RECENT OBSERVATIONS ON A HORIZONTAL INSTABILITY IN THE DAΦNE POSITRON RING

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Abstract

A strong horizontal instability limits the maximum positron current storable in the DAFNE Phi-Factory. A powerful feedback system makes it possible to store and put in collision more than 1300 mA of positron current in 105-109 bunches. Nevertheless, a much higher current (>2.4A) has been successfully stored in the twin electron ring. Measurements have been carried out to understand the positron current limit and to characterize the behavior of the horizontal instability at high current with different bunch patterns. Grow/damp turn-by-turn data obtained by turning off the horizontal feedback have been acquired and analyzed. Spectral analysis and growth rates of the instability are shown. In particular, the -1 mode has strong evidence and fast growth rate. Its growth rate behavior is analyzed at different beam currents and bunch patterns.

INTRODUCTION

In DAΦNE [1], after the 2003 shutdown, a very fast horizontal instability limits the maximum positron current storable in the DAFNE Phi-Factory at ~ 0.5A. A powerful feedback system makes it possible to store and put in collision more than 1300 mA of positron current in 105-109 bunches. The ring has been filled almost completely (the harmonic number is 120) with contiguous bunches spaced by 2.7 nsec.

Nevertheless, a much higher current (> 2.4A) has been successfully stored in the twin electron ring.

Measurements have been carried out to understand the positron current limit and to characterize the behavior of the horizontal instability at high current with different bunch spacings and patterns.

SYSTEMS AND TOOLS DESCRIPTION

To study the strong horizontal multibunch instability, the authors have recorded and analyzed the transverse displacements for each bunch on a turn-by-turn basis.

The data acquisition system and preliminary measurements have been presented in a previous paper[2]. The apparatus is able to switch off one or both the transverse feedbacks for short time periods and to put the recorded data in ASCII formatted files. A LABVIEW recording program generates automatically a time stamp directory tree database with the data files [3]. Other LAVIEW analysis tools allow evaluating the stored data.

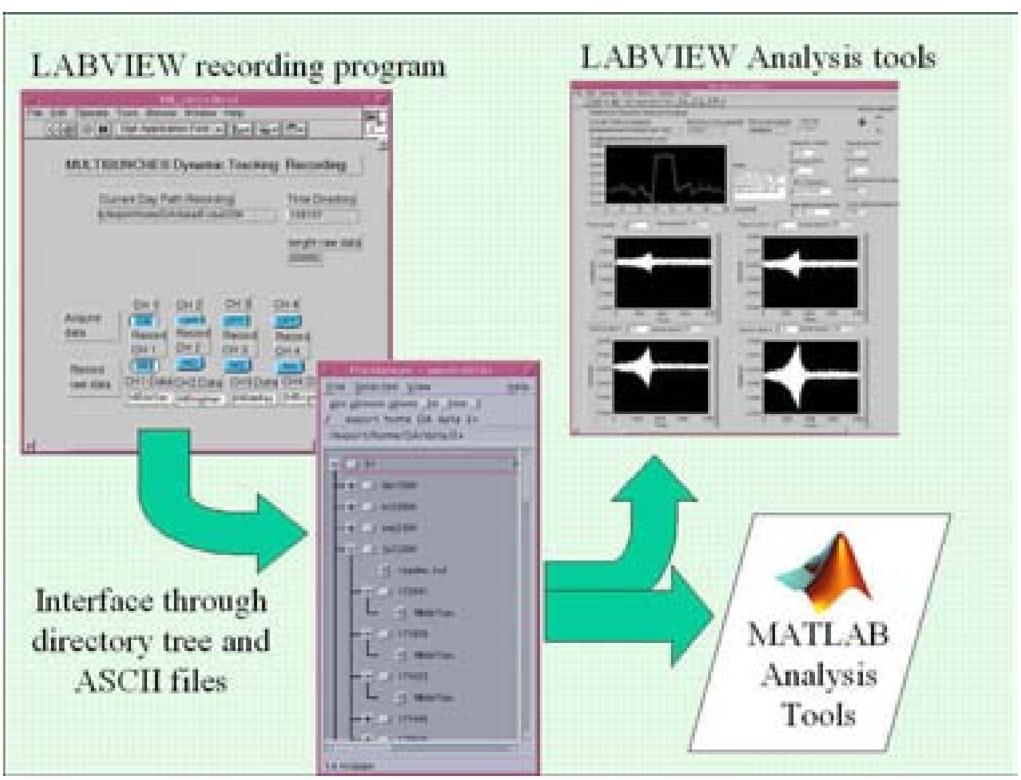

Figure 1: Scheme of the software tools used to record the transients and to analyze the data.

