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TRACKING DOWN A FAST INSTABILITY IN THE PEP-II LER*

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Abstract

During Run 5, the beam in the PEP-II Low Energy Ring (LER) became affected by a predominantly vertical instability with very fast growth rate of 10...60/ms and varying threshold. The coherent amplitude of the oscillation was limited to approx. 1 mm peak and would damp down over a few tens of turns, however, beam loss set in even as the amplitude signal damped, causing a beam abort. This led to the conclusion that the bunches were actually blowing up. The appearance of a $2\nu_s$ line in the spectrum suggested a possible head-tail nature of the instability, although chromaticity was not effective in changing the threshold. The crucial hints in tracking down the cause turned out to be vacuum activity near the rf cavities and observance of signals on the cavity probes of certain rf cavities.

INTRODUCTION

Fig. 1 shows the signature in the vertical plane of the observed transverse instability in the PEP-II LER.[1] The growth rate of the initial transient is between 10 and 60 ms^{-1}, much faster than any previously known instability in the LER. The max. coherent amplitude was limited, typically no more than ±1 mm peak. Damping of the coherent motion occurred on a similar time scale, although residual coherent motion remained detectable until loss of charge triggered the beam-loss-rate interlock. The loss of charge occured *after* the coherent signal was already significantly reduced, indicating growth of the bunches rather than coherent oscillation. The motion observed involved the whole beam as indicated in Fig. 2. A modal spectrum shows only low-lying modes (Fig. 3).

The transverse profile of a typical bunch in the ring was imaged on every 80th turn (0.6 ms spacing) by a synchrotron-light diagnostic using a rotating mirror[2]. Light from each turn is narrowed in one plane and stretched in the other to separate the images while showing the change in vertical size. A small centroid motion is visible in one image just before the onset of a rapid blow-up, which was seen in both x and y projections, followed by the abort (Fig. 4). A further signature specific to this instability were spectral lines at $2\nu_s$ which are not normally seen in the LER. Fig. 5 shows a "spectrogram" (frequency *vs* turn number) for about 4800 turns, at the end the beam aborted. Onset of the instability is clearly seen as is the onset of the $2\nu_s$ line. This hinted at a possible head-tail nature of the instability.

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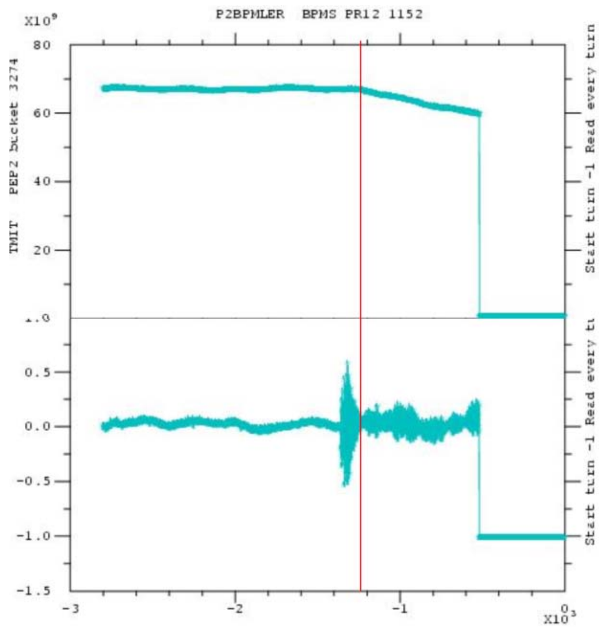

Figure 1: Loss of bunch charge (top). Fast LER coherent instability (bottom).

