PROTOTYPING FOR ALS-U FAST KICKERS *

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Abstract

Prototyping of major components for the ALS-U kickers is in progress. A tapered stripline kicker has been built for installation and testing in the ALS, and multiple modulator options to meet the fast rise time required for swap out injection have been considered. High voltage feedthroughs that are matched into the multi GHz range are also being studied.

SWAP OUT INJECTION REQUIREMENTS

ALS-U [1] is a proposed upgrade of the existing ALS to a diffraction limited storage ring. In addition to replacing the three dipole magnets per sector with nine weaker ones and adding more quadrupole magnets to reduce dispersion, the accelerator will require an accumulator ring, and a swap out injection scheme [2]. The system requirements for the swap out kicker are shown in Table 1 [3].

Table 1: ALS-U kicker requirements

Parameter	Value
Beam Energy	2 GeV
Bend Angle	3.5 mrad
Magnetic Length	2 m
Aperture	10×6 mm (H×V)
B Field	5.83 mT
E Field	1.75 MV/m
Rise/Fall Time	<10 ns
Pulse Width	50 ns
PRF	1 Hz
Inter/Intra Pulse Ripple	<10/1 % FS

MAGNET DESIGN AND PROTOTYPING

A tapered stripline magnet designed to better match the odd (50 Ω) and the even (68 Ω) mode has been designed, and a non-vacuum compatible "cold model" of a magnet designed to install in the ALS is being fabricated, Fig. 1. We plan to use this magnet for beam impedance and field strength and uniformity studies to provide confidence in our modelling. Because of the larger emittance in the ALS, the horizontal aperture of this magnet has been opened to 35 mm, and the use of tapered fenders in the chamber was not implemented. A cross section with flux lines of this magnet is shown in Fig. 2.

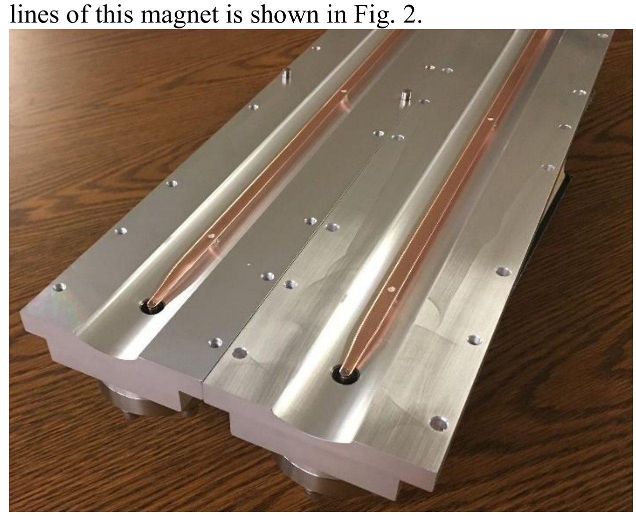

Figure 1. "Cold model" tapered stripline magnet.

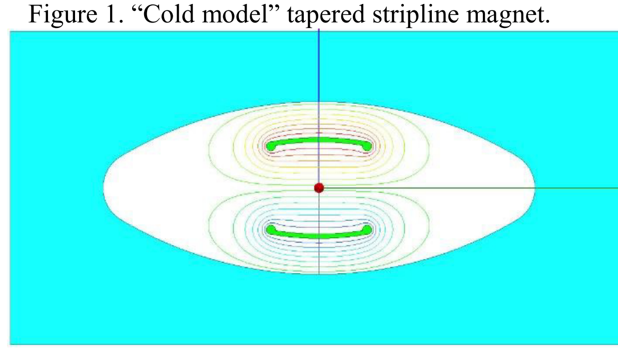

Figure 2. Cross section of ALS prototype magnet.

Beam Coupling Impedance Modelling

Since bunches will transit through the kicker in close proximity of the striplines (~ 3 mm), an accurate analysis of the beam coupling impedance assumes special relevance from two points of view. Firstly, we want to be sure that installing the kicker module will not negatively affect the circulating beam. Secondly, we need to evaluate the power deposited by the beam onto the stripline to estimate their temperature rise during operations.

We carried out extensive Particle Studio simulations using a model adapted from the kicker mechanical design, simulating the transit of the 500 mA ALS beam (σ_z = 9 mm). The energy loss caused by the kicker is of the order of a few 100's eV, which is negligible. While on the horizontal axis the kicker's aperture corresponds to the standard ALS vacuum chamber size, the narrow vertical gap between striplines is a source of transverse impedance (Fig. 3).

