How accurately can we measure the temperature in a laser heated diamond anvil cell?

Martin Kunz, Jinyuan Yan, Alastair MacDowell, Andrew Doran, Christine Beavers, Quentin Williams

While laser heating samples in a diamond anvil cell (DAC) has come of age (Ming & Bassett, 1974), and is now quite routine, reliably determining the temperature of the heated sample under investigation has remained a challenge. A promising development in the quest for honest temperature assessment within a DAC is the peak-scaling method (e.g. Rainey and Kavner, 2014). This method combines the spectro-radiometric analysis of the average radiation from the entire hotspot with an intensity map at a single color (wavelength) to establish a temperature map of the entire hot-spot. For this to work, it requires knowing the temperature at one point of the intensity map: this is normally the peak temperature. By simplifying the experimental input to the average hot spot radiation and one monochromatic image, the method relaxes many of the possible experimental artifacts such as misalignment and chromatic aberration. The accuracy of the derived temperature map, however, hinges on how well we are able to know the peak temperature.

To assess the sensitivity of the method on the accuracy of the assumed peak temperature, we explored the mutual relationship between 'average' temperature (i.e. temperature derived from a fitting a Planck curve to the averaged intensity from the entire hot spot) and peak temperature as a function of a series of practically relevant parameters such as size and position of the segment of the Planck curve used for temperature fitting (fitting window), peak shape and peak size as well as the dependence of the emissivity on wavelength and temperature.

The derived peak temperatures vary systematically by about 10 – 15 % depending on the size and position (mostly position) of the fitting window. These variations are systematic and can – in principle - be accounted for. The dependence of the emissivity on temperature and wavelength contributes another 5 – 15 % (depending on the temperature) of possible variability. The inherent lack of information on the emissivity of a hot sample at high temperature limits the ability to correct for this with current experimental set-ups.

Future outlooks aim at combining the averaged hot-spot intensity with monochromatic intensity maps at several wavelengths to account for the inherently unknown emissivity and an iterative process to establish a temperature map with correct scaling across the entire temperature distribution.

Ming, L-C, Bassett, W.A. (1974): Rev. Sci. Instrum. 45, 1115; http://dx.doi.org/10.1063/1.168682

Rainey ESG and Kavner A (2014): Journal of Geophysical Research: Solid Earth, 119(11), 8154–8170; DOI: 10.1002/2014JB011267