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# A TRANSVERSE BEAM INSTABILITY IN THE PEP-II HER INDUCED BY DISCHARGES IN THE VACUUM SYSTEM[*]

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## *Abstract*

Towards the end of Run 5, transverse instability in the High Energy Ring (HER) curtailed the maximum beam current achievable during physics running. Techniques used in tracking down this instability included fast monitoring of background radiation, temperatures and vacuum pressure. In this way, the origin of the instability was localized and inspection of the vacuum system revealed several damaged bellows shields. Replacing these units significantly reduced the incident rate but did not eliminate it fully. After the end of the run, a number of damaged rf seals were found, possibly having caused the remaining incidents of instability. In Run 6, instability has recurred. In this paper we will outline the steps taken to diagnose the issue and compare the different signatures of instabilities we have seen in PEP-II.

## CHARACTERISTICS OF INSTABILITY

Two different signatures have emerged, termed “tiny Y” and “Ridge” according to the visual signature seen on a 3-d plot of beam position *vs* turn# and bunch#. Figure 1 shows an example of each. The data are acquired upon a beam abort with a fast digitizing system using signals from the transverse feedback systems[1]. Vacuum activity was seen coincident with many (though not every) occurrences of either instability.

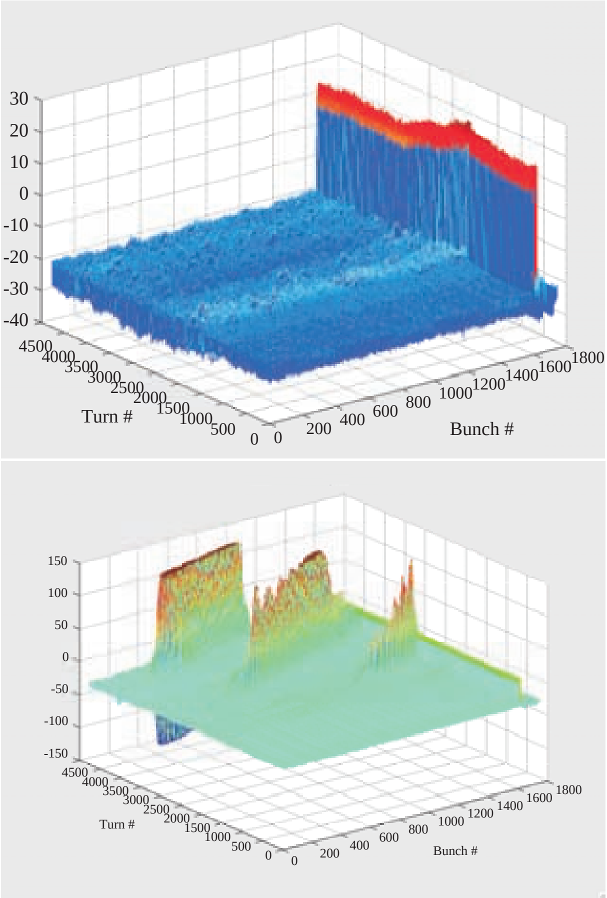

Figure 1: Transverse motion of “Tiny Y” instability (top, the abort gap is at high bunch numbers; “tiny-Y” motion starts at about turn 1500) and “Ridge” instability (bottom).

### *“Tiny Y” Instability*

This instability is characterized by quite small coherent amplitude, setting in along the whole bunch train at once. The spectrogram (tune *vs* time, Fig. 2) is rather noisy although it is clearly dominated by the vertical betatron frequency. Occasionally the horizontal betatron tune is also seen with significant, or even dominant amplitude. The similarity to the “fast vertical” instability in the LER[2] is rather striking even though in case of the HER there is no observable effect in the longitudinal plane. The modal spectrum is shown in Fig. 3 for the first 20 modes. There appears to be rapid initial growth of the 0 mode whereas a cluster around modes 8…10 is seen to grow at a slower rate, when the 0 mode is actually damping.

The instability leads to beam abort due to increased background in the detector, often within 10…20 ms of instability onset. In many cases a coincident pressure spike is observed, as shown in Fig. 4. Analysis of a number of such events allowed us to identify a few locations in the HER where vacuum components may be failing. This evidence is sometimes corroborated by thermal activity.

