Photon Beam Position Monitors suitable for a Local Feedback System at ELETTRA

Andrea Galimberti, Alessandro Abrami, Quian-Hong Chen, Dario Giuressi, Luca Olivi, Rudi Sergo
and Adolfo Savoia, Sincrotrone Trieste, Trieste, Italy

ABSTRACT

A high flux Photon Beam Position Monitor (PBPM) has been designed, realized and installed at ELETTRA for increasing the beam stability with local-bump-orbit feedbacks (LF), for beam diagnostic and for beam alignment. An electronic equipment has been designed and built for the calculation of the photon beam center positions and the beam angles both on the vertical and horizontal planes. A description of the PBPM system and its performances is presented. Measurements and test runs reveal a high precision and reliability of the PBPM and its electronics. A submicron sensitivity in the beam center positions and a submicroradiant sensitivity for the beam angles detection are achieved. At present, a PBPM system is installed in each Front-End (FE) of beamlines from Undulator (UND) and Wiggler (WIG) at Elettra. Starting from the results presented, further applications of the PBPM system for third generation Synchrotron Radiation (SR) machines are discussed in this paper.

1 INTRODUCTION

The main feature of third generation SR sources, like ELETTRA, is a radiation of high intensity with low emittance and high brilliance obtained by using Insertion Devices (ID) like UND and WIG. This high quality radiation opens a lot of new opportunities for experiments in a wide range of fields but it also introduces a great number of difficulties and technical problems. It is of great importance to determine very accurately the position of the beam by using a PBPM system. The need for such a device arises from the fact that the beam moves during operation due to thermal drifts, power supply ripple and mechanical instabilities. In addition, every change of UND gap determines a small orbit variation which must be corrected automatically, a very important feature in a user controlled UND operation.

As a consequence the most important application of the information obtained from PBPM, is related to the LFs that act on Corrector Magnets (M) in the straight sections, with the target of stabilizing the beam position. In fact, it is of primary importance that the end-users of SR can rely on a beam fixed in a constant position during their experiments. Moreover an analysis of the PBPM signals, in the time and frequency domains, can give valuable information about beam quality and beam perturbations in the storage ring.

2 DESIGN CONSIDERATIONS

The PBPM developed at Elettra is based on the well-known photoemission principle. We have chosen, as photon sensor, a very robust device capable of withstanding high radiation flux present in ID beamlines. The idea is not new at all [1] [2] [3], but the mechanical design, materials and electronics have been carefully studied. The PBPM intercepts only the fringes of the SR. Each PBPM has four blades of TZM alloy, that act as sensitive elements, mounted on a water cooled copper block, spaced 90° from each other. The copper block and the TZM blades are electrically insulated by berilla blades, which also allow the heat transmission from the TZM and the block itself. A high voltage bias is applied to the copper block in order to remove the cloud of photoemitted electrons that arises between the blades when they are hit by the beam.

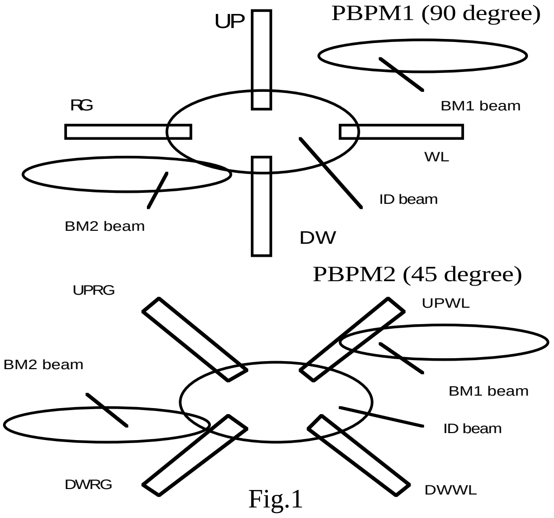

Fig.1

The PBPM system calculates the coordinates of the photon beam center on the horizontal and vertical planes. To compute the angles of the beam axis, on each FE from ID, two PBPMs are installed at a distance of 1m from each other. The first monitor has a 90° blade assembly while the second has the blades rotated 45° with respect to the first one as shown in fig.1. They are mounted on a motorized x-z translation system and their position is read by optical encoders with 0.1μm sensitivity.

The Bending Magnet (BM) radiation has to be considered carefully for its effect on the detection of the UND beam position. In fact, spatially, on an orthogonal section of the photon beam three spots are visible, one due to the ID beam and the others to the BMs at the beginning and at the end of the straight section (fig.1). These spots, if not carefully accounted for, introduce an error on the ID beam center position.

3 ELECTRONICS

The PBPMs are extremely sensitive and have a high dynamic range of operation. A complete data acquisition system, dedicated to the PBPM, has been developed, built and tested.

