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DETECTION OF INSTRUMENTAL DRIFTS IN THE PEP II LER BPM SYSTEM.*

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Abstract

During the last PEP-II run a major goal was to bring the Low-Energy Ring optics as close as possible to the design. A large number of BPMs exhibited sudden artificial jumps that interfered with this effort. The source of the majority of these jumps had been traced to the filter-isolator boxes (FIBs) near the BPM buttons. A systematic approach to find and repair the failing units had been developed and implemented. Despite this effort, the instrumental orbit jumps never completely disappeared. To trace the source of this behavior a test setup, using a spare Bergoz MX-BPM processor (kindly provided by SPEAR III at SSRL), was connected in parallel to various PEP-II BPM processors. In the course of these measurements a slow instrumental orbit drift was found which was clearly not induced by a moving positron beam. Based on the size of the system and the limited time before PEP-II closes in Oct.2008, an accelerator improvement project was initiated to install BERGOZ BPM-MX processors close to all sextupoles.

INTRODUCTION

To correct the chromaticity in the low energy ring (LER) at PEP II, 52 sextupoles are distributed around the ring. Ideally the particle beam passes through the center of these. In the real machine this is not the case due to alignment errors of the sextupoles and other sources of orbit distortion. This introduces the so called feed-down errors, which are skew and normal quadrupole fields. These fields cause considerable errors in the linear optics.

Dynamic changes of the orbit, caused by e.g. warming of vacuum pipes, constantly change the optics. This makes it very difficult to optimize the performance by operator tuning as well as dedicated machine development shifts to correct these errors. After optimization, the machine's performance drifts rapidly from this operating point.

To optimize the performance of the machine a feedback system had been built to stabilize the orbit through the sextupoles.

During the use of this feedback the operators had observed an acceleration of the problems described above. The cause of this behavior was traced back to the BPM system which showed sudden artificial jumps in the orbit reading. These jumps were interpreted as orbit changes by the feedback and it would steer "back" to its set point.

To analyze the magnitude of this problem and to find the source of these jumps a test setup, consisting of a BERGOZ BPM-MX unit, was installed during the last run. The results of these measurements will be shown in this paper.

These results led to the formulation of an Accelerator Improvement Project (AIP) to install 52 BERGOZ BPM-MX electronic processing modules in parallel with the existing electronics in the locations of all sextupoles. This proposal has been implemented during this run and is currently being commissioned. First results are discussed. The main goal of the AIP is to put the sextupole feedback successfully back into operation by using the orbit data of the new BERGOZ units. The feedback code is currently changed to accommodate the new system.

BERGOZ BPM-MX TEST INSTALLATION

The choice of hardware was driven first by availability and second by integrability into the existing control system. The BPM-MX module was available through SPEAR where they are used in standard operation. These modules provide as output an analog signal which can be integrated using the Stanford Analog Module (SAM), which digitizes the analog signal and also acts as an interface to the Stanford Control Program (SCP).

Measurement Setup

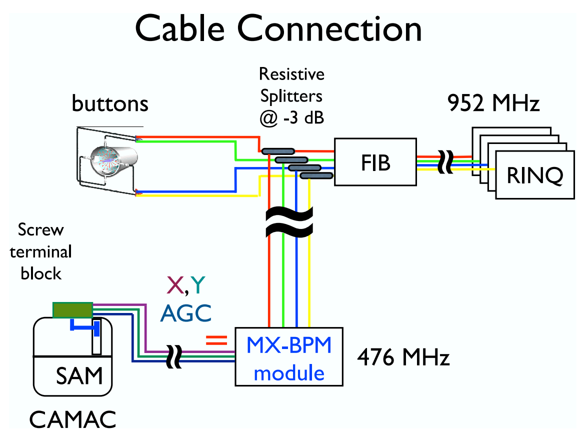

Figure 1: Test setup used in LER of PEP II. The upper path describes the original PEP II BPM installation. Before the the FIB the signal is split and half of the signal is brought to the BERGOZ module. The position analog output is digitized by the SAM and included in the SCP as Analog STatuS (ASTS) channel.

To eliminate all possible error sources hidden in the existing BPM system the signal coming from the four beam pickups had to be split before the Filter Isolation Box (FIB). This was done by installing resistive splitters. To

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be able to adjust the setup during operations and to not expose the electronics to radiation it was decided to have the BERGOZ module installed in one of the surface support buildings. Consequently, we were restricted to choosing BPMs with their standard electronics (RINQ modules) in such buildings. In addition the FIB, which is installed in the tunnel a few feet away from the pickups, had to be brought up to these buildings. A schematic of the test installation is shown in fig.1.