### *“Ridge” Instability*

As time progresses a wave of motion is moving from the head towards the tail of the beam, Fig. 1, bottom. At the kicker gap, the process appears to be interrupted, bunches at the head of the train tend to have rather smaller amplitudes of oscillation. The modal decomposition of the motion is shown in Fig. 5. A cluster of modes around 5…10 is growing to dominance. Overall amplitude of the oscillation is much larger than in the “tiny Y” case, somewhat

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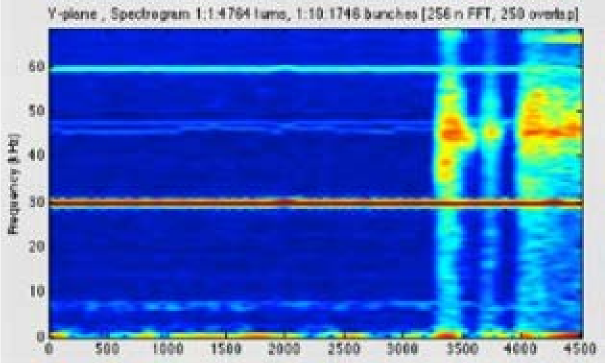

Figure 2: Spectrogram of “tiny-Y” instability.

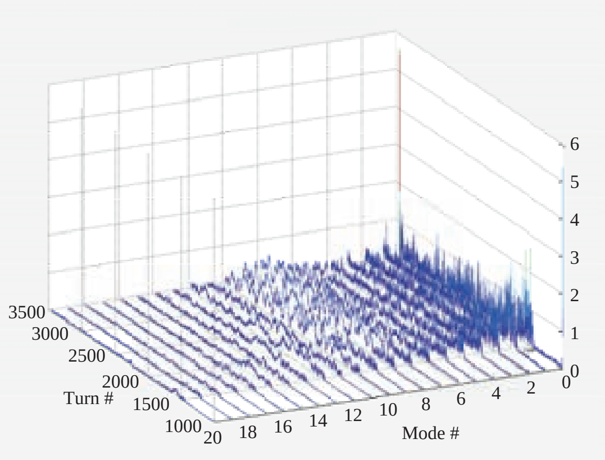

Figure 3: Modal spectrum *vs* turn # of “tiny-Y” instability.

obscuring the amplitude of the 0 mode which is comparable to the one seen in the “tiny Y” instability. Growth rates are on the order of 1 /ms, much slower than for the “tiny-Y” signature but still quite fast. Again, “Ridge”-type instability is often accompanied by vacuum activity. In addition the apparent interruption of coupling between the bunches suggests that trapped ions could be the origin of this instability; the species being light enough to be swept out by the gap.

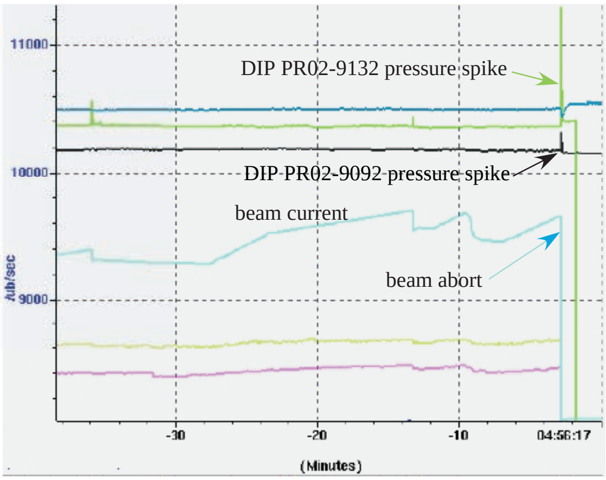

Figure 4: Vacuum pressure spike at a beam abort.

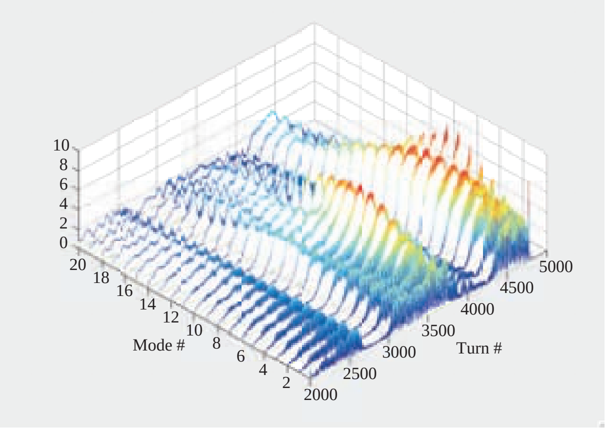

Figure 5: Modal spectrum *vs* turn # of “Ridge” instability.

