Title
Update on Kicker developement for NGLS

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UPDATE ON KICKER DEVELOPMENT FOR THE NGLS*

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Abstract

The latest requirements for the Next Generation Light Source (NGLS) beam spreader call for a kicker to deflect a 2.6 GeV electron beam by an angle of 0.7 mrad over a length of 1.8 meters. The rise and fall time requirements for the integrated **B** field are <50 ns, the pulse frequency is up to 100 kHz, and the inter-pulse and pulse to pulse ripple requirements are 0.004 % and <0.01 % respectively of full scale. These requirements, along with the basic design of the beam spreader are still evolving, and several magnet types and modulator topologies have been considered. This paper will discuss this evolution as it pertains to the kickers, what the current status is of the R&D effort, and the plan to build a full power prototype system.

SYSTEM REQUIREMENTS

The requirements for the NGLS kicker system are still in the process of being refined [1][2], however, the latest requirements are summarized in Table 1. The most significant change was to reduce the rise and fall time of the integrated field from 5 ns to 50 ns [3], since in addition to being extremely difficult to achieve, the faster rise time requires the use of a strip line magnet, and increases the severity of interpulse and intrapulse ripple.

Table 1: Kicker Requirements

Beam Energy	2.6 GeV
Bend Angle	0.7 mrad
Kicker Length	1.8 m
Magnetic Strength	33.7 G
Magnet Aperture	17×17 mm
Integrated **B** Field Rise/Fall Time	50 ns
Repetition Frequency	100 kHz
Pulse to Pulse Stability	4×10^{-4}
Interpulse Ripple	1×10^{-4}

The slower rise times allow for the use of single turn ferrite loaded magnets with a metalized ceramic beam chamber. The baseline design for the system uses several short magnets, each driven by a parallel array of MOSFET switches. The length of each of the short magnets is determined by both the fill time of the magnet, and the maximum operational voltage for a single MOSFET switch, which was selected to be less than 700 V. Initial calculations indicate a total of 15 magnets of less than 12 cm each is acceptable, assuming a fill time of <30 ns. Figure 1 shows the physical layout of the kickers, while Table 2 summarizes the system specifications.

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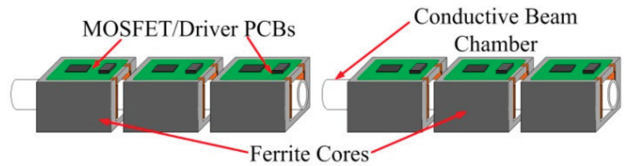

Figure 1: Layout of kicker system.

Table 2: Kicker System Specifications

Magnet Current	45.59 A
MOSFET Voltage	< 700 V
Switch Rise/Fall Time	< 10 ns
Magnet Fill Time	< 30 ns
Magnet Length	0.12 m
# of Magnets	15
Average Power (System)	1.91 kW
Chamber Resistance	50 mΩ/sq
Chamber Dissipation	28.9 W/m @ 1 nC/bunch

The ceramic chamber will likely be alumina coated on the inside by evaporating titanium in vacuum. Initial calculations show that the dissipation from the beam currents will be high, almost 30 W for a meter long chamber with a 50 Ω/square coating. There will also be dissipation due to the eddy currents caused by the magnet current which need to be investigated further. In any event, cooling of the chamber will be required, which would be more easily accomplished with the coating on the outside of the chamber. This would also decrease the dissipation due to the beam image current, but it would be more difficult to apply the coating.

THE MODULATOR

The MOSFET switches selected are IXYS DE275-102N06A power RF devices driven by IXDD415SI low side drivers. This configuration resulted in the MOSFET oscillating at turn-off until a small gate resistance was added and a negative DC bias was applied to the gate. The optimal series gate resistance was found to be approximately 0.3 Ω, with a bias of approximately -3 VDC or higher. A photo of a PCB board with a single switch and driver is shown in Figure 2. Figure 3 shows the results of switching with this PCB into a resitive load of 15 Ω.