Results

The first phase of the test was to ensure, that the BERGOZ unit was working properly in the PEP II environment. This is important as a light source such as SPEAR typically has smaller orbit deviations, usually less than one millimeter, from the design orbit than does LER, where differences of up to 20 millimeter are measured. Therefore a location was chosen where the standard position reading showed no problems. Fig. 2 compares simultaneous BPM readings using the RINQ and BERGOZ modules. The two position readings tracked closely. After this test, the setup

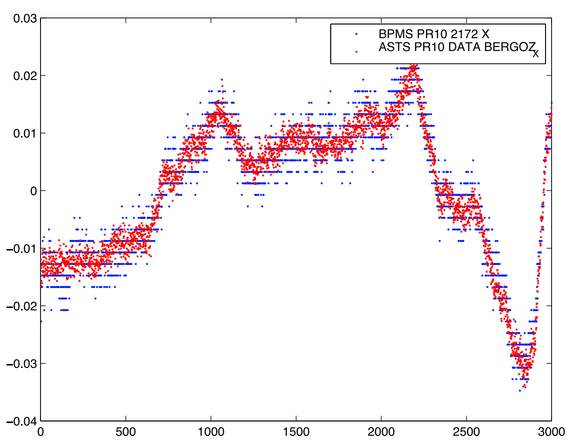

Figure 2: Correlation plot data comparing the position horizontal position reading from the BERGOZ module to the PEP II unit. The BERGOZ unit is scaled and offset corrected, since it was set for SPEAR. The blue trace shows the PEP and the red the BERGOZ unit.

was moved to a location with a known bad position reading. Since the position jumps occur at random, the correlation plot tool was not suitable for this test. Instead the EPICS channel archive data were analyzed. Every BPM and selected ASTS channels are archived at rates between one and ten seconds. The disadvantage is that these data are taken asynchronously and the comparison is only possible on a long time scale. These are also raw data, which means the BERGOZ positions are not scaled and offset corrected. Fig.3 displays horizontal and vertical position readings of two neighboring RINGQS and the BERGOZ unit. The second PEP unit, separated only by a main dipole from the unit of interest, is used as reference to determine if the beam is moving. Unit 3041 shows jumps that are not seen in the other two units. This plot also shows an effect

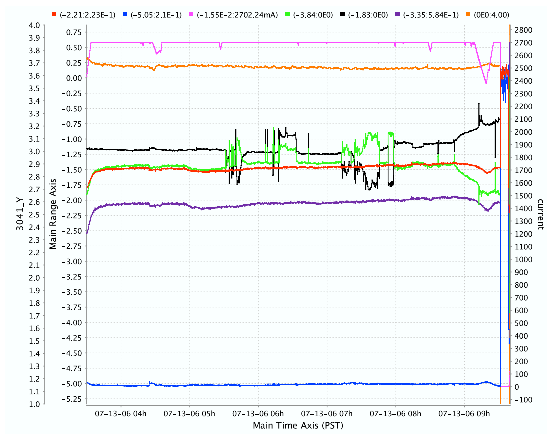

Figure 3: EPICS channel archive data showing the position readings of two PEP and the BERGOZ unit during one fill. The magenta trace indicates the LER beam current which is stable at 2.8 Ampere during most of the fill. The unit 3042 (x green, y black) shows jumps and beam motion. Neither is exhibited by either the BERGOZ unit (x-red, y-blue), which shares the position signal from the same pickups, or by the neighboring unit 3041 (x-purple,y-orange).

which was undetected until these measurements. At the end of this fill, the horizontal and vertical position readings of unit 4032 start to slowly drift while the other units show no orbit change. When first observed, it was unclear what was happening. Either the BERGOZ unit could not track real beam motion or the PEP unit was drifting. The second PEP unit confirmed that the bad unit not only jumped but drifted. This is particularly bad since, as contrary to the jumping, it is not possible to determine if a BPM is drifting only from its position reading. A detailed analysis of the data showed no pattern of this behavior. Neither period, start time, or maximum change in position reading showed dependence on other parameters like beam current, beam motion, etc. These results triggered a closer analysis of the hardware, which showed that a batch of FIBs had bad solder joints. These were not detected using standard test procedures. During the last downtime an effort was begun to find and repair all these FIBs.