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Using this system, it has been possible to estimate the instability growth rates for each bunch at different beam currents and to evaluate the tune shift along the bunch train. In particular, a strong dependence of oscillation amplitudes on the bunch position along the train has been observed.

The database files can be converted offline to standard format to be analyzed by the MATLAB analysis tools developed by the SLAC feedback team [4], [5].

Fig.1 shows a scheme of the software tools used to record the transients and to analyze the data.

The transverse feedbacks utilize, as input to the low power electronics, the same type of pickups and hybrid junctions used by the data acquisition system. The feedback system front-end is composed by a baseband amplification stage, a high pass filter to cut the 50Hz noise and a low pass filter to avoid the aliasing in the following section. The low pass filter is a commercial device with flat group delay for low pulse distortion.

The feedback system generates the correction signal by a partially digital approach [6]. An 8-bits analog to digital converter samples the oscillation signal for each bunch. Simple operations, like bunch-by-bunch timed multiplication for 1, -1 or zero, are implemented to manage the input data flow at 368 MHz. The signal sampling is useful also to stretch the output signal to a bucket period and to make less critical the feedback timing.

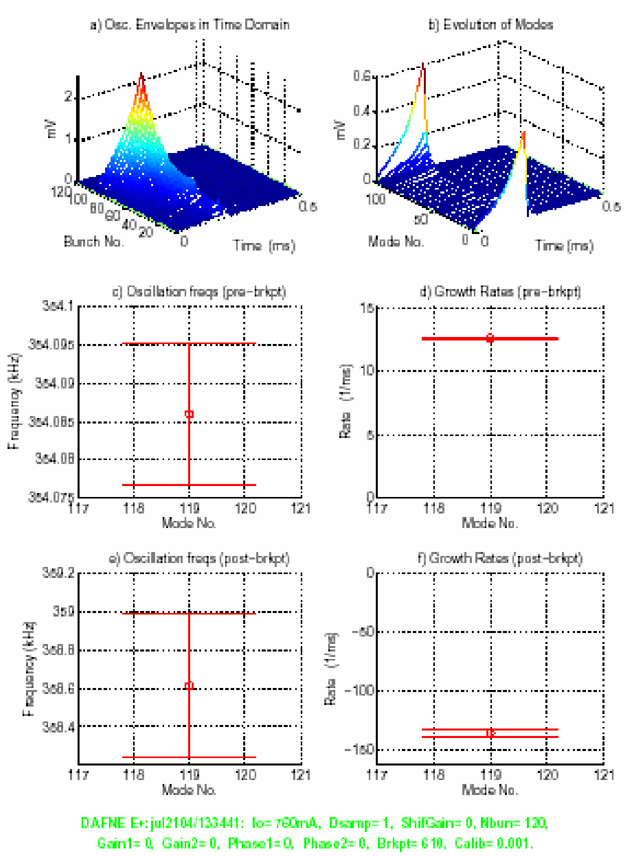

Figure 2: Horizontal grow-damp in the e^+ main ring.

In real time every 2.7 nsec, through a digital to analog converter, a bunch-by-bunch correction signal is sent to the power section and to the kickers. The feedback system can manage for each bunch oscillation frequencies up to the Nyquist limit (revolution frequency divided by two). Each feedback makes use of two 250W power amplifiers.

OBSERVATIONS ON THE INSTABILITY

Grow/damp measurements have been done with the setup plotted in Fig.1. A typical grow/damp shows very fast damping with a high transverse feedback gain. We consistently see only one eigenmode in all horizontal grow/damps: -1. Fig.2 shows results from a horizontal grow-damp in the e^+ main ring. There is some tune shift between open and closed loop. The eigenvalue shift is 148 * 10^3 s-1 + 28 * 10^3 rad/s.

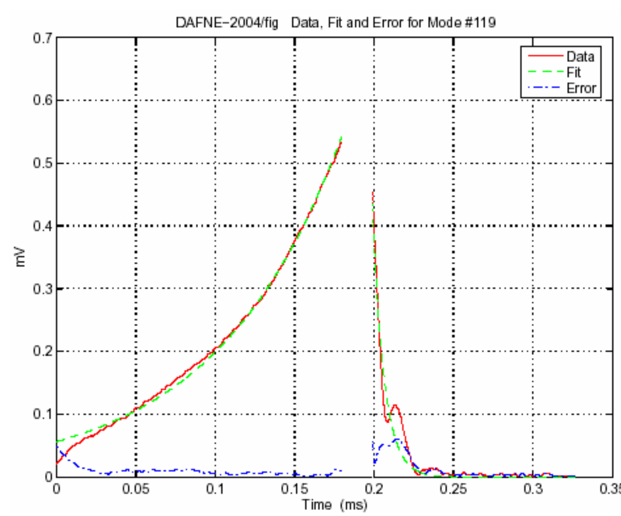

Figure 3: Data fit and error for mode #119.