## VACUUM SYSTEM SYMPTOMS

Given the vacuum activity seen and the corroborating evidence obtained from thermal monitoring, suspect vacuum joints were opened and the adjacent components inspected. The first find was a shielded bellows unit with its shield fingers severely damaged and with clear signs of heat and sputtering or evaporation of the Ag coating, Fig. 6. Replacement of three units damaged in this way immediately brought relief in the rate of beam aborts although it did not reduce the vacuum-induced aborts to zero. In the following downtime a number of other locations were inspected. No more damaged bellows were found but a number of rf seals across flange joints were found to be damaged showing evidence of heat and melting (Fig. 7). This went undetected as these flanges were not thermally monitored. All of the problems arose at joints involving “flex flanges”[3], at

Figure 6: Damaged rf shield of a bellows unit.

Figure 7: Damaged rf seal from a flex-flange connection.

which the two chamber ends can move (flex) against each other with the rf seal fingers supposedly following such movement. However, once crushed the GlidCop fingers used provide for very low spring-back. This can lead to bad contact and subsequent arcing, thus destroying the seal fingers. A number of such seals were replaced in the machine and thermal monitoring installed at the Flex Flanges.

## ANALYSIS

The “Ridge” type instability suggests a mechanism coupling the bunches together. The appearance suggests a disturbance that originates at a certain point in time and via bunch-to-bunch coupling travels along the train until it reaches the gap, which appears to a certain extent stopping the disturbance. After that it may start again. The dominance of modes 5. . . 10 arises from a fine-structure visible within the ridges in Fig. 1 as shown in the magnified view in Fig. 8. The period of the fine structure is 60. . . 100 turns depending on the amplitude, or a frequency of about 1 to a few MHz. This is consistent with typical ion-oscillation frequency in the HER, seen e.g. when vacuum conditions are poor[4]. We therefore may conclude that the observed instability indeed is consistent with being induced by ions.

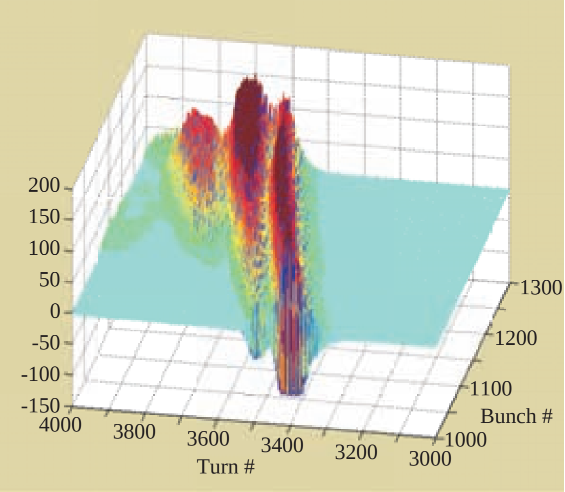

Figure 8: Fine structure of beam motion within a ridge.

The “tiny-Y” signature is different and defies an easy explanation. The small observed amplitude is inconsistent with the radiation it caused in the BaBar detector. However, there is evidence of bunch growth from fast synchrotron light monitoring, Fig. 9, hinting at a single-bunch effect or at scattering of particles off material. The rather similar “fast vertical instability” seen in the LER[2] was most likely caused by metal vapor injected into the beam. These potentially fairly heavy and ionized objects may not move appreciably on the time scale of the observation (35 ms); on the other hand, if quantity and state of ionization are sufficiently high they may affect the beam motion, leading to the small observed coherent signal.

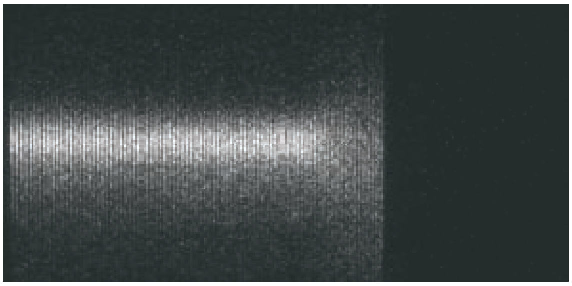

Figure 9: Vertical bunch size *vs* time, 80 turns increment.

Modes in the bellows structure have been analyzed[5] up to 4 GHz; the lowest mode would be about 100. However, estimating the exact frequency spectrum of an actual bellows is very difficult due to the uncertainty in the exact compression of the unit, therefore, the estimate cannot be conclusive.

## CONCLUSION

The observed transverse instability in the HER appears to be connected with transient effects like discharge and heating in the vacuum system. While one type may be explained as an ion-induced instability, the other type is harder to explain and no convincing mechanism has been identified. At the same time, coincident vacuum activity is used to localize the source of the instability.

## REFERENCES

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