High-Power THz Sources for High-Energy-Density–Physics Applications

G. BRUHAUG,¹ H. G. RINDERKNECHT,¹ M. S. WEI,¹ G. W. COLLINS,¹ J. R. RYGG,¹ Y. E,² K. GARRIGA,² and X. C. ZHANG²

¹University of Rochester, Laboratory for Laser Energetics; ²University of Rochester, Institute of Optics

Summary

• THz radiation provides a unique probe and pump for HED matter, but are currently no available options at large HED facilities.
• THz probes can provide measurements of dc conductivity, while THz pumps can alter the structural state of materials.
• A suite of THz capabilities are being developed for use in HED and plasma-physics experiments.

THz Radiation

• THz radiation typically refers to electromagnetic radiation that lies between 0.1 and 10 THz.
• THz radiation is considered “quasi-optical” and can act in ways similar to both microwaves and optical light.
• THz is currently used as a powerful diagnostic for materials science via time-domain spectroscopy (TDS).
• THz-TDS is used for dc measurements of conductivity, a non-contact temperature probe, and a method of identifying chemical structures in situ.

Example THz-TDS Measurement of an Amino Acid

NEWFIGURE: A SPRINGER GRAPHIC

• These measurements provide unique measurements into HED materials.
• Powerful THz sources have recently been developed that can drive nonlinear phenomena in materials.
• None of these unique sources or detectors are available at the Laboratory for Laser Energetics.

OMEGA EP THz Source

<table>
<thead>
<tr>
<th>THz generation source</th>
<th>Peak power (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlinear crystal</td>
<td>5</td>
</tr>
<tr>
<td>Particle accelerator</td>
<td>1.5</td>
</tr>
<tr>
<td>Air plasma</td>
<td>1</td>
</tr>
<tr>
<td>Metal foil plasma</td>
<td>38</td>
</tr>
<tr>
<td>OMEGA EP metal foil plasma</td>
<td>~700</td>
</tr>
</tbody>
</table>

THz Diagnostic Development

• Two separate THz diagnostics are under development to support future THz campaigns.

THz Background/Energy Meter

• The first step in developing THz radiation capabilities will be to measure the broadband THz background during laser compression experiments and act as an energy meter for THz source development.
• The detector utilizes a THz sensitive pyrometer behind a series of mirrors, filters, and radiation shields to ensure that only THz radiation impacts the detector.
  – It will be able to detect broadband sources with 4π emission as low as ~40 µJ with options to go lower.

THz Polychromator

• A polychromator using multiple bandpass filters and the same THz pyrometers to provide rough spectral information is also in development.
• The polychromator will sample the spectrum at seven points in the current design.

Future Plans

• Driving targets with high-intensity THz radiation
  – high-intensity, short-pulse THz radiation can provide quasi-static dc fields in excess of 100 MV/cm onto targets.
  – these extreme fields can drive matter into unique states and efficiently accelerate charged particles.

• Develop a THz-TDS system on OMEGA EP
  – single shot THz-TDS has already been shown.
  – commercial THz-TDS systems are available and meet the specifications needed to perform THz-TDS on relevant time scales for HED experiments.
  – coupling to OMEGA EP will require precise co-timing.

References