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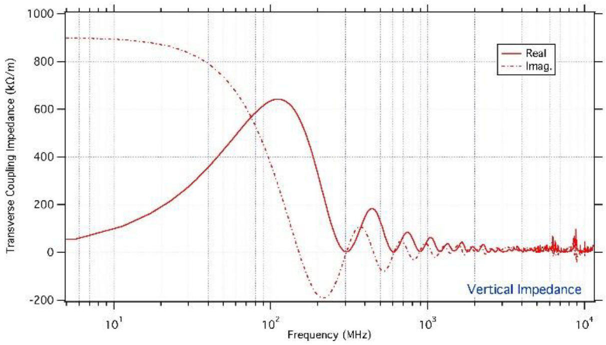

Figure 3. Transverse coupling impedance (vertical).

To assess the beam power deposited on the striplines, we assumed a uniformly filled machine with 328 identical bunches. The relative power spectrum does not differ substantially from the actual ALS single train of 296 bunches for the purpose of our calculations.

The longitudinal impedance was simulated with ideal feedthroughs and compared to an ideal, lossless, stripline and to the actual design, including dispersive dielctrics for supports and a roughly designed, non-optimized feedthrough (Fig.4). By running simulations with the copper striplines and stainless steel vacuum chamber alternatively set to zero it is possible to estimate the amount of power lost by the beam, which does not flow out the feedthroughs. Our calculations point to a value around 1 W per stripline in the best scenario, increasing to 3 W per stripline, when feedthrough impedance mismatch over the beam spectrum is included.

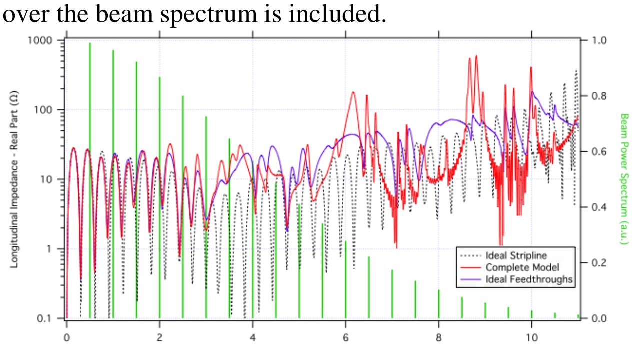

Figure. 4. Longitudinal coupling impedance (real part) for our stripline kicker, with (red) and without (blue) feedthroughs. The impedance for an ideal kicker (dashed line) and the ALS beam power spectrum (green) added for reference.

Thermal Modelling

Thermal calculations for the magnet to install in ALS were preformed assuming losses of 2 W for each strip, and 6 W lost in the chamber. Both the electrodes and the inside of the chamber are assumed to be blacked to increase the emissivity and the supporting ceramic for the strips are assumed to conduct some heat. Fig. 5 shows the results of this analysis and shows a maximum temperature rise on the electrodes of approximately 19 °C.

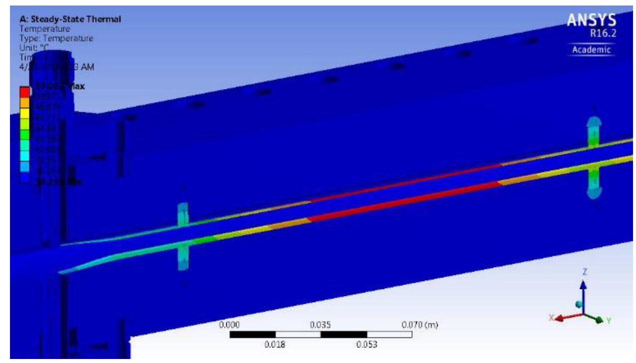

Figure 5. Thermal model of the cold model magnet.

MODULATOR PROTOTYPING

The design requirements for the power modulators to drive the magnets is given in Table 2. A solid state inductive adder modulator has been build and is in the test phase, and a solid state transmission line adder is in the process of being fabricated. In addition a unipolar pulser from FID technologies was bought for evaluation.

Table 2: Pulsed power requirements for the kickers

Parameter	Value
System Impedance	50 Ω
Magnet Current	± 106 A
Magnet Voltage	± 5300 V
# of Adder Cells	8
# of MOSFETs/ Cell	8

The inductive adder circuit was built using eight parallel MOSFETs to drive each core, and there are eight cores [4]. Two stalks running in opposite directions through the cores produce a bipolar pulse. Because the delay time of the gate drive and MOSFET circuit varies by up to 2 ns, an 8-bit, programmable, digital delay line with 250 ps resolution is used to adjust the delays for each switch. Fig. 6 shows the assembled inductive adder modulator, and Fig. 7 shows the outputs into 50 Ω attenuators used as a load. For the data shown, the timing was set so that the delays of the emitter voltage falling edges were the same for all MOSFETs. It may be possible to improve the adder switching speed by delaying the MOSFETs near either end of the structure, and this is being investigated.

