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High Power Magnetron Testbed for Metamaterial Cathodes

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2. C. J. Leach, S. Prasad, M. Fuks, E. Schamiloglu, Mode Purification in a Relativistic Magnetron with Diffraction Output, to appear in Proc. 2013 IEEE International Conf. on Pulsed Power and Plasma Science (in press).

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This is a final technical report for an FY 2012 AFOSR DURIP instrumentation grant.

14. ABSTRACT
This final report describes the acquisition and installation of instrumentation purchased under the auspices of the FY2012 DURIP program. All of the proposed instrumentation has been acquired and initial testing will be underway by the end of Fall 2013. The purpose of the acquired instrumentation was to prepare a high power microwave (HPM) testbed to assess metamaterial cathodes. A relativistic magnetron with diffraction output (MDO) is the HPM source that was custom manufactured in order to be used as the testbed.
The instrumentation acquired can be summarized as comprising two systems:
System I – Magnetron with Diffraction Output (Construction of MDO, Vacuum System Components, Pulsed Magnetic System Charging and Control)
System II – Microwave Diagnostics to Characterize the Output

15. SUBJECT TERMS
High power microwaves, relativistic magnetron, diffraction output, metamaterial cathode, transparent cathode

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ABSTRACT

This final report describes the acquisition and installation of instrumentation purchased under the auspices of the FY2012 DURIP program. All of the proposed instrumentation has been acquired and initial testing will be underway by the end of Fall 2013.

The purpose of the acquired instrumentation was to prepare a high power microwave (HPM) testbed to assess metamaterial cathodes. A relativistic magnetron with diffraction output (MDO) is the HPM source that was custom manufactured in order to be used as the testbed.

The instrumentation acquired can be summarized as comprising two systems:

System I – Magnetron with Diffraction Output

- Construction of MDO
- Vacuum System Components
- Pulsed Magnetic System Charging and Control

System II – Microwave Diagnostics to Characterize the Output

Graduate and undergraduate student education was an important component of the installation of the acquired instrumentation.

DESCRIPTION OF INSTRUMENTATION

The goal of this basic research project was to assemble a high power microwave testbed for metamaterial cathodes to gain fundamental knowledge regarding the limitations of magnetrons and techniques to push the boundaries on the limitations. This DURIP grant allowed us to implement in hardware the **Magnetron with Diffraction Output (MDO)**.

The instrumentation acquired can be summarized as comprising two systems:

System I – Magnetron with Diffraction Output
- Construction of MDO
- Vacuum System Components
- Pulsed Magnetic System Charging and Control

System II – Microwave Diagnostics to Characterize the Output

Construction of MDO

Continental Machining (Albuquerque, NM) was the only vendor to respond to the RFQ for the manufacture of the MDO. The material used was stainless steel. Figures 1 and 2 present the drawings that were generated for the manufacture of the MDO.

