

# TESTING OF A PROTOTYPE STRIPLINE KICKER FOR DIAMOND-II

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## Abstract

Diamond-II will use fast stripline kickers for transparent single bunch injection during top-up operations. A prototype stripline and pulser have been developed and have undergone evaluation in the existing Diamond accelerator. Two types of feedthrough connector have been tested, and suitable cables and attenuators have been identified. We present results from an array of checks for the stripline assembly both in isolation and installed in the accelerator with beam. This includes impedance analysis and other effects on electron beam dynamics, as well as analysis of kick strength and timing.

## INTRODUCTION

Diamond-II [1] is the upcoming upgrade to the Diamond synchrotron light source. Diamond currently uses a standard four kicker bump for injection, including in top-up mode during user operations, but despite effort to reduce disturbance to the stored beam [2] there is significant impact visible to some beamlines. Diamond-II will instead use six fast stripline kickers [3] to kick only a single bunch during top-up operation. The kick-and-cancel injection scheme [4] uses two kicks spaced a few turns apart to kick the injected bunch inside the dynamic aperture while putting the stored beam back on axis. This significantly reduces the impact of collective effects as well as further reducing the effect on brightness for beamlines compared to aperture-sharing.

A prototype stripline and pulser have been tested at Diamond to prove the feasibility of this kick-and-cancel scheme. The stripline was first connected to a test bench for electrical testing, and then to a pulser providing lower voltage (5.3 kV) than the final design (21 kV). It was then installed in the booster-to-storage (BTS) transfer line using the same pulser for testing with single-pass beam. Finally, the stripline was installed in the storage ring with a fully capable pulser to test the effectiveness of the kick-and-cancel scheme, as well as for investigations into impedance and beam heating effects.

Due to the smaller apertures required for Diamond-II compared to the existing storage ring, the prototype stripline was installed in a vertical orientation and designed with a slightly larger aperture than the Diamond-II striplines to avoid interfering with injection.

## INITIAL HARDWARE TESTS

S-parameter measurements were taken, comparing output signal from the four ports for a given input signal at one port. Figure 1 shows simulated and measured reflections back to the input port. The simulation uses a model with no cables and perfect 50  $\Omega$  matching, while measurements are

shown for the prototype including feedthroughs, and with long cables in addition. There is generally a good match between model and measurement, with the larger amplitude of the dip around 0.9 GHz likely due to the feedthroughs not being perfectly matched. The cables introduce additional noise, especially around the 1 GHz region.

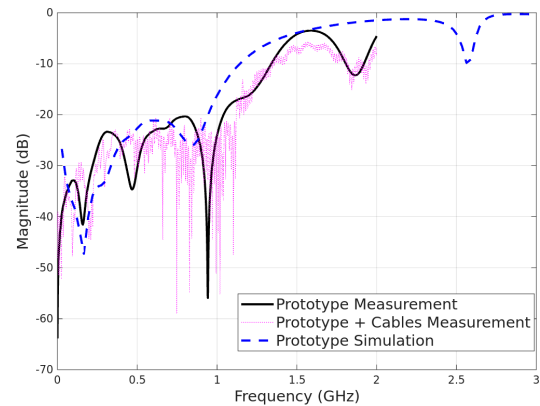


Figure 1: Comparison of simulated and measured reflections in the prototype stripline.

## TESTING WITH BEAM IN TRANSFER LINE

The stripline was installed near the beginning of the BTS transfer line in March 2025, as shown in Fig. 2. The pulser and cabling were inside the tunnel nearby to the stripline. An OTR fluorescent screen just under 3 m downstream was used to measure the position of the beam. Since the kick is intended to affect only a single bunch, the injector was operated in single bunch mode for these tests, since a multibunch train of 120 bunches would drown out the target signal. Timing was scanned to obtain the maximum deflection to the bunch. A kick of 65  $\mu\text{rad}$  vertical kick was found, compared to 54  $\mu\text{rad}$  predicted using a simple parallel-plate model.

