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Influence of Distributed Ion Pump Voltage on the Anomalous Instability in CESR

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We have measured the horizontal coupled bunch instability growth rate for positrons as a function of the anode voltage of subsets of distributed ion pumps in CESR. We find that the growth rate increases linearly with the pump voltage. The current dependence of the growth rate does not significantly change with pump voltage. We present evidence that the contributions of individual pumps to the growth rate are additive.

1 Introduction

A horizontal coupled bunch instability ("anomalous antidamping") that is a highly nonlinear function of current has long been observed in CESR [1]. The effect is present only when the distributed ion pumps are powered [2]. The lowest frequency mode has the largest growth rate. At the present CESR fractional horizontal tune, above 1/2, this mode has frequency $f_0 - f_h$. It has recently been proposed that photoelectrons trapped in the beam chamber will result in a coupled bunch instability [3]. These photoelectrons are trapped horizontally by the dipole magnetic field and vertically by the electrostatic leakage field [4] of the distributed ion pumps (DIPs). A computer simulation using a simplified model is in good qualitative agreement with experiment [3]. The horizontal oscillation of the beam produces a modulation of the trapped photoelectron charge density, which in turn deflects the beam horizontally, creating a growth or damping of the horizontal oscillation. Because the maximum trapped charge density is proportional to the leakage field of the DIPs, we expect that the coupled bunch growth rates will decrease with decreasing DIP anode voltage. To test this hypothesis, we measured the growth rate of the $f_0 - f_h$ mode as we varied the output voltage of subsets of the DIP power supplies from 0 to +7.4 kV DC.

2 Instrumentation

Four CESR DIP power supply chassis were modified so that their output voltage could be varied continuously. In each chassis are two independent unregulated +7.4 kV DC supplies with monitoring and control circuits which normally share the same 208 VAC line input. Each power supply was modified to so that the primary of the high voltage transformer had an independent AC line input. This input voltage was provided by an autotransformer, and thus could be varied continuously from 0 to 208 VAC. The DC output voltage of a modified supply was measured as a function of AC input voltage and output current, and was found to be linear in AC input voltage, as anticipated.

The autotransformers were located outside the CESR tunnel for accessibility during CESR operation, with AC lines running through the shielding walls to the pump power supplies. The voltage drop along these lines was measured and was found to be negligibly small. An AC voltmeter was attached to the secondary of each autotransformer, and this voltage was recorded during the studies with beam to provide knowledge of the DC output voltage of each power supply. The output current of each supply was monitored by the CESR control system.

Most CESR dipoles contain two identical DIPs, which are normally powered from a single power supply through a junction box. In these experiments, additional junction boxes were used to allow us to power more than one pair of pumps from each supply.

The growth rate of the $f_0 - f_h$ coupled bunch mode was measured by driving the beam at that frequency for several milliseconds with a gated horizontal shaker and measuring the subsequent decay of the oscillation amplitude with a narrowband tune receiver and spectrum analyzer [5] operated in zero span (fixed frequency, time domain) mode.

3 Measurements

3.1 Measurements with eight pumps

In this set of measurements, a single power supply chassis under autotransformer control was used to power eight DIPs [6]. All other DIPs were turned off. All transverse feedback loops were turned off, and the horizontal chromaticity was adjusted to provide just enough damping to stabilize the beam for the full set of measurements. We filled CESR with 9 trains of two bunches of positrons with a 28 ns spacing between bunches in the train. The horizontal growth rate of the $f_0 - f_h$ coupled bunch mode (at 171 kHz) was measured with the eight DIPs on and off [7]. The difference in DIP on and DIP off growth rates is plotted in Fig. 1 as a function of positron bunch current. The error bars in this figure correspond to the level of reproducibility of the measurement of damping time, $\pm$ 0.1 ms. The growth rate increases with increasing DIP voltage, but the current dependence of the growth rate does not depend significantly on voltage. The same data, normalized to the number of DIPs powered, are plotted in Fig. 2 as a function of DIP anode voltage. The growth rate is approximately linear in voltage at each bunch current. There is an indication that the growth rate may vanish below a threshold of approximately +1 kV.