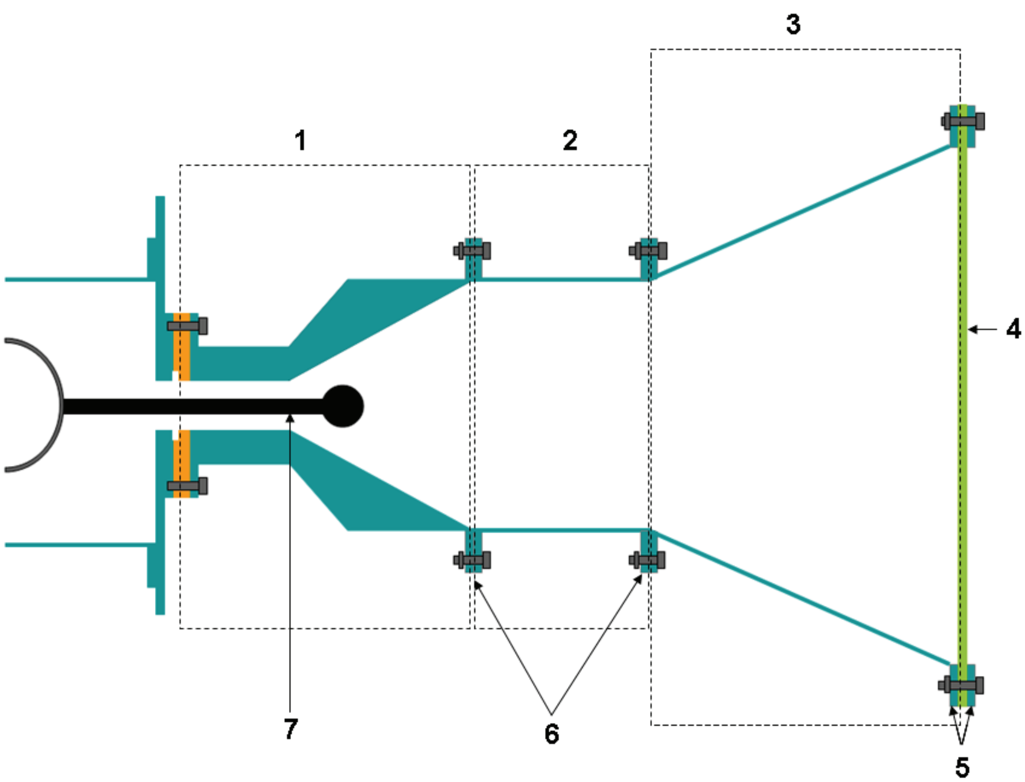


Figure 1. Diagrammatic overview of the MDO experimental setup. 1: MDO: 2. Cylindrical waveguide section (electron beam dump, surface mount probe); 3. Conical horn antenna (load, radiate microwave); 4. Microwave window; 5. SS 304 L 26" Flange; 6. SS 304 L 12" Flange; 7. Metamaterial cathode.

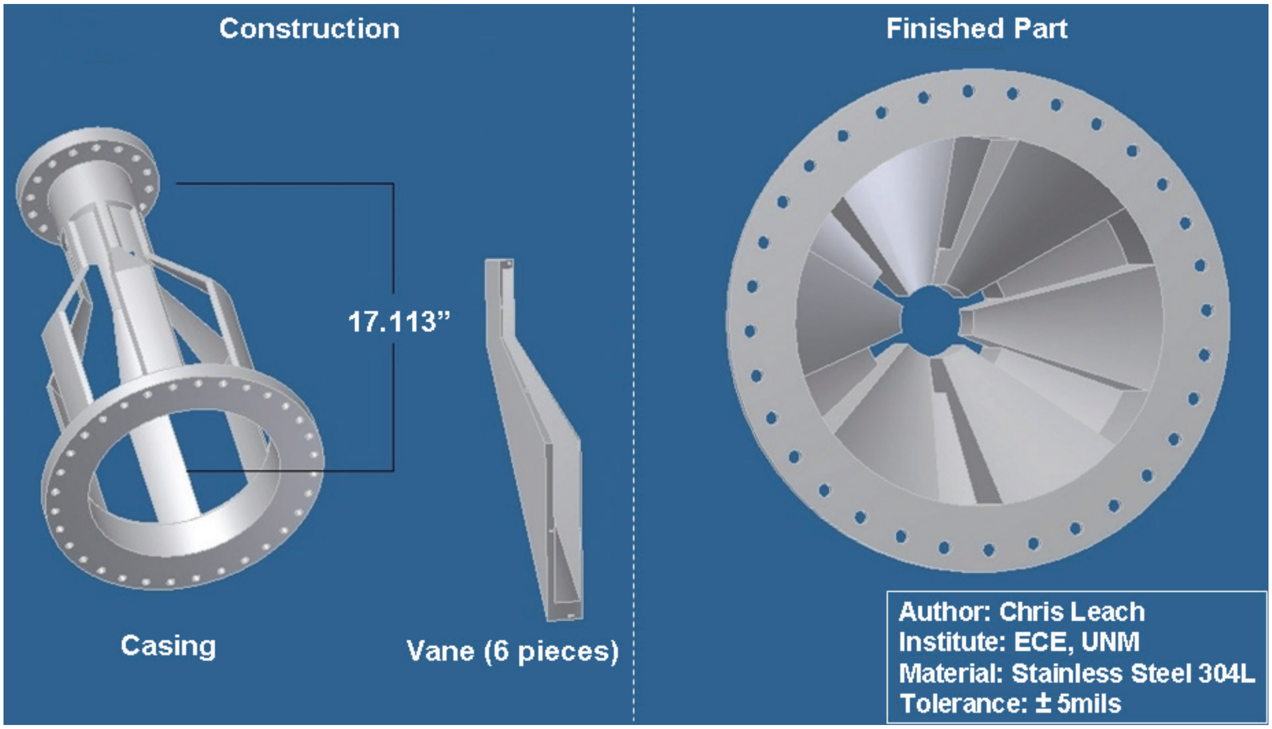


Figure 2. CAD drawing of MDO used for obtaining bids.