## TESTING IN STORAGE RING

### Beam Induced Heating

The stripline was moved to straight 19 of the storage ring in June 2025, upstream of the insertion device (ID) already installed. Cables about 20 m long were run outside the tunnel to avoid radiation damage to the pulser and electronics. Initially the pulser was not connected and all four ports were connected to 100 W attenuators. Thermocouples were attached at various positions externally to monitor temperatures, including on the ports and flanges. Stored current was gradually increased in 75 mA steps and temperatures left to stabilise for about 1.5 hours at each step. Temperature at the

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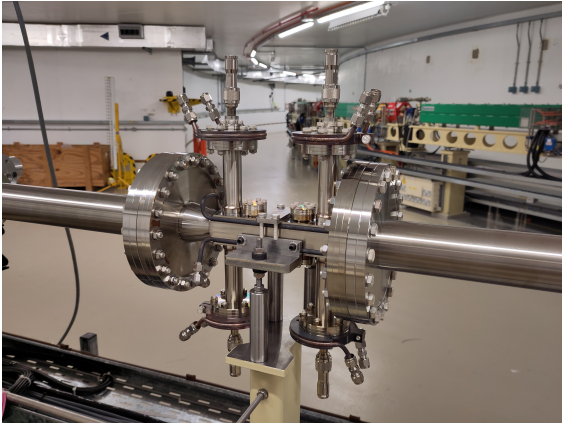


Figure 2: Prototype stripline kicker installed in the BTS transfer line, before cable and pulser connections.

ports is shown in Fig. 3. No parts of the installation were observed to reach temperatures of concern. A quadratic dependence of temperature with current was seen, indicating RF induced heating as expected, not synchrotron radiation.

Once the system had proven safe to run with stored beam and power levels verified, a new pulser able to run at 20 kV was connected to the stripline in November 2025, with attenuators still in place on the other ports, as shown in Fig. 4. A planned change of the feedthroughs was carried out after the stripline had been installed, from HN to 7/16. The maximum temperature seen on the vacuum assembly reduced from 32 °C to 30 °C, indicating better matching and transmission of beam-induced power to the attenuators.

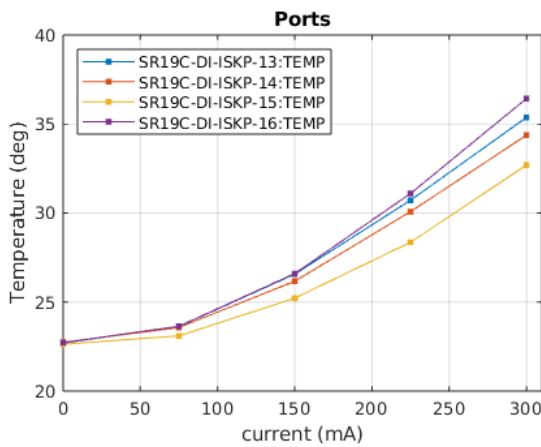


Figure 3: Temperature at the stripline ports as a function of storage ring current.

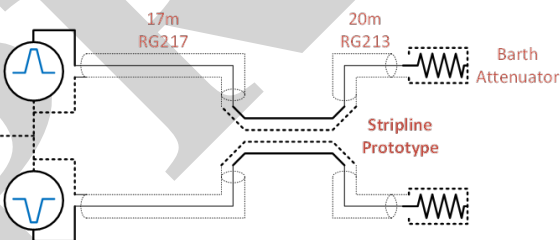


Figure 4: Schematic of stripline installation in storage ring.

## Impedance and Collective Effects

Impedance and collective effects were assessed by comparing a variety of measurements taken during the run before the stripline was installed to the same measurements taken after installation. The vertical kick factor was measured by the difference of closed orbits at different bunch charges with and without an orbit bump in the region of interest, as described in [5]. The measurement was repeated with the ID at different gaps, to obtain two similar curves with the stripline adding a constant offset that does not depend on ID gap. Measurements were repeated over a few months both before and after installation of the stripline (see Fig. 5).

