which means that even if the net position reading is correct on the two pBPM's, the position of the ID part of the radiation is not exactly correct. To overcome these limitations we are studying new kinds of pBPM's that perform an energy analysis of the photo-electrons in order to distinguish the higher energy photons from the ID compared to those of the bending magnet fringe field [8].

In parallel, the possibilities for using upgraded electron BPM's in a feedback system are being studied. This involves both the development of a new analog receiver and digital demodulator with high precision/large dynamic range, as well as a new BPM design mounted on the low gap ID vessels for greater sensitivity, but with enhanced long and short term mechanical stability [9].

4 NEW INSERTION DEVICES

4.1 Magnetic Systems

Six new insertion device modules for 3 ID straight sections are under various stages of design and construction [10]. All of these will be APPLE-2 type devices in order to provide horizontal, circular and vertical polarisation for user experiments. All previous IDs (apart from the EEW) were based on a standard 1.5 m long support structure, and in most cases 3 such modules were accommodated in each straight section. These new devices will be split into 2 sections rather than 3 and are based on a 2-2.2 m long standard support with integrated phase motion for polarisation adjustment. The first 6 cm period device is under construction; a short 7-period prototype has already been tested and given very encouraging results. The second device will be a novel quasi-periodic variably-polarised device.

4.2 Vacuum Chambers

A first 4.8 m long narrow gap, pump-free, ID vacuum vessel was installed in ELETTRA in August '97. The chamber was made of machined stainless steel halves, welded together, with an internal(external) apertures of 15(17) mm. Unfortunately the experience with this chamber was negative: after a long conditioning time the vacuum level and beam lifetime improved, however a higher gamma radiation remained which forced the removal of the chamber. Various laboratory tests have since been carried out but no clear explanation has emerged so far for the observed effects. On the other hand a simpler pump-free chamber for the EEW, based on a seamless stainless-steel elliptical tube, conditioned quickly without difficulties [11]. For the future IDs, another technique is being investigated based on an Aluminium extrusion which provides a higher mechanical accuracy together with much lower cost, with the advantage of higher conductivity which will be useful for future smaller gap vessels. A first vessel is under construction, with internal(external) dimensions of 14(17) mm.

The production of circularly (and even more so vertically) polarised radiation is a potential problem in ELETTRA due to the heat load on the 10 mm high radiation slot in the downstream bending magnet vessel. Calculations have shown that the existing external water cooling of the stainless-steel vessel is not sufficient in the case of the lower energy undulators with high K values. To overcome this problem a new Aluminium vacuum vessel has been designed and the first chamber is presently under construction.

5 FEL DEVELOPMENT PROJECT

A major research and technological development (RTD) project has recently been funded by the European Commission under its program for improvements to Large Scale Facilities, for the development of a UV/VUV storage ring FEL on ELETTRA. The other partners in the project are CEA/LURE, CLRC-Daresbury Laboratory, Univ. Dortmund, ENEA-Frascati and MAX-lab. The aims of the project are related to the potential use of the FEL as a user facility, i.e. stable lasing over a broad range, at least between 350 and 190 nm, while still permitting the operation of other synchrotron radiation beamlines. Initial operation will be at 1 GeV, although higher energy operation will also be explored, most probably in a 4-bunch mode (depending on the choice of optical cavity length).

6 INJECTION SYSTEM UPGRADE

Looking beyond the machine developments discussed above, it is clear that the major remaining limitation to the continuing improvement of the performance of ELETTRA is the fact that the beam has to be injected at 1 GeV and ramped to 2 GeV. Despite the operational improvements [1] to reduce the injection time to a minimum there are still a number of important consequences of the present arrangement:

• the possibility of implementing IDs with smaller gaps is severely compromised since this would imply reduced lifetime, a more frequent injection, and hence a greater percentage of time lost;

• a major limitation to the closed orbit stability that can be achieved is the thermal cycling that occurs. Injection at full-energy opens the possibility of regular or top-up injection in order to maintain constant thermal conditions. In addition, if this can be achieved with undulators closed and beam shutters open, the thermal load on optical elements is also kept constant.

The specification for an upgrade to the injection system is therefore compatibility with the maximum envisaged storage ring operational energy (2.4 GeV), with the possibility of performing a top-up injection. The two options that are being studied are an upgrade to the linac injector, by means of a recycling scheme, and a booster synchrotron.

A booster could be conveniently located in the open space on the inside of the storage ring building. Leaving allowance for shielding etc., a machine with a maximum radius of around 25 m can be accommodated, which allows an energy of 2.5 GeV to be comfortably reached. A costing of the building modifications, the booster, and the changes to the injection system is presently being carried out to be in a position to make a decision on whether to proceed at the end of this year.

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