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# DEVELOPMENT OF A DIELECTRIC-LOADED TEST ACCELERATOR*

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*Abstract*

This paper presents a progress report on a joint project by the Naval Research Laboratory (NRL) and Argonne National Laboratory (ANL), in collaboration with the Stanford Linear Accelerator Center (SLAC) and Euclid Techlabs, LLC, to develop an X-band dielectric-loaded test accelerator in the NRL Magnicon Facility. The magnicon is a high-power 11.4-GHz amplifier tube that can produce up to 25 MW of power in 200-ns pulses at up to 10 Hz. The dielectric accelerating structures are developed by ANL and Euclid Techlabs, and tested at NRL and SLAC. The accelerator will include a 5-MeV electron injector developed by the Accelerator Laboratory of Tsinghua University, Beijing, China. SLAC has developed a means to combine the two magnicon output arms, in order to drive an injector and accelerator with separate control of the power ratio and relative phase. The initial operation of the injector should take place later this year, and the first test with a DLA structure, and a spectrometer should take place within the next year.

## INTRODUCTION

In recent years, there has been a major effort to understand the high gradient limits of conventional disk-loaded metal accelerating structures, as well as to develop alternative structures that may be capable of higher gradient operation. One promising concept is the dielectric-loaded accelerating (DLA) structure, in which a smooth dielectric-lined metal tube replaces the periodic metal structure [1]. A DLA structure can be used as a slow-wave electron accelerator by choosing an appropriate liner material, typically a low-loss ceramic with high dielectric constant, and choosing the inner and outer radii of the dielectric to match the phase velocity of the $TM_{01}$ accelerating mode to *c*. Argonne National Laboratory (ANL) and the Naval Research Laboratory (NRL) are carrying out a joint program, in collaboration with the Stanford Linear Accelerator Center (SLAC) and Euclid Techlabs, LLC, to develop DLA structures for possible use in future high-gradient linear accelerators. The DLA geometry is simpler and may be easier to fabricate than a conventional copper slow-wave structure, can have comparable shunt impedance, and permits simple suppression of higher-order modes [2]. In addition, DLA structures have no field enhancements at the dielectric surface, while conventional disk-loaded structures have a typical factor-of-two field enhancement on the metal irises. However, there are other problems unique to DLA structures, including resonant single-surface multipactor, due to the normal component of electric field at the dielectric surface, and field enhancements at discontinuities in the dielectrics. These phenomena are under intensive investigation [3,4]. The dielectric structures are developed by ANL in collaboration with Euclid Techlabs, and tests to characterize these structures at high accelerating gradients are carried out at NRL and SLAC. Other papers in this Proceedings present results from recent high-power tests of fused silica DLA structures [5] and discuss the development of a gapless dielectric structure to eliminate field enhancements at dielectric joints [6]. The focus of this paper is developing a facility for testing these structures as part of a working accelerator.

## DESCRIPTION OF THE NRL MAGNICON FACILITY

Fig. 1 shows a schematic diagram of the NRL Magnicon Facility. Its heart is a high-power magnicon amplifier tube that was developed jointly by NRL and Omega-P, Inc. as an alternative to klystrons to power X-band accelerating structures [7]. The magnicon operates over the frequency range of 11.424-11.430 GHz, and can produce ~25 MW of output power in 200-ns FWHM pulses at up to 10 Hz, and 10 MW in 1-μs flat-top pulses. Its output is extracted through two SLAC-style WR-90 waveguide lines, each with a high power $TE_{01}$ output window and SLAC-style directional couplers. These two lines were recently connected to a power combiner assembly that was developed by SLAC for this program. Using the combiner permits the power from the two arms to drive a sin-

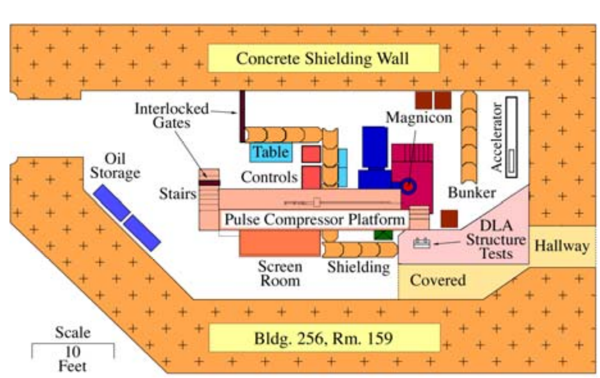


Figure 1: Floor plan of NRL Magnicon Facility.

