ADVANCES IN BEAM ORBIT STABILITY AT THE LNLS ELECTRON STORAGE RING

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Abstract

We describe recent efforts made at the Brazilian Synchrotron Light Source (LNLS) to improve beam orbit stability. The main driving force is the high positional stability required by some specific experiments and particularly by a high resolution undulator beamline which is being built at LNLS. Recent steps taken to improve orbit stability include the development of x-ray BPMs to measure the vertical position of the x-ray beam, analysis of RF BPM movement due to thermal load induced by synchrotron radiation after injection, new algorithms to deal with BPM electronics or control board false readings and revision and modification of their installations. In addition, a weighted least squares method was developed to account for global correction while simultaneously privileging some local source point position. These upgrades are part of an ongoing work to improve beam orbit stability at LNLS.

INTRODUCTION

LNLS is a synchrotron light source in operation for users since 1997. The 1.37 GeV electron storage ring has a natural emittance of 100 nm.rad and beam sizes on the order of 300 and 200 μm respectively in the horizontal and vertical planes at dipole sources. The beam orbit stability achieved so far with the global orbit correction scheme can reach the value of 5 μm in the vertical plane, whereas in the horizontal plane, stability of 10 μm is achieved in about 0.5 hour and 30 μm in a 12h run. These values are measured by RF BPMs and, at least for the vertical plane, are better than the usual specification of 1/10 of the beam size. These numbers satisfy most of LNLS users most of the time. However, we still have essentially two kinds of problems that can trouble some experiments: a slow drift component on beam motion and false BPM readings either in the form of spikes or increased noise or else bizarre variations (going up and down randomly). Recently some activities have been performed to try to understand these problems and minimize them.

X-ray BPMs are being developed to measure the vertical position of the photon beam at the beamlines. We have already commissioned one system at the x-ray beam diagnostics line [1]. We are also analysing the RF BPM movement due to vacuum chamber heating and expansion induced by synchrotron radiation after injection. The body of some monitors are heated in a non uniform way and can be deformed. We have installed several mechanical gauges and temperature measurements on two BPMs in the storage ring to study these effects. Numerical simulations on distortions induced by heating on the BPM body and striplines have been carried out to better understand the results. We also implemented a *despiking* method in the high level correction system to avoid the catastrophic effects of such spikes. BPM noise could be reduced by better shielding the electronics, by shortening the rf cables and by joining the electronics and AD converter grounds. In addition, a weighted least squares method was implemented to improve horizontal orbit stability at more sensitive beamlines.

THE LNLS ORBIT CORRECTION SYSTEM

The LNLS 1.37 GeV electron storage ring is a 6-fold symmetric double-bend lattice with a circumference of 93.2 m. Injection is accomplished with a 500 MeV synchrotron booster and we refill the storage ring twice a day with 250 mA. The orbit correction system is implemented using 24 BPMs, 18 horizontal and 24 vertical correctors. The betatron tunes are 5.27 and 2.17 in the horizontal and vertical planes, respectively. The vertical correctors are divided into 2 groups with 12 correctors each: a group with coarser correction step but larger range and a group with smaller range but finer step. The reference orbit was defined at a certain moment by using only the large range correctors. The small range ones were kept at zero. The correction algorithm uses the calculated orbit response matrix inverted using SVD. The BPM data is an average over 64 readings performed at low level. The high level makes additional average over the last 30 readings and the calculated orbit correction is applied every 24 seconds. The BPMs 4 stripline signals are multiplexed at 12 kHz using Bergoz MX-BPM electronics and 16 bit AD converter boards with 4 differential inputs. Passive low pass filters limit the bandpass of the AD cards to 16 Hz and additional digital filtering reduces the overall bandwidth to 2 Hz.

The monitors at LNLS are mounted in the vacuum chamber sections without bellows and fixed to the girders in both transverse and longitudinal directions.

RECENT IMPROVEMENTS

X-ray BPMs

We have installed two X-ray BPMs in the front end of our beam diagnostics beamline. The first is a commercial monitor and the second was built at LNLS. Both monitors are based on the measurement of photocurrent signals induced by the photon beam on two pairs of blades mounted just to scrap the edge of the x-ray beam. The XBPMs were calibrated using translation stages and data acquisition has recently been completed at this test station. The detailed results can be found in ref. [1] in these proceedings. Figure 1 shows measurements from the 2 XBPMs along 4 days. The beam positions measured with the XBPM are compatible with the ones measured by the neighbouring RF BPMs. In fact, a very interesting result could be drawn from these measurements regarding the matched readings of some pairs of neighbour RF BPMs described in ref [2]. We suspected this could be related to the fact that the same shielding box houses the corresponding pair of BPM electronics, but, at least in the vertical plane and for the pair close to the XBPM, the matched readings seem to be real orbit motion since small details in the RF BPM measurements also appear in the XBPM, a completely independent position measurement.