LER SEXTUPOLE BPM UPGRADE PROJECT

Based on these findings and on calculations simulating the error caused by such orbit drifts in sextupoles, an Accelerator Improvement Project (AIP) was initiated to upgrade all LER Sextupole BPM's with BERGOZ BPM-MX modules in September 2006. These operate in parallel with the existing BPM system by coupling out -15dB of signal using directional stripline couplers. The LER has 52 Sextupoles installed, mostly located evenly distributed in the arcs. To minimize cost and time, no crates are used. Instead the modules are installed in single unit enclosures with external power supplies, located beneath the nearest HER dipole, to shield them from synchrotron radiation. These enclosures are internally coated with a thin conducting layer for RF-shielding. Six foot jumper cables connect the couplers to the electronic units. Shielded twisted pair cables are used to transport the dc position signal to the SAM modules, installed in the closest CAMAC crates. With four crates per arc, these cable runs were minimized as well. An additional advantage of this installation is that the units can be easily moved to other positions for use as diagnostics units.

The hardware, BERGOZ BPM-MX modules, single unit enclosures, directional strip line couplers and cables were installed in the first two weeks of May 2007.

Preliminary Commissioning Results

In preparation for commissioning, the EPICS channel archiver was changed to record all new BPM ASTS channels. The first phase checked the functionality of the units by comparing them to their PEP counterparts. The position signals of three of the 52 installed units were found to be unphysical despite testing of the electronic boards and external power supplies before installation. Therefore it is anticipated that the dc signal cable path is defective.

Correlation plots compare the readings of the two BPM systems under different conditions (constant or increasing beam current, etc.). These data were analyzed to assure that the calibrations of the BERGOZ units are correct ($1V = 2mm$). In addition, offsets can be corrected using these data sets assuming that the PEP system reads the offset correctly. These calculated offsets will be initially used to correct the positions measured by the new system.

During this analysis, another failure mode of the existing BPM system has emerged. As shown in Fig. 4, which depicts the PEP position reading in blue and the BERGOZ in green, the PEP unit has a two state position reading with an average difference of 400 μm. The BERGOZ unit is centered between them due to the algorithm calculating the offset. The correct interpretation is that the correct position is shown by the upper part of the blue trace while the lower is a bad reading. This indicates that jumps can occur more frequently than expected.

Sextupole Position Feedback

The existing code in the SCP for sextupole feedback loops in the LER is presently being modified to read the BERGOZ BPM units. These loops correct the position on the sextupoles simultaneously in each arc for the vertical plane. These will initially be used to test the BPMs' long term stability and used in operation. In order to correct the orbit separately in both planes at each sextupole location new code will have to be written. Doing this in the SCP is very time consuming. The final feedback loops will use a recently developed software package that combines AIDA [2], for low-level hardware access, and MATLAB Middle Layer [3], for high-level control and data manegement.

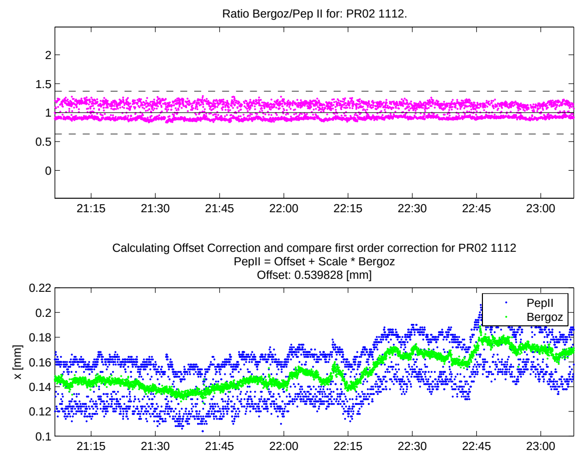

Figure 4: Correlation plot results for the units installed in location PR02 1112 in the LER for the horizontal plane. The upper plot shows the ratio of the BERGOZ position measurement to the PEP. The lower shows the actual position readings with the BERGOZ units (green trace) with offset corrected. The PEP unit's (blue trace) position readings depicts a two state behavior which is unphysical.

Measuring Vibration Induced Beam Motion

During the first months of the current run, the luminosity signal has shown an $\approx$ 10 Hz signal component. The support tube inside BABAR was suspected as the source of this AC signal. To measure the magnitude of this motion, one BERGOZ installation was modified. The position signal, which is read at a maximum of 2kHz and is therefore capable of measuring a 10 Hz signal, was split at the exit of the electronic module and connected to a spectrum analyzer. This measurement confirmed beam motion in LER as the source of this luminosity fluctuation. A mechanical damper was installed and its functionality was confirmed through this measurement.

CONCLUSIONS

So far the AIP and installation is according to schedule. The new installed BERGOZ BPM-MX units work as anticipated. The next step will be to test the modified sextupole feedback loops. A great improvement in linear optics stability is expected.

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[3] J. Corbett, G. Portmann and A. Terebilo, "ACCELERATOR CONTROL MIDDLE LAYER," PAC'03, June 2003, Portland, p. 2369, http://www.JACoW.org.