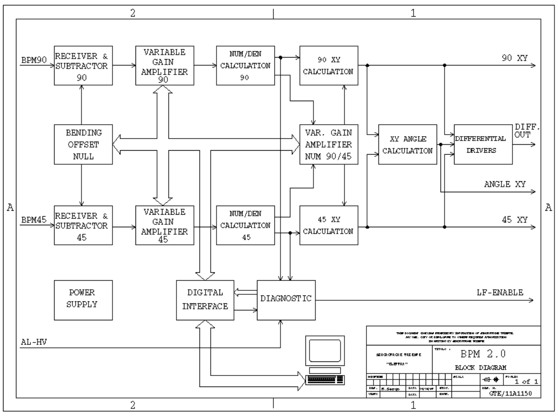

Fig.2

The electronic instrumentation is divided in two parts: a pre-amplification stage and a signal conditioning stage. The first part is located into two shielded boxes directly mounted on the feedthroughs of the PBPMs vacuum chambers. A current-to-voltage stage detects photocurrents from 1pA up to tens of mA with only few gain settings. An ultra-low bias current and offset of the stage assure a high sensitivity to the whole system. A differential analog signal transmission is used for the link between the two stages, in order to reject the common mode noise component.

The main purpose of the signal conditioning stage (fig.2) is to compute the beam center coordinates both at the PBPM1 and at the PBPM2, and the beam angles both on the horizontal and vertical planes. All the calculations are performed with analog components in order to assure a fast response of the system.

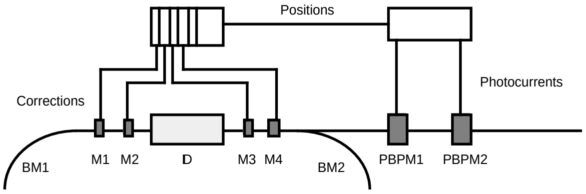

Fig.3

This electronics has also the possibility to compensate that part of the signal produced by photons coming from BMs. This is done by introducing an offset, whose value is determined at the beginning and scales linearly with ring current. This contribution does not change, to a first approximation, with the UND gap movements. The values of this component can be inserted in a look-up table and subtracted from the signals coming from the PBPMs. Eight 12-bit D/A converters allow to compensate for all input channels the offsets due to the BM radiation in order to obtain a submicron accuracy on the ID beam position. Another feature of the signal conditioning board, is the possibility to set overall gains. This is important to assure a wide signal dynamic range. Twelve 10-bit MDAC converters perform this task. Some additional support logic has been developed using the fully programmable gate array technology (FPGA). These custom components allow to decrease the space and the number of gates on the board and permit to fit exactly the requirements that arise from the project specifications. The PBPM instrumentation is fully controllable by a digital I/O card from a host computer.

A 16-bit A/D converter stage is present on the signal conditioning board. By this stage all the signals of the instrument are read by an external computer. In the normal operation mode, this instrument is interfaced with a dedicated Beamline Control System (BCS)[4] unit that supervises all the actions on a beamline. On the other hand, via the differential outputs, the board sends the beam positions to an instrumentation set that will perform a LF correction on the electron orbit in the storage ring, acting on four steering magnets (M) in order to stabilize the beam position within the beamline (fig.3).

4 PERFORMANCES

The linearity of the PBPM, for the vertical blades, is shown in fig.4. Over the 4mm of linearity range, the slope is 25±2nA/µm.

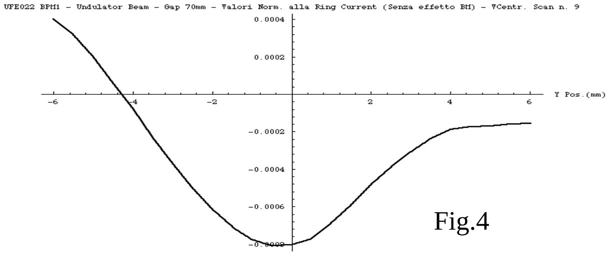

Fig.4

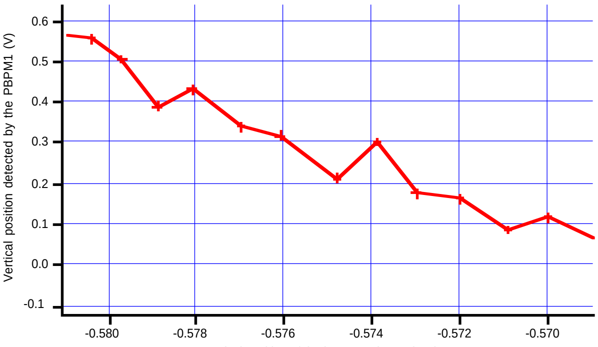

Fig.5

In the fig. 5 is clearly visible the micron sensitivity of the PBPM. The data are obtained moving the PBPM with the motorized translation system on the vertical axis and reading the position with the optical encoder. The noise on the data is due to the beam oscillations. Moreover a submicron sensitivity can be obtained with a better signal filtering. The angular sensitivity strictly depends upon two main factors: the linear sensitivity of the detectors and the distance between the two monitors that involve the angle detection. So for a linear sensitivity of 1µm, we need only a distance of 1m to have an angular sensitivity of 1µrad.

