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Increasing the Number of Bunches in PEP-II

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INCREASING THE NUMBER OF BUNCHES IN PEP-II*

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Abstract

The PEP-II B-factory at SLAC has delivered a luminosity of 4.6×10^{33} $cm^{-2}s^{-1}$. The bunch pattern now used in PEP-II has colliding bunches spaced every 4th rf bucket in what we call the "by4" pattern. During the past year we have increased the number of bunches per train in the by4 pattern from 21 to 23, out of a possible 24 bunches per train, for a total of 728 to 796 bunches respectively. The bunch trains were initially necessary to allow the electron cloud around the positron beam, which induces a transverse size beam blow-up, to dissipate. By adding solenoid windings around the low energy ring straight and arc section vacuum chambers the beam size blow-up has been reduced which has allowed us to run without gaps between trains. Presently, we use a straight by4 pattern with 836 bunches. At this point the increase in machine luminosity requires an introduction of a new bunch pattern that permits a large number of bunches since the bunch charge is already limited by the beam-beam effects.

Increasing the number of bunches in the PEP-II ring should linearly raise the luminosity when the charge per bunch is kept constant. Since we reached the maximum number of bunches possible in the by4 pattern, we have been exploring different patterns for higher luminosity operations. Present limitations for higher beam current are, higher order mode heating, electron cloud effects, differential tune shift along the bunch train, availability of rf power, and phase margin in the longitudinal feedback system. All of these limitations are directly or indirectly related to the bunch pattern.

1 ELECTRON CLOUD

Over the last two years solenoids were wound around the low-energy ring (LER) vacuum chamber [1] to suppress the electron cloud transverse beam size blow-up. The program began with solenoid windings around the straight sections and has recently concluded with winding the arc sections. Measurements have shown that with the present solenoid field used in the LER that the electron cloud is benign in the by4 pattern.

To increase the luminosity of PEP-II more colliding bunches are needed and therefore two new bunch patterns have been tested. For the two patterns, which have a smaller distance between bunches compared to the by4 pattern, the electron cloud induced beam size increase was detected. Details of the measurements are described below.

1.1 By2-By4 Pattern

The by2-by4 pattern has colliding bunches alternating with two and four rf bucket spacing. This pattern was chosen for its 50% increase in the number of bunches without two parasitic crossings at the interaction region. The total number of bunches, without mini-gaps for this pattern is 1106 bunches. The by2-by4 pattern was tested with colliding beams. Three mini-gaps were inserted in the bunch pattern to obtain 1030 total number of bunches in each ring. The currents were 1.65 mA per bunch in LER and 1.0 mA per bunch in HER. Figure 1 is the single bunch luminosity for the first two trains as a function of bucket number. It is evident from figure 1 that the bunches that are two rf buckets apart have a lower luminosity ($2 \times 10^{30} cm^{-2}s^{-1}$) compared to bunches that are 4 rf buckets apart ($4 \times 10^{30} cm^{-2}s^{-1}$). Bunches at the front of the train that are 4 rf buckets apart have low luminosity due to the flip-flopped effect [2]. The transverse beam size of several of the bunches in the first two trains were measured and they are denoted in fig. 1 by the black symbols.

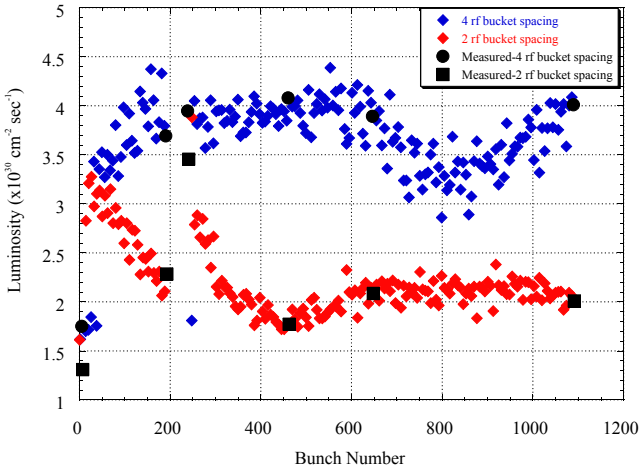

Figure 1: The single bunch luminosity for the first two trains in the by2-by4 pattern.

Figures 2(a)-(b) are the horizontal beam sizes and single bunch specific luminosity for the denoted bunches in figure 1. The beam size difference between the two differently spaced bunches confirms the basic behavior that i) positron bunches at the front of the train are not blown-up due to the electron cloud, ii) the positron bunches that are 2 rf buckets apart have a 20% larger beam size. Since the LER beam is highly coupled at the point of the synchrotron light extraction the effect in the vertical plane may be explained by the increase in the horizontal beam size only.