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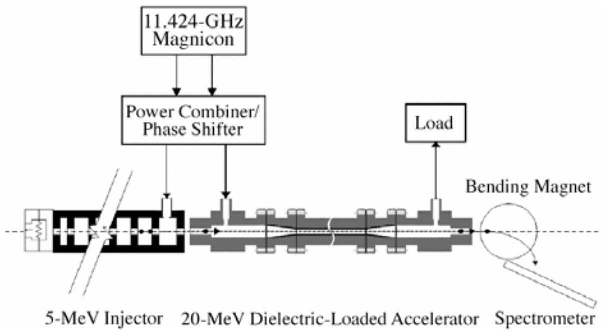


Figure 2: Schematic diagram of a dielectric-loaded test accelerator.

gle load, or to be split unequally to drive two separate loads. Two test stands are located adjacent to the magnicon output. The first, a 5'x25' raised platform, 8' high, is used for pulse compressor experiments, and passes over the concrete shielding wall. The second, a 10'-high concrete deck area, is used for testing DLA structures. A concrete bunker was recently installed for the planned accelerator experiments.

## THE DIELECTRIC-LOADED TEST ACCELERATOR

Fig. 2 shows a diagram of the planned dielectric-loaded test accelerator. It will be located in a bunker behind the shielding wall in the Magnicon Facility (see Fig. 3). A 5-MeV injector [8] developed by the Accelerator Laboratory of Tsinghua University, Beijing, China (see Fig. 4) will inject ~5 pC electron bunches into dielectric structures up to 50 cm long. The injector uses a $LaB_6$ cathode, and a 23 1/2-cell disk and washer accelerating structure, and is designed to be driven by ~2-5 MW of rf power from the magnicon. The injector and structure will be fed by separate waveguides from a power combiner/ phase shifter assembly. This will allow the injector to operate at constant power while the power and relative phase of the accelerator section is varied. The energy gain will be measured with a magnetic spectrometer.

Figure 3: Photograph of concrete bunker, showing accelerator table and 5-MeV injector.

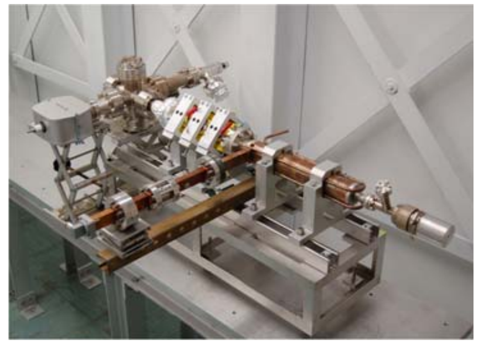

Figure 4: Photo of injector in accelerator bunker.

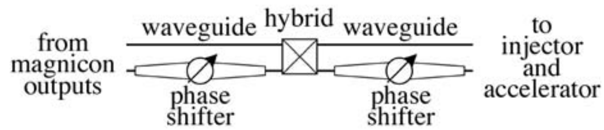


Figure 5: Schematic of the power combiner assembly.

