DEPENDENCE OF VERTICAL BEAM DYNAMICS INFLUENCED BY ELECTRON CLOUDS AT CESRTA ON VARIATIONS IN BUNCH SPACING AND VERTICAL CHROMATICITY*

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Abstract

Experiments have been performed on the Cornell Electron-Positron Storage Ring Test Accelerator (CESRTA) to probe the interaction of the electron cloud with a 2-Gev stored positron beam. The purpose of these experiments was to characterize the beam–electron cloud interactions by varying the vertical chromaticity and bunch spacing. These experiments were performed on a 30-bunch positron train, at a fixed current of 0.75mA/bunch, where the bunch spacing was varied between 4 and 28ns at three different vertical chromaticity settings. The vertical beam dynamics of the stored beam, in the presence of the electron cloud, was quantified using the x-ray beam size monitor (xBSM) that is used to measure the bunch-by-bunch, turn-by-turn vertical beam size of the bunch trains. In this paper, we report the results from these experiments and discuss the effects of the electron cloud on the CESRTA beam dynamics.

X-RAY BEAM SIZE MONITOR BASICS

We study the vertical beam size of bunch trains in the presence of the electron cloud [1] using the synchrotron radiation produced in a horizontal hard-bend magnet. The xBSM detector is a vertical array of 32 InGaAs diodes with 50 µm pitch and which has sub-nanosecond time response, enabling bunch-by-bunch, turn-by-turn beam size measurements. The xBSM beamline has an optical element located 4.6 m downstream of the x-ray source point and the detector sits 10.0 m further downstream. The analysis reported here employs a simple optical element, a vertically-limiting slit, adjusted so as to minimize the width of the resulting single-peaked image on the detector. A 4.4 µm-thick diamond filter hardens the x-ray spectrum incident on the detector, which has an average energy of about 2.5 keV for E_{beam}=2.085 GeV. Each turn's 32-pixel image is fit to an expected shape convolved with a Gaussian of floating width and position. The device has sensitivity to vertical beam sizes at the source point of ~10-150 µm, and relative turn-to-turn vertical beam motion of ~5-10 µm.

CESRTA Parameters

The experiments presented in this paper were made with bunch trains at 2.085 GeV in the low emittance lattice. Each bunch train consisted of 30 bunches of positrons with bunch spacing's of 4, 8, 12, 14, 16, 20, 24, and 28ns with a bunch current of 0.75mA ($1.2x10^{10}$ particles) per bunch. At each bunch spacing's, the vertical chromaticity was varied by a specific criteria [2]. During the experiments, the vertical and longitudinal feedback was turned off and the horizontal feedback was set to 20% of its normal operational value. Concurrent to measuring the vertical beam size, the bunch-by-bunch frequency spectrum of the self-excited bunch train using a gated Beam Position Monitor (BPM) and a spectrum analyzer and will be compared to the xBSM results. Machine parameters for the experiments are shown in table 1.

Table 1: CESRTA machine parameters during vertical beam size experiments.

Parameter	Value
Energy	2.085 GeV
Horizontal emittance	2.6 nm
Vertical emittance	~20pm
Bunch length	10.8 mm
Synchrotron tune	0.065
Momentum compaction	$6.8x10^{-3}$
Revolution frequency	390.13 kHz

EXPERIMENTS

The following are results from experiments performed on CESRTA that describe the vertical beam dynamics dependence on bunch spacing, vertical chromaticity, and beam position and size spectra of a 30-bunch train of positrons.

Vertical Beam Dynamics Dependence on Bunch Spacing

The key observations of vertical beam dynamics dependence on bunch spacing along the 30-bunch train (figure 1a) are:

- The vertical beam size for bunch 1-2 at short bunch spacing (4-12ns/bunch) is large but it is very unlikely this is result of the electron cloud [3].
- At the bunch spacing measured, no significant vertical beam size growth is observed until bunch 10.
- Between bunch 10 and 25, the increase in the vertical beam size with bunch number roughly linear. Closer

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spaced bunches lead to a more rapid increase in vertical beam size.

