A PRELIMINARY STUDY ON HIGH PRECISION PHOTON BEAM POSITION MONITOR DESIGN FOR LOCAL FEEDBACK SYSTEMS

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Abstract

In the last generation of SR sources, a great effort has been spent on beam stability improvements. For the incoming users' requests, also the photon beam position in each beamline is controlled in various facilities. Local bump orbit feedback systems are actually under development for improving the stability of the delivered radiation. Photon Beam Position Monitors (PBPM) are used to detect the beam motions at low and high frequency and their performance play a key role for a successful local feedback system. In this scenario the design of the PBPM becomes a great challenge for the high precision and sensitivity requested. A lot of real error sources, as bending magnet contamination, electrical noise, mechanical tolerances and crosstalks, affect and degrade the performances of the actual devices. Starting from a background of operational experience using these devices, a preliminary study for a new generation of photon beam position monitors is presented in this paper. Some possible solutions, suitable to overcome the actual PBPM problem, are proposed.

1 INTRODUCTION

1.1 The actual PBPM System

The conventional approach to a PBPM system for a high flux beamline from an Insertion Device (ID) is to provide a couple of sensors based on four blades which intercept the fringes of the beam and photoemit electrons. The positions of the beam centre in the vertical and horizontal planes and the angles of emission are then computed from the eight photocurrents measured. At ELETTRA, in all the front-ends of the ID beamlines, a PBPM system is installed [1]. A lot of effort has been spent the last year in order to develop a local orbit feedback system (LF), based on the PBPM, with the target to stabilise the residual beam oscillations seen at the experimental chambers locations [2-5]. Some very interesting results have been achieved with the LF development. In particular the control algorithms obtained to completely damp the photon beam oscillations at the location of the PBPMs. But at the experimental chamber location the situation was quite different: the beam oscillations were not damped. This phenomena is due to the actual PBPMs which are not able to assure the high level of precision requested for such a kind of applications. A precision of 0.1μm is desirable for position measurements while 0.1 μrad is necessary for angle of emission. Moreover for any fast feedback application, a signal bandwidth of at least 5Khz is required. We examine the more significant sources of error in order to clarify the scenario and to allow the design of a second generation of PBPM fully oriented towards local and global feedback applications.

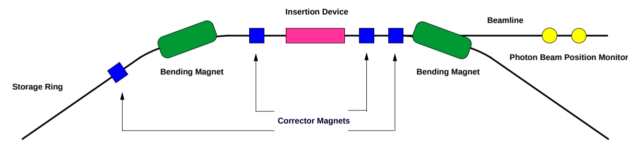

Figure 1: The layout of a straight section and the front-end of the beamline.

2 ERROR SOURCES

2.1 The Dipole Contamination

The most unwanted effect is due to dipole radiation that hits the PBPMs. The storage ring configuration allows a significant part of the radiation from the upstream and downstream dipoles to go down the ID beamline (fig. 1). The distance from the source gives a wide spatial distribution of the radiation coming from the upstream BM while the distance of few meters from the downstream BM gives a stronger effect but in a more limited area.

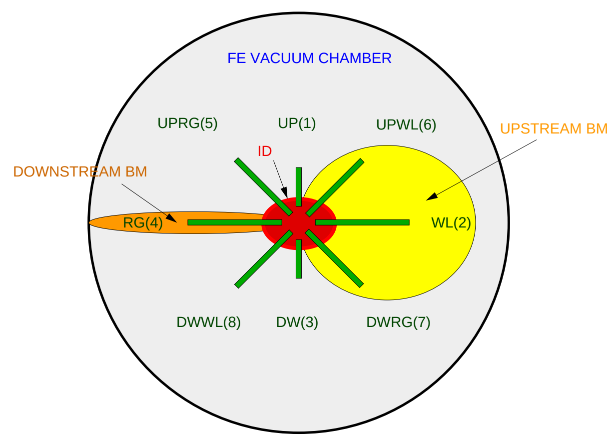

Figure 2: A section of the vacuum chamber with the displacements of the three theoretical beam spots compared to the dimensions of the PBPM active element .