It is remarkable to note from the figure that the horizontal feedback damping time is ~7 µsec.

Fig. 3 shows a complex exponential that fits to growth and damping transients.

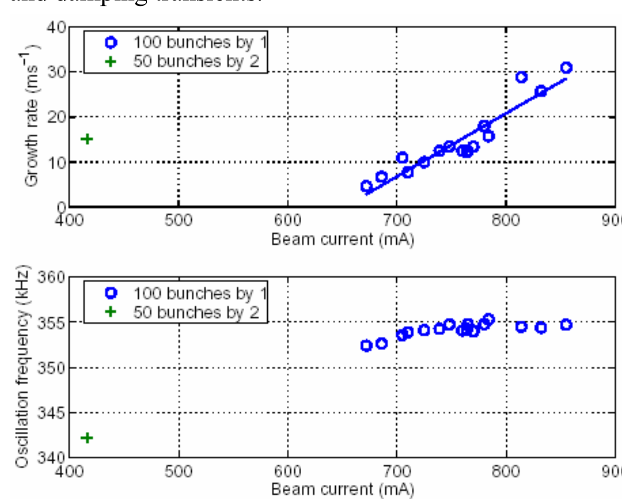

Figure 4: Horizontal growth rate and tune shift recorded on July 21, 2004.

Excellent open-loop fit indicates that growth rate and oscillation frequency have weak dependence on oscillation amplitude.

The growth rates of mode -1 versus beam current and fill pattern are plotted in Fig. 4: these data have been recorded on July 21.

The growth rate shows a roughly linear behavior versus current, as it is plotted in the figure. However changing bunch spacing from one to two RF buckets scales the growth rate by a factor 2. Growth rates induced by constant impedance should scale with total current. The instability behavior could be compatible with the presence of an electron cloud [7].

To understand better the problem, other data have been recorded the day after changing the bunch spacing. The results are plotted in Fig. 5.

The growth rate increases with beam current spacing the bunches by one or two or three. Instead, it decreases with bunch spacing by four or more.

This behaviour could be compatible with an electron cloud decay time of ~9 nsec.

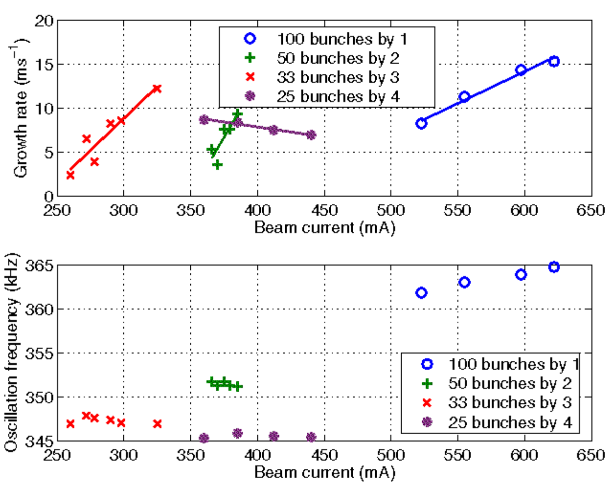

Figure 5: Horizontal growth rate and tune shift recorded on July 22, 2004.

DISCUSSION

Grow/damp turn-by-turn data obtained by turning off the horizontal feedback have been acquired and analyzed. Spectral analysis and growth rates of the instability have been shown. In particular, the -1 mode has strong evidence and fast growth time (~10µs).

The instability is very fast.

A so fast instability growth rate cannot be explained only by the beam interaction with HOMs or resistive walls. Growth rates as a function of fill pattern show that this motion is not due to fixed impedance (resistive wall). Its growth rate behavior is analyzed at different beam currents and bunch patterns. The growth rate increases with beam current spacing the bunches by one or two or three. Differently, it decreases with bunch spacing at least four.

Besides, the rise time scales almost linearly with bunch current (at least, for bunch patterns with spacing 1, 2, 3), while a conventional multibunch instability due to HOMs should scale with the total beam current.

When the bunch spacing becomes larger (4 or more), the rise time decreases. This is compatible with the presence of an electron cloud with ~9 nsec decay time. These measurements, together with observations of anomalous vacuum pressure rise and with numerical simulations reported in [7], are in favor of interpreting the instability as an electron cloud one.

CONCLUSIONS

A very fast (10 µsec) horizontal instability limits the utmost beam current storable in the DAΦNE positron ring. A strong feedback system helps to increase the current limit from 0.5A to >1.3A. In the twin ring, the electron beam current is not limited by a similar instability. Transverse grow-damp measurements give results that are compatible with electron cloud instability with a decay time of ~9 nsec.

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