- Toward the end of the train, large oscillations in vertical position were observed. Typically the oscillation amplitude is outside of the range of the xBSM detector.

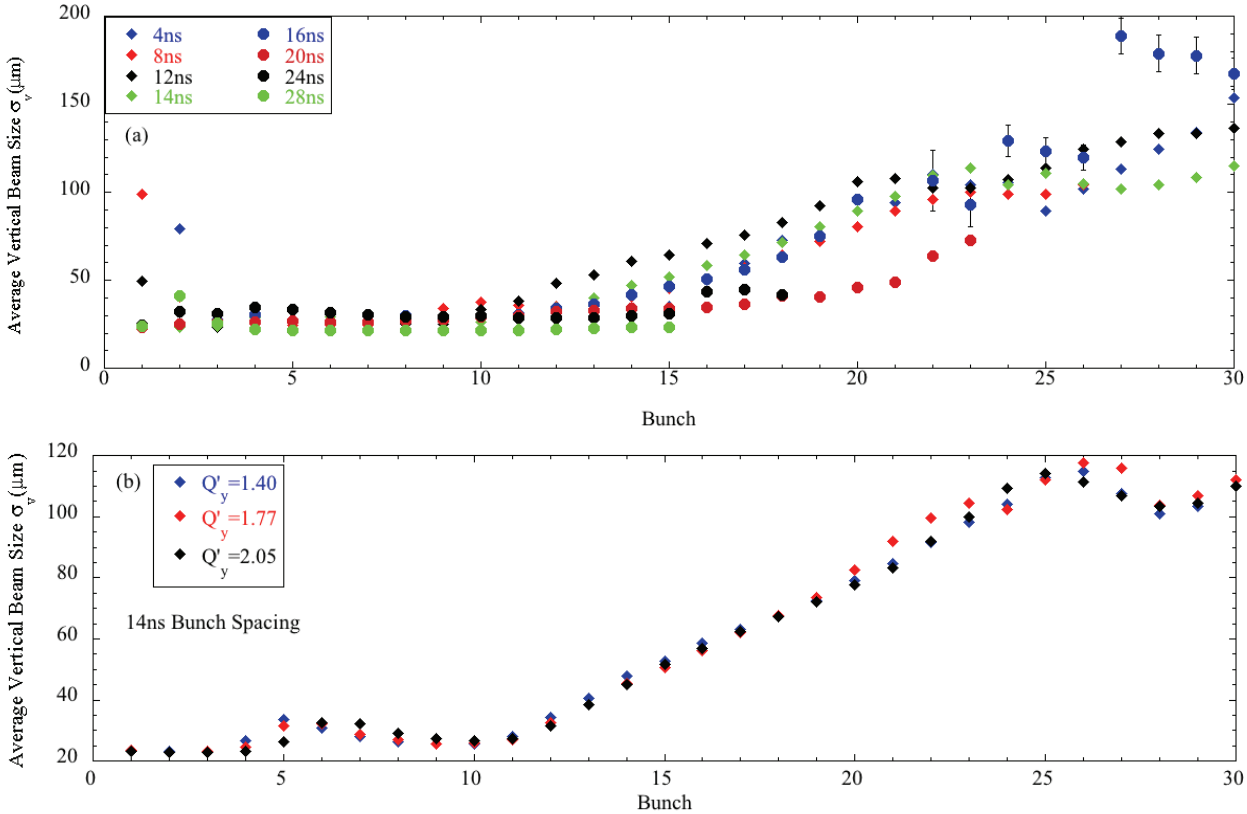
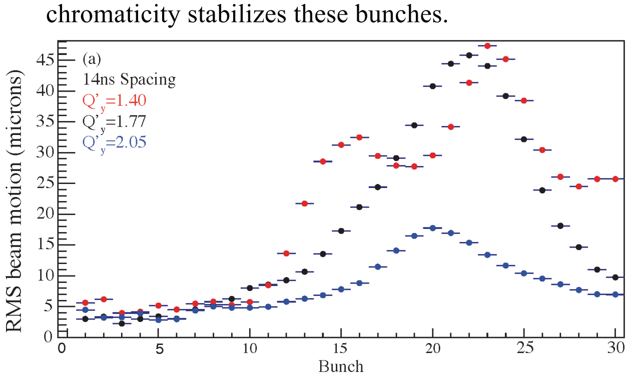


