Collaborative Research on Novel High Power Sources for, and Physics of Ionospheric Modification
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Participating Universities:

Institute for Research in Electronics and Applied Physics (IREAP), University of Maryland
Space and Plasma Physics (SPP), University of Maryland
Texas Tech University
University of California, Los Angles

DOD Points of Contact:
Dr. John Luginsland - AFOSR
Dr. Kent Miller - AFOSR
Goals/Objectives

**Develop** prototypes of EM sources for mobile, reconfigurable ionospheric heaters based on:

(i) Comprehensive understanding of the current status of IM research and applications;

(ii) Combination of theoretical/modeling with laboratory experiments scaled to simulate ionospheric plasma parameters at different geomagnetic latitudes and diurnal variation and solar cycle;

(iii) Understanding of modern high power RF source technology and antenna engineering including meta-materials.
Specifications of radiated power, ERP frequency and waveform

MURI Interactions

UMD Space Plasma Physics

Laboratory validation

UMD Charged Particle Beams

Antenna designs and system considerations

Texas Tech University
Teams

**UMD SPP**
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Bengt Eliasson

**Students**
Aram Vartanyan
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**Texas Tech**
Andreas Neuber
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**Students**
Daniel Mauch,
David Thomas,
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**UMD CPB**
Thomas Antonsen
John Rodgers
Brian Beaudoin
Tim Koeth

**Students**
Kiersten Ruisard
Dmytro Kashyn

**UCLA**
Walter Gekelmann
Yuhou Wang

**Advisors**
Simon London
Irv Haber
Edward Wright
UMD SPP Objectives

• Identify and Explore the Ionospheric Modifications (IM) Physics Areas impacting the design of Mobile Ionospheric Heating sources (MIHs) where
  • No heating experiments were performed (e.g. equatorial regions)
  • Heating experiments were performed using low power heaters (e.g. mid-latitude)
  • Important new high latitude experiments with incomplete or controversial understanding (e.g. artificial ionization)
  • New concepts requiring mobile sources (e.g. monitor Coronal Mass Ejections)
• Design and, in collaboration with UCLA, conduct PoP experiments of the new physics concepts
• Collaborate with the Arecibo, HAARP, SURA and EISCAT experimental programs
• Provide design input to the source development teams
Examples of Investigations

1. Maximum Usable Frequency at 1-2 GHz – Learning to control the irregularity spectrum at Super Small Size (few cm) scales at equatorial and mid-latitudes and use it to create Field Aligned Scattering (FAS) mirrors

2. C³ Artificial Ionization

3. Virtual Antennae in Equator

4. Bi-static Early CME Monitoring
Texas Tech Photoconductive Sources - PCSS

**Project Objectives**

Development of a compact, high voltage (10-25 kV) photoconductive switch capable of ~ 10 MHz operation at ~1-2 MW

**Background**

- Switch geometry
- Material parameters and modification
  - Electron irradiation
  - Annealing
  - Laser enhanced diffusion
- Triggering Wavelengths
- Other switch design parameters

**Demonstrated Performance**

- Blocking of DC electric fields up to 700 kV/cm
- Maximum switched current of 1kA at 30 kV
- Switched 250 A at 20 kV at a burst repetition frequency of 65 MHz
## Challenges

- Device Efficiency
  - Recombination at defect sites
    - Mid-gap defect sites
    - Surface Recombination
  - Contact resistance
- Device Lifetime
  - Space charge effects
  - Current density at SiC/metal interface

## Device Lifetime

- Vary current density, record any changes in switch properties (V-I curve)
- Simulation (Silvaco – Atlas)
  - Joule heating
  - Space charge effects
    - Hole mobility
    - Transient trapping effects
- AFM / SEM analysis of failed devices
- Sub-contact doping effects

## Characterization of Defect States

- Thermally stimulated current spectroscopy (TSC)
- Extraction of trap parameters from experimental IV curves and simulation fitting
- Sub-bandgap IR illumination at cryogenic temperatures
**Texas Tech Electrically Small Antennas**

**Design Goals**
- Electrically small – a few meters in size
- High power – Megawatt output
- Instantaneous bandwidth – a few percent
- Tuning – adjust resonant frequency with structural modification

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**Project Objective**
Design and simulate an electrically small antenna for the 2 – 10 MHz range capable of high power applications

**Approach**
- Simulate and optimize the design in HFSS for the operational frequency range
- Consider physical limits (electric breakdown)
- Build a scaled version of the design for operation around 100 MHz

**Current Issues**
- Tradeoff between size and bandwidth
  - Resonant structure
- High field on surface of dielectric
  - Limits input power
- Losses in the dielectric
  - Increase bandwidth, decrease efficiency

**Future**
- Evaluate magnetic materials (ferrites)
Goal: Design, develop and demonstrate a high power MBIOT operating as a class D amplifier.

Advantages of Pulse Modulation:

- Simplifies driver circuitry
- Improves phase/frequency control
- Enhanced efficiency

Technical Challenges:

- Grid-beam interception and heat load
- Cavity tuning over 3 octaves while maintaining matched R/Q
- Guide field uniformity
- Output matching
Device Concept

Electron gun w/ coaxial grid-cathode geometry

- RF frequency, phase and amplitude are pulse modulated
- Pulse Width AM
- Pulse Period FM
- Pulse Timing Phase
System Challenges - What might a more compact system look like?

ITER and Compact are not usually mentioned in the same sentence

ICRH System: 2 antennas, 20 MW/each, 40-55 MHz

# Agenda

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<thead>
<tr>
<th>Time</th>
<th>Topics</th>
<th>Speakers</th>
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<tbody>
<tr>
<td>9:00 AM</td>
<td>Greetings</td>
<td>Tom Murphy Director IREAP</td>
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<tr>
<td>9:05 AM</td>
<td>Agency Perspectives</td>
<td>Kent Miller/John Luginsland</td>
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<tr>
<td>9:20 AM</td>
<td>Collaboration Overview/Technical Challenges</td>
<td>Tom Antonsen UMD/IREAP</td>
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<tr>
<td>9:45 AM</td>
<td>The Physics of Ionospheric Modifications - Issues and Impact on the Source Design</td>
<td>Dennis Papadopoulos</td>
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<td>10:30 AM</td>
<td>Coffee Break</td>
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<tr>
<td>10:45 AM</td>
<td>Continuation of UMD/SPP - UCLA Plans</td>
<td>Walter Gekelman</td>
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<tr>
<td>11:30 AM</td>
<td>Texas Tech Effort Overview Road to PCSS based RF generator</td>
<td>Andreas Neuber/James Dickens</td>
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<td>12:30 PM</td>
<td>Lunch</td>
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<tr>
<td>1:00 PM</td>
<td>Electrically Small Antennas</td>
<td>John Mankowski</td>
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<tr>
<td>1:30 PM</td>
<td>UMD Charged Particle Beam Group Overview of IOT Technical challenge Initial Experiments/Cavity Design Beam simulations</td>
<td>John Rodgers/Brian Beaudoin/Kiersten Ruisard/Dmytro Kashyn</td>
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<td>3:00 PM</td>
<td>Lab tour</td>
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<td>3:30 PM</td>
<td>Government Caucus</td>
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<td>4:00 PM</td>
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