THE LOW GAP BPM SYSTEM AT ELETTRA: COMMISSIONING RESULTS

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Abstract

Two Low Gap BPMs have been successfully installed at ELETTRA and have now completed the commissioning phase. The main purpose of these new devices is to provide stable beam position measurement, at sub-micron level, to monitor the stability of the light delivered to the Users. The improvements with respect to the normal BPM system have been obtained adopting both a new Low Gap BPM sensor and a new non-multiplexed BPM detector, the latter being developed in co-operation with the SLS diagnostic group at the PSI. Beside the Closed Orbit mode, thanks to the digitally selectable bandwidth, the new BPM detector can be operated also in the Turn-by-Turn mode and provide the position signal to feedback loops.

In this paper we first briefly review the system architecture, describing its mechanical and electronic parts. Then, we present the digital BPM detector set-up used at ELETTRA and the associated firmware required by the four-channel BPM detector to guarantee performance over the full dynamic range. The BPM-position monitoring system is also described and its integration in the BPM system presented. Laboratory tests confirmed sub-micron resolution at 10kHz data rate. A series of beam based measurements have been performed in order to test this system and to verify the improvement in performance. The system is presently used in the control room as a powerful beam quality monitor; its extension to other Storage Ring straight sections is under evaluation.

1 SYSTEM OVERVIEW

To provide a stable photon source point is a well-known challenge in third-generation synchrotron light sources. The stabilization over long time periods, typically 24-hours, of the position of the electron beam can be achieved only using high- resolution, high-stability beam position monitoring systems in feedback loops, high meaning here at the sub-micron level.

The Low Gap Beam Position Monitor (LG-BPM) system at ELETTRA [1] has been developed to provide both high resolution and high accuracy beam position measurements. Two main developments have been completed to satisfy the requirements: the new digital programmable detector and the new sensor with its dedicated support system. The new digital detector has been jointly developed between the Swiss Light Source (SLS) Diagnostic group, the Instrumentation Technology Company [2] and the ELETTRA diagnostic group. This is a completely new four-channel system using parallel processing of the four button signals, to avoid errors due to multiplexingand to improve read out rate. Furthermore, thanks to direct IF signal under-sampling and digital filtering, the receiver bandwidth can be tuned to any of the operation modes: closed orbit, feedback mode or turn-by-turn [3].

The new Low Gap BPM sensor has been developed at ELETTRA [4] and it has been designed taking full advantage of the 14mm, low gap, new aluminum ID chamber installed at ELETTRA. Furthermore, this new sensor is fitted with bellows on each side to reduce mechanical coupling to the vacuum chamber.

Two sensors have been located in straight section 2, close to the undulator, using a dedicated support system. The position of each sensor is monitored in real time with respect to a reference column made of carbon fiber. The absolute position of the electron beam is therefore measured at sub-micron accuracy with a suitable resolution.

2 DIGITAL DETECTOR AT ELETTRA

2.1 System configuration

The Digital Detector system installed at ELETTRA relies on the Quad Digital Receiver (QDR) VME board and on the Front-End (FE) VME board. Both units are four channel devices for non-multiplexed acquisition of the button electrode signals and have been described in [3]. At ELETTRA two pairs of QDR+FE have been installed to acquire the signals of the LG-BPM.

2.2 Software Configuration

Two different software environments have been created. The first one runs under the Windows operating system and it is written in ‘C’ language using National Instruments CVI. With this software it is possible to perform all the hardware settings and tests on the Digital Receiver VME boards. The results are graphically displayed in real-time. The second environment has a completely different architecture and is used for field operation with the same hardware. The requirements for field operation are: continuous real time data acquisition, network (Ethernet) connectivity, data reliability and compatibility with the Elettra Control System, remote control access capability (telnet). To meet all these requirements, Linux with real time extensions (RTAI) has

been chosen and implemented. The code has been written in 'C' language with the GNU Gcc Compiler.
The software is structured in multiple parts. The core of the system is a Real Time kernel module that acquires continuously the data from the VME Digital Receiver boards and performs the X and Y position calculations. The core module is synchronised by an interrupt generated by the DDC boards at 4, 8, 16 and 32kHz. It writes the acquired data in a common memory area that can be accessed by other non real-time user processes. This area is also used to pass all of the calibration factors and settings to the Digital Receiver boards. The user processes are the following. MEAN calculates all the average and rms values triggered by the acquisition core every 500 acquisitions via a RT FIFO. RS_RCV receives and manages the mechanical movements of the LG-BPM sensors. BEAM_INFO_CL reads the current beam parameters. ACQUI collects all the data and stores them in log files. AUTOAGC manages automatically the gains of the RF front ends. MONITOR simply displays the internal acquisition system data and allows setting some parameters. The real-time data pass to the Pentek 'C40' DSP for the Elettra local feedback system. The delay introduced by the acquisition system when delivering the XY position to the DSP via the VME bus has been measured to be equal 30 µSec.