3.2 Measurements with 35 pumps

In this set of measurements, four power supply chassis under autotransformer control were used to power 35 DIPs [8]. These comprise 25% of the 141 operating pumps in CESR which do not possess screens that prevent penetration of the electrostatic leakage fields into the beam chamber. The chromaticity was raised and the digital transverse feedback gain was adjusted to the minimum necessary to stabilize the beam. We again filled CESR with 9 trains of two bunches of positrons and measured the horizontal growth rate of the $f_0 - f_h$ coupled bunch mode (at 172 kHz) as the anode voltage of the 35 DIPs was varied, with all other DIPs off [9]. Figure 3 shows the growth rate per DIP vs. DIP anode voltage for three different bunch currents [10]. Again the growth rate is seen to be approximately linear with voltage, with a possible threshold at low voltage. Growth rates were also measured at 2.1 mA bunch current with the remaining 106 pumps always powered at +7.4 kV. These data are included in Fig. 4.

4 Scaling with number of pumps

We have found that the coupled bunch mode growth rate increases linearly with DIP anode voltage when a subset of CESR DIPs are powered. We wish to be able to scale these results to predict the growth rate as a function of voltage when all of the DIPs are powered. We expect that the growth rates from each DIP will simply add, because each DIP is expected to interact with the beam independently of the others. Thus the growth rate per DIP should be independent of the number of DIPs powered. Figure 4 combines all of the per DIP growth rate data described above. Included in Fig. 4 is a data point showing the difference in growth rate between all 141 DIPs on at +7.4 kV and off. For this point, the growth rate was determined by gating off the CESR digital horizontal feedback system for several milliseconds while measuring the exponentially growing amplitude of the coupled bunch motion as a function of time [11], as shown in Fig. 5. The growth rates per DIP are independent of the number of DIPs powered to within the error of our observations, with the exception of the growth rate at 2.7 mA with 35 DIPs powered. The reason for this discrepancy is not known.

5 Conclusions

We find that the anomalous antidamping growth rate increases linearly with DIP anode voltage for voltages greater than about +1 kV. The current dependence of the growth rate does not significantly change with voltage. By comparison of measurements made with eight, 35, and all 141 unscreened pumps, we find that the contributions of individual DIPs to the total coupled bunch growth rate are additive. Because the DIP pumping rate remains relatively constant from +7.4 kV down to +1.8 kV [12], reducing the anode voltage in all CESR DIPs should be a practical and effective way to reduce the effect of the anomalous coupled bunch instability.

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References

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[2] R. Littauer, Cornell LNS report CLNS 88/847 (1988).

[3] J. Rogers, Cornell LNS report CBN 95-2 (1995).

[4] D. Sagan and J.J. Welch, Cornell LNS report CBN 92-01 (1992).

[5] Model 3588A, Hewlett-Packard Co.

[6] The pumps powered by the modified supplies were in bending magnets 13W through 16W.

[7] CESR Log 119, pp. 84-88, Feb. 20, 1995.

[8] The pumps powered by the modified supplies were in bending magnets 13W through 18W, 20W through 23W, 23E through 20E, and 16E through 13E. The south pump in bending magnet 23E is inoperable because of an internal short.

[9] CESR Log 120, pp. 80-81, Apr. 5, 1995.

[10] The 35 pump data, unlike the other data, were taken after the DC current monitor ("CERN current monitor") was removed from CESR. Currents were measured with the 9 bunch monitor, which was calibrated from the DC current monitor using the log file from the eight-pump measurements when both monitors were operating.

[11] CESR Log 116, pp. 38-40, Oct. 24, 1994.

[12] Y. Li, unpublished LNS internal report (1995).