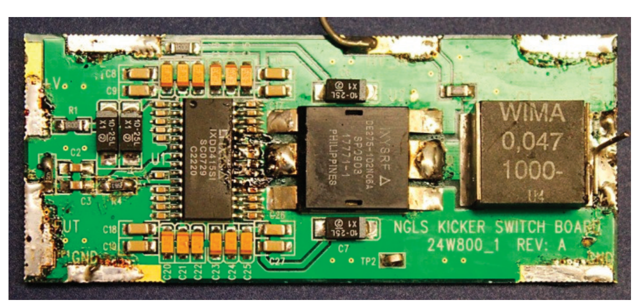

Figure 2: Photo of MOSFET PCB.

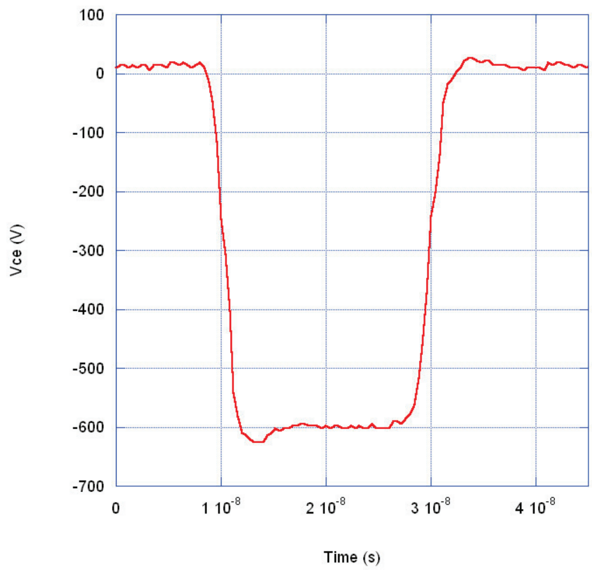

Figure 3: Voltage pulse from MOSFET PCB with 15 Ω load.

To achieve the over 45 A needed for the kicker it should be possible to use only one MOSFET per magnet. It is planned to delay the triggering of each of the magnets to correspond with the beam passing though a particular magnet. In order to do this a programmable digital delay chip will be used. This should also alleviate any variations in the turn on delay of the MOSFET drivers and switches,

The charging system is planned to use a DC power supply for each of the MOSFET PCBs, with an inductor for pulsed isolation. The supplies will be specified to meet the pulse to pulse ripple requirements, which can be reduced by a factor of N^{-2} since each of the charging systems is independent. The system is planned to be operated without significant changes to the duty cycle so all of the components will be in thermal equilibrium in order to meet the ripple requirements.

THE MAGNET

The cross section of a magnet is shown in Figure 4. It consists of two CMD5005 ferrite C cores separated by a copper shim to prevent flux from coupling between the two halves. There will be a single turn buss carrying the pulsed current, and as mentioned above a coated ceramic beam chamber. The magnitude of the magnetic field across the center of the aperture is shown in Figure 5.

The coating of the chamber should appear as a low impedance for the beam image current, but a high impedance to the kicker pulse. Figure 6 shows the attenuation of the chamber as a function of frequency for several coating conductances. A coating of 50 Ω/sq applied to the inside of a 17 mm diameter chamber will result in 28.9 W of dissipation due to the image current with a beam of 1 nC/bunch at 10 MHz. There is some discussion of even higher bunch rates, however, at least for now it is planned not increase the RMS current so the dissipation should not increase.

