TDR MEASUREMENTS IN SUPPORT OF ILC COLLIMATOR STUDIES*

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Abstract

Time domain reflectrometry using a stretched wire has been used to charachterise accelerator components for several decades. This enables the resultant impedance imposed on the beam to be calculated. In this report the validity of the "Stretched wire" bench test for ILC parameters is investigated. A wire is stretched through the centre of a vessel along the axis that the electron beam would follow and a voltage pulse representing the electron bunch is passed along the wire. The parasitic mode loss parameter from this voltage can then be measured. The bunch length for the ILC is 0.3mm, requiring a pulse rise time of ~1ps. The fastest rise time available from an off-the-shelf time domain reflector- metry (TDR) scope is ~10ps. By benchmarking the results with numerical simulations, an extrapolation of the results along with further calculations is considered. Reference vessels have been examined to evaluate the suitability of the test gear for measurements using ILC bunch structures.

INTRODUCTION

To assist with the development of the ILC beam delivery system, a technique to understand the electromagnetic interaction of the beam with the BDS components is required. Collimators are introduced to remove halo particles to reduce the background noise in detectors. These devices require small apertures, and as a result impose high impedance to the beam. As the demand for high beam energies and lower transverse and longitudinal emittance is required for the interaction point, a full assessment of the induced impedance needs to be assessed.

Techniques to measure the scale of this force have been developed for particle accelerators, however, not to the high resolution required for the ILC. This paper investigates the potential value for one such technique, approaching the ILC requirements.

HISTORY

Over the years the TDR technique has seen considerable development. Initially copper rods were used as the transmission medium to transport the pulse. Now thin wires stretched through the centre of the cavity are used. The procedure has been benchmarked, with the advancement of network analyser technology operation at higher frequencies is now possible. Broad band impedances towards the timescales of that for the ILC can thus be achieved.

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Bench tests have been widely used in synchrotron light sources (bunch length 10^s of mm) to measure the broad band impedance that the electron beam sees as it passes through a vessel[1]. The original apparatus used at Daresbury consists of a pulse generator with a rise time of approximately 25 picoseconds. Currently the fastest analysers available have a rise time 16 ps. This would be a factor of >10 longer than is required from the ILC bunch length (~1ps).

In order to have direct comparison with these bench tests and the ILC design the results must be scaled. The scaling law for these tests is unclear however, by measuring the wakefield effects at say 100ps, 50ps, 25ps and 10ps it should be possible to perform a best fit analysis to the curve and predict the trend for shorter timescales. The predicted losses at 1ps could then be compared with beam time data obtained on the wakefield experimental set-up at SLAC[2].

METHOD

In order to simulate a beam passing through a cavity it is essential to ensure that the launch of the pulse does not introduce additional numerical noise. To do this launch cones are designed to minimise any impedance mismatch caused by the transition from a suitable connector (N-type or SMA) towards the dimensions of the device under test. Figure 1, displays the launch cone with N-type connector and screw thread that is used for tensioning the wire.

Although this technique minimises the impedance mismatch that the beam will witness, each connection and step change would still introduce unwanted impedance change. The sum of these errors would affect the results for the device under test (DUT), since in the accelerator these components are omitted.

Figure 1: Launch cone, wire tensioner and N-type connector.

In order to calibrate out the effect of the launch cones, a reference vessel with an equal aperture to the beam pipe and the same effective length of the cavity is measured and the results subtracted from the measurements taken with the cavity. Figure 2 demonstrates the test set-up, with a reference vessel having the same length drift space and dimensions of the DUT should the cavity be omitted.

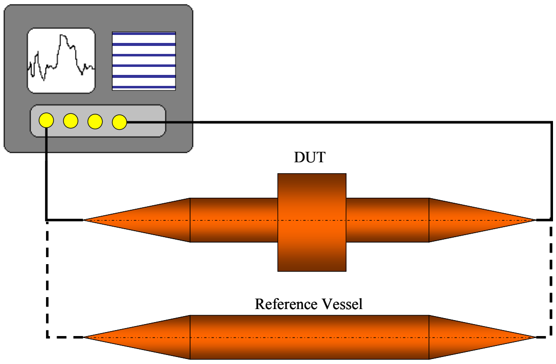

Figure 2: Schematic of the wire test apparatus.