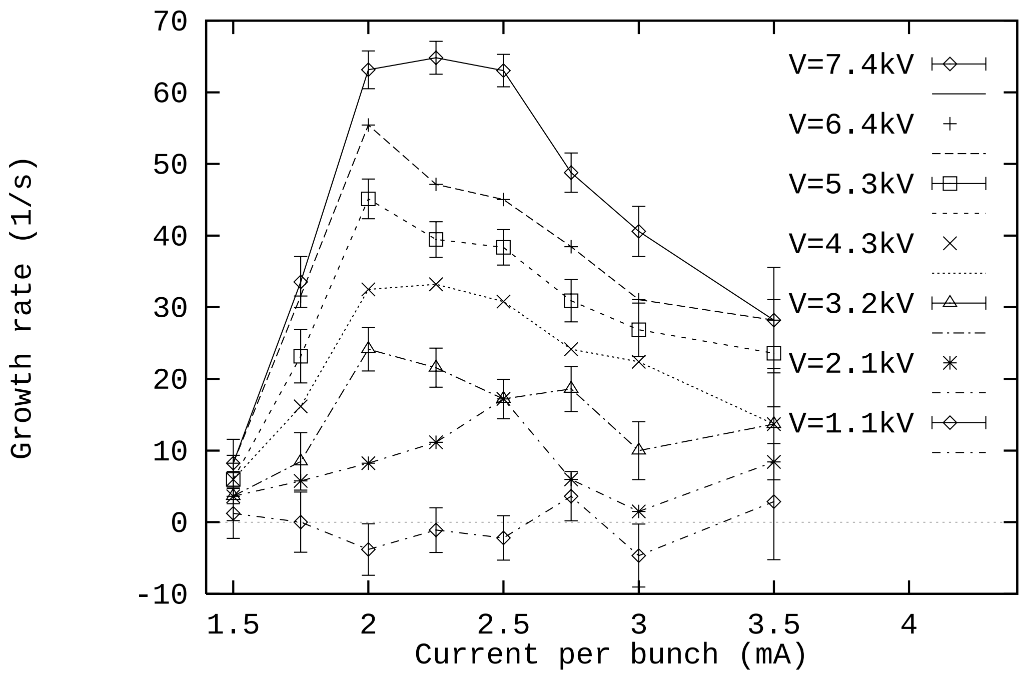

Figure 1: Growth rate of the $f_0 - f_h$ mode vs. positron bunch current for distributed ion pump anode voltages from +1.1 to +7.4 kV. Eight DIPs were powered. The background growth rate with these eight pumps turned off has been subtracted. Error bars on alternate sets of data points have been omitted for clarity.