To remove the beam-beam effects from the data, the measurement was repeated with no beam in the HER. Figure 3 is the single beam horizontal beam size and, as in the colliding beam data, the electron cloud beam blow-up affects the bunches spaced by 2 rf buckets.

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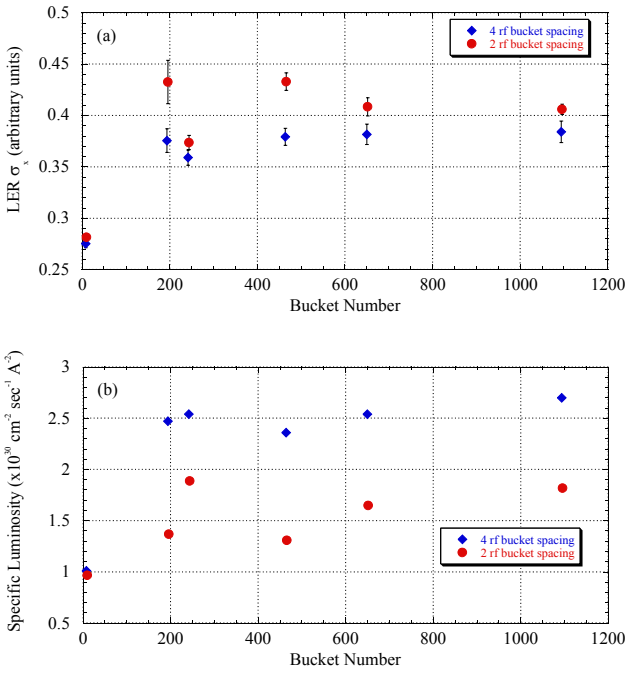

Figure 2: The (a) LER horizontal beam size and (b) single bunch luminosity for selected bunches in the first 2 trains for the by2-by4 bunch pattern.

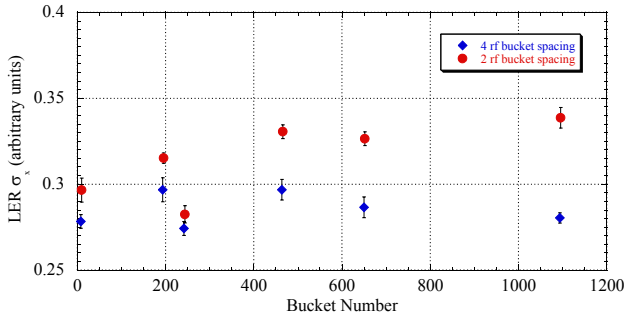

Figure 3: The single beam horizontal beam size along the first two trains in the low energy ring.

1.2 By2 Pattern

The by2 pattern, where colliding bunches are spaced every 2 rf buckets, was tested as well. To observe the electron cloud build up over time, the first train consisted of 72 bunches, followed by a gap of 24 bunches. Thereafter, 24 bunches than 24 bunch gaps were repeated for a total of 864 bunches. The by2 pattern was first tested with colliding beams but the nominal beam current could not be achieved due to a poor LER lifetime (~50 minutes) as a result of parasitic beam crossings on both sides of the interaction region. Nonetheless, the single bunch luminosity was measured at low current (I_{LER}=1.03A and I_{HER}=0.95A) in the by2 pattern is shown in fig. 4. The single bunch luminosity shows that: 1) there is a luminosity degradation along the bunch train which is a signature of the electron cloud, 2) the first and last bunch in each train has a higher luminosity possibly because those bunches have only one parasitic crossing.

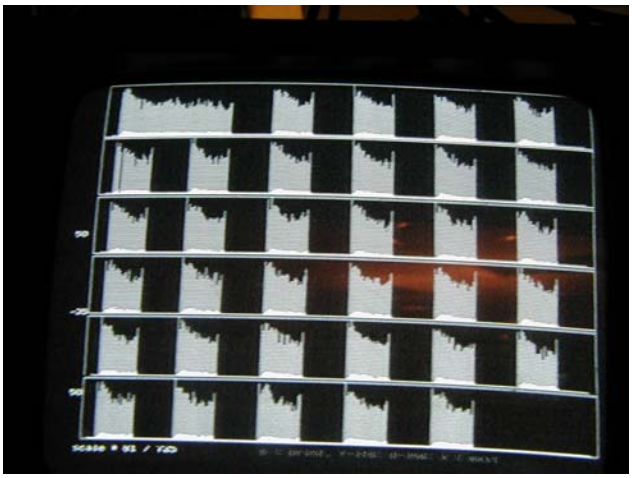

Figure 4: The PEP-II single bunch luminosity in the by2 pattern at low current.