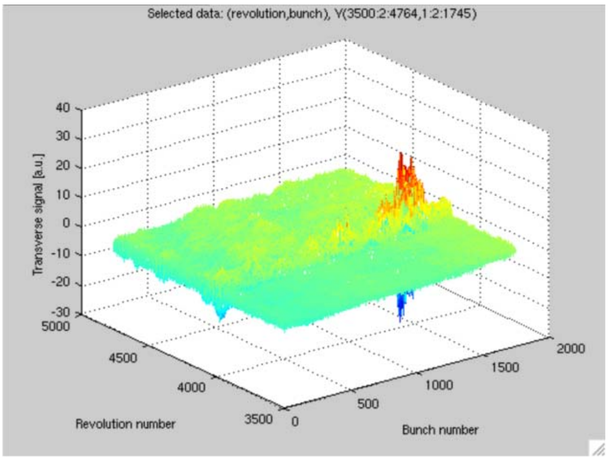

Figure 2: Bunch-by-bunch vertical position of the beam.

EXPERIMENTS

To further analyze and determine the nature of the instability a series of experiments was undertaken:

- Threshold *vs* tune chromaticity
- Threshold *vs* bunch current
- Threshold *vs* rf voltage (bunch length)
- Running with TFB system off

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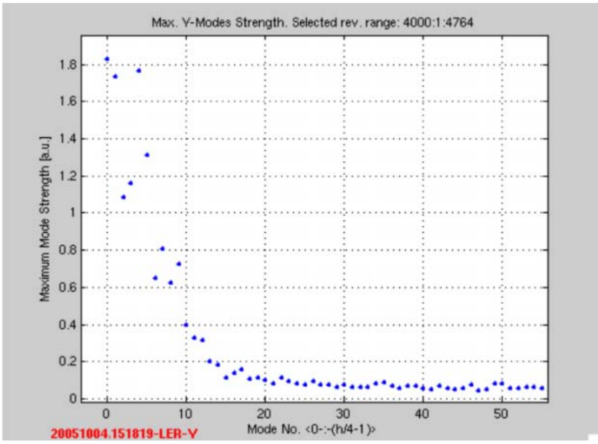

Figure 3: Modal spectrum of the motion during instability.

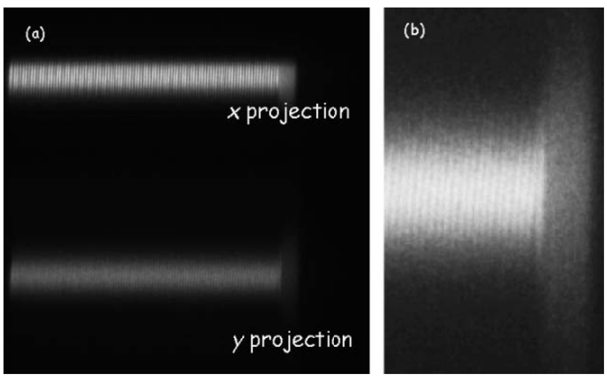

Figure 4: Sudden beam-blow-up in the LER, followed by an abort. (a) 125 images of one bunch, taken on every 80th turn (73 ms total). (b) A magnified view of the lower trace of (a), starting just before the instability. Centroid motion is visible in one image before the blow-up begins.

No significant dependence of the threshold on chromaticity was found over the somewhat limited range accessible in the experiment, ± 2 in y and $+2 \ldots -4$ in x. The current dependence for various fill patterns established that there was not much dependence on bunch current either, which might be naively taken to suggest the phenomenon to be somehow sensitive to synchrotron radiation. Finally, running with the transverse bunch-by-bunch feedback off was done to discriminate against transients possibly caused by the feedback system itself. This test is possible because of the strong beam-beam damping [3] overcoming the growth rates normally occurring in the rings of PEP-II.

