AN OPTICAL SYSTEM FOR THE OBSERVATION OF TRANVERSE BEAM MOTION

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ABSTRACT

An electro-optical system, named Slow Beam Motion Monitor (SBMM), has been developed at ELETTRA to monitor the beam motion in the transverse plane. The system is composed of a two dimensional linear position sensing photodiode which is installed at the light port used also for the profile monitor. The horizontal and vertical signals are digitized by a VME board and the results of the measurement are presented on a dedicated graphical panel. A bandwidth of up to 2.5 kHz is achieved with the present implementation.

1 BACKGROUND

1.1 Beam slow motion

During the local feedback system commissioning for the ELETTRA Storage Ring (SR), some low frequency motion components have been observed. The first observations have been made by looking at the spectra of the signals of the Photon Beam Position Monitors (PBPM). A first photodiode, battery powered, has been installed at the light port of the Synchrotron Radiation Profile Monitor (SRPM). By carefully positioning this simple photodiode on the beam tails, again signal intensity variations have been observed due to slow beam motion in the transverse plane. After this second, and definitive, observation the design of a permanent system for monitoring slow beam motion in the transverse plane started late last year.

1.2 Scientific co-operation

Due to the short time schedule and the high workload of the group, and also to take advantage of the availability of an opto-electronic company (CARSO) present in the AREA Scientific Park, here in Trieste, it was decided to jointly develop the system described in this paper.

2 SYSTEM REQUIREMENTS

The main requirements for the SBMM system are listed below:

- to operate in both vertical and horizontal planes
- to not interfere with the SRPM
- to be accurate down to the micron level
- to be insensitive to beam current variations
- to monitor beam motion up to a few kilohertz
- to be permanently in operation
- to be integrated in the ELETTRA control system

In order to rapidly install the SBMM, it was decided to put it into the optical laboratory of the SRPM and to use the same bending radiation. Nevertheless, no beam splitter has been used to avoid wavefront distortion of the beam used by the SRPM.

3 DESCRIPTION OF THE SYSTEM

To fulfill the above mentioned requirements the SBMM system is composed of:

- a square linear position sensing photodiode
- a Front End electronic module
- an A/D VME conversion board
- a graphical panel for displaying the time signals and frequency spectra.

To improve the S/N ratio of the photodiode signals and the mechanical/thermic operating conditions of the photodiode, both the photodiode and the Front End electronics are mounted in a Front End box.

3.1 The SBMM Location

The SBMM is located in the optical laboratory that has been set-up two years ago for the installation of the SRPM. In this laboratory, located in the Experimental Area of the SR, the light from a bending port (S12.2) is acquired by a CCD camera, placed on an optical table.

In order not to interfere with the SRPM itself, by distorting the wavefront passing through a beam splitter, the SBMM operates with the light reflected backward by a filter placed just in front of the CCD camera of the SRPM.

3.2 The Sensor: a Linear Photodiode

The linear position sensing photodiode is an opto-electronic device which behaves like an optical potentiometer (see figure 1).

The current generated by a light spot impinging on the diode surface and flowing through a high resistance bulk material separates according to Ohm’s law among the four contacts at the edges.

The difference of currents between opposite contacts is a linear function of the position of the light spot between the contacts.

The absolute information of the spot position is achieved by forming the ratio of the difference current (Δ) to the sum (Σ) of the same current components.

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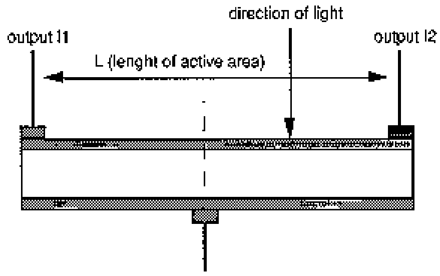

Figure 1: Schematic drawing of the linear position sensing photodiode.

In this way the sensor transfer function is independent from the spot brightness variations as well.

Since the actual parameter being sensed is the centroid of the image spot, linearity is almost independent of the spot profile and size and it is mainly a function of the uniformity of the bulk resistivity: the typical guaranteed position accuracy can be better than 1% over 90% of the sensing area.

These devices are provided by a number of companies and are widely used in position sensing and in dynamic measurements that require noncontact sensors with wide frequency bandwidth (up to tens of kHz).

The UDT super linear position sensor, type DLS 10, has been chosen as suitable for this application.

The main features of the sensor are listed in Table 1

active area	10 x 10	mm
max. responsivity	0.6 (@900 nm)	A/W
spectral range	600÷1050	nm
rise time	2	µsec
max power density	10	mW/cm^2
spot size	$\Phi < 1$	mm

Table 1: sensor characteristics.

3.2 The Front End electronics

The UDT-DLS10 sensor has two anodes on the upper surface and two cathodes on the back surface. Each of the four current signals coming from the sensor are sent to an amplifier with gain of about 10^9 V/A, which can be varied to some extent by remote control; the bandwidth is 2.5 kHz. The two difference signals are then derived, one for the anodes and one for the cathodes, as well as the summation signal from the anodes. With the use of an analog precision divider the ratios of the differences to the sum provide the spot coordinates (x,y) with respect to the sensor electrical center. These two signals, along with the summation, which may be used to monitor the relative synchrotron beam intensity, are then ready for being acquired by the control system. In order to improve the S/N ratio at the acquisition system side a differential output line driver and a connection through a twisted pair shielded cable are used.

