Experimental Plan for Testing the UNM Metamaterial Slow Wave Structure for High Power Microwave Generation

Kevin Shipman
University of New Mexico
Albuquerque, NM
MURI Teleseminar August 5, 2016
Outline

1. Metamaterial (MTM) structure design and simulation
2. Experimental setup
3. Diagnostics
4. Timeline for Experiment
5. Acknowledgements
UNM MTM SWS

Alternating split-ring resonators

Ring Inner Radius = 14 mm
Ring Outer Radius = 19 mm
Tab Inner Radius = 19 mm
Tab Outer Radius = 24 mm
Ring Gap = 5 mm
Tube Inner Radius = 24 mm
Total # of Ring = 14
Simulation Setup

3-dimensional fully electromagnetic and fully relativistic particle-in-cell (PIC) code MAGIC was used to simulate and optimize the MTM SWS
Simulation Results

Figure 1: Diode Voltage
- Voltage: 400 kV

Figure 2: Diode Current
- Current: 4.5 kA

Figure 3: Input Power
- Power: 1.8 GW

Figure 4: Output Power
- Power: 160 MW
- Efficiency: \( \eta \approx 9\% \)
Early Simulation Results Cont.

- **Figure 1**: RF Signal Measured at Output
- **Figure 2**: FFT of RF Signal
  - 1.45 GHz (L-Band)
- **Figure 3**: TFA of RF Signal
- **Figure 4**: RF Output Mode
  - 2.472 ns
  - 12.097
  - 12.451

---

**Table**: Time-Restricted Electrical Output

<table>
<thead>
<tr>
<th>Event</th>
<th>Time (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFA</td>
<td>2.472</td>
</tr>
<tr>
<td>Time</td>
<td>12.097</td>
</tr>
<tr>
<td>Delay</td>
<td>12.451</td>
</tr>
</tbody>
</table>
Experimental Setup

SINUS-6 Electron Beam Accelerator

1. Prime Power
2. Tesla Transformer (700 kV, 6kA)
3. Nitrogen Switch (200 psi)
4. Impedance Transformer (20 Ω - 100 Ω)
5. Magnetically Insulated Oil-Vacuum Interface
6. Load

- Drive Voltage: 400 kV
- Load Current: 4.5 kA
- B-field: 1.6 T
Voltage and Current Diode Diagnostics

Rogowski Coil: Current Diagnostic

Capacitive Divider Probe: Voltage Diagnostic

9 Solenoid Magnets: 1.6 Tesla

MTM SWS 14 Split Rings

Beam Collection Tube and RF Coupler

Oil to Vacuum Interface

Microwave Window

Cathode Shank

Graphite Cathode
A calorimeter is used to measure RF power

The calorimeter constitutes a cavity constructed from plexi-glass plates that is filled with ethanol

The calorimeter is placed opposite the radiating antenna

Incident microwave energy causes expansion of ethanol into capillary tube

Ethanol moving into the capillary tube provides a voltage change between two parallel filaments
A Waveguide detector will be used to detect the RF frequency

Positioned where E-field is at a maximum

A waveguide to coax adapter is used to deliver the RF signal to an Oscilloscope
Use a Neon grid to verify RF mode

Electric Field incident on board causes excitation in neon bulbs

A time integrated image will be taken with an open shutter camera
The maximum RF voltage measured between two rings and between the ring and the tube is about 250 kV with gap between the rings being 5mm.

Because the spacing between the rings is so small there is a concern for breakdown.

To minimize the chances of breakdown the corners and edges will be rounded and the rings are going to be polished.
16 Ch. Linear Array Multi-anode PMT: H10515B-20

- Developed by Hamamatsu Photonics
- 0.6-ns response time
- Gain of 120 dB's
- Convert light from breakdown to electrical signal
- 4 collimating lenses will be used to collect light
Breakdown Diagnostic Setup

- Load
- Fiber Optic Patch Cables
- Screen Room
- Fiber Optic Bulk Head
- Oscilloscope
- PMT Array
- Optical Mount
- Collimating Lenses
- Antenna
We will mask off the center part of the lenses to block any light coming out of the beam collector tube.

Lenses will collect light from top and bottom of rings where breakdown is more likely to occur.

Blue light has been present in previous experiments on the SINUS-6. Filtering out this blue light maybe needed so the PMT doesn’t Saturate.
August 8\textsuperscript{th}: Receive SWS and antenna from machining

August 9\textsuperscript{th}-12\textsuperscript{th}: Preliminary checks on SINUS-6

August 15\textsuperscript{th}-24\textsuperscript{th}: Experimental setup

August 25\textsuperscript{th}-31\textsuperscript{st}: Run Experiments and Results Analysis
Acknowledgments

Dr. Sarita Prasad- Research Professor ECE

Dmitrii A. Andreev Undergraduate Electrical Engineering

Dr. Mark Gilmore – Associate Professor, Associate Chair ECE

Dr. Edl Schamiloglu-Distinguished Professor, Director of COSMIAC