BEAM ORBIT STABILITY AT THE BRAZILIAN SYNCHROTRON LIGHT SOURCE

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Abstract

The Brazilian Synchrotron Light Source (LNLS), which is based on a 1.37 GeV electron storage ring, has suffered from severe beam orbit stability problems immediately after the installation of a new RF cavity in the ring. These problems together with the requirement to improve orbit stability led to the creation of a beam stability task force at LNLS. The aim was to start a more detailed investigation of beam stability-related problems. The data presented here are part of these ongoing investigations.

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 is about 5 μm in the vertical plane, better than the usual specification of 1/10 of the beam size, and satisfies most of LNLS users. However, some experiments detect very small signal differences and require even higher beam stability. For a high resolution undulator beam line which is under construction also further beam stabilization is required. Combined with these request for better orbit stability we faced, conversely, severe instability problems after the installation of a new RF cavity in the ring. The interaction of the beam with a HOM in the new cavity induced a longitudinal dipole oscillation in the beam which appeared as a horizontal orbit distortion proportional to the second order dispersion function. In this case, even horizontal distortions as small as 3 μm could be perfectly correlated to undesirable features in users data. The additional electromagnetic noise in the hall also seemed to increase the noise level in the beam position monitors. To deal with these problems a beam stability task force was created at LNLS to investigate the orbit stability-related problems in a more detailed and systematic way.

ORBIT STABILITY PROBLEMS AND INVESTIGATIONS

We have observed various orbit stability problems in the beam right after the upgrade of the RF system with the installation of a new cavity[1]. A sudden 6-fold symmetric distortion in the horizontal orbit occurred sometimes with positive and negative amplitudes while the vertical orbit was not affected, as shown in Figure 1. This instability could be cured by applying a phase modulation to the RF voltage. We also observed instrumental problems in the BPMs which were affected by an increased electromagnetic noise level in the machine hall. Other problems include step changes in the measured orbit values and slow (hours) orbit drift during the users run due to the heating of the vacuum chamber. Our position monitors are rigidly connected to the vacuum chambers and fixed to the girders.

Interaction of the beam with the RF cavity HOM

The sudden 6-fold symmetric change in the horizontal orbit was found to be due to the interaction of the beam with an RF cavity HOM at ~904 MHz, mode L1. A longitudinal dipole oscillation is induced with twice the synchrotron frequency and causes a horizontal orbit distortion which is proportional to the second order dispersion function. In fact, if the energy δ oscillates with frequency Ω and amplitude ε,

$$\delta(t) = \varepsilon \cos(\Omega t)$$

an orbit distortion x_e is created, given by

$$x_e(s,t) = \delta(t)\eta(s) + \delta^2(t)\eta_1(s)$$

where η and η_1 are the first and second order dispersion function respectively. Since the frequency Ω is much higher than the BPM response, the monitors see a time averaged signal proportional to the second order dispersion function:

$$\langle \Delta x_e(s) \rangle = \frac{1}{2}\eta_1(s)\ \Delta\varepsilon^2$$

Any change in the amplitude of the perturbation will cause an orbit change. We note that this orbit change is a second order effect in $\Delta\varepsilon$ but the energy oscillation also causes a beam size change which is a first order effect. Probably the correlation found between orbit distortions as small as 3 μm and features in users experiments is trough this energy oscillation. In a few times we could see distortions up to 40 μm in amplitude. At first we tried to cure this instability by shifting the 904 MHz mode by using plungers and the cavity temperature. The shifting of the mode was not sufficient for the available range of variation for these parameters. We tried then an active solution in the form of a phase modulation to the RF voltage with about the same frequency as the perturbation Ω. The mode can be damped by a factor larger than 50 dB. The optimum phase modulation frequency, however, drifted along the users run. We introduced then a modulation in the frequency of the RF voltage phase modulation. The approach was successful and this instability is now under control.

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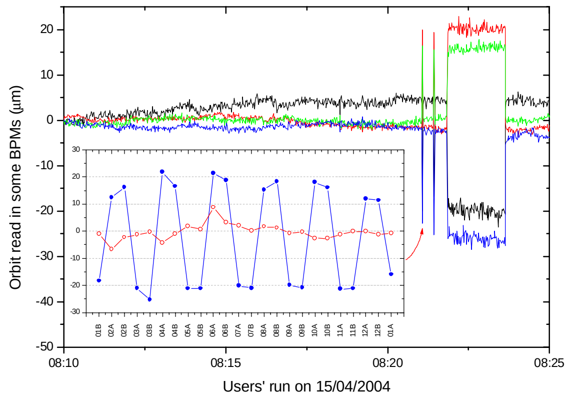

Figure 1: 6-fold symmetric horizontal orbit variation due to interaction with a HOM in the RF cavity.

Noise level in BPMs

We also observed an increased noise level in the readings of some BPMs. Sometimes there was a sudden increase in the noise level of individual monitors, as shown in Figure 2. Other times the change occurred simultaneously in a group of monitors. Investigations suggested that part of the problems can be improved by changing the BPM multiplexer sampling frequency. For the group of monitors there was a problem in their common control crate. An overall improvement can be achieved by shielding carefully the BPM electronics. A large effort has therefore been taken to produce special shielding boxes for the electronics and change their positions to allow shorter cable lengths for the RF signals from the BPMs. Even after all these achievements we still have BPMs with large noise level. The subject is still under investigation.

