ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME080

REFLECTIVE STREAK CAMERA BUNCH LENGTH MEASUREMENTS AT THE AUSTRALIAN SYNCHROTRON

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Abstract

The bunch length of the 3 GeV electron storage ring at the Australian Synchrotron has been measured using reflective input optics feeding a streak camera. An Offner optical design was employed to reduce the chromatic broadening of the input optics of the streak camera. Using the reflective input optics the bunch length is measured to be 15% shorter than with the refractive input optics. The measured bunch length is now in good agreement with the model of the storage ring and the values are being used for calibration, monitoring and optimisation of the machine.

BACKGROUND

A streak camera system is used on the optical diagnostic beamline [1] to measure the bunch length in the storage ring. The bunch length distortions are measured against a single bunch current and storage ring cavity voltages to determine various lattice parameters. Previous measurements have not agreed with the natural bunch length of the storage ring, see for example references [4, 5]. A bandpass filter has been used to reduce the bunch length broadening due to chromatic effects of the streak camera optics, however this reduces the light input signal at low bunch current to levels that make measurements very noisy or unreliable. A solution has been implemented using an Offner relay reflective input optics following [2, 3] to reduce the chromatic effects without reducing the light intensity. Fig. 1 shows a cutaway side view of the reflective input optics. SR light is focussed using an apochromatic lens at the entrance to the adjustable parallel vertical slits and horizontal V-slits. A series of flat, focussing and defocussing mirrors in an Offner relay system are used to focus the light onto the streak camera cathode with minimal chromatic aberrations.

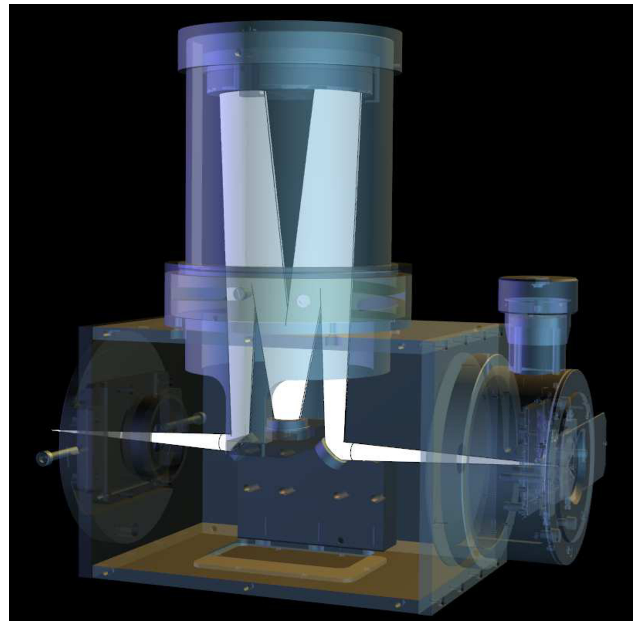

Figure 1: Offner relay system for streak camera reflective input optics. SR is beam focussed on the entrance slits on the right and focussed onto the cathode on the left.

INTENSITY DEPENDENCE

The bunch length measurements are broadened when the input light intensity is increased, probably due to space charge effects at the cathode. To measure the effect, a single bunch of $I_b \approx 8$ mA was injected into the storage ring and bunch length measurements made for a range of neutral density filters. The measured bunch length increases by 27% with in increase in the light peak intensity of a factor of 100 (see Fig. 2). This effect needs to be accounted for especially for measurements requiring a large range of single bunch currents, for example determining the zero current bunch lengths.

