FIRST USE OF CURRENT AND CHARGE MEASUREMENT SYSTEMS IN THE COMMISSIONING OF DIAMOND

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Abstract

We present an overview of the results obtained from the charge and current measurement systems installed in Diamond during the commissioning stage. The charge measurements are gathered from integrating current transformers and Faraday cups, while the current is measured using a parametric current transformer in each ring.

OVERVIEW

Beam current and charge measurements are made using four different types of devices in the Diamond injector and storage ring: Faraday cups (FC) are used in the LINAC as well as the linac to booster and booster to storage ring transfer paths (LTB and BTS respectively) to provide an absolute measure of charge, wall current monitors (WCM) give high bandwidth temporal structure of the bunch train, integrating current transformers (ICT) provide a non interceptive measure of the transfer efficiency and parametric current transformers (PCT) give the stored current in the booster (BST) and storage ring (SR). Table 1 summarises the numbers of systems and their locations.

	LINAC	LTB	BST	BTS	SR
FC	2	2	-	1	-
WCM	1	1	-	1	-
ICT	-	3	1	3	-
PCT	-	-	1	-	1

Table 1: Locations of charge and current measurements

WALL CURRENT MONITORS

Wall current monitors are used for high speed monitoring of the beam. They channel the mirror current flowing on the vessel wall through a known resistance. By measuring the voltage generated across the resistance the current can be calculated. We use a design similar to the Swiss Light Source [1] with the gap resistance increased from 1 Ω to 3.33 Ω which improved the bandwidth and RF matching. These WCMs are fast enough to precisely resolve the bunch train envelope as well as to show individual bunches and their length (within limits).

The positions of the WCMs have been chosen to allow us to characterise the bunch train and shape at the different stages of acceleration.

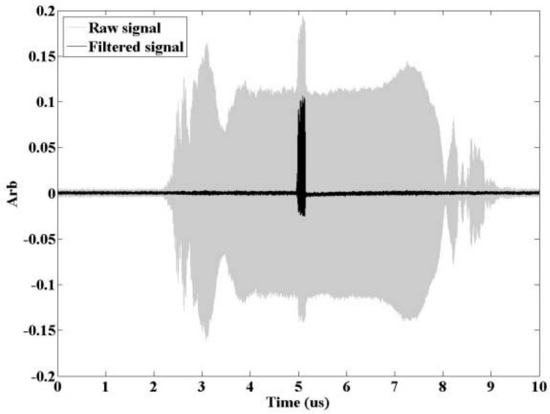

Figure 1: Structure of the bunch train

Signals from the WCMs near the LINAC taken with a 10 GHz bandwidth oscilloscope had to be filtered as strong 6 GHz and 9 GHz signals (harmonics of the accelerating voltage) were picked up. It would appear that these frequencies are able to propagate down the beam pipe so that this interference was particularly noticeable on the WCM at the end of the LINAC which is just 0.2 m from the second accelerating structure.

Figure 1 shows both the raw and the filtered signal. The bunch train contains approximately 100 pulses 2 ns apart so the train is about 200 ns long, which is clearly shown on the filtered data. The longer time scale structure visible in the raw signal has the shape of the RF pulse from the klystron. It remains unclear, where exactly the harmonics of the 3 GHz accelerating voltage are produced.

Figure 2 shows the changes in the envelope of the bunch train which has been produced by low pass filtering the WCM signals. The general deviation from the ideal case square pulse is due to the non linear response of the gun gate to a modulation pulse which shows some oscillation. Other than that, the LINAC output closely resembles the gun output, whereas the deviation of the booster output shows that there is further room for optimisation of the booster injection / extraction.

Figure 3 shows the evolution of the pulse shape. The shortest pulse is a test pulse to illustrate the resolution of the oscilloscope used. The pulse from the gun has a FWHM of 625 ps, after the 3 GHz bunching and acceleration in the LINAC this has reduced to 170 ps. Finally, after acceleration in the booster the peak has broadened slightly to

