Temperature Characterization of Impact-Generated Plasma

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The formation and time evolution of impact-generated plasma clouds is of great interest across many disciplines in physics and engineering. Impact ionization is used in space as a dust detection mechanism on many missions, including Ulysses, Galileo and Cassini. In the case of Cassini, mass spectroscopy of the impact-generated ions provides information about the composition of the dust grain. Hypervelocity impacts are also thought to be sources of impulsive electric fields and radio emission; in addition to the possibility of remote sensing, transient electromagnetic effects are of concern for spacecraft operations.

We present time-resolved temperature measurements of the gas and plasma cloud generated by hypervelocity dust impact. Micron- and submicron-sized iron dust grains were launched at speeds from 1-60 km/sec, using the electrostatic dust accelerator facility at the Colorado Center for Lunar Dust and Atmospheric Studies (CCLDAS). Dust grain impacts at these speeds produce a 1-100 microsecond long flash of light in the visible spectrum. A set of four photomultiplier tubes equipped with narrowband interference filters observe the flash in each of four spectral bands; this information is then used to reconstruct the temperature and radiating area of the debris cloud as a function of time.

Experiments were carried out for a variety of target materials including tungsten, quartz, tantalum, vanadium, and gold. In the case of tungsten, we find a temperature drop on the 10-microsecond timescale consistent with radiative cooling. Variation of temperature with material and scaling of impact effects with projectile speed are also discussed.