To quantify the effect at the electron cloud on the beam size in the by2 pattern, without beam-beam effects, the beam size was measured for a single beam for the first train of 72 bunches (fig. 5). Notice the beam size increases linearly over the first 30 bunches.

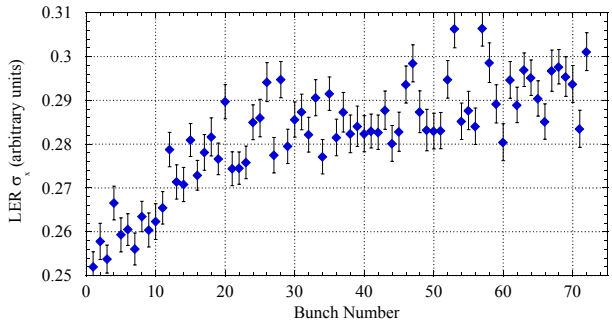

Figure 5: The LER single beam horizontal beam size along first 72 bunches in the by2 pattern.

In the past, the presence of the electron cloud was detected by correlating ion pump current with beam current [1]. Figure 6 shows straight section vacuum pump readout as a function of LER current. Notice the sharp increase in the read-out pressure above 1500 mA with the by2 pattern. The luminosity and beam size measurements are consistent with the hypothesis that the electron cloud is responsible for transverse beam-size blow-up in the by2 pattern.

No beam size growth has been measured due to the electron cloud with the solenoids on in the by4 pattern. Since the solenoids do not cover the whole ring, some multipacting is observed in the ring.

2 SUMMARY

In this paper a description of the hurdles presented to increase the number of bunches in the PEP-II ring has been discussed. We have discovered that strong electron multipacting has been detected in the straight sections of the LER in the by2 and by2-by4 bunch patterns. Increasing the straight section solenoids field might

suppress the electron cloud. Higher order mode heating limits the total LER current and requires operation with a larger than necessary bunch length. The hot spots have been identified and will be fixed this summer [3].

Although many problems prevented putting much more bunches into the rings, the number of bunches increased from 660 to 830 over the last 1½ years in the by4 bunch pattern (fig. 7). We have reached the maximum allowable bunches in the by4 pattern. With the HOM heating problems fixed this summer the by3 and by2 bunch patterns will be tested again in the fall.

3 REFERENCES

[1] A. Kulikov et al., "The Electron Cloud Instability at PEP-II", PAC'01, Chicago, June 2001.

[2] R.L. Holtzapple et al., "Observation of Beam Size Flip-Flop in PEP-II", EPAC'02, Paris, June 2002.

[3] S. Ecklund et al., "High Order Mode Heating Observations in the PEP-II Interaction Region", PAC'01, Chicago, June 2001.

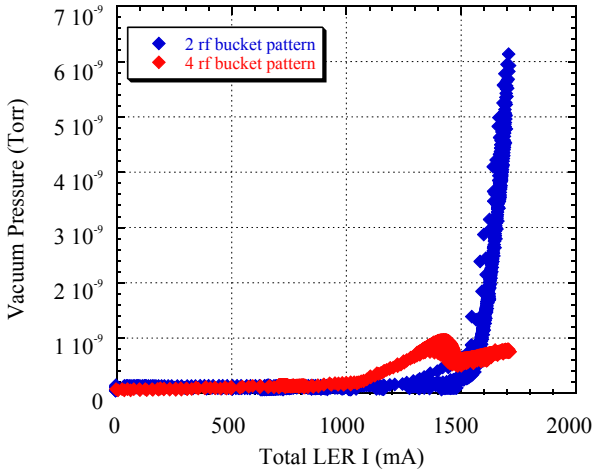

Figure 6: The vacuum pressure of a straight section as a function of current for the by2 and by4 patterns.

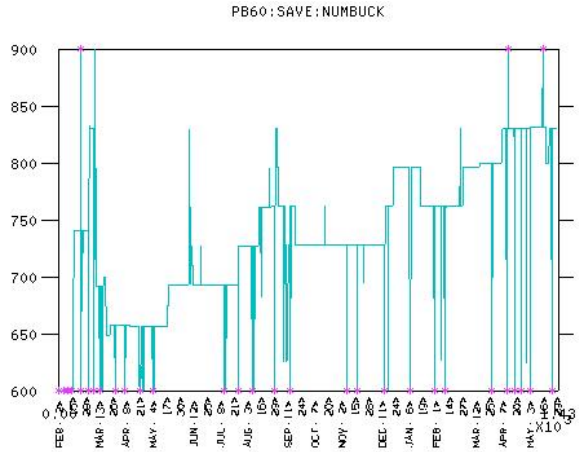

Figure 7. The number of bunches in the two rings over the past 1-½ years.