## THE POWER COMBINER

The two output waveguides of the magnicon have equal power and a fixed phase relationship. The injector will require a fixed input power of ~2-5 MW, while optimization of the accelerator operation will require varying its drive power as well as the relative phase of the accelerator rf. SLAC has developed a system that combines the two magnicon outputs in a 3-dB hybrid coupler. Fig. 5 shows a block diagram of this system. A magic-H type hybrid [9] is used for the power combination and splitting. A new $TE_{01}$-mode mechanical phase shifter, flanked by $TE_{10}$-$TE_{01}$ rectangular-to-circular mode converters, varies the phase of one of the two magnicon lines feeding the hybrid to vary the ratio of power in the two output arms of the hybrid. Fig. 6 shows this assembly attached at the magnicon output for high power testing. The phase shifter provides ~65° of phase adjustment, which is sufficient to change continuously between a state where one arm has

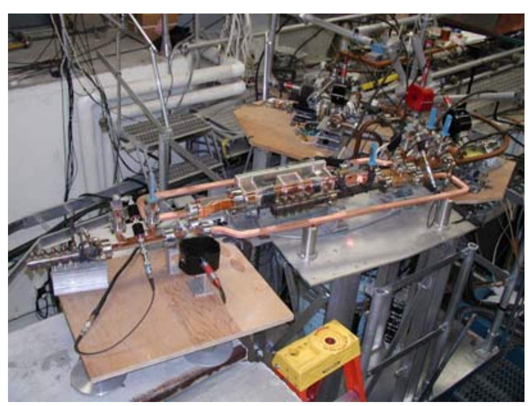

Figure 6: Photograph of power combiner assembly installed at magnicon output.

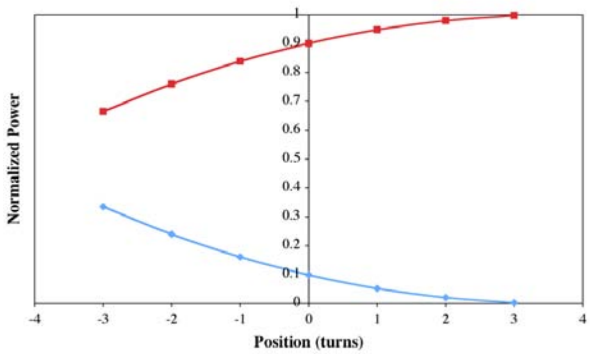


Figure 7: Normalized power into left and right output waveguides versus phase shifter position.

essentially all of the power and a 65:35 power split. Fig. 7 shows a measurement of the power split as a function of phase shifter adjustment, using the magnicon output, and Fig. 8 shows a 20-MW, 200-ns rf pulse at the output of the power combiner. A second phase shifter with the same adjustment range will be added at a later date for use in tuning the accelerator by adjusting the relative phase in the injector and accelerating structure. This phase adjustment will be supplemented by varying the physical spacing between the injector and accelerating section.

## SUMMARY

The goal of this project is develop a test facility to study acceleration through dielectric-loaded accelerating structures, and perhaps other structure-based advanced accelerator structures in X-band. The facility will make use of rf from an 11.4-GHz magnicon amplifier that can produce 25 MW of output power in 200-ns FWHM pulses. A 5-MeV electron injector built by the Tsinghua University in Beijing, China was delivered to NRL in December, 2006, and has been installed in a new concrete bunker in the Magnicon Facility. It is designed to produce ~5 pC electrons bunches for injection into accelerating structures. The accelerator will require separate control of the power and rf phase for the injector and the accelerating structure. To accomplish the power adjustment, a power combiner was developed by SLAC, delivered to NRL in December, 2006, and installed and tested. A second phase shifter assembly will be delivered in the future to provide for output phase adjustment. Our goal is to demonstrate a working dielectric-loaded test accelerator within the next year.

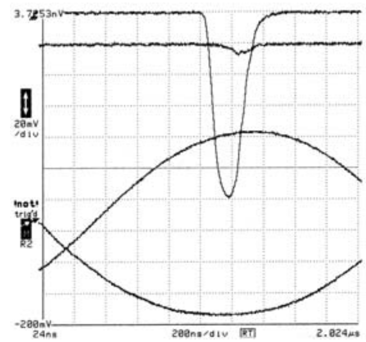


Figure 8: Experimental traces, showing (top to bottom) 20 MW output pulse from left arm of power combiner, small output pulse from right arm of power combiner, modulator voltage, and gun current (inverted).

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