Depicted in the fig. 2 is the ideal photon spatial distribution integrated over the energy of the main beams present into the beamline [6]. This figure has been obtained by simple geometric considerations starting from an ideal orbit shape. The beam sizes and the blades are drawn in the same scale. In fig.3 the real situation, detected in the undulator FE of section 2.2, is shown. The real electron orbit causes a mutual shift of the two BM spots and an intersection between them, but the behaviour confirms the theoretical calculations. From experimental measurements we noticed that the absolute photocurrent values due to the dipoles are very similar to those due to the ID. This happens because the length of the blades integrates spatially a big portion of the BM spots and because the tungsten photoyield integrates the wide dipole radiation's energy distribution. These effects magnify the strength of the dipoles seen by the blades inside the FE from ID. It seems to be hard to work with such a contamination using any conventional photoemission type PBPM. This effect is due to the DC component of the BM radiation and in principle might be compensated. Unfortunately the orbit drifts, in each BM, and this drift is not fully predictable. In addition the BM radiation has an AC component which cannot be compensated at all. In fact when the ID is closed there are not data about these oscillations in the horizontal and vertical planes. These points are very critical for any feedback system implementation because these undetected movements are comparable to the ID movements that they would correct.

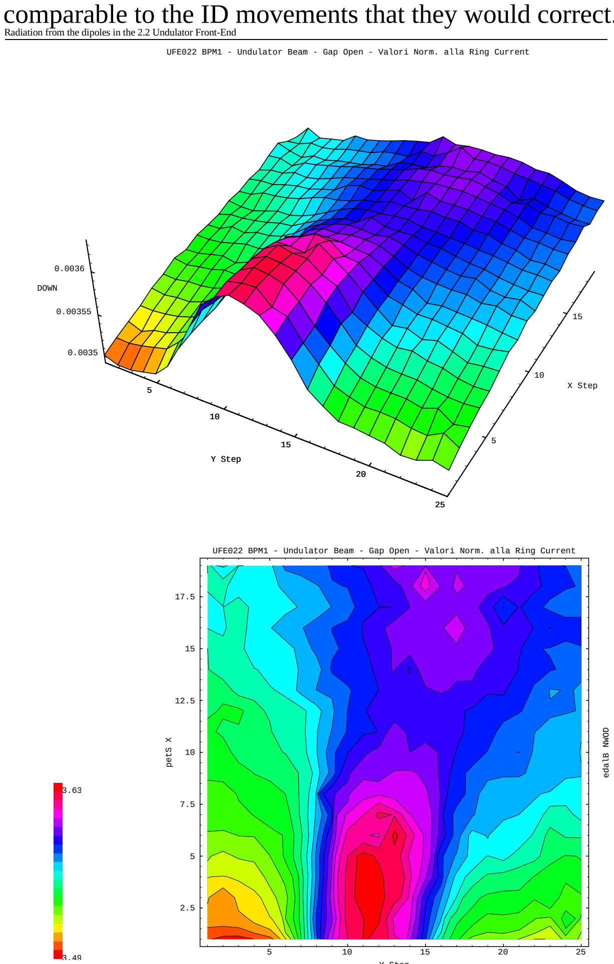

Figure 3: A real displacement of the dipole radiation detected in the undulator beamline from the section 2.2. There are clearly visible the two spots with different sizes and intensity.

2.2 The Electrical Noise

A SR facility is a particularly noisy environment. Power supply units, RF equipment, ground loops and switching electronic devices are only some examples of electrical noise sources. The PBPMs are usually placed inside the storage ring tunnel far from the instrumentation racks. Long cables and multiple connections are critical for high precision signals. The problem is not the signal level as an absolute value, usually some mA, but the position information contained in the ratios, differences and sums calculated from each photocurrent. In a fine position control, done by the feedbacks, the system is always working with photocurrents of about the same value. So the performance of the system is due to the minimum delta of the signals detectable above the noise level.

2.3 Crosstalk

Another source error is the mutual crosstalk between the vertical and horizontal planes. There are various causes for this effect: mechanical asymmetries of the active elements, asymmetrical working point with respect to the beam, asymmetric effects due to the photoemitted electron cloud, asymmetries due to the dipole contamination and defects of the steerer magnet coils. In particular this effect has been noticed on the second PBPM which is mounted with a rotation of 45° with respect to the axis. In this case each blade has a contribution due to the two components of the different planes and mechanical asymmetries of 0.1 mm may also cause a crosstalk error of over 10%.

2.4 Vibrations and Mechanical Defects

Another aspect is the importance of the mechanical construction. As we have seen before, the majority of the defects of the PBPM may be grouped as asymmetry problems. In fact, these sensors are built for the detection of the centre of a beam that we assume to be intrinsically symmetric with respect to the two axis. External effects and defect in construction may decrease this mutual symmetry (detector-beam) and introduce a position reading error. So the mechanical constraint is to preserve, as much as possible, this symmetry. A tolerance of 0.01 mm is acceptable for almost all components. The assembling has to be done with great accuracy in order to assure that each blade is aligned with respect to the others in all the planes. Linked to the mechanics is the aspect of the vibrations. Vibrations mean mechanical noise that the sensor might understand as beam movements. Ground vibrations might be critical for the monitors used for feedback systems. The 5 Hz to 100 Hz is the most dangerous range for mechanical vibrations [6]. Particular supports may be used in overcoming these effects.