Initial Evaluation

Due to the lead time required for production of the launch cones, it has only been possible to carry out preliminary tests of a suitable cavity. For the purpose of the verification a cavity BPM from the synchrotron light source (SRS) has been chosen, since there is a cavity and reference vessel available.

Figure 3: Cavity BPM, Device under test.

The cavity is a simple pillbox cavity with on axis beam pipes attached. The radius of the cavity is 100 mm with cavity length 290mm and beam pipe radius of 80mm. Figure 3 is a photograph of the device under test. Figure 4 is the matching reference vessel with launch cones attached.

Figure 4: Reference vessel with launch cones conected.

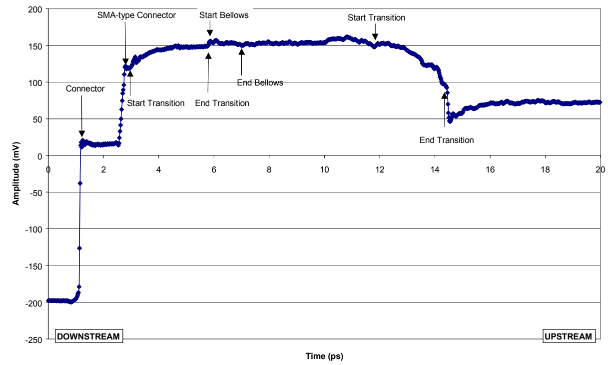

Figure 5: Example of the TDR Response.

Figure 5, highlights an example of the type of response available from the TDR measurements[3]. Through careful analysis, it is possible to identify the impedance mismatch of each component along the transmission line.

NUMERICAL CALCULATIONS

Numerical simulations have been carried out to assist the bench tests with RF simulations to further verify the suitability of the measurements for ILC applications.

Advances in network analyser technology have made it possible to characterise the broadband impedance of the vessels up to 10 picoseconds. This is also well within the threshold for computer simulations. A comparison of bunch lengths of 25 ps, 16 ps and eventually 10 ps will be carried out.

A fourier transform of the wakepotentials into the frequency domain yields the beam impedance. Therefore a direct comparison of the RF simulations and the TDR measurements is possible.

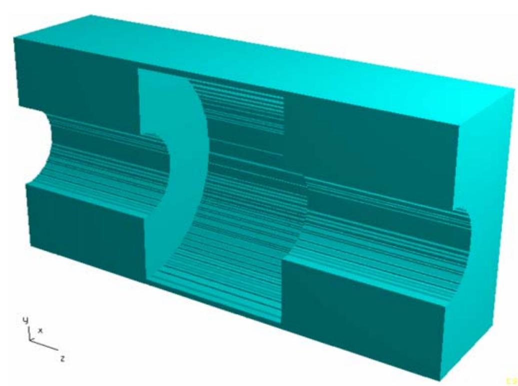

Figure 6: Mafia model of Cavity BPM.

For this reason a model of a cavity BPM has been created in MAFIA and the resultant wakepotentials measured. Figure 7 displays the longitudinal wakepotential of the cavity excited by a 20mm bunch length, along with the plot of the bunch profile.

At present the simulations for bunch lengths of 25mm, 20mm, 15mm, 10mm and 6mm have been completed and the resultant loss factor plotted (see figure 9).