2.3 Laboratory measurements

Multiple laboratory measurements have been performed to optimize the system for the required accuracy, resolution and long term stability. In fig. 1 the longterm stability test is shown: the acquisition rate was 10kHz.

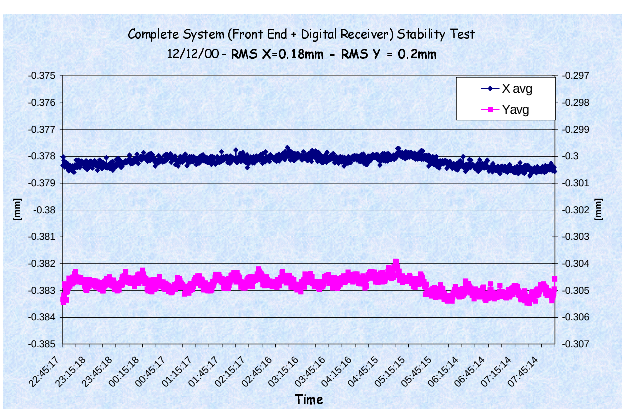


Fig. 1: 10-hour, long-term stability measurements performed in the laboratory on a complete system: Front End plus Digital Receiver. X_{rms}=0.18µm Y_{rms}=0.20µm.

3 THE BPM MONITORING SYSTEM

3.1 System description

The BPM monitoring system [1] is in operation since fall 1999. It is used to monitor in real-time the actual horizontal and vertical position of each Low Gap BPM with respect to a reference column installed adjacent to each LG-BPM. The temperatures are also monitored.

Movements of the LG-BPM body are measured using Capacitive Sensors by Physik Instrumente [5], which proved to be ideally suited for this task. The Capacitive Sensor provides an output voltage that is linearly related to the distance between its capacitor plates, with <50nm resolution in the 400µm range. Preliminary measurements have been made in the ELETTRA tunnel [1] before adopting this solution. No vibrations of significant (>200nm) amplitude were recorded while the tunnel air temperature was stable to within ±0.5°C. Under these assumptions, a column made of Carbon Epoxy Laminate (CTE=-0.1µm/°Km) and free from any mechanical load, can be considered as a reference for the position measurement of the LG-BPM.

3.2 Model of the support system

To gain a deeper knowledge on the position and temperature measurements, a simple model has been derived for the LG-BPM support system both for the vertical and horizontal axis (see fig.2).

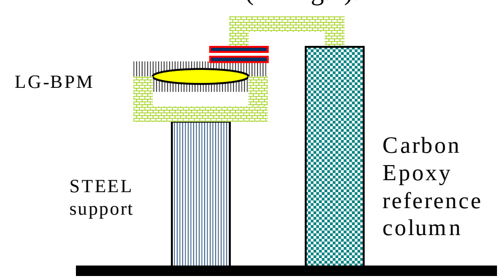


Fig. 2: drawing (not to scale) of the model of the LG-BPM support system, vertical axis. *Vertical lines*=steel, *bricks*=aluminum, *squares*=Carbon Epoxy laminate and *solid*=capacitive sensors.

The measured position drifts are in good agreement (see fig.3) with the computed one, obtained with following formula, which holds for the vertical axis.

$$\Delta L_y = \alpha_{steel}\Delta T_{air} L_{steel} + \Delta T_{LG-BPM} * \left(\alpha_{steel} L_{LG-BPM} + \alpha_{alu} L_{eq}\right)$$

with:

$\alpha_{steel,\ alu}$ Coeff. of Therm. Exp. of steel and aluminum
$\Delta L_{y,x}$ the computed drift along Y or X
ΔT_{air} the measured tunnel air temperature variation
L_{steel} the length of the LG-BPM support
ΔT_{LG-BPM} the measured LG-BPM temperature variation
L_{LG-BPM} the size of the LG-BPM along Y or X
L_{eq} the length of the aluminum LG-BPM holder

3.3 Integration into the LG-BPM system

A Peripheral Intelligent Node (PIN) is fitted to each LG-BPM installed in the storage ring tunnel.