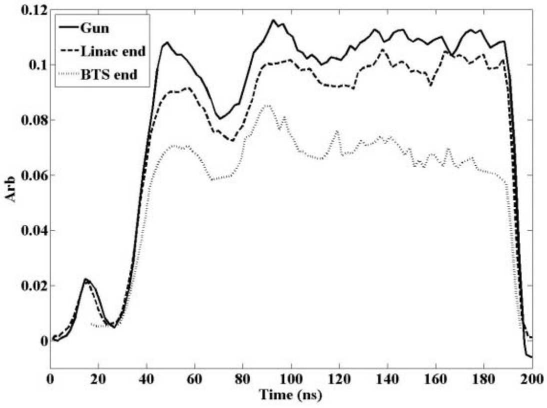

Figure 2: Structure of the bunch train

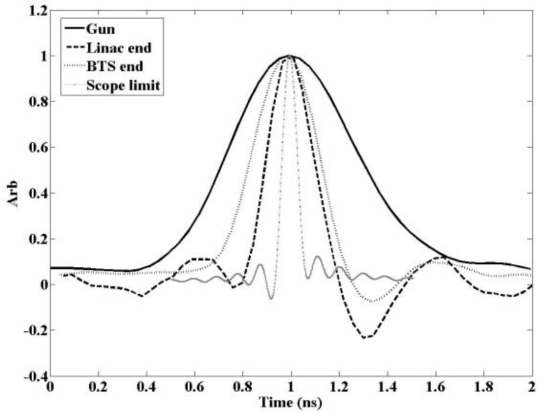

Figure 3: The bunch shape

208 ps.

Figure 4 shows the frequency response of the WCM up to 4 GHz, both from lab tests with a coaxial line and a network analyser and from data obtained from a fourier transform of the LTB signal (corrected for cable losses). A roll off from 2 GHz is visible and the both measurements show reasonable agreement.

FARADAY CUPS

Faraday cups are the simplest charge measurement device. The electron beam is fired into the cup which absorbs the electrons and charges up. The captured charge is then allowed to escape through a known leakage path to ground. By using an oscilloscope or voltmeter across the leakage path the beam charge can be deduced.

The mechanical details and design considerations of the four FCs have been published earlier [2].

Due to their small mass and largely coaxial structure the two low energy cups have enough bandwidth to determine the train structure. These results agree closely with the results from the first WCM in the linac. The 90 keV cup was also used to commission the gun prior to its installation into the linac.

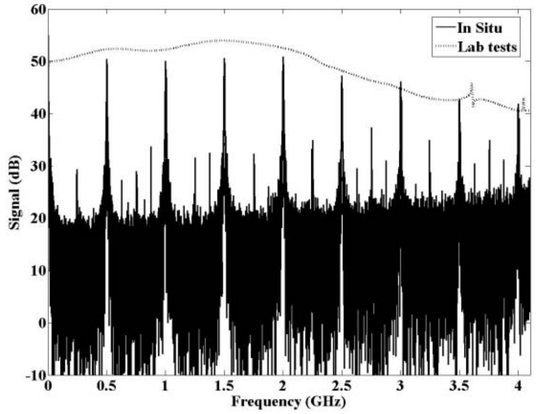

Figure 4: The frequency response of the BTS WCM

The FCs in the transfer paths have mainly been designed as beam stops with a charge measurement facility, so they have been optimised for charge collection efficiency rather than bandwidth. As a result, they are not able to resolve individual bunches and even the shape of the train envelope is distorted. However, the overall charge can still be reliably obtained from an integral of the measured current. Figure 5 shows data from the different Faraday cups

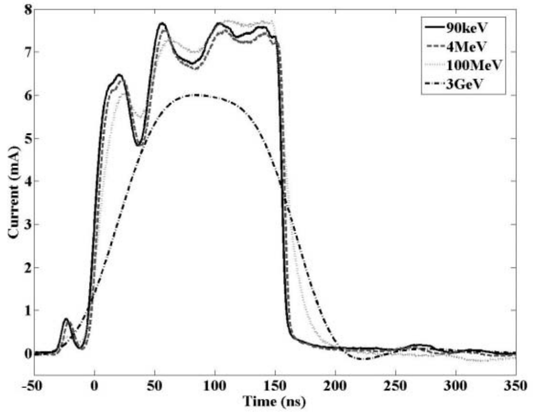

Figure 5: Signal from the faraday cups

INTEGRATING CURRENT TRANSFORMERS

Integrating current transformers (ICT) use a coil around the beam pipe to act as a secondary winding in a transformer with the beam acting as a primary winding. The resulting signal is passed to signal processing electronics which uses an integrate and hold circuit to output the charge in each pulse.