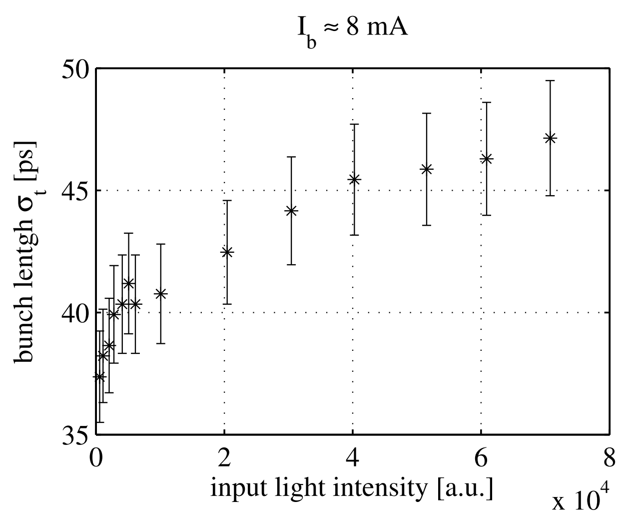

Figure 2: Variation in the measured bunch length against the input light intensity into the streak camera. Bunch current was kept constant and the intensity modified with an ND filter.

A comparison of bunch length versus single bunch current with and without intensity corrections is shown in Fig. 3. The deviation at high currents make a big difference in the slope used to fit for impedance or instability break points.

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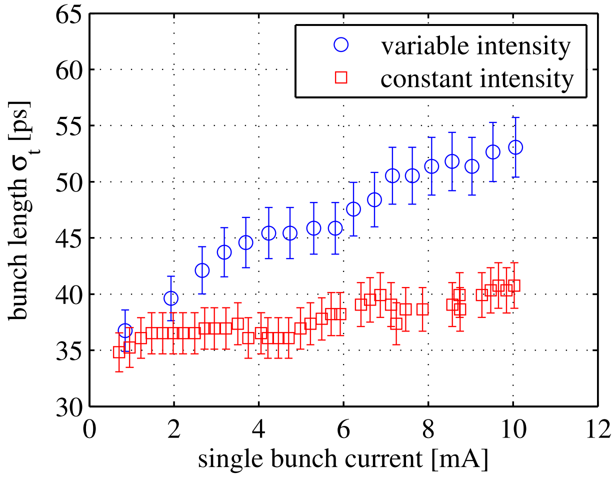

Figure 3: Comparison between fixed and variable light intensity on the streak camera.

PHASE DEPENDENCE CALIBRATION

A calibration curve was generated by measuring the screen pixel distance between two pulses (separated by a known time period) while varying the phase of synchroscan 250 MHz sweep voltage. Fig. 4 shows a strong non-linear effect due to the sinusoidal sweep voltage amplitude covering a large area of the image. These calibration curves are only for a specific sweep speed and MCP gain (intensity) and therefore measurements that use these calibrations must also use the same conditions. A future study will be to determine how the calibration curves changes for different MCP gains (intensity). The optics leading to the streak camera are currently under development and will include optical delay elements to be able to calibrate the streak camera before making measurements.

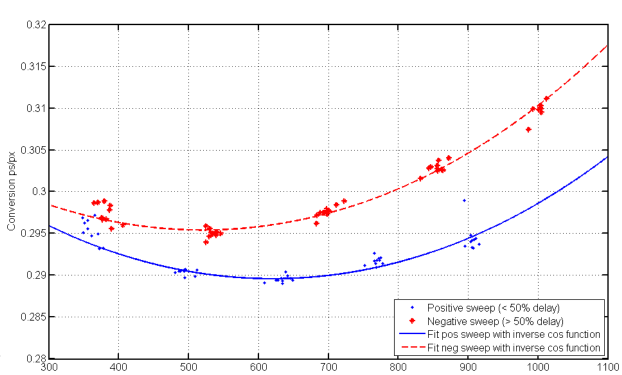

Figure 4: Non-linear calibration curve for the streak camera. Note the difference in the calibration curves between the different sweep directions. The cause might be a result of distortions on the RF input that drives the synchroscan.

