Destructive Beam Diagnostics at ELETTRA

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Abstract

The beam diagnostic system for ELETTRA includes some destructive monitors: fluorescent screens and scrapers. In this paper a description of the mechanical and electronic parts of the destructive monitors is given. There are altogether 19 fluorescent screens placed along the Transfer Line and the Storage Ring. Different designs have been adopted due to the more stringent requirements for the Storage Ring. The fluorescent screens have shown to be reliable and accurate instruments to transfer the beam from the linac to the storage ring and to injection conditions. One scraper is located in the Transfer Line dispersive region and it is used for energy spread measurement and for linac energy optimisation. Three scrapers are located around the Storage Ring and they are used for dynamic aperture and for emittance measurements. The design and the performance of the instruments are presented.

1. INTRODUCTION

ELETTRA is a third generation synchrotron radiation light source. A full energy beam is transferred from a Linac to the Storage Ring by a Transfer Line. Both the Transfer Line and the Storage Ring instrumentation are controlled from the Control Room. Destructive beam diagnostics include fluorescent screens and scrapers. These have been extensively used during the Transfer Line and Storage Ring commissioning and in normal operation.

2. FLUORESCENT SCREENS

Fluorescent screens are simple though very useful diagnostic tools. A total number of 19 screens is placed along the Transfer Line and the Storage Ring. The whole design of the system was developed in house, including mechanics, vacuum, electronics and control.

From the image produced by the beam on the screen, both beam positions and dimensions can be evaluated, due to an accurate assembly and alignment and to an image analysis software. The whole system is integrated in the ELETTRA Control System.

2.1 Mechanics and vacuum design.

The mechanical design of the Transfer Line Fluorescent Screens aimed at producing a reliable and precise instrument having good Ultra High Vacuum (UHV) characteristics.

The fluorescent screen is a doped ceramic disc provided with accurately centred reference marks and is installed facing the beam at 45^{o} on a black anodised aluminium support. The thick fluorescent disks are made of ceramic, doped with Chromium Sesquioxide (Cromox 6) and have been developed at CERN [1]. Custom markings were required for the calibration (centre of screen and scale factor). They showed a very good behaviour in terms of conversion efficiency and reliability. During the first year of operation no damage or break was observed.

The UHV seal is obtained by clamping the copper seal between the fluorescent screen container ring and the bellow flange.

The fluorescent screen support is enclosed within a 1.5 mm thick stainless steel container sealed at the bottom and terminating with a rotatable 40 CF ring.

The support is fitted with a stray light screen, designed to surround also the front portion of the camera objective. A number of small lamps are also mounted inside to illuminate the screen for focusing and for calibration [2].

The camera is mounted on an adjustable system. An adjustable system has been designed to easily remove the camera for magnet re-alignment and to ensure its precise repositioning. To protect the camera, it is enclosed within a 5 mm lead box.

As for mechanics, the design of the Storage Ring Fluorescent Screen is very similar to the one described above.

This approach turned out to be very economical as we did not have to make a completely new project and because many components could be manufactured from already existing drawings. The Storage Ring Fluorescent Screens have, however, a few extra features which are worth mentioning.

In order to keep the impedance of the vacuum chamber as constant as possible, the housing is machined out of a solid block of 316 LN stainless steel to reproduce the internal geometry of the storage ring vacuum chamber and to match the impedance free flanging used throughout the storage ring. Furthermore, the necessary opening of the fluorescent screen inside the vacuum chamber is closed by a plate that recreates the chamber wall, on retraction of the fluorescent screen. Only a small longitudinal slot on the plate ensures that the volume behind is also pumped when the screen is retracted.

2.2 Electronics (control and acquisition)

A commercial CCD camera is used for imaging the screen through a remotely controlled lens (iris and focus control). Limit switches detect the actual screen position. Peripheral control units have been designed to enable remote control of both mechanical and optical functions of each fluorescent screen. Two dedicated serial communication busses (Transfer Line and Storage Ring) connect the peripherals to the CPU. The CPU is a 68030 VME board placed in a crate together with the Frame Grabber for the image acquisition. The CPU is a Local Process Computer (LPC) and it is integrated in the

Control System. The image of the beam is displayed on a monitor in the Control Room [2].

2.3 Software

The software for the control of the fluorescent screens is based on the following modules: a data structure, a low level library for mechanical control, an image acquisition and processing module, an RPC server for communication with the Control System [3].

Two different operation modes are available on the fluorescent screen: live beam image and on-line beam analysis. The first one performs a beam image acquisition synchronised with the Linac shots. Any variation in both Linac conditions or machine optics set-up can be immediately detected. The second one runs the beam analysis at a rate of 1 sec. and it computes both beam position and size. Before using the analysis routine a calibration has to be performed to find the screen absolute centre (1 mm of total absolute accuracy) and to compute the scale factor between pixel and the measurement units of the image.

2.4 First operation results

The Fluorescent screens were extensively used during the commissioning of ELETTRA (the Linac, the Transfer Line and the Storage Ring). The Linac energy is usually set up by centring the electron beam on a fluorescent screen placed just after the first horizontal bending magnet of the Transfer Line. The Fluorescent Screen turned out to be very useful for steering the beam through the Transfer Line. In particular by visualising the beam image on the screen a quadrupole polarity inversion was found.