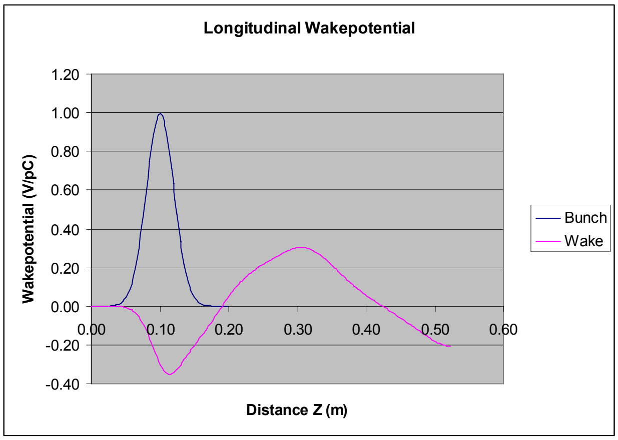

Figure 7: Longitudinal wakepotential for 20mm bunch.

Figure 8 displays the wakepotential of the cavity excited by a 6mm bunch length. A plot of the bunch has also been included to highlight the intrabunch short range wake effects.

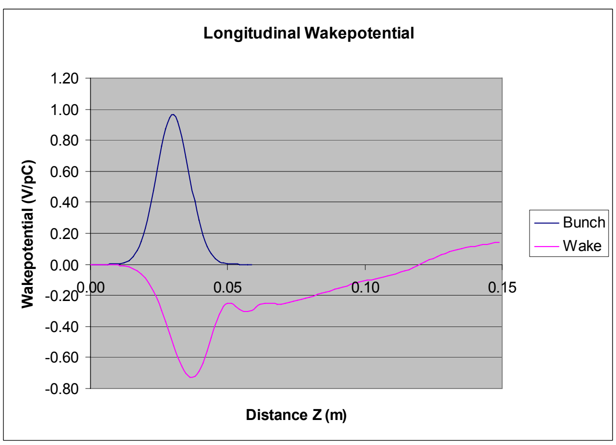

Figure 8: Longitudinal wakepotential for 6mm bunch.

The loss factor has been calculated for a range of bunch lengths as shown in table 1, these have been plotted in figure 9 to determine if the scaling of the bunches would be linear. Due to the uncertainty in the simulations, the linearity of the profile is uncertain and further calculations are required.

Table 1 Bunch length dependance on loss factors

Bunch Length (mm)	Loss Factor (V/pC)
25	0.197
20	0.231
15	0.274
10	0.325
6	0.382

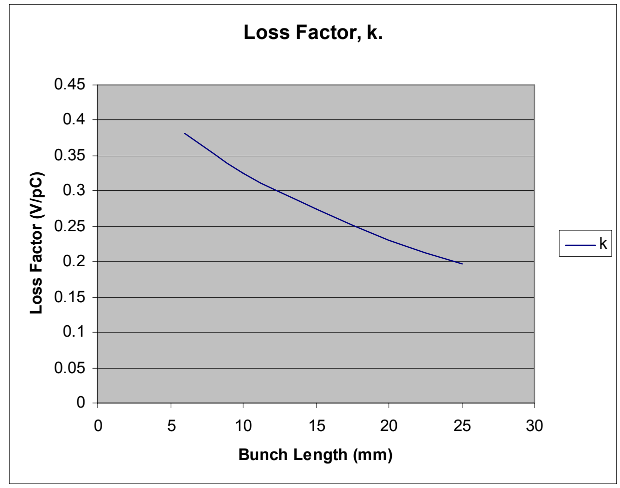

Figure 9: Loss factor versus bunch length.

FUTURE MEASUREMENTS

Should the technique prove successful for bunch lengths towards that of the ILC, it would be possible to carry out a similar analysis on the collimator shapes studied as part of the ESA wakefield tests [2]. These are to be carried out using rectangular launch cones already available.

CONCLUSIONS

Early indications suggest that valuable information would be gained by carrying out bench tests on collimator designs, albeit at a longer beam pulse.

The information gained from completing such measurements will not give an exact representation of what would happen within the parameters of the ILC. However, the trend with regards to broad band impedance will be obtained. This data could be extrapolated for shorter bunch lengths.

ACKNOWLEDGEMENTS

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