NATURAL BUNCH LENGTH

The natural bunch length was measured by looking at the trend for the bunch lengthening with single bunch current. The deduced zero current bunch length is in reasonable agreement with the theoretical zero current bunch length of 31 ps at a cavity voltage of 1.8 MV (see Fig. 5). A more complete analysis and a fit to the cavity impedance is presented in the **IMPEDANCE ESTIMATION** section.

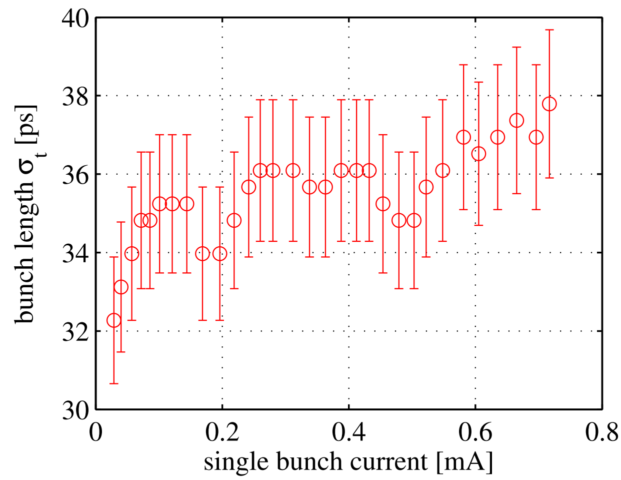

Figure 5: Measurement of the natural bunch length with reflective input optics and constant light intensity in the streak camera (cavity voltage 1.8 MV).

CAVITY VOLTAGE

The bunch lengthening effects were measured by lowering the storage ring cavity voltage for a fixed single bunch current of $I_b = 0.57$ mA. This is the nominal user beam bunch current and give a good signal in the streak camera without too much broadening due to impedance effects (see Fig. 5).

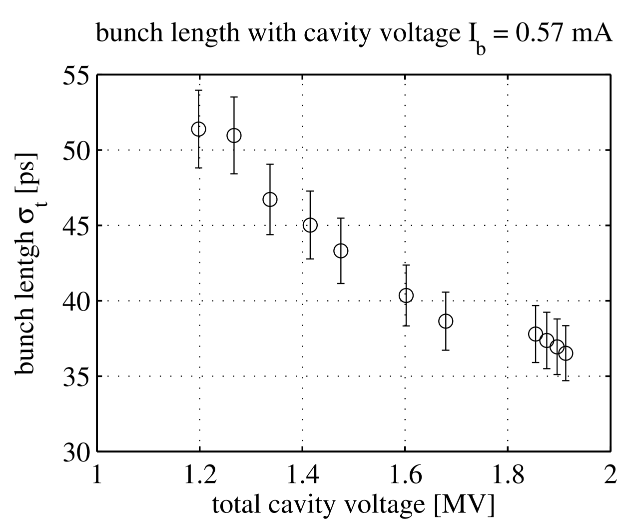

Figure 6: Bunch length against cavity voltage.