Figure 1: (a) The average vertical beam size along the 30-bunch train for bunch spacing's that vary between 4 to 28ns/bunch. (b) The average vertical beam size along the 30-bunch train of positrons with 14 ns spaced bunches at three different vertical chromaticity settings where $Q_y'=dQ_y/d\delta$ where Q_y is the vertical tune and δ is the fractional change in energy [2].

Vertical Dynamics Dependence on Chromaticity

The experiments on vertical dynamics dependence on vertical chromaticity show that:

- Varying the vertical chromaticity does not change the equilibrium vertical beam size of the first 10 bunches (figure 1b).
- Towards the end of the train, the vertical position and size stability can vary depending on the vertical chromaticity (figure 2a-b). Increasing the vertical chromaticity stabilizes these bunches.



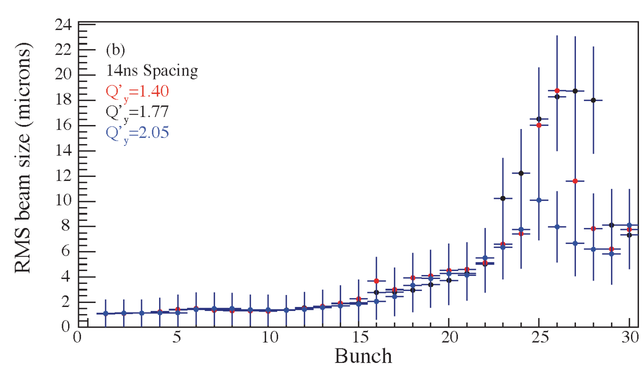


Figure 2: (a) The RMS beam motion (b) RMS beam size along the 30-bunch train with 14 ns spacing at three different vertical chromaticities.

Vertical Position and Size Beam Spectra

Features of beam dynamics that develop along the train can be detected in the turn-by-turn variation in the beam size and position spectra measured for each bunch. The spectra was obtained from: 1) A BPM detector connected to a spectrum analyzer whose frequency range was set between 195-330 kHz. 2) Fast Fourier transform (FFT) of the xBSM measurements of vertical position and size. A comparison between these two independent devices shows good agreement (figure 3 a-b) but also points out a feature of the xBSM data. Toward the end of the train, due to their large oscillation amplitudes, bunches periodically stray beyond the range of detection of the xBSM. This produces large background noise in the spectra (figure 3b).