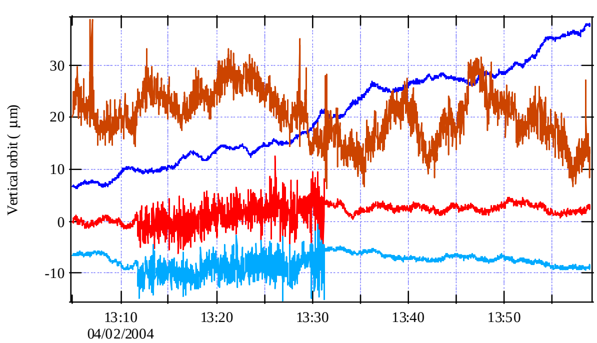

Figure 2: Examples of altered noise level affecting individual and group of monitors. Beam with no orbit correction.

Change in the BPM readings

Some BPMs show a change in their readings in the form of a smooth step as is shown in Figure 3. These changes occur mainly in the monitors just upstream the dipoles in the dispersive sections of the ring. These are also the monitors that are the most heated by synchrotron radiation. The changes occur approximately at the same beam current although they do not always occur. We suspect that there is a real movement of the BPMs due to radiation heating. Experiments using mechanical gauges to measure BPM movements are planned.

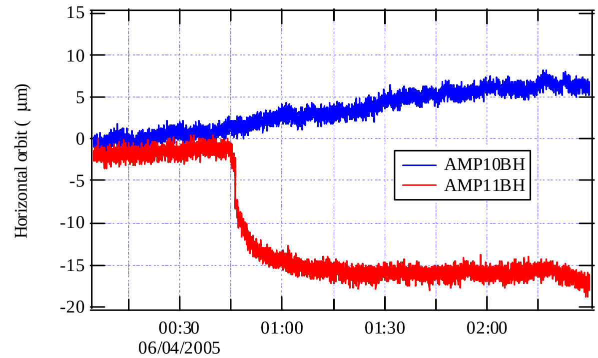

Figure 3: Smooth step change in the horizontal orbit at BPM AMP11B. Beam with no orbit correction.

Matched readings of a pair of BPMs

Each shielding box contains the electronics for 2 BPMs. We noticed some features in the readings of these BPMs which are identical. A test made by changing the monitors connected to the electronics showed that there are some features in the signal which are not induced by the beam affecting the two 'brother' monitors. Experiments are under way to localize which part of the circuit is causing or capturing the spurious signal.

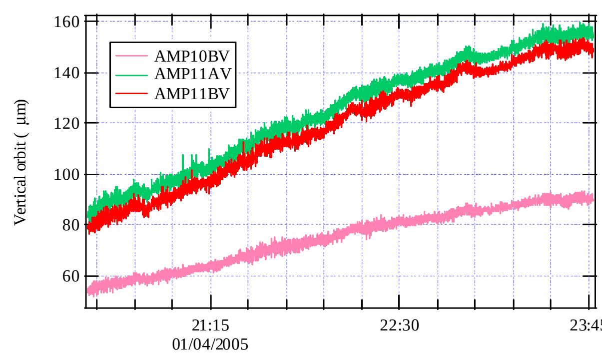

Figure 4: Example of matched readings for a pair of BPMs in the same shielding box (AMP11A and AMP11B).

IMPROVEMENTS AND FUTURE PLANS

The analysis described in this report was made possible by the development of a series of software tools for data acquisition and analysis. All machine parameters are registered every second for 24 hours a day. This huge amount of data required the development of software tools for data analysis. Also the PCs in the control room and in the beamlines were all synchronized to allow correlations between users data and machine data.

We are also commissioning the first x-ray photon BPM[2] to complement and check for the consistency of the rf BPM readings. We plan to have these photon BPMs in all dipoles in the future and integrate their readings into the orbit correction algorithm.

A beam based alignment procedure to measure the BPM offsets with respect to the centre of the nearby quadrupoles has also been tested and is planed for the following accelerator physics runs. At first we plan to use only one power supply to power the quadrupolar extra windings available in all quadrupoles, one at a time.

We are also planning to measure the physical positions of some BPMs with respect to the girders. Depending on the results, a change in their support geometry can be implemented to allow for free longitudinal movement while restricting the transverse positions.

We also expect the temperature in the machine tunnel to be more stable after we closed it by the addition of concrete shielding around (inner side) and over the machine. The concrete added amounts to about 350 tons and we expect to realign the machine in the near future.

An in-house development is under way to increase the orbit corrector resolution by using 20 bit, instead of 16 bit, DA converters.

The orbit measurement and correction system at LNLS is continually improving since last year (2004) after the RF system upgrade. We plan to continue with small advances both in the beam operation conditions and individual components performance.

REFERENCES

[1] R.H.A.Farias et al, ‘Upgrade and Commissioning of the LNLS RF System’, EPAC2004.

[2] S.R.Marques et al, ‘An X-Ray BPM and Accompanying Electronics’, these proceedings.

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