Measurement of Thermal Conductivity of Iron Using Laser-Driven Ramp Compression

T.M. Perez, J.K. Wicks, C. Krill, S. Narayanan (Johns Hopkins University)
J.H. Eggert, R.F. Smith, D.E. Fratanduono, Y. Ping, P. Sterne (LLNL)

Thermal conductivity is one of the most important physical properties of Earth materials and yet is very difficult to measure at extreme pressure-temperature conditions (135-360 GPa, 2500-5000 K). Within the Earth's core, the thermal conductivity of iron and iron rich alloys plays an important role in numerous physical properties of the Earth. These include the interior temperature profile[1] and the generation of Earth's magnetic field[2]. An accurate measurement of the thermal conductivity of iron would have direct relevance to our understanding of the formation and evolution of the Earth's as well as other planets' interiors[3]. Currently, there is very little work that experimentally constrains thermal conductivity at high pressures and temperatures. Some of the most recent studies have sought to derive thermal conductivity from measured electrical conductivity[4] or using pulse laser heating and fast optics to measure thermal conductivity directly[5]. In this study, we determine thermal conductivity from dynamic compression experiments in which we seek to study a heat wave travelling through the compressed sample.

Laser-driven ramp compression experiments of stepped iron targets were conducted at the Omega laser at the Laboratory for Laser Energetics (LLE). This technique uses a laser to irradiate the interior of a gold hohlraum, creating x-rays that ablate a low-Z material foil, which propagates across a vacuum gap and impinges on a stepped-Fe sample, which generates a smooth ramp-stress through the sample and a heat wave that travels through the sample after it is compressed[6]. Streaked Optical Pyrometry (SOP) was used to measure emitted photons of the iron-window interface as a function of experiment time on different step thicknesses. We approach the analysis by applying heat transport equations to the experimental data as well as matching the data with forward modelling from the hydrodynamic code package, HYADES.

1. Lay, T., Hernlund, J. & Buffett, B. A. Core–mantle boundary heat flow. *Nat. Geosci.* **1**, 25 (2008).
2. Stevenson, D. J. Planetary magnetic fields. *Earth Planet. Sci. Lett.* **208**, 1–11 (2003).
3. Labrosse, S., Poirier, J.-P. & Le Mouël, J.-L. On cooling of the Earth's core. *Phys. Earth Planet. Inter.* **99**, 1–17 (1997).
4. Ohta, K., Kuwayama, Y., Hirose, K., Shimizu, K. & Ohishi, Y. Experimental determination of the electrical resistivity of iron at Earth's core conditions. *Nature* **534**, 95 (2016).
5. Konôpková, Z., McWilliams, R. S., Gómez-Pérez, N. & Goncharov, A. F. Direct measurement of thermal conductivity in solid iron at planetary core conditions. *Nature* **534**, 99–101 (2016).
6. Smith, R. F. *et al.* High planarity x-ray drive for ultrafast shockless-compression experiments. *Phys. Plasmas* **14**, 057105 (2007).