Beam Diagnostics at ELETTRA

M. Ferianis, A. Carniel, M. Bossi, R. De Monte, G. Mian,
T. Monaci, R. Passini, P. Surace, L. Tosi.
Sincrotrone Trieste
Padriciano 99 - 34012 Trieste - Italy

Abstract

ELETTRA is a third generation synchrotron radiation source. Very accurate monitoring of the beam is required in order to stabilise the beam position for the users. The beam diagnostics for ELETTRA and the first results, are presented in this paper. The diagnostics provided to the machine operator are: the Beam Positton Monitoring (BPM) system, tune measurement system, intensity monitors, striplines, fluorescent screen system, synchrotron radiation profile monitor and scrapers. The instrumentation is fully integrated in the machine Control System, since commissioning started. Up to now, the diagnostics have fulfilled the requirements and have shown a good reliability. The first turn was performed in a very short time, using BPMs, fluorescent screens and intensity monitors. Some general results are presented.

1. INTRODUCTION

Elettra is a third generation Storage Ring with a full energy Linac and a Transfer Line in between. The available diagnostics for the commissioning of ELETTRA were: BPMs, intensity monitors, fluorescent screens, transverse profile monitor, tune measurement system and scrapers. The machine commissioning has been easily carried out by performing extensive measurements with these tools. At the present, all diagnostic instruments are integrated in the Control System and measurements may be performed by the use of user graphical interfaces running on UNIX workstations. In this paper a general overview of the performances of the above mentioned instruments in the Transfer Line and in the Storage Ring is given.

2. TRANSFER LINE DIAGNOSTICS

The Transfer Line instrumentation has been used for beam steering and for tuning the linac energy and it includes BPMs, fluorescent screens, intensity monitors and a horizontal scraper.

Twelve fluorescent screens [1], which are essentially doped ceramic disks capable of detecting the electron beam, are located between the Linac and the injection tank. Since the start of operation (April '93) only one bellow and a couple of ccd cameras have been substituted, in spite of the high radiation level.The fluorescent screens are used for Linac energy optimization. The image of the beam is transferred in the control room on a monitor. By these means, a quadrupole polarity inversion has been detected.

Three pulsed current transformers detect the current pulse (up to 20 MHz) coming from the linac. A permalloy toroid is placed around the vacuum chamber after a ceramic gap and a magnetic shield improves the signal-to-noise ratio. By means of a calibration winding it is possible to calibrate each toroid with the coaxial cable up to the acquisition rack. The analogue signals of the toroids are multiplexed over a long coaxial cable and they can be seen directly on a control room scope.

The BPMs [2] are striplines and they are rotated of 45 degrees to avoid direct beam impinging on the electrodes. The acquisition electronics comprise two hybrid circuits for the sum and difference analogue computations, two levels of multiplexing and a digital scope for the acquisition. A slow,software, feedback loop has been implemented to desensitise the injection from linac exit conditions. A process takes the BPM readings and applies the computed signal variation to the appropriate correctors A correction rate of 1/s is foreseen. When the loop is active, only the two BPMs used by the feedback are read.

One horizontal scraper [1] has been placed in the dispersive region of the first bend section of the transfer line. Its main purpose is to define the beam energy range before injection. An automatic linac energy spread measurement program is under implementation. While a slit, of a given width, is scanning the transfer line vacuum chamber in the dispersive region, the toroid current is read to measure the charge present at any transverse position. Due to its heavily irradiated position the scraper requires periodic maintenance.

3. STORAGE RING DIAGNOSTICS. MAIN RESULTS.

At the ELETTRA commissioning start-up the BPM system, the fluorescent screen system, the DCCT, a provisional tune measurement and the scrapers were available. Within eight months of commissioning period, the following new instruments were brought to operation: definitive tune measurement and feedback system, transverse profile monitor, a provisional Insertion Device (ID) interlock system, a fast beam dump, a bunch length measurement and a synchronous phase measurement set-up. In the meantime, the already existing instruments were continuously improved.

3.1 BPM system

The BPM system is the backbone of any Storage Ring instrumentation. This system has been developed in house [3]. The final hardware and software implementation, together with the first operation results, can be found in [4]. The system has provided, from the start of commissioning, both first turn and closed orbit operation. All the electronic part showed a good behaviour. A 150 μm rms value of the corrected orbit in both planes has been achieved.