3 A SIMULATION APPROACH

In order to quantify the effect of dipole motion on the PBPM we have carried out a numerical simulation based on experimental data. We assume that the photon flux, for each of the three sources, has a gaussian distribution. This assumption allows us to use some semi-analytical formulas to speed up considerably the calculations. We obtained the relative photon flux intensities from the scans taken in section 2.2. Namely we set the maximum intensity for downstream BM to 1, for upstream BM to 0.3 and for the ID to 1.3. This is the scenario for an ID gap closed at about 80 mm. The simulation proceeds in two steps, following the standard calibration procedure of the real PBPM. First we calculate the four blade signals due only to the BM radiation. Then we calculate the signals adding the ID contribution. The simulation proceeds by moving the upstream BM source, scanning a small area around the reference position, while the ID source is kept fixed. Finally we calculate the positions after a subtraction, from each blade, of the reference BM contribution. The result is a table giving us the apparent beam position as seen from the PBPM for each displacement of the upstream BM source (tab. 1). For the purpose of comparison we calculate another table in which we move the ID source of the same amount. The simulation has been repeated varying the relative intensity of the ID photon flux to examine its effect on the global response. The results confirm the high sensitivity of the PBPM with respect the BM movements. When the ID/BM ratio is increased of an order of magnitude, the sensitivity to the BM shifts is reduced by a factor ten.

ID/BM	1.3/1	13/1	130/1
ΔXpbpm/ΔXbm	1.92E+00	1.90E-01	2.00E-02
ΔYpbpm/ΔYbm	7.70E-03	9.20E-04	8.50E-05
ΔXpbpm/ΔYbm	7.50E-03	9.10E-04	8.40E-05

Table 1: Apparent ID movements, seen by the PBPM, due to BM shifts. The ID/BM ratio changes for different weights given to the sources .

4 NEW PERSPECTIVES FOR PBPM

The continuous request of increasing beam stability by high brightness beamline users, forces to investigate other solutions for overcoming the PBPM limitations. Here is a brief analysis of the most promising ones.

4.1 A Geometric Solution

Starting from the fact that at the PBPM there are three beam spots mixed together in the centre of the vacuum chamber, one idea is to move the ID beam with respect to the BM beams. This effect might be obtained with a drastic movement of the orbit in the straight section in order to move the dipole spots inside the beamline [7]. A spatial shift of at least 10 mm on both planes is essential. This technique is difficult to adopt because it requires a test beamline from an ID, which is not available at ELETTRA. Another approach might be to filter out the BM radiation with a sort of pin-hole placed in the outer region of the PBPM. This tool might be a spatial shield for intercepting the external part of the BM radiation. Another version might be a graphite filter which cut off the high energy contribution of the dipole [8]. Any filter type device has to take in account the heat load present into the FE from ID. A more simple variation is to modify the geometry of the active elements. The blades in fact may be placed in the less contaminated areas [9]. This is a possible low cost way to decrease the ID/BM ratio, but it is not the final solution at the problem.

4.2 Photon Energy Discrimination

A completely different approach is to acquire the photoemitted electrons instead of measuring the photocurrents. In this case it is possible to discriminate in energy the electrons and so the photons. It is known that the BM radiation is emitted in a wide energy range from few eV to over 10 keV while the undulator radiation is peaked in a narrow energy bandwidth, usually from 100 eV to 400 eV. The first attempt done is to cut off the low energies contributions. A biased grid set placed, in front of the blades, before the biased collectors acts as a highpass filter for the photoemitted electrons [10]. The results look very promising and the BM contamination may be reduced to values lower than 10%. At ELETTRA we are actually studying a new generation of PBPM based on the electron energy discrimination. In particular we are developing a new kind of technique able to do a sort of bandpass filter, over the electron energies, centred on the undulator peak. The expected residual BM contamination is about 0.05%. This ID/BM ratio is fully compatible with any feedback implementation. Results from a first prototype are planned for the beginning of the next year.

5 CONCLUSIONS

A brief summary about the problems of the design of PBPM for ID beamlines has been presented. In spite of the intrinsic difficulties, to build a device that detects with very high precision and sensitivity the ID movements, the demand from users and machine people for PBPM is increasing. Some new perspectives are actually investigated in various facilities around the world. In particular a new technique, based on the energy discrimination of the photoemitted electrons is under development at ELETTRA and, from the first calculations, looks very promising to solve the PBPM problem.

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