In this way, no significant effect on the instability threshold could be produced. There was, however, a coincident spike in vacuum pressure observed in the rf cavities of the first rf station in Region 4. This spike was puzzling initially since the cavities are not aperture limits and only these two cavities showed such activity. Once the nearly 100% correlation of the vacuum spikes with beam aborts of this type was established, however, the spikes became a strong indicator towards the trouble spot. Fig. 6 shows an example of such an event. It should be noted that a pump in between

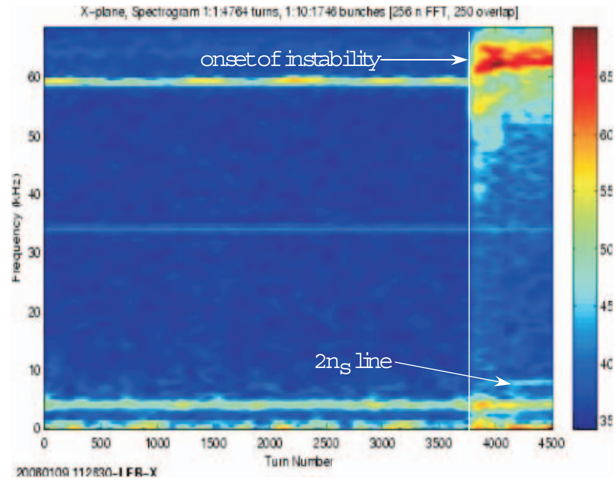

Figure 5: Vertical frequency spectrum *vs* turn.

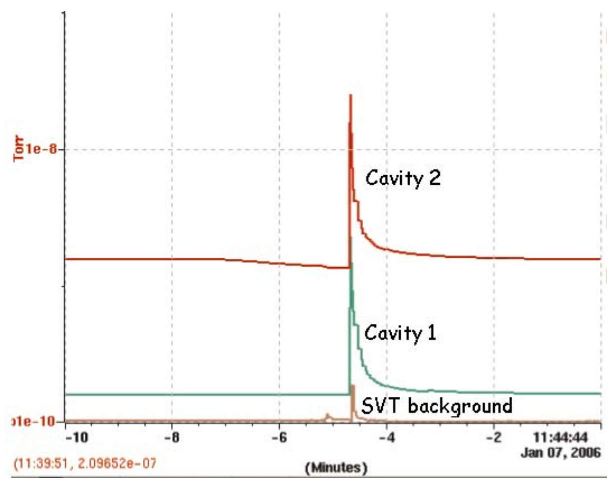

Figure 6: Spike in rf station 4-2 cavity vacuum pressure coincident with beam abort.

the cavities showed an even stronger signal, suggesting a source in between the cavities.

The observation of this effect caused renewed scrutiny of the fault-file data for the LER rf system following this kind of beam abort, and a signal was now seen on the field probes of the rf cavities in RF station 4-2 of the LER. Fig. 7 shows a representative plot of the observed signals. Note that such signals were not seen for the other rf cavities in the same region. The size of the signal was found to be about equal in both cavities, again consistent with the source being in between the cavities. A beam-phase detector showed a 1.6° phase transient (see Fig. 8); quantitative analysis gives an estimate of 110 keV total energy loss over 18 turns or 6 keV/turn and a total dissipation of $1 \ldots 2$ J for the entire event up to the beam abort.

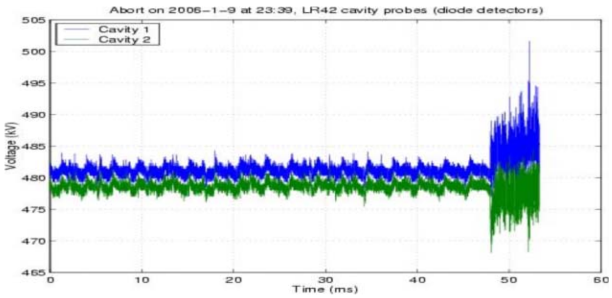

Figure 7: Signal of LER Rf 4-2 cavity probes during instability.