Some problems come from the support system and from the thermal load on the BPMs near the bending ports. Solutions are presently under study. The BPM system also provides the readings for an Insertion Devices (ID) interlock system. This system checks for beam position and angle in the ID centre point, once the ID has been closed. If the limit values of position or angle are exceeded, the ID interlock system dumps the beam by means of an hardware micro-interruption (5 ms) on the RF master oscillator. A provisional system is now in operation, which allows three insertion devices to be closed simultaneously. Due to a cable miss-routing a heavy network communication takes place among three CPUs during interlock operation, not advisable from the reliability point of view.

3.2 DCCT

A Parametric Current Transformer [1], built by BERGOZ (France) provides the beam current measurement. The specifications are listed in Table 1.

Table 1

Full range scale	-500 mA + 500 mA
Linearity Error	< ±0.001 %
Resolution	1 μA rms
Zero drift (1 hour)	10 μA rms

The toroid core is made of a thin ribbon of a high permeability alloy of an amorphous structure. The electronic equipment consists of an active current transformer and a magnetic parametric amplifier in a common feedback loop; this allows a large dynamic range and a high resolution. A filter had to be added on the electronics, since the system showed a tendency of saturating when the ring was filled with few buckiets at high current. An additional magnetic shielding has been designed in house and consists of a double shielding of ARMCO iron, giving a total attenuation to external magnetic field better than 2000 times. A seven digit digital voltmeter (mod. Datron 1281), connected through GPIB to an VME CPU, provides high accuracy acquisitions of the amplifier output. An associated software, running under OS/9 operative system, collects the readings and calculates the lifetime or the injection efficiency.

3.3 Fluorescent Screens

The fluorescent screens for the storage ring are similar to those of the Transfer Line with more stringent vacuum requirements, to give zero impedance. A detailed description of this mechanical design is given in [1]. Besides the first turn steering, fluorescent screens are used for injection elements tuning, when needed.

3.4 Tune Measurement System

The tune measurement system [5] has been designed in order to provide also a tune feedback. Two channels link the Control System to the beam: upstream channel (pick-up) and downstream one (excitation).

The upstream channel takes the signals from a four button electrode pick-up, feeds them to a synchronous detector where the horizontal and vertical components of beam movements are extracted and converted to base band. These low frequency signals are switched to a spectrum analyser input.

Downstream, the source signal from the same spectrum analyser is connected to a power amplifier for beam excitation. By means of a coupling unit, in phase or off-phase signals are fed to four stripline electrodes.

The system is fully integrated in the Control System and measurements may be commanded from the workstation,

3.5 Transverse Profile Monitor

The ELETTRA transverse profile monitor has shown to be a fundamental instrument for the machine commissioning and operation. The light from a bending magnet is focused onto a ccd camera by means of an optical line. After an exhaustive study [6] of the light propagation through the optical components and an evaluation of the consequent wave front distortion, high quality optical components have been installed to optimise the focused beam image. The radiation heated vacuum mirror, the most critical part of the system, showed a significative distortion at high energy current (I_b >200 mA @2 GeV). Future improvements are under study. At lower energies and/or currents, the operation of the instrument is as predicted, with a diffraction limited resolution of 55 μm (vertical plane) and 64 μm (horizontal plane).

3.6 Scraper

One vertical and two horizontal scrapers [1] are placed in the ELETTRA Storage Ring. Whereas one horizontal scraper is in a dispersive region the other two are in a non dispersive region. During several months of operation no problems were found. A value of 2.5 μm for relative accuracy and reproducibility, measured in the laboratory before the installation, has been confirmed.

3.7 Single button electrode

Twelve single button electrodes are distributed around the ring. The electrode is a 50 Ohms feed through with a button of 10 mm in diameter, like those used for the BPMs. These electrodes are wide bandwidth pick-ups and have been used for bunch length and beam spectra measurements. The scattering parameter S_{11} has been measured with a network analyser and a flat behaviour was found up to 14 GHz [7].