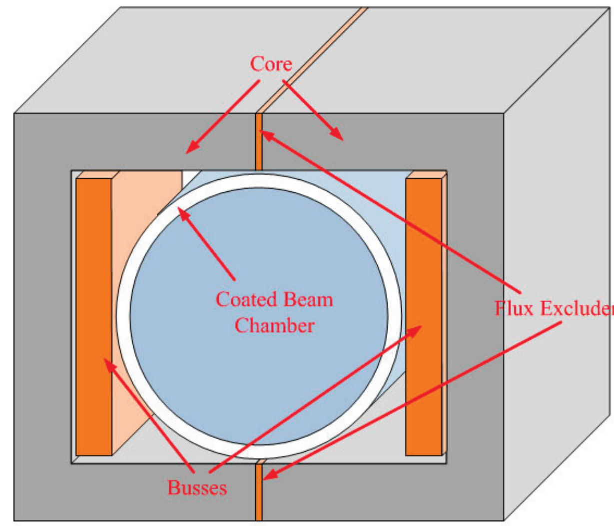

Figure 4: Cross section of ferrite magnet.

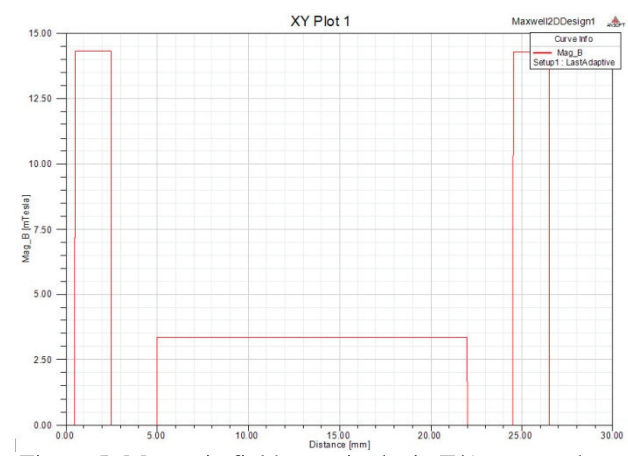

Figure 5: Magnetic field magnitude, in T/A, across the center of the magnet.

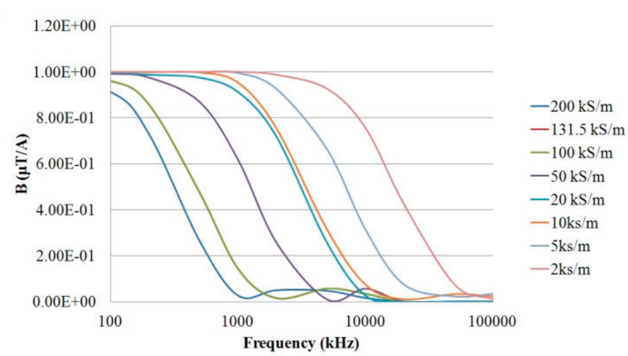

Figure 6: Pulse attenuation of the chamber vs frequency.

STATUS

At this time, a MOSFET/driver PCB has been built and tested and it exceeds the full peak power requirements of the system. A resistive load and a charging system have yet to be designed, however there seems to be no reason to think they cannot be built to the specification outlined in Table 2. Cores have been purchased, and parts are ready to be machined to build a prototype magnet. Conversations have begun with ceramic manufacturers about the chamber, it is planned to apply the coating in the LBNL shops.

The plan is to build a full power prototype of the ferrite magnet system presented here. This prototype would have minimal controls, so at present, not much thought has gone into the design of the control system. The biggest challenges now seem to be thermal management of the PCBs, loads, and the chamber, as well as the very low inter and intra pulse ripple requirements. Even measuring the ripple requirements will be difficult and a machine will need to be found where the prototype can be tested on a real beam.

The system requirements have been evolving over the past several years, and even though a CDR is now being readied for publication, they may evolve further. In particular, there has been discussion of raising the pulse repetition frequency for the kicker to beyond 100 kHz. It should be possible for the system discussed in this paper to work at rep rates up to a few hundred kHz, going beyond that would require a different type of system for kicking the beam, such as a transverse deflecting cavity.

REFERENCES

[1] J. Corlett, et al., “Next Generation Light Source R&D and Design Studies at LBNL”, TUPPP070, these proceedings.

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[3] G. C. Pappas, "Fast Kickers for the Next Generation Light Source", IPAC'10, Kyoto, WEPD098, p. 3329.