LINAC AND TRANSFER LINE BEAM POSITION MONITOR AT ELETTRA

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Abstract

A Beam Position Monitor (BPM) system, based on Log Ratio detectors (Bergoz LR-BPM), has been designed, built and commissioned at ELETTRA. Currently, the system is installed on the ELETTRA Linac and Transfer Line and it is integrated in the ELETTRA control system. The system is being used to monitor the trajectory along the Transfer Line; in the Linac, it monitors and controls the Linac beam stability. Furthermore, the Transfer Line BPMs are integrated in the program TOCA for the correction of the trajectory and the optimisation of the injection efficiency. The paper describes the system and the measurements performed both in laboratory and on the ELETTRA electron beam. Future possible applications of the LR-BPM system for the upgraded ELETTRA Linac, to be used for the new seeded FEL source, are here briefly presented.

INTRODUCTION

The old BPM system for the Linac and Transfer Line [5] based on a two GPIB-controlled oscilloscope acquisition system and multiplexer system, has been upgraded.

The system has been developed for the new ELETTRA full energy injector [1] composed by a 100 MeV Linac and a 3Hz cycling Booster synchrotron, up to 2.5GeV. The system will be used for the measurement of the beam position along the Linac and the two new Transfer Lines; it will be integrated in the beam trajectory feedback system for the optimization top up operation.

The single shot acquisitions can be averaged to improve the resolution for the trajectory's optimization. For the injection efficiency evaluation instead, a single shot charge measurement is required.

The main specifications of the system are the acquisition of the position with a resolution of less than 100 μm in a circular vacuum chamber, 40 mm diameter; the minimum beam charge goes down to 50pC, both in single bunch and multi bunch mode.

The theoretical sensitivity [2] of a Log Ratio BPM can be calculated with the following formula referred to Figure 1 and calculated for the dimensions of the actual linac to storage ring transfer line.

$$20Log_{10}\left(\frac{A}{B}\right) = yS_y \cong \frac{160}{Ln(10)}\frac{\sin\left(\frac{\phi}{2}\right)}{\phi}\frac{y}{r} = \frac{160}{Ln(10)}\frac{\sin\left(\frac{\pi/4}{2}\right)}{\pi/4}\frac{1}{22.65} = 1.495dB/mm \quad (1)$$

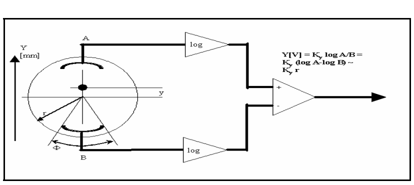

Figure 1: Log Ratio Principle of operation

SYSTEM DESCRIPTION

The system is based on the Bergoz Log Ratio Beam Position Monitor (LR-BPM) electronic board, fitted with sample and hold module to acquire position and charge. Each electronic board can process signals either from orthogonal or rotated pick-ups (user configurable). Two analog outputs, for the x and y position, generate a signal of ±2V. A third analog output gives a signal (sum of logs) the area of which is proportional to charge [3].

There is also a digital output which detects a beam passage, to be used for triggering the A/D converter. The LR-BPM boards are housed in a 19" 3U RF shielded chassis (provided by Bergoz) including 2 power supply units and up to 16 BPM stations, connected to the pick-ups on the rear panel. A custom connection board collecting signals from four BPM stations has been developed to route signals to the A/D converter boards. The A/D converters adopt a CAEN V265 (8 ch.) charge integrating converter and two INCAA VD10 8 ch. 16 bit differential A/D converter. The timing signals to operate the system are provided by a CAEN V462 dual gate generator. All the VME boards are controlled by a Motorola VME5100 CPU, running a server application integrated in the ELETTRA control system, via RPC protocol. Each BPM station, equipped with a CPU, a dual gate board, a charge integrating converter, and two A/D converter boards can manage up to 8 groups of BPM. A group of BPM shares a LR-BPM front-end, and two A/D converter channels via four RF multiplexers that connect the LR-BPM input to each selected pick –up.