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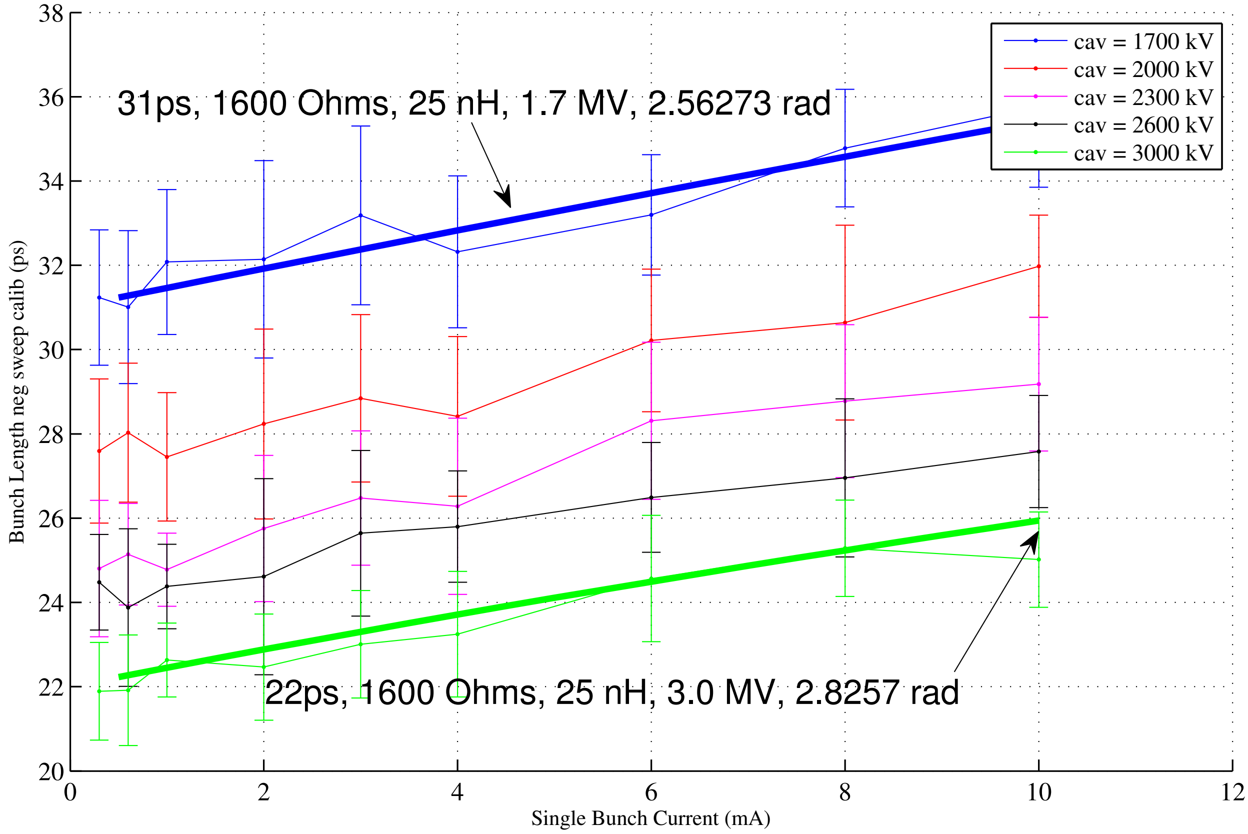

Figure 7: Estimation of the storage ring impedance.

IMPEDANCE ESTIMATION

The bunch length with bunch current was measured and fitted with the Hassinski equation [6] to obtain the ring impedance. The measurements were repeated for a range of cavity voltages and were in good agreement with each other (see Fig. 7). The theoretical zero bunch lengths are 32.5, 29.2, 26.8, 25.0 and 23.1 ps for cavity voltages of 1.7, 2.0, 2.3, 2.6 and 3.0 MV. However the measured zero bunch lengths appear to be 31.0, 27.5, 25.0, 24.0 and 22.0 ps. The measurements are systematically 6% smaller than expected. It is unlikely to be an error in the cavity voltage as such a discrepancy would require a systematic error of 10% in the cavity voltage (known to 2%). Another source of error is a change in the input signal that drives the fast synchroscan sweep unit (change from a digitally reconstructed 500 MHz signal to the original source). Since the change the calibration curves have not been re-measured.

CONCLUSIONS

For accurate measurements of the bunch length in the storage ring using the streak camera, care must be taken to reduce the effects of non-linear streak voltage calibrations, intensity dependent bunch lengthening and chromatic broadening. A series for measurement were taken with the Offner relay reflective input optics, while keeping the input light intensity constant with bunch current using a filter and using a non-linear pixel to time conversion. As further work a complete set of data will be taken to measure the bunch lengthening effects, using the new input optics, keeping the input intensity constant and using a non-linear pixel-to-time calibration curve.

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