3.4 The Acquisition Board

The acquisition board is a VME board, developed in-house, with two 14-bit analog inputs and one 20-bit high precision input. As a consequence of the two different gains, which can be set on the Front End electronics, two dynamic ranges can be obtained for the 14-bit ADCs (see Table 2):

MODE	sensitivity	A/D conversion
±1 mm	8 mV/µm	0.16 µm/bit
±5 mm	2 mV/µm	0.61 µm/bit

Table 2: Front End different sensitivities

Considering the actual beam slow motion amplitude (few microns) the high sensitivity gain is normally used, whereas the lower sensitivity is used for aligment purposes.

The board is equipped with a 16-bit micro-processor (µP), V25 by NEC, and a 2k-Byte dual port RAM for memory sharing between the on-board µP and VME master Central Processing Unit (CPU).

Normally the µP reads both 14-bit inputs and loads the acquired samples into two 1 k-Byte long arrays.

3.5 The Graphic User Interface

As usual in the ELETTRA control system a dedicated GUI interface has been developed.

The GUI is based on the X11/Motif standard, a set of specialized widget has been developed for this and other similar application (i.e. the SRPM). The communication between the GUI and the field is made by a set of specialized Remote Procedure Calls based on the CERN NC/SPC.

3.6 Position control feedback

As stated above, the SBMM normally operates in the high resolution mode as slow beam motion are in micron range. In this case the measurement is performed on an active area of (1.3x1.3) mm placed around the photodiode mechanical center. The Front End box has therefore to be aligned to the photodiode center.

It may happen that, due to a different SR orbit loaded at the run start-up, the reflected beam falls outside the whole photodiode area. Therefore, to further improve the SBMM reliability, an automatic aligment process is implemented on the A/D VME board µP.

The following steps are implemented by this process:

- set the Front End gain to ±5 mm
- go to the reference position (X and Y)
- search for beam spot position in the reference frame
- align the photodiode center to the beam 100 µm accuracy
- set the Front End gain to ± 1.3 mm
- repeat previous steps with 10 µm accuracy

4 TESTS AND CALIBRATION

Before operating the SBMM with the beam, a test in the optical laboratory and a calibration of the mV/μm characteristic have been carried out.

In particular the following parameters were investigated:

- system noise
- sensitivity
- linearity over full range
- light beam intensity independance

The calibration results listed below have been obtained with a prototype Front End box and a one-dimensional photodiode. Due to the SBMM high sensitivity it has to be operated on the optical table, in the absence of vibrations and avoiding any air flow.

4.1 The test set-up

The test set-up is composed of the Front End box and an aligment laser. To reproduce the final system operation, it has been decided to keep the laser fixed and to scan the potodiode by moving the whole Front End box with a X-Y translation stage (10 μm resolution). The calibration has been carried out on a prototype electronics which is equipped with a one dimensional (10 mm long) linear photodiode. The two signals generated by the Front End electronics have been measured: the Δ signal, being proportional to the beam position along the axis, and the Σ signal which is constant along the main axis but varies rapidly as the light spot exits the active area.

4.2 The test results

The test results were very good and confirmed the choice made for the sensor.

The noise measured on the prototype is 10 mV-pp on a total output swing of ± 13.8 V. In the high sensitivity mode this means that the SBMM prototype has less than 1 μm noise level, which is within the specifications.

The spectrum of the output signals are flat, below 100 μV rms, in the 0÷800 Hz range independent of the intensity of the impinging beam.

The linearity of the SBMM has been tested in steps of 10 μm at different absolute positions of the linear photodiode. The measured linearity error is smaller then 0.5 μm rms.

Finally, a full range scan has been performed at four different intensities to check signal dependance on beam current (see figure 2). With a factor of three in current variation the position readings are within 5 μm rms for the ±1.3 mm range.

4.3 The calibration results

The calibration of the mV/μm characteristics gives a slope of 12.68 mV/μm on a 200 μm scan around the center of the photodiode.

For the full range the average slope is 10.68 mV/μm: this data however is of little importance as the beam slow motion is in the micron range.

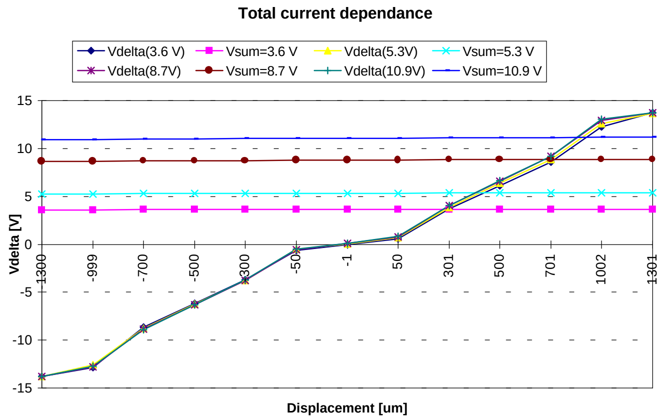

Figure 2: Σ and Δ signals plotted at different laser beam intensities. Scan of ± 1.3 mm.

The Δ signals are almost independent on beam intensities and therefore overlaid.

The Σ signals are constant on the whole sensor surface.

5 TESTS WITH BEAM

The SBMM prototype has been tested with beam and the first results are consistent with the previous measurements carried out both with PBPM and single photodiode.

Obviously, the SBMM is very sensitive to air convection which occurs between the SR tunnel and the optical laboratory. To reduce this phenomenon a provisional air protection system has been mounted from the vacuum window to the optical laboratory. By doing so a reduction (10 dB) of the random noise floor in the 0÷100 Hz region has been measured.

6 CONCLUSIONS

In this paper a simple though very accurate system for monitoring slow beam motion in the transverse plane has been presented. The results are in a very good agreement wih the expectations.

The SBMM is foreseen to be put into routine operation in the next few months as soon as the final two-dimensional device will be available.

7 REFERENCES

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