We have found that a careful alignment of the XBPM is very important since its response is highly non-linear. The XBPM data will be useful as an independent measurement of the beam position at a source point, not suffering from the errors affecting the RF BPMs. In the near future, we intend to include the XBPM data in the vertical orbit correction loop. The software has already been changed to allow for this option but we still have to deal with some problems such as the unavailability of data when the beamline shutter is closed.

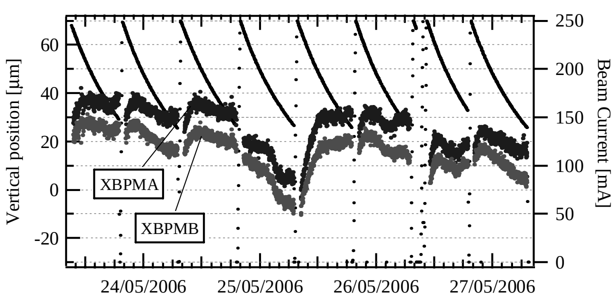

Figure 1: Measurement from the commercial XBPM (blue) and the one built at LNLS (red). Both are installed on the same diagnostics line very close to each other.

BPM Noise Reduction

The noise level in our BPM readings first attracted our attention for the large spread in their values, ranging from 0.4 μm to 2 μm rms. We could also see sudden changes in the noise level of the same BPM. Changing the multiplexing frequency did not help much. About 2 years ago we concluded that we needed better shielding from the electromagnetic noise produced in the machine tunnel. We had some indications for this, first, the fact that the noise level was very dependent upon positioning of the equipment and, second, the problems appeared, or got much worse, just after the installation of a second RF power plant inside the machine. We started then the construction of special shielding boxes to house the BPM electronics. These boxes were to be installed spread around the storage ring, close to the corresponding BPMs. The boxes were installed last year and we could see already an overall improvement. Nevertheless, some BPMs still had large noise [2]. The problem could be definitely minimized by also shortening the cables, changing them from RGC-58 to MR-195 (the latter has 30 dB better isolation) and taking care on the grounding of the electronics outputs and AD converters. The converter boards and the electronics now use the vacuum chamber as the common ground to neighboring BPMs. Figure 2 shows the noise reduction with the new electronics arrangement. For the monitor shown the noise is reduced from 0.9 μm to 0.35 μm rms. The reduction in the BPM noise level will allow us to increase the reading update rate and corresponding correction system bandwidth.

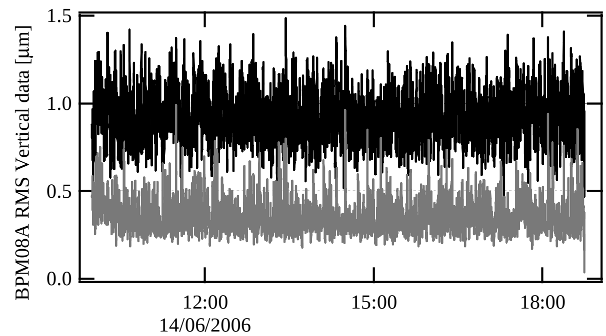

Figure 2: Noise of BPM 08A vertical data. The graph shows the orbit rms deviation over 30 measurements. The BPM signal is split into the new and old electronics setups. The rms noise is reduced from 0.9 μm to 0.35 μm.

Study of BPM bizarre behavior

We have presently two BPMs that are not being used in the orbit feedback system due to their strange behavior when the current decays to approximately 190 mA. The measured position ‘shakes’ for about 10 minutes. See Figure 3. Several tests indicate that the problem does not come from the electronics or connecting cables but from the BPM body and it is related to its temperature gradient. We have checked that the problem is not related to the input signal power level since attenuating it did not solve the problem. We have also made parallel checks by splitting and recombining the stripline signals into various configurations to convince ourselves the problem was not with the electronics.

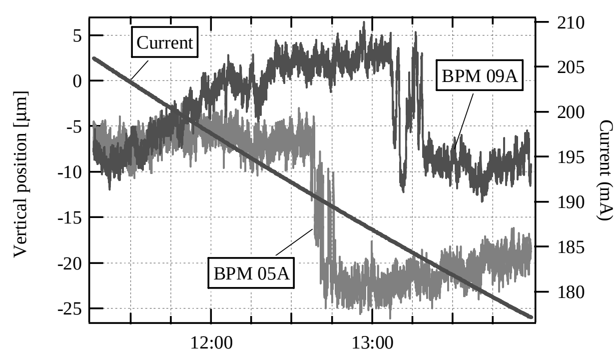

Figure 3: BPMs 05A and 09A show strange behavior when the beam current is about 190 mA. These monitors are not being used in the orbit feedback.