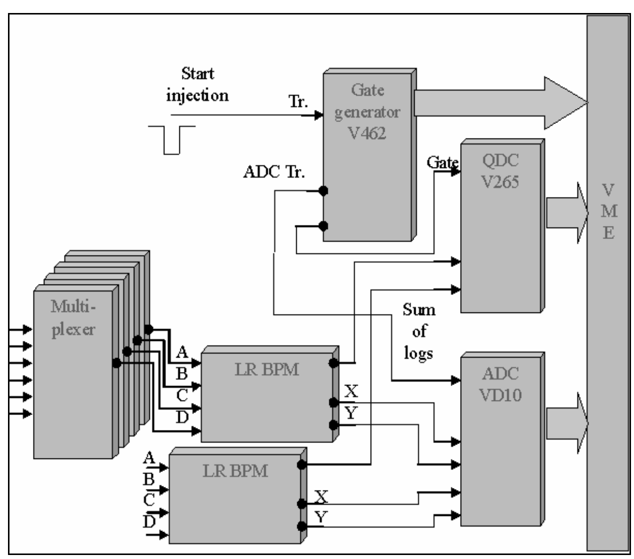

Figure 2: System layout

For each trigger pulse, data are acquired from the selected BPM inside each group.

For a better performance a single pick up for each group has been chosen. For each trigger pulse a complete trajectory is acquired using the same bunch's train in order to check for shot-to-shot stability.

To improve the sensitivity of the system to low charge bunches a set of four amplifier and band pass filters (f_0=500MHz, BW=54MHz) have been inserted between each pick-up's electrode and the LR-BPM input.

SYSTEM CHARACTERIZATION MEASUREMENTS

Bench Top Measurements

Some preliminary measurements have been carried out simulating the beam signal with a generator to check the best performance of the system, in the ideal case of a perfectly stable beam. A series of acquisitions has been done with the system in the final configuration as shown in Figure 3.

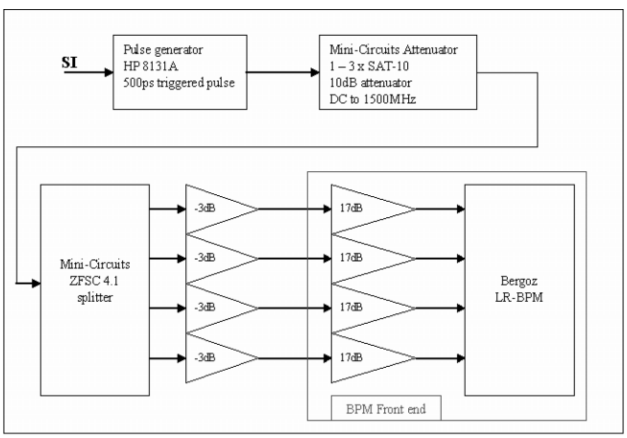

Figure 3: Bench top measurements layout

The acquisitions have been made varying the generator output amplitude to simulate a beam charge variation. The acquired charge and position information show a good linearity for the charge. The RMS of measured position is 75μm and 40μm, for single and multi bunch simulating signal respectively.

Charge sensitivity

A second set of measurements has been performed on the real beam to evaluate the minimum beam charge detectable by the system. The Linac charge, measured with a toroid, has been decreased till the system loosed the trigger with the beam; the measurements were performed both in multi and single bunch. For current injection in multi bunch (MB) mode (70ns macropulse) 500 pC charge is used; the BPM correctly detected down to 25 pC (-26dB from nominal value).

In single bunch (SB) mode only a relative measurement was possible, the toroid being not calibrated. A relative measurement between standard SB beam and the lower detected value also showed a similar dynamic of 28 dB.