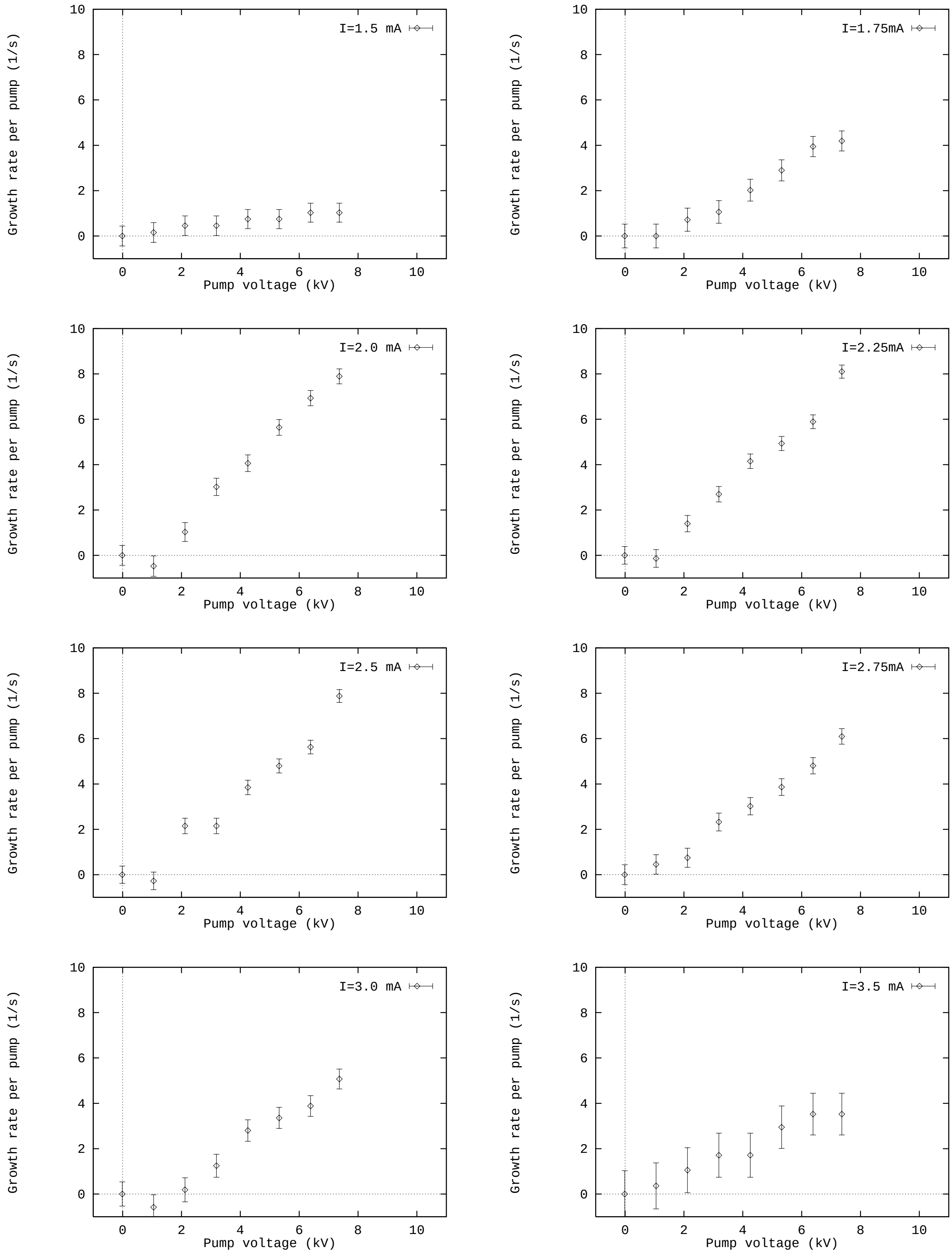

Figure 2: Growth rate per pump of the $f_0 - f_h$ mode vs. DIP anode voltage for positron currents from 1.5 to 3.5 mA per bunch. Eight DIPs were powered. The background growth rate with these eight pumps turned off has been subtracted. These are the data of Fig. 1, divided by the number of DIPs powered.