The mechanical gauges probing the monitor horizontal and vertical movements also do not show any strange motion. Finally a test where the body of BPM 09A was heated with baking stripes shows that the odd behavior of the monitor occurs at smaller currents for higher baking temperatures. This may be an indication that the problem could be caused by an uneven temperature distribution affecting the striplines. Baking in this case helps the uniformization of the BPM temperature distribution. The subject is still under investigation.

BPM Motion and Deformation Measurement

Most of the BPMs in our ring are connected rigidly to the vacuum chamber and are fixed to the girder by a support which limits both the transverse and longitudinal movements. Nevertheless, as the vacuum chamber heats with synchrotron radiation, the BPMs will also move causing at least part of the slow beam drift. Our first idea was to measure the BPM movement with mechanical gauges fixed to the girder and make this value available to the orbit correction software. However, during the tests, we found out that BPMs close to the dipole output in the short sections become very hot and have the body shape deformed since the heat distribution is not uniform. By the way, the monitors described in the previous section are not in this group. We have installed 3 mechanical gauges and temperature measurements in a monitor in this high heat load condition to study its mechanical deformation and movement. Finite element simulations have been carried out using stainless steel monitor models heated by a 13.5 W source concentrated in the radiation protection screen of the monitor. The results are consistent with the measurements and show radial variations of 20µm between both sides of the monitor in the horizontal plane. The temperature distribution is highly non-uniform. In view of these results we are planning a new geometry for these monitors (there are six monitors in this high heating situation). Also, this means we cannot use a single gauge measurement to estimate the centroid movement of these BPMs. Figure 4 shows the measured horizontal motion on both sides of BPM 12A.

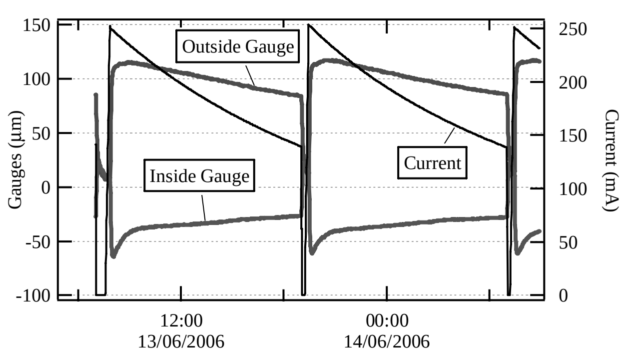

Figure 4: Horizontal movement of a BPM measured by two mechanical gauges installed on the inside (blue) and outside (red) sides of the monitor 12A.

Despiking algorithm

The spikes can cause unwanted beam motion since the orbit correction system will generate a real bump in the orbit to compensate for the apparent error. In our case, this is more severe in the vertical plane, since we use as many correctors as there are monitors in this plane, making it possible, in principle, to correct the orbit exactly at the monitors. This fact, together with the fact that the occurrence of spikes have increased with the new communication boards (based on Ethernet protocol) to an average of one spike per day, led us to implement a very simple despiking algorithm: we eliminate the largest absolute value in the set of 30 readings and average over the 29 left. A spike always occurs as one very high and isolated peak. We have never seen two spikes very close in time, although this should be possible.

Orbit correction algorithm

The orbit correction algorithm implemented at LNLS uses the calculated beam orbit response matrix inverted using SVD. Individual monitors and/or correctors can be ignored with the recalculation of the inverse response matrix. Since it takes some time to make this calculation, some inverted matrices with combinations of off monitors are previously calculated. Even so we only take monitors out before the users run. We have recently added a weight function to the monitors with the aim of improving the orbit stability in the horizontal plane at the most critical experiment sources. A change in the monitor weight also requires the recalculation of the inverse response matrix. We also implemented a correction loop in which the vertical readings of the XBPMs can be included. We plan to start experiments in the near future.

CONCLUSIONS

A series of experiments have been conducted recently at LNLS to map the beam orbit stability conditions in the storage ring. Several machine experiments were carried out together with the users. A very interesting result from this user-machine physicist interaction is the new reference orbit that maximizes flux at the beamlines and resulted from a systematic scan of orbit bumps. New instruments such as the XBPMs, mechanical gauges and stabilization of the storage ring tunnel temperature, are being added to the correction system. We have also identified the causes of some BPM and corrector instrumental problems. The ground mesh and the distribution of equipment cabling inside the storage ring have been revised and changed. We still have to improve the beam slow drift and solve some instrumental problems in the BPMs. Regarding the BPM heating and deformation problem we are designing a new pumping station to extract radiation power before it hits the BPM. In addition we are considering a gradual change of the RF BPM electrodes from stripline to button.

REFERENCES

[1] S.Marques *et al*, ‘Commissioning of the LNLS X-Ray BPMs’, these Proceedings.

[2] L.Liu *et al*, ‘Beam Orbit Stability at the Brazilian Synchrotron Light Source’, Proc. of the 2005 PAC.