Figure 3 presents a photograph of the as-delivered MDO.

Figure 3. Photograph of the as-delivered MDO, Spring 2013.

Vacuum System Components

The following components were acquired for the vacuum system for the MDO:

- TriScroll Pump
- Full Range Vacuum Gauge Controller
- Numerous vacuum pipes, flanges, *etc.*

Pulsed Magnetic System Charging and Control

The following components were acquired for the pulsed magnet system for the MDO:

- Discharge Switch Assembly - Quotation #: 5SVT 020108D
- General Atomic High Voltage Storage Capacitors – 32259
- LabView - Controlled Charging Supplies
- Probes, multimeter, delay generator

Microwave Components

- Microwave Absorbers
- Waveguide components
- Connectors and Adaptors (SMA and BNC)
- Attenuators, Filters, Mixers

These are shown in Figs. 4-9.

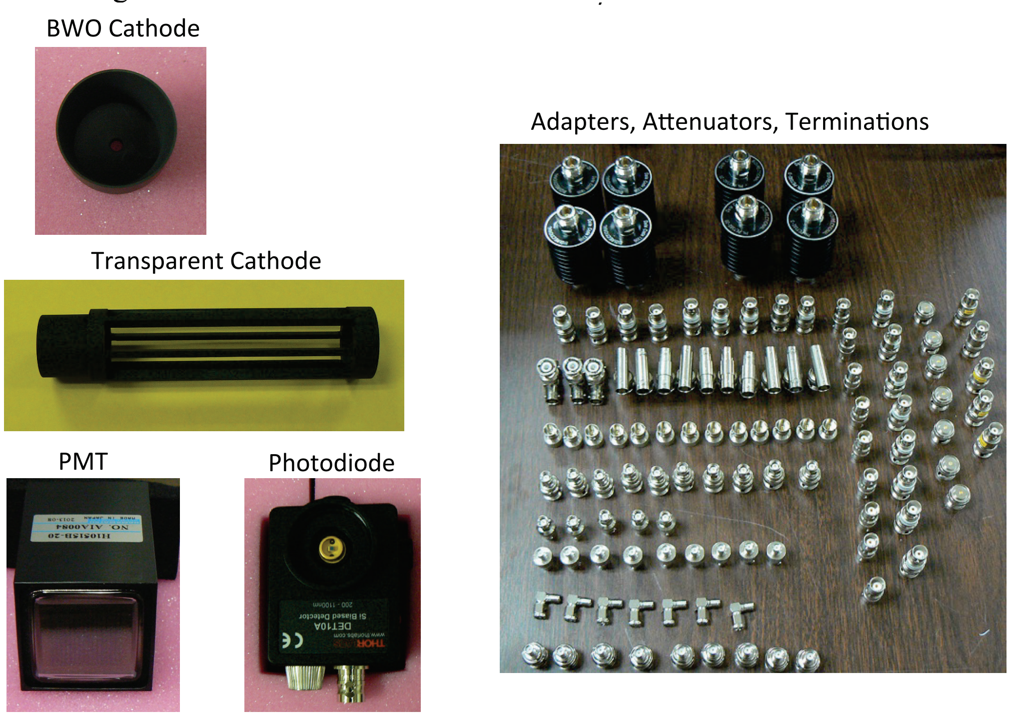
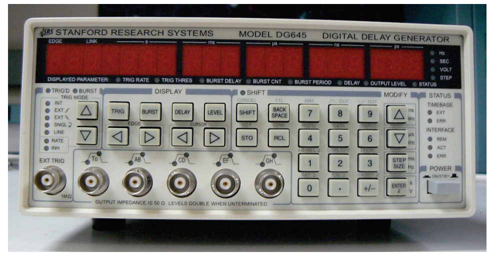


Figure 4. Photograph of acquired instrumentation.