Calibration and Position Resolution

To cross-calibrate the system, a series of measurements have been performed acquiring the position of the beam at two consecutive BPMs and a downstream fluorescent screen (FLSC), all located on a drift, while horizontal/ vertical scans were performed using a corrector pair.
The beam positions read by the BPMs and by the FLSC were simultaneously acquired to check for the calibration constant, previously computed. For each beam position, several tens of acquisitions have been stored to a file for off-line processing.
Two derived series of data have been generated averaging respectively five and ten samples. For a fixed number of samples (50) of each of these series the average and rms was computed and then plotted versus the corrector current.

The result of the scan shows a good linearity between the corrector current and the position acquired by the BPM.

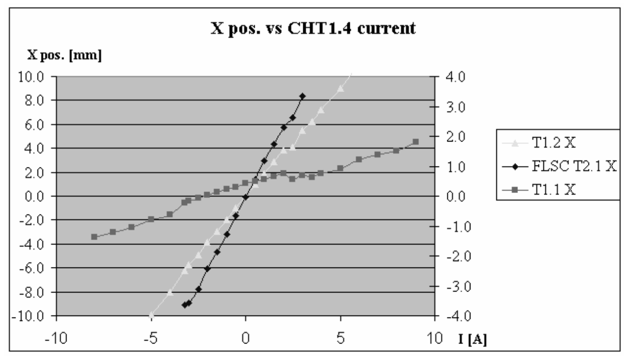

Figure 4 Horizontal beam position read by the BPMs and the fluorescent screen during a horizontal scan. BPMT1.1 is located near the corrector (0.6m) while BPMT1.2 and FLSCT2.1 are at 5.5m and 5.87m respectively. (BPMT1.1 beam position refers to the Y axis on the right of the graph).

The RMS, giving the uncertainty of the measurement, is ≈150μm. Considering the 40μm RMS, due to the electronics, we get a beam position stability of about

$$RMS_b = \sqrt{RMS_T^2 - RMS_e^2} = \sqrt{150^2 - 40^2} = 144\mu m \qquad (2)$$

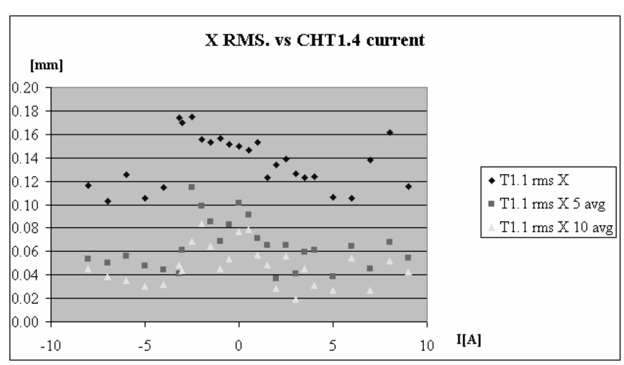

Figure 5 Total measured RMS

TRANSFER LINE TRAJECTORY OPTIMIZATION

The BPM system is installed on the injector Linac and the Linac to Storage Ring Transfer Line. It is used for the monitoring of the Linac beam stability and for the beam trajectory optimization along the Transfer Line.

The data acquired by the system and made available to the ELETTRA control system, via RPC calls, have been used by the application program TOCA [4]; a test has been performed with beam. The response matrix has been measured by the program for both horizontal and vertical planes. The figures below show the beam trajectory before and after a single correction calculated using the measured response matrix.

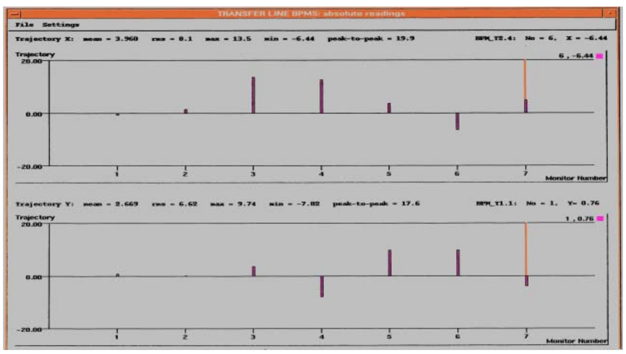

Figure 6: BPM readings before correction. The last BPM orange bar means that the BPM is not reached by the beam due to a beam stopper closed.