There are ICTs in both transfer lines and the booster ring, which allows us to optimise the injection efficiency.

During the initial optimisation when the position control of the beam was poor, the main target was to increase the amount of charge transported. The ICT readings were vital at this stage as they are position insensitive.

Position	Transfer efficiency	Standard deviation
End of LTB	81.4%	± 0.2%
Booster ramp start	79.7%	± 1.7%
Booster ramp end	59.6%	± 1.3%
Start of BTS	54.6%	± 1.3%

Table 2: Transfer efficiency in the injector (relative to LINAC output)

Table 2 shows a transfer efficiency measurement during the commissioning of the injector system as measured by the transfer line ICTs and the booster ring PCT. All efficiencies are averaged over ten shots and the reproducibility of the measurement is generally good. The measurement also shows that at this stage of commissioning further improvement of the transport through the LTB and of the booster accelerating cycle is required, whereas injection and extraction from the booster creates very little losses.

PARAMETRIC CURRENT TRANSFORMERS

Both PCTs are manufactured by Bergoz [3]: The booster ring uses an older type MPCT while the storage ring uses the more recent NPCT with lower noise and better stability.

These devices were used to optimize the injection into the rings as well as maximising beam survival.

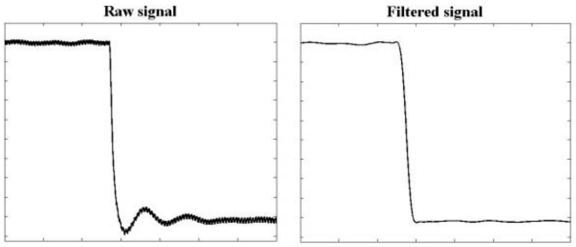

Figure 6: The step response of the booster PCT before and after filtering

The signal from the PCT electronics needed to be filtered to remove a 7 kHz signal and a 500 Hz ringing which the capture electronics had introduced (Fig. 6). This was done using an FIR filter in the EPICS control system (Fig. 7).

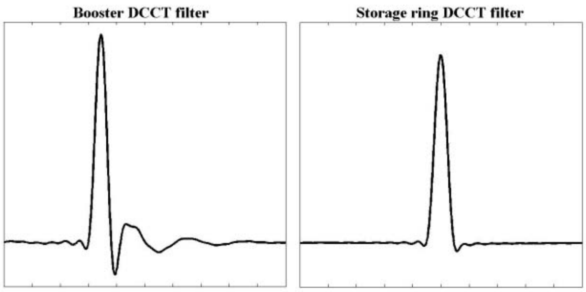

Figure 7: The filters used in the PCT processing chain

The Storage ring PCT was also filtered, but as the drive signal of the NPCT is at a higher frequency and the bandwidth is higher, the filter required here is mainly a low pass filter.

Most recently, the PCT in the Storage ring has been used to show that we achieved stacking, giving us a stored current of 2.1mA (Fig. 8).

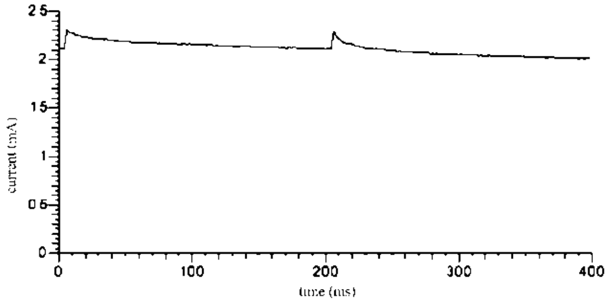

Figure 8: 2.1mA in the storage ring

SUMMARY

The charge and current diagnostics have been instrumental in the commissioning of diamond. The Faraday cups and wall current monitors were used primarily in the initial stages in order to get first beam, while the Integrating current transformers and the DC current transformers in particular have been useful during the beam optimisation phase.

The fact that we have good agreement with the cross correlation measurements gives us confidence that the systems are behaving as expected and the results can be trusted.

REFERENCES

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[2] A.F.D. Morgan, “Design Of The Faraday Cups In Diamond”, in *DIPAC Proceedings (2005) 51-53*

[3] http://www.bergoz.com/