Tektronix 500 MHz Scope

Stanford Delay Generator



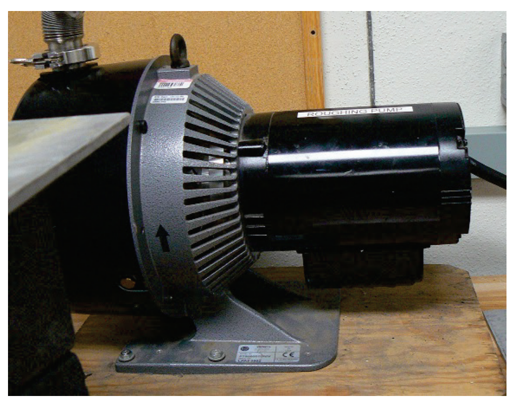
Lakeshore Digital Gaussmeter

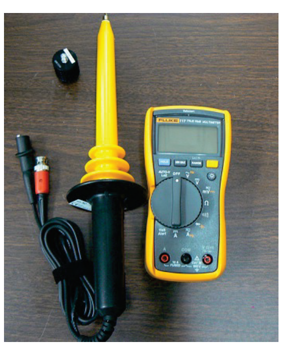
Agilent LCR Meter (20 Hz – 2 MHz)

Figure 5. Photograph of acquired instrumentation. Oscilloscope and meters for output characterization.

Varian Gauge Controller

TriScroll Pump Module Exchange





Multimeters and High Voltage Probes

Figure 6. Photograph of acquired instrumentation. Vacuum pump and instrumentation.

Bolts and Nuts

Figure 7. Photograph of acquired instrumentation. Bolts and nuts for vacuum assembly and waveguide assembly.

Waveguide Components

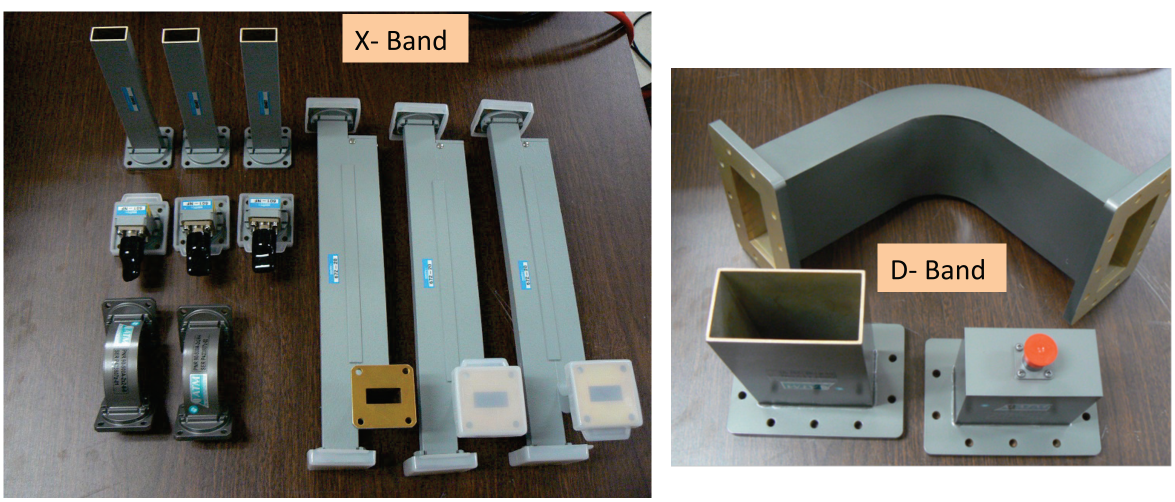


Figure 8. Photograph of acquired instrumentation. Waveguide components.

Capacitor Bank and Discharge Circuit for Pulsed Electromagnet

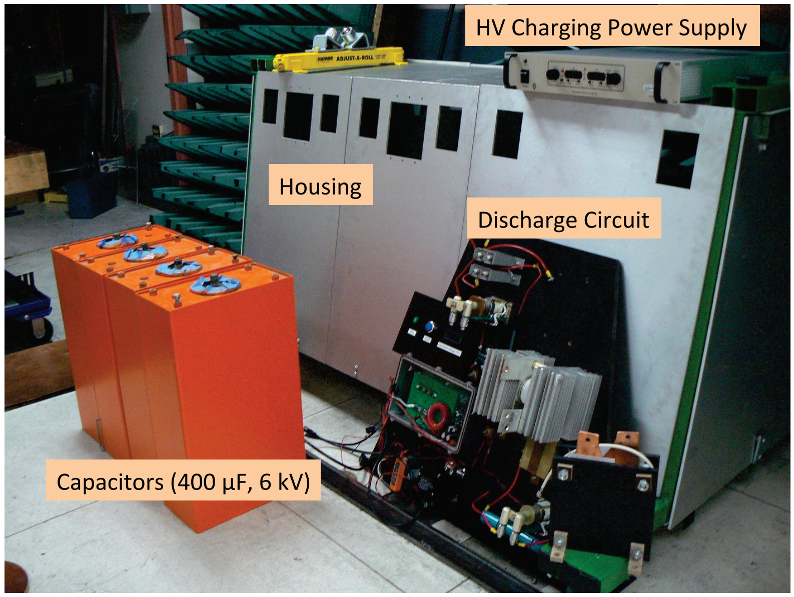


Figure 9. Photograph of acquired instrumentation. Pulsed electromagnet hardware.