5 APPLICATIONS

In the commissioning phase of each beamline the PBPMs are used as reference points for the alignment of the optics. The combined usage of the PBPMs data, the entrance and exit slits of the monochromator data and the BCS gives the possibility to find an automatic alignment procedure of the beamline optics [5].

The PBPM system is also an interesting aid for beam diagnostic. Scanning the beam area with a PBPM we can obtain a 3D image of the ID beam purified of the BM components (fig.6). Moreover a continuos monitoring of the beam center coordinates on the horizontal and vertical planes may be correlated with any change of parameters related to storage ring instrumentation. Practically, these data may be added to the information arriving from the e^- beam position monitors (BPM) of the storage ring.

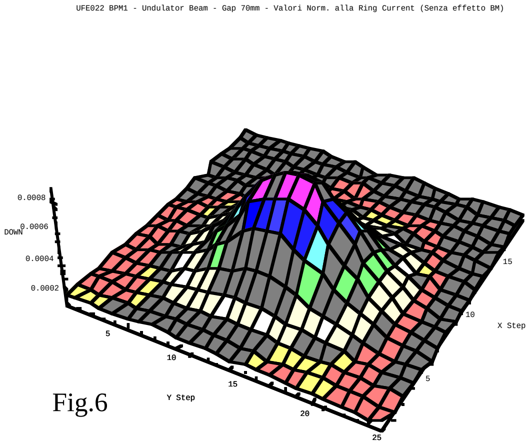

Fig.6

The linear PBPM sensitivity is about one order of magnitude greater than the BPM. Moreover, the angular sensitivity is the major feature of the PBPM system. It is trivial to notice that also a little output angle of the photon beam from an UND can cause a significant beam shift in the beamline tens of meters far from the source. So, for the beam stability, it is more important to detect and then correct any photon beam axis angle error than the linear positions of the beam referred at the ID center. A wide number of problems reduces the photon beam quality and stability. Such problems force beam oscillations, usually at low frequency. Moreover some well known problems, as the electric 50 Hz and its armonics, may be very difficult to eliminate at the sources.

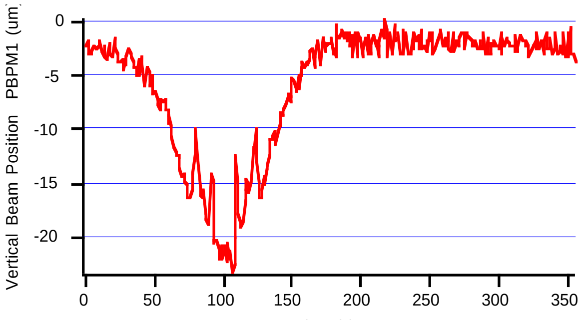

Fig.7

So, it is desirable a feedback loop that eliminates or at least reduces the beam oscillations. A LF (fig.3) is under development for this purpose. It has to eliminate the low frequency (0-10Hz) beam oscillations and to attenuate the frequency from 10 to 50 Hz. The LF is also suitable to eliminate the very low frequency oscillations (under 1Hz) due to mechanical vibrations. For instance the opening and the closing of an UND gap may perturbate the orbit in the storage ring moving the photon beam in other sections. This slow effect may be prevented using a LF system based on the PBPM. In fig.7 a first result is presented. The measure was done at the 6.2 ID section, while on the 3.2 ID section the UND gap was being changed. At t=20s (LF off) the UND gap started closing from over 200mm, at t=100s the UND gap was closed to 32mm. Then the UND gap was opened until the initial aperture was reached again (t=180s). The beam shift at the position of the first PBPM of the 6.2 section was about 20µm. At t=200s the LF was turned on and the gap movement on the section 3.2 was repeated. No beam shifts into the FE 6.2 were detected.

REFERENCES

[1] P. Mortazavi, M. Woodle, H. Rarback and D. Shu, "High Flux Beam Monitor", Nucl. Instrum. and Meth., A246 (1986)

[2] D. Shu, J.T. Collins, J. Barraza, T.M. Kuzay "The Advanced Photon Source X-ray transmitting beam-position-monitor tests at the national synchrotron light source X-25 beamline", Nucl. Instrum. and Meth.in Phys. Res. A 347 (1994) 577-580.

[3] D. Shu, B. Rodricks, J. Barraza, T. Sanchez and T.M. Kuzay "The APS X-ray undulator photon beam position monitor and tests at CHESS and NSLS", Nucl. Instrum. and Meth., 1th Aug 1992 v319 n1/3 page56

[4] A. Abrami, F. Gagliardi, A. Galimberti, A. Savoia. "The ELETTRA Beamlines Control System.", ST/S-TN-92/9., Technical Note (May 1992)

[5] R. Poboni, R. Pugliese "On Line Optimization of the Synchrotron Beam Alignment Using a Linguistic Self-Organized Optimizing Control Scheme", ICALEPS95 International Conference on Accelerator and Large Experimental Physics Control Systems 1995, Chicago (U.S.A.).