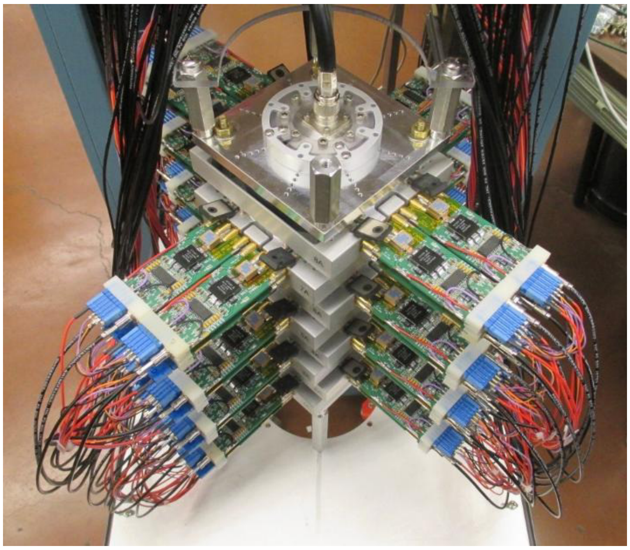

Figure 6. Inductive adder prototype modulator.

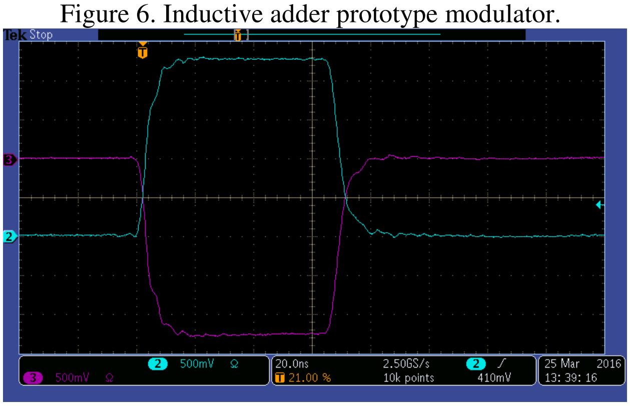

Figure 7. Inductive adder output pulses.

A FPG8-001NM50 mono-polar pulser from FID Technology was purchased and tested. Fig. 8 shows an output pulse into a 50 Ω load. Accelerated reliability and stability testing was done for approximately 6.5×10^6 total shots. There were no failures during the test period.

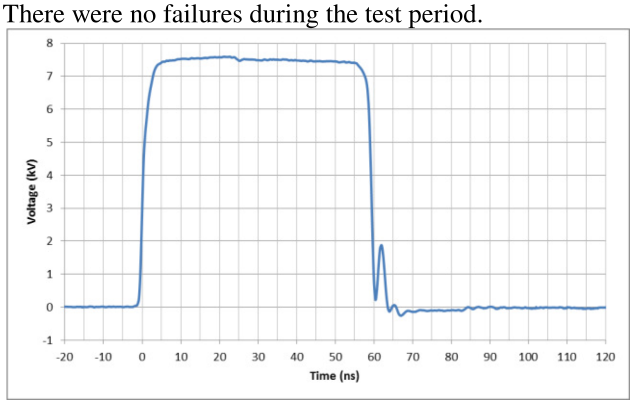

Figure 8. Output pulse from a FID pulser.

A transmission line adder has also been designed and the PCBs are being built. The adder uses 64 of the same MOSFETs and drivers as the inductive adder, and will be built using rigid/flex PCB technology. The MOSFETs are mounted on the rigid portion and eight parallel devices feed a flexible three layer stripline embedded in the PCB. The striplines are brought out through a core around each for isolation, then are clamped together to add the voltages in opposite directions for a bipolar pulse. A drawing of the stacked PCBs is shown in Fig. 9.

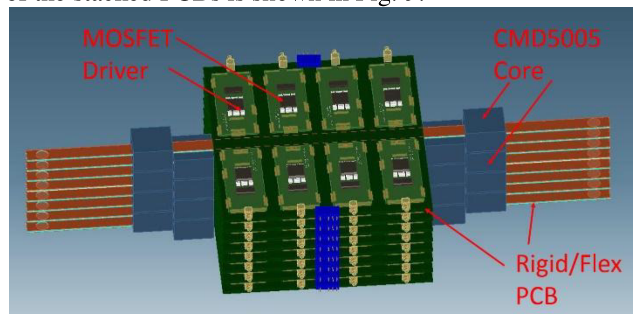

Figure 8. Stacked rigid/flex PCB and cores for isolation.

CONCLUSIONS

The beam impedance of tapered stripline magnets designed with 50 Ω odd mode impedance for both ALS installation and ALS-U have been studied. The analysis shows dependence to the power dissipated in the chamber due to the high frequency response of the feedthrough, thus we are also evaluating feedthroughs from various vendors. However, HOMs and magnet heating are manageable even for the worst case. Initial of the inductive adder is encouraging, and it may be possible to improve the rise and fall times by adjusting the triggering delays to individual MOSFETs. The FID pulser meets the pulse requirements, but a bi-polar pulser has not been tested. The transmission line adder has been challenging to have designed and build, and has yet to be tested. The results to date show the concept of a tapered stripline magnet driven by either an adder or step recovery diode pulse is encouraging.

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