Metamaterial Cathode

A metamaterial cathode can be thought of as a transparent cathode whose inside includes additional rods, as is shown in Fig. 10. This is merely one conceptual design.

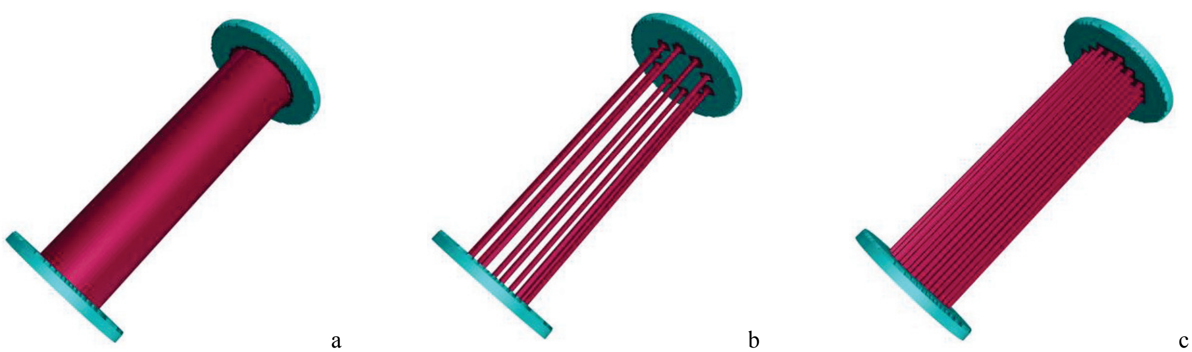
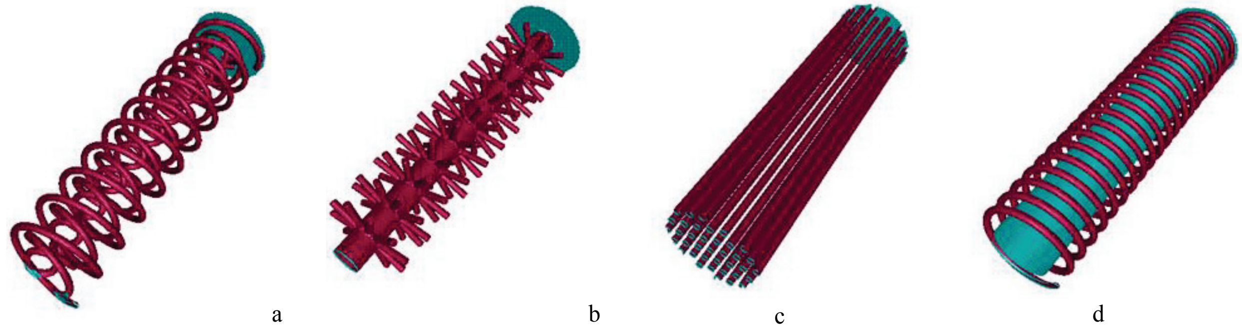


Figure 10. ICEPIC mock-up of a solid cathode (a), transparent cathode (b), and a metamaterial cathode (c) (courtesy A. Andreev).

Additional designs of a metamaterial cathode envisaged by Andreev are shown as well in Figure 11.



a b c d

Figure 11. ICEPIC mock-up of a multi-helix structure with metal wires and metal rings (a), multi-point structure with metal wires (multi-point cathode) (b), multi-rod structure with metal wires (quasi-metamaterial or rodded cathode) (c), standard helical cathode with non-emitting central back-current electrode (d) (from A. Andreev).

These cathodes will be characterized in the metamaterial cathode testbed that is being assembled and experiments will commence late Fall 2013.

STUDENTS TRAINED IN ASSEMBLING THE TESTBED

- Christopher Leach, Ph.D. candidate

- Matthew Dill**, undergraduate**
- Jeremy McConaha**, undergraduate**
- Michael Padilla, undergraduate

PUBLICATIONS

1. S. Prasad, C. Leach, C. J. Buchenauer, M. Fuks, E. Schamiloglu, "UNM Transparent Cathode Experiments Revisited," to appear in *Proc. 2013 IEEE International Conf. on Pulsed Power and Plasma Science* (in press).

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