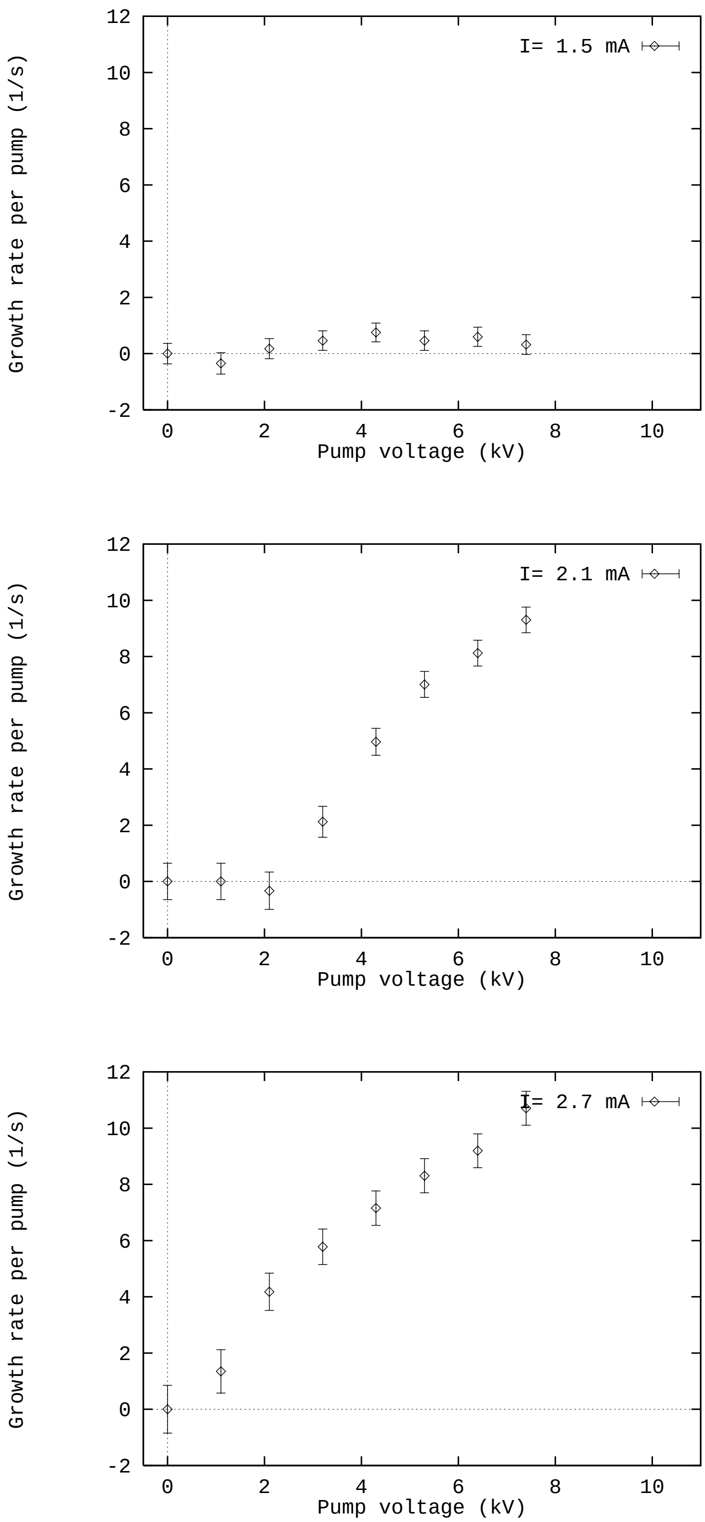

Figure 3: Growth rate per pump of the $f_0 - f_h$ mode vs. DIP anode voltage for positron currents from 1.5 to 2.7 mA per bunch. Thirty-five DIPs were powered. The background growth rate with these 35 pumps turned off has been subtracted.