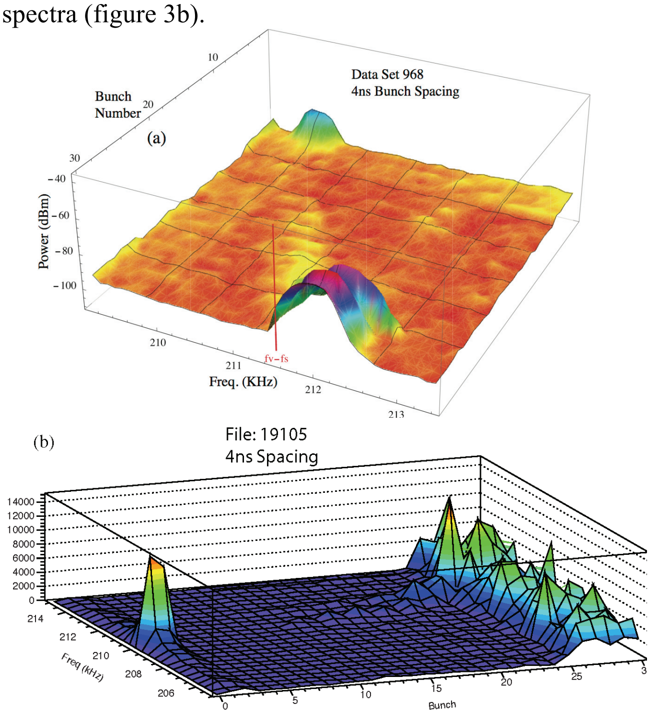


Figure 3. Self-excited beam position spectra at the m=-1 vertical head tail line from (a) the beam position monitor and (b) xBSM for a 30-bunch train of positrons with 4ns spacing.

Previous analysis showed many interesting features in the beam position spectra from the BPM [4]. Here we would like to point out interesting features from the beam position and size spectra from the xBSM such as:

- A strong synchrotron tune signal, f_s, is present in the xBSM position spectra which denotes that bunches in the latter part of the train are longitudinally unstable (figure 4). The signal amplitude is dependent on the vertical chromaticity and its arrival correlates with increase in RMS beam motion shown in figure 2(a).
- A peak in the beam size spectra at $2*f_v$ has been detected for several bunch spacings (figure 5). This signal amplitude depends on the vertical chromaticity and has a frequency shift that is consistent with the vertical tune shift observed along the bunch train.

CONCLUSIONS

We see good correspondence between the xBSM and BPM measurements, which were made simultaneously but used independent beam instrumentation. Along a 30 bunch train of positrons, we see slow linear growth in the vertical beam size, until there is a transition to a more nonlinear behavior where large beam position oscillations are observed.

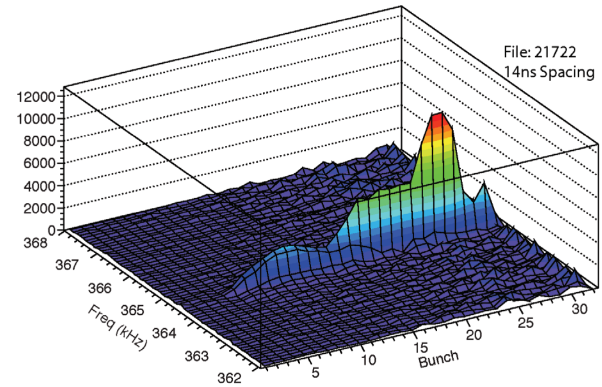


Figure 4. Self-excited beam position spectra in the range of the (f_{rev}-f_s) signal for a 30-bunch train of positrons with 14 ns spacing's.

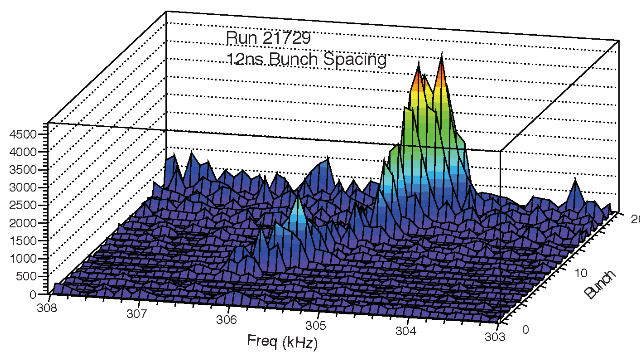


Figure 5. Self-excited beam size spectra at the $2*f_v$ line for the first 20 bunches in the train with 12 ns spacing. The signal is first detected at bunch 5. Notice that the signal moves to lower frequencies as you move down the train because this signal is the mirror image $2*(f_{rev}-f_v)$.

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