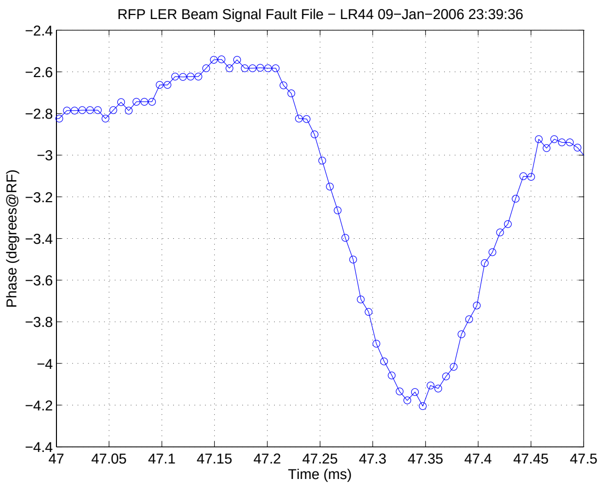

Figure 8: Phase transient of the beam at the onset of the instability.

THE CULPRIT

At this point the vacuum system between the cavities was opened for inspection. Borescoping the area revealed an rf seal ("gap ring") that was misplaced, apparently during installation of this pair of rf cavities. The misplaced ring is visible in Fig. 9. On removal the ring showed discoloration and evidence of discharge. Moreover, copper could be seen having coated the vacuum chamber near the gap ring, indicating significant sputtering. The fields from the discharge apparently were broadband enough to be detectable by the cavity probe even though cutoff of the vacuum pipe is around 2.5 GHz, compared to 476 MHz rf frequency.

During disassembly, burn marks were found on the beam-line solenoid wound around the flange containing the offending seal, Fig. 10. Originally thought to arise from overheating of the solenoid winding it became clear that the burn marks, which were fairly local to the flange, did in fact indicate heating of the flange, which is not LCW cooled.

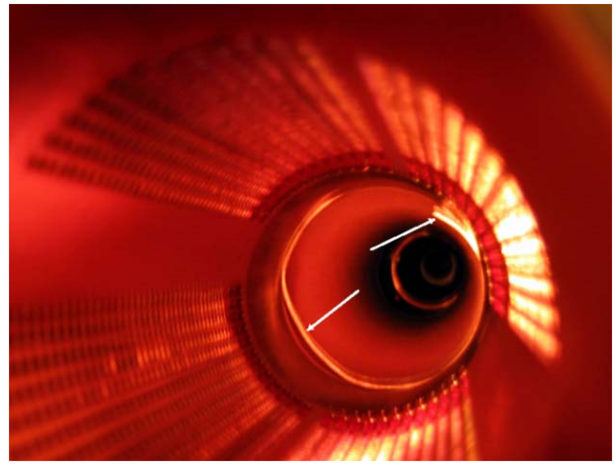

Figure 9: Dislocated rf seal in the LER vacuum chamber.

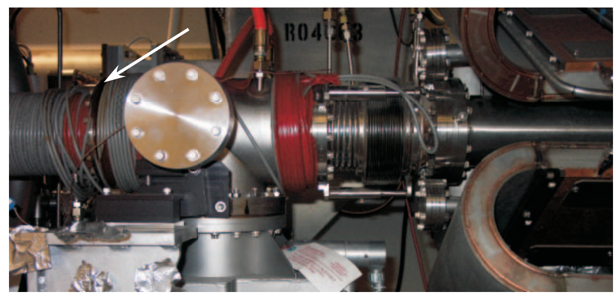

Figure 10: Flange with dislocated gap ring.

CONCLUSION

Once the offending rf seal (and a couple of others looking suspect) were replaced, operation quickly established the absence of this kind of instability in the LER, all but proving the source had been eliminated. The physics process has not been fully established, however. The amount of gas liberated is not sufficient to directly cause the observed beam loss by means of beam-gas scattering. The observed energy loss likely fed the discharge, which could thus act as an impedance causing instability although direct effect of the e-m fields from the discharge on the beam cannot be ruled out. The very fast growth rates also suggest the possibility of an electron cloud generated by the discharge causing beam instability as the electron-cloud instability can cause very fast growth rates.[4]

REFERENCES

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