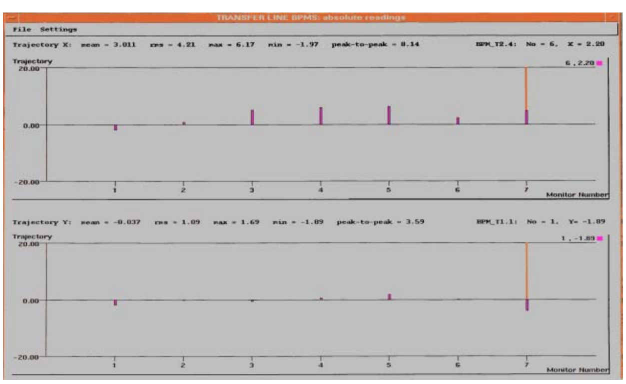

Figure 7: BPM readings after correction.

The vertical trajectory looks better corrected with respect to the horizontal one probably due to an energy variation of the linac beam.

The improvement in the TL trajectory appears evident also by comparing the beam loss monitor (BLM) readings, before and after the correction.

FUTURE APPLICATIONS

The present work on the LR-BPM system will be integrated in the design of an up-graded BPM system, to be used on the up-graded ELETTRA Linac for the new IV Generation Light Source, FERMI@ELETTRA.

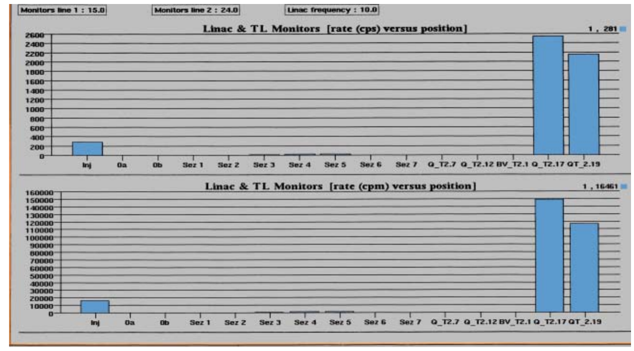

Figure 8: BLM readings before correction.

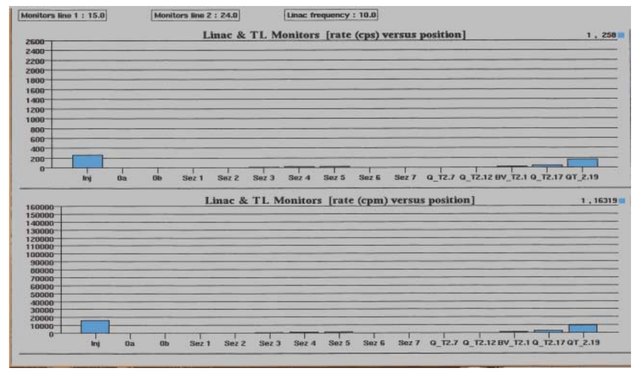

Figure 9: BLM readings after correction.

Equipped with new Photo injector, two bunch compressors and vertical ramp, the 1.2GeV electron beam will feed an Undulator straight section where seeded FEL radiation will be produced. Two sets of BPM will be most probably used for this new machine: an EM pick-up based type for the Linac and a Cavity pick-up based type for the Undulator straight section. The LR detector is a candidate for the first type of BPM although its performance needs to be pushed in order to reach 10-20μm_{RMS} in single shot, single bunch.

REFERENCES

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[4] F.Iazzourene, “TOCA: A highly User Friendly Application program for the Tune, Orbit, Dispersion and Chromaticity Correction.”, PAC 1999.

[5] M. Ferianis et al. “The upgrade BPM systems for the ELETTRA Linac and Transfer Line”, DIPAC 1997 proceedings