Quasi-DC Probing of Electrical Conductivity in Warm Dense Matter

Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract
We report transient terahertz (1 THz = 10^{12} Hz) measurements of the electrical conductivity of intense ultrashort laser-heated solids, transforming from the cold solid to the dense plasma state. Using optical-pump, THz-probe spectroscopy, we measured the phase shifts and absorption of THz probe pulses reflected from the warm dense plasma. In contrast to the previous measurements of conductivities at optical frequencies, our THz non-contact probe method can directly measure quasi-DC electrical conductivities, revealing potential discrepancies with the Drude model and thus providing further insight into the transport nature of warm dense matter. In the case of warm dense aluminum, we observe a noticeable deviation from the Drude model even in the \( 10^{12} \) W/cm\(^2 \) laser intensity regime. In addition, we observe strong coherent THz emission produced by a current pulse in the laser-produced plasma.

1. Optical-pump THz-probe spectroscopy

Thz conductivity measurements of laser-heated aluminum

2. Experimental Layout

3. Single-shot THz diagnostic

Chiped pulse spectral encoding 2:

4. Experimental results

Experimental result I:

5. Data analysis

From this field (real & imaginary parts) temporal waveforms, we extract conductivity from reflection measurements using Fresnel relations and the reflected THz amplitude.

6. Conclusions

We have measured the electrical conductivity of femtosecond intense laser-heated aluminum at THz frequencies using optical-pump, THz-probe reflection spectroscopy. For a warm \( (\sim 2.6 \text{ eV}) \) and near solid density \( (\sim 2.7 \text{ g/cm}^3) \) aluminum, we measured the real part of electrical conductivity \( \sigma \) at \( 1.2 \text{ THz} \), which is at least order of magnitude lower compared to the AC conductivity measurements under similar conditions. However, it is in good agreement with other direct DC conductivity measurements using exploding wires.

References