A PIN is a micro-controller [6] based unit, which acquire the position and temperature signals and send them to a Master Unit via CAN-bus.

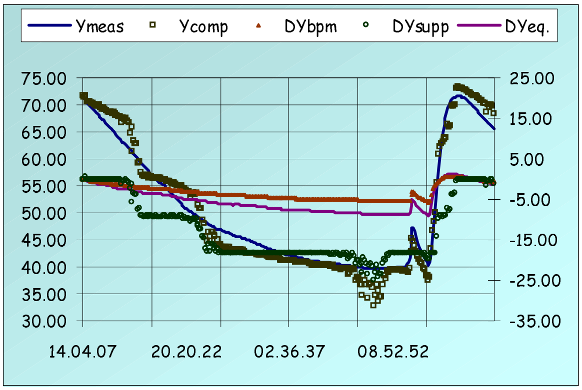


Fig.3: plots of measured and computed vertical position drift of the LG-BPM; vertical scales: 5µm/div

The acquisition runs continuously at 1Hz. In normal operation mode, the Master Unit collects the data from the PINs and at regular, user-definable time intervals (typically equal to 1 minute) computes the average and root mean square values for each PIN buffer and sends them the LG-BPM Linux CPU via a serial line. Vibration measurements are possible running the acquisition at 4kHz as the maximum output bandwidth of the Capacitive Sensor readout electronic is 3kHz.

4 THE COMMISSIONING RESULTS

4.1 Long term measurements

The electron beam position has been measured with the LG-BPM system over a 5-hour period (see fig.4). The SLOW Feedback process was running for the first two hours while it was OFF for the rest of the time. The SLOW Feedback process relies on the readings from the standard e-BPM of ELETTRA.

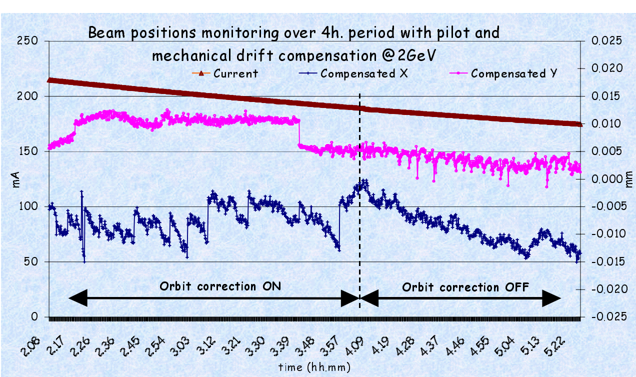


Fig.4: beam position measurement over 5 hour time; vertical scale:5µm/div.

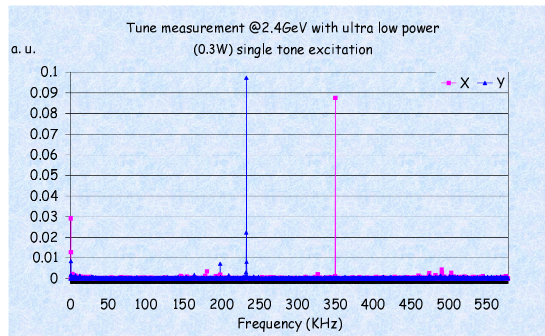
Two main considerations can be drawn from fig.4:

- the vertical beam position is stable within few microns over many hours
- the sub-micron resolution of the Digital Detector, measured in the laboratory, is confirmed here by the granularity of the beam position reading.

4.2 Fast acquisitions and turn-by-turn

The Digital Receiver is fully programmable by the User; the bandwidth of the position readings can be tuned to the different operation modes, like close orbit, feedback or turn-by-turn. Thanks to turn-by-turn mode a parassitic tune measurement can be performed on line (fig.5). In the close orbit and feedback mode, the lower frequency beam spectrum can be measured and proper error signal can be delivered to a feedback system.

Fig.5: tune measurement with turn-by-turn acquisition.



5 CONCLUSIONS

The LG-BPM system has proved sub-micron resolution and accuracy; it is therefore suitable for driving a feedback system at ELETTRA.

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