The steering through the Transfer Line was optimised by a HLS program that corrects the orbit after reading the beam position at twelve different positions in the Transfer Line.

The injection parameters were also optimised by looking at the fluorescent screen in the Storage Ring. The optimum injection conditions were defined by given positions of the beam and injection elements' parameters were adjusted until the optimum position was reached.

Finally, first turn steering had been successfully performed by checking the beam position and shape at six places around the Storage Ring.

3. SCRAPERS

The scrapers used at ELETTRA are of two different types.

The Transfer Line scraper was developed first and has less severe mechanical and impedance requirements than those of the Storage Ring. It is placed in a dispersive region of the Transfer Line and it is used for energy spread measurement.

The Storage Ring scrapers have to fulfil the zero impedance requirement, when not in use, and they have to perform very accurate and reproducible motion of the blades.

Three scrapers are mounted on the storage ring vacuum chamber: two horizontal and one vertical. The first horizontal scraper is placed in a dispersive region, whereas the second one, together with the vertical one, are placed in a non-dispersive region.

3.1 Mechanical design of the Transfer Line scraper

The Transfer Line Scraper design had to take into account the narrow space available at its chosen location.

The assemblies carrying the two scraping rods are connected to a screw housed inside a slotted tube that is clamped on the drive mechanics assembly. The tube is grounded and precisely guides the rod translation.

The scraping rods are made of OFHC copper and the UHV seal between the bellow and the rod is machined on the rod itself. The counter flange is a CF 16, drilled out for the rod extension. This was required for dissipating the thermal energy deposited on the rod by the beam .

The driving screws are connected to stepping motors and two springs ensure a backlash free movement.

Two high precision micro switches give the driving control the necessary reference to position the rods as required.

3.2 Mechanical design of the Storage Ring scraper

The mechanical design aim of the storage ring scraper project was to produce an instrument with a setting precision and repeatability better than 5 μm and having as little as possible influence on vacuum chamber impedance.

The housing of the scrapers was, like that of the Storage Ring fluorescent screens, machined to have the same inside geometry of the vacuum chamber with a smooth transition from both sides to a flat area in correspondence of the scraper rods bore. The flanging to the vacuum chamber was designed to take the impedance free sealing gasket used throughout the ring.

The gap between the scraping blades and the bore was kept small, keeping in mind that the volume behind (bellows) had to be pumped through it. Very close to the surface a beryllium copper ring, with spaced contact fingers, was inserted to short circuit the rod with the housing. The scraping rods are water-cooled through a manifold system that brings the cooling fluid in up to the rod face trough a central tube, the fluid returns to the manifold exit through the annular space left between the central tube and the rod bore.

Each rod is mounted on a sliding block, moved by a high precision ball screw connected by a toothed belt to a stepping motor. The sliding blocks are guided by precision ball bushes running on ground rods.

To obtain the required precision it was necessary to compensate the spring action of the sealing bellows. This was done with a cam system acting against the bellow spring in compression and in favour of elongation and remaining neutral across the bellow free length. This design ensured that only the constant force of atmospheric pressure acting on the evacuated sealing bellows was applied to the driving mechanism. The instrument has a repeatability of better than 2.5 μm.

3.3 Electronics

The electronics for controlling the stepping motors includes one controller board for each motor plus the brake circuits and the limit switch control.

The electromagnetic brake prevents the blades from moving in case of power supply failure.

Each motor is equipped with an optical encoder whose output is directly fed back into the motor controller.

The resolution of the position control was set to 2 steps of the motor controller (equal to 2.5μm). The scraper blade cooling is connected to an interlock system that inhibits the blades' movements if the water flow is under the set threshold.

As the distance between the motor and the controller has to be limited, the controller boards have been placed in dedicated crates, near the scraper location.

A single CPU (68030 VME board) controls all three scrapers by a serial RS-485 serial link. All the functions of the scrapers are integrated in the control system.

3.4 Control software

All the variables for motor control and for the communication with the Control System are placed in a data structure, called Data Module.

A library of "C" functions has been developed for accessing the motor controllers. One process, running in background, monitors the status of each controller. In case of any fault (motor over temperature, communication problem or system fault) the appropriate flag is set in the Data Module and the message is reported in the workstation operator panel.

A second process checks for any service request from the workstation; if no errors are present on that scraper, the action is acknowledged and started, by sending an event signal to the motor controlling process. After action completion the status of that scraper is updated and another action can take place. During the motion, actual scraper position is displayed on the WS, in real time, giving the user the feeling of the action.

3.5 Measurements performed with the scrapers

The Transfer Line scraper has been implemented for an eventual Linac energy spread measurement. For this purpose a low level routine moves the slit and reads the beam current with a downstream toroid.

The Storage Ring scrapers are used for lifetime measurements, to find lifetime limiting effects. Extensive data on this measurement can be found in [3].

4. SUMMARY

In this paper the destructive monitors of ELETTRA have been presented. After more than one year of operation they showed to be reliable and accurate.

The fluorescent screens have been successfully used for the commissioning of the machine, for Transfer Line steering and for injection optimisation.

The scrapers have been used for beam lifetime studies

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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