3.8 Stripline electrode

An accurate design and construction allowed to obtain electrodes which flush to the vacuum pipe profile, while keeping the impedance closely equal to 50 Ohms. The stripline has been used for single bunch measurements.

Terminated at the downstream end with a high-frequency 50 Ohm load [7], it was connected by 10 meters of wide bandwidth cable (Suhner 12272-04) to a single shot very-fast digitiser (TEK SCD 5000). This instrument has an analogue bandwidth of 4.5 GHz, with a risetime resolution of 65 ps.. By measuring the rise time of the direct pulse, a measurement of the bunch length (supposed gaussian) is possible [8],[9].

4. CONTROL OF THE ELETTRA DIAGNOSTICS

At the present state the diagnostics are fully integrated in the machine Control system. According to the philosophy of the distributed control [10], six VME CPUs control the machine timing, the Transfer Line and the Storage Ring diagnostics. Twelve Equipment Interface Units (EIU) are linked to the BPMs' VME for data acquisition through their detector boards.

4.1 Control room instrumentation

Besides the information flowing from the field to the machine consoles by the control system, some analogue signals and instruments have been installed. Two monitors display the images from the fluorescent screen and the transverse profile monitor. An analogue scope is used for visualization of the storage ring filling pattern. A digital scope displays the signal of the Transfer Line intensity monitors (linac pulse length, intensity). One spectrum analyser is dedicated to the tune measurement system and another spectrum analyser, with a 1.8 GHz bandwidth, is used for explorations of beam instabilities.

4.2 The Beam Instrumentation Graphical User Interface.

The Beam Instrumentation Graphical User Interface is a collection of control panels embedded in the ELETTRA control system. Any beam instrument can be reached through the ELETTRA synoptic representation [11] by a simple mouse click on the related item. The control panels have been built with an extensive use of the Control Panel Editor (CPE) [12]. Special functions have been added to the fluorescent screen panel, where the operator can pick-up the beam image.

5. FUTURE DEVELOPMENT

Soon, a Local feedback system will be tested on an ID straight section. The system computes from the associated photon beam position monitors the currents to be applied in order to keep the beam position and angle stable at the centre of an Insertion Devices. A microprocessor based board will compute the correction voltages within a range of 200 µm @ 10 Hz. Field trials are foreseen in the near future. Also a definitive ID interlock system will be soon installed. A single CPU computes beam orbit variation in the ID straight, from two adjacent BPM signals. If the threshold is exceeded, than a hardware cabled signal will reach the RF generator to perform a µ-interruption (5 ms).

The final solution will overcame this problem, by routing the cables in the proper way, concentrating in a single CPU each ID interlock.

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7. REFERENCES

[1] M. Ferianis et al., "Destructive Beam Diagnostics at ELETTRA", this conference.

[2] R. Ursic et al., "Measuring the Beam Position in the Elettra Linac", rd European Particle Accelerator Conference.

[3] R. Ursic et al., "High Stability Beam position monitoring of Elettra",

[4] R. De Monte et al., "Elettra BPM system (hardware and software); first results", this conference

[5] A. Carniel et al., "Tune feedback system at Elettra", this conference.

[6] M. Ferianis et al., "The Optics of the Elettra Transverse Profile Monitor", this conference.

[7] M. Ferianis et al., "Measurement set-up for broad band signals", 61th Elettra Commissioning meeting minutes attached note.

[8] S. L. Kramer, "Longitudinal Bunch Profile Measurements with Striplines", 3 rd European Particle Acxcelerator Conference (1992).

[9] E. Karantzoulis et al., "Observation of Instabilities in the Elettra Storage Ring", this conference.

[10] D. Bulfone, Status and Prospects of the ELETTRA Control System,Proc. of the International Conf. on Accelerator and Large Experimental Physics Control Systems, Berlin, Germany, 1993; to be published on Nucl. Instr. and Meth. in Phys. Res., Section A.

[11] F. Potepan et al, An Integrated Set of UNIX Based System Tools at Control Room Level, Proc. of the International Conf. on Accelerator and Large Experimental Physics Control Systems, Berlin, Germany, 1993; to be published on Nucl. Instr. and Meth. in Phys. Res., Section A

[12] G. Surace, " Control Panel Editor- developer's guide", Sincrotrone Trieste note ST/M-93/6.