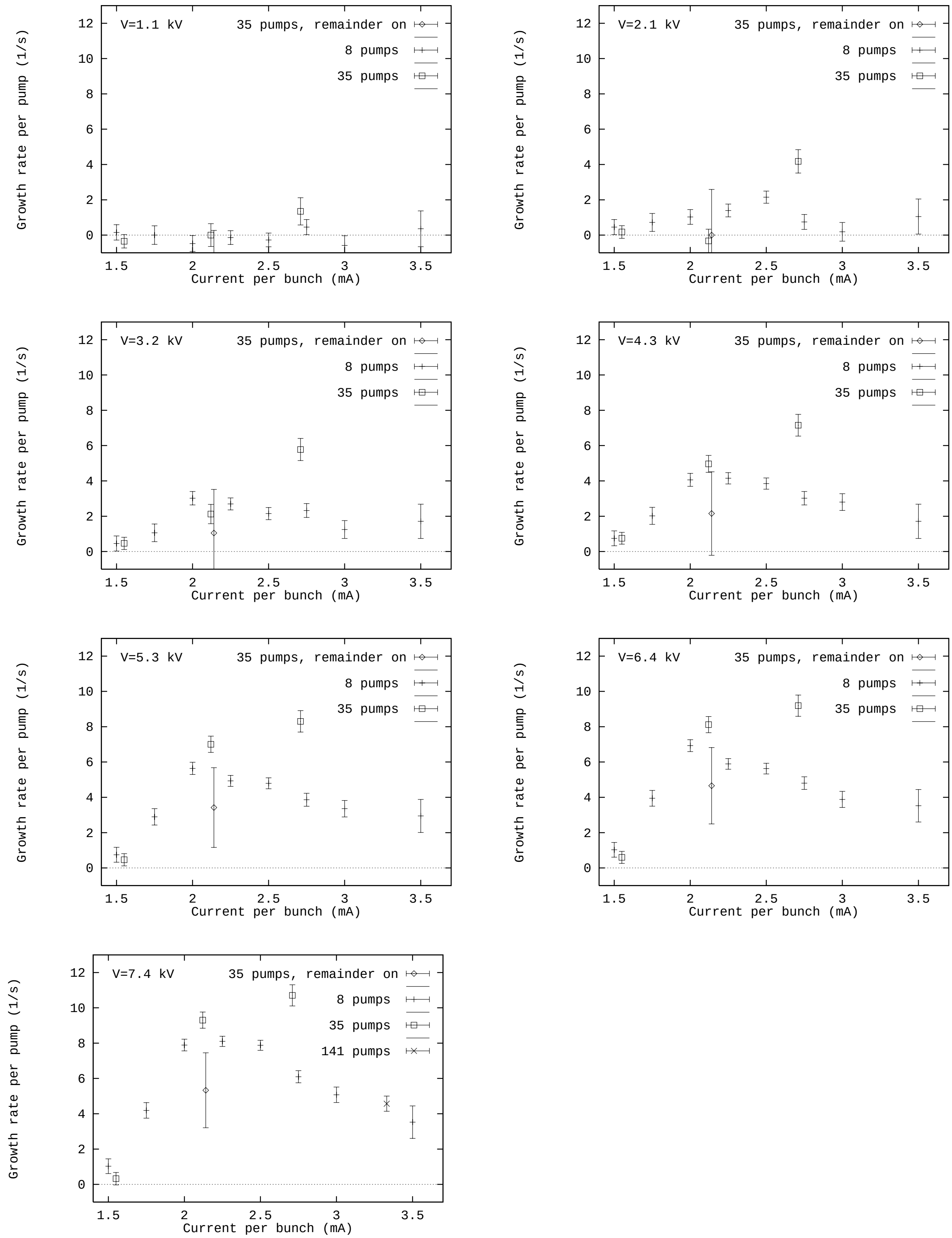

Figure 4: Growth rate per pump of the $f_0 - f_h$ mode vs. positron bunch current. Data with eight DIPs powered, 35 powered, and 35 powered with the remainder of the DIPs on at +7.4 kV are combined on each graph. The +7.4 kV graph also shows a point with all 141 unshielded DIPs turned on. In each case the background growth rate with the variable-voltage pumps turned off has been subtracted.

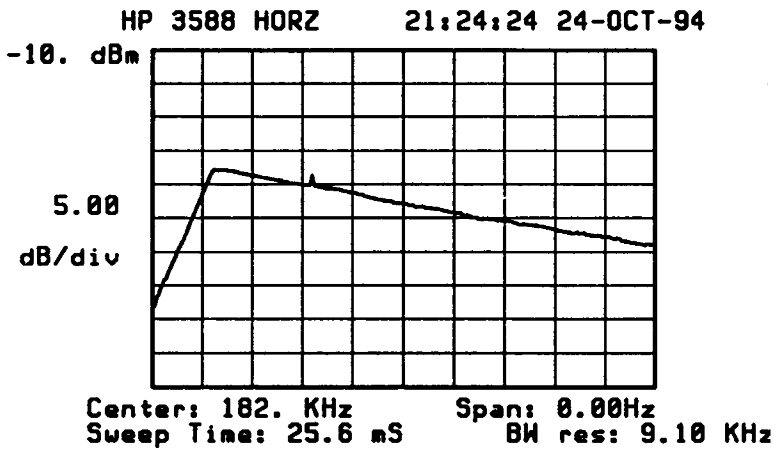

Figure 5: Amplitude of the $f_0 - f_h$ mode vs. time with all DIPs on at +7.4 kV anode voltage. The transverse feedback system has been gated off for the first 3 ms. The horizontal scale is 2.56 ms/div. The vertical scale is in arbitrary units.