These results were compared with wakefield simulations conducted using CST Studio [6]. The measured  $\Delta k_y = 1176 \text{ V/pC/m}$  compares to the simulated value of  $\Delta k_y = 109 \text{ V/pC/m}$ . It is not clear why there is such a large discrepancy, although it can be seen that the measurement is quite noisy over the course of weeks, and it is not possible to perform back-to-back measurements with and without the stripline under identical conditions.

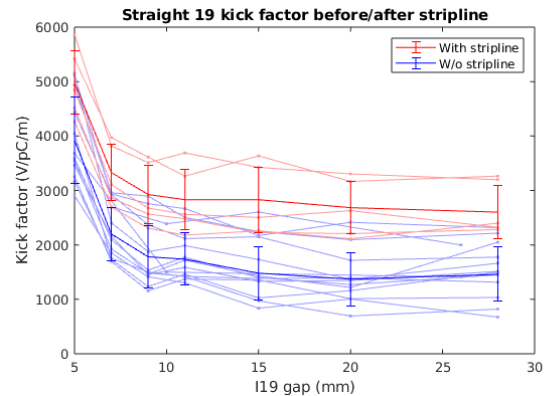


Figure 5: Mean (bold lines) and standard deviation (bars) of vertical kick factor measured in straight 19 before and after installation of prototype stripline.

Other impedance-dependent beam parameters such as tune shift with current, bunch lengthening with current, and microwave instability thresholds were also measured with and without the stripline installed. There was no measurable impact on any of these metrics.

## Beam Kicking

With the pulser connected and operating in single-kick mode, the timing was scanned in the same manner as in the BTS to find the peak amplitude of the kick. With the kick located correctly, bunch motion was measured by capturing position data from all EBPMs around the ring with a single stored bunch. The resulting oscillation from a 15 kV pulse (measured on the attenuator side, corresponding to about 18 kV at the kicker port) is shown in Fig. 6, with the measured data in blue and a comparison to simulations in red. The difference indicates the kick is 10-15 % larger than predicted, in agreement with the earlier BTS tests.

Variability of the kick amplitude was measured with a 900 bunch fill using the multibunch feedback (MBF) system

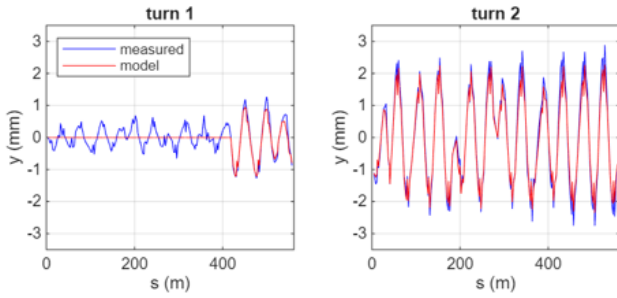


Figure 6: Bunch oscillation following a kick on turn 1. The stripline kicker is located at approximately 410 m in the ring.

by taking 100 consecutive shots and calculating the mean and standard deviation from the data for the turns before and after the kicker is fired, as shown in Fig. 7. Data for the 100 individual shots is shown in grey, with the mean value overlaid in blue and the standard deviation plotted below. Variability is around 2.5 %, with a noise floor of about 1 %.

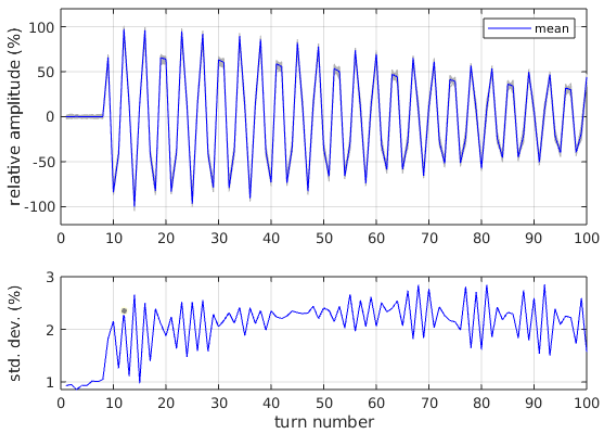


Figure 7: Pulse-to-pulse variability of kick to stored beam. Spread and mean (top) and standard deviation (bottom) of 100 shots.

Leakage of the kick was measured using the MBF system by recording the amplitude of one bunch in the filling pattern and scanning the timing of the kick by a few nanoseconds. RF buckets are spaced 2 ns apart, so the range scanned covers several bunches both ahead and behind the target, shown in Fig. 8. It can be seen that bunches ahead of the target (positive time) have zero kick, while the two trailing bunches at -2 and -4 ns see some kick around 10 percent of the peak. Rise and fall times of the pulse are similar, so the majority of the trailing kick is attributed to reflections within the stripline kicker.

Finally, the pulser was tested using the two pulses required for kick-and-cancel operation. Vertical tune was set to  $Q_y = 13.300$  to give cancellation after five turns. Figure 9 shows turn-by-turn amplitude of motion from the MBF with a single kick, and with the double kick enabled. Very good cancellation is achieved, and it is anticipated that this could be further improved by tuning the kicks independently and adjusting  $Q_y$  to compensate for tune shift with amplitude. It was also verified that a 3 nC single bunch charge can be

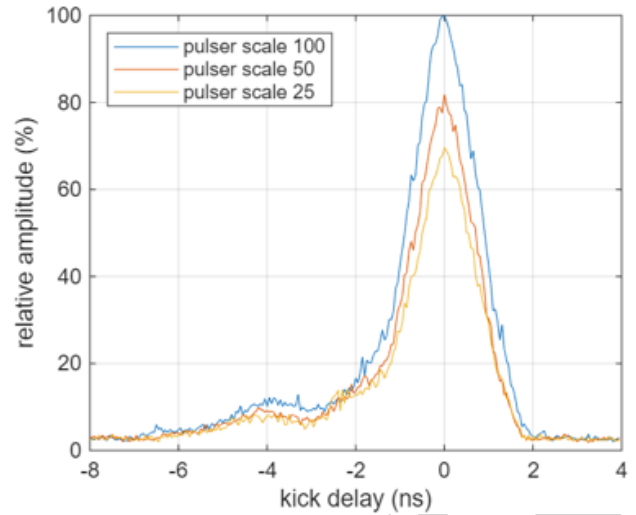


Figure 8: Kick amplitude vs. time offset.

stored while firing the double kick, but the bunch becomes unstable and is lost when using only a single kick, showing the expected benefit of the kick-and-cancel scheme over aperture sharing in suppressing wakefields.

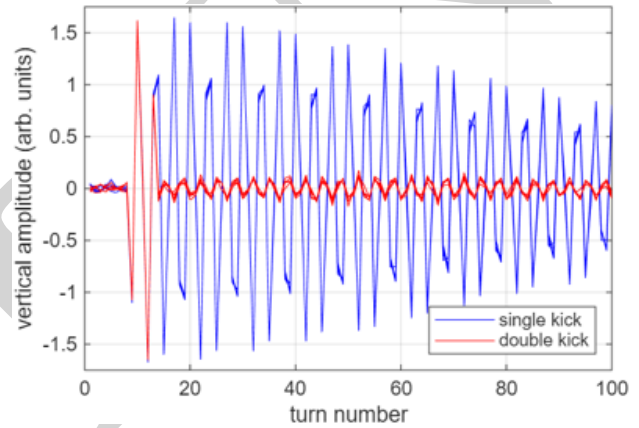


Figure 9: Orbit distortion with single and double pulse.

## CONCLUSIONS AND NEXT STEPS

A prototype stripline kicker and double-kick high voltage pulser have been developed, and testing has been conducted both in the lab and in the Diamond transfer lines and storage ring. This has verified that the stripline design can be safely installed in a synchrotron with full stored current without significant impact on the beam or induced heating to the stripline system. The pulser meets requirements for voltage and pulse length, and the ability to fire multiple pulses a few turns apart. The kick-and-cancel scheme has been successfully demonstrated with clear benefits over aperture sharing with a single kick. Work is ongoing to tune the system to give even better cancellation.

## ACKNOWLEDGEMENTS

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