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Correction Appended

Plasmadynamics and lasers

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When an optical signal of some aperture size propagates through a fluid with a variation in its index of refraction, the signal's wavefront is distorted, reducing the performance of the system that uses the signal. Affected systems include optical and infrared tracking systems and directed energy weapons. Atmospheric propagation occurs when the distortion is over a large distance compared with the aperture, and the temporal aberration scale is less than 0.3 kHz. Sensing the time-resolved wavefront aberration and compensating with adaptive optics improves system performance.

Aero-optics deals with distortion over a short distance (as in shear layers) relative to the aperture. The temporal frequencies are now one to several orders of magnitude larger than 0.3 kHz.

Until recently, aero-optical problems have been treated statistically. Based on the principle that wavefront distortions in a convecting turbulent flow are themselves convecting, Jaycor invented a measurement device to accurately assess the rms optical path difference using a single probe beam.

A sparse-sensor, time-resolved measuring device was developed by the University of Notre Dame. Measurements were made through a Mach 0.8 free-shear layer that simulates propagation through an aperture in the side of an aircraft. Researchers at Calspan have also measured the line-of-sight error associated with optical sensing through windows in hypersonic vehicles. At Phillips Lab, the University of New Mexico, and the University of Notre Dame, measured time series of aero-optical aberrations are leading to new research avenues in the study of turbulent flows.

Tethered satellites can provide the space station with auxiliary power at the kilowatt level and furnish plasma and aerodynamic information that is otherwise impossible to obtain. Although the tether broke during February's Shuttle flight, these benefits are sufficient for maintaining the program and continuing experiments. The tether was 1 km short of its full 20.7-km deployment and ruptured within the boom. For upward tether deployment, the Shuttle flies backward to facilitate ion collection by its propulsion nozzles. The failure resulted from a small hole in the tether insulation that released air trapped in the woven copper wire strands. The ionized oxygen leaving the cable at the hole supported electric arcing to the metal Shuttle frame, resulting in cable degradation. Failure occurred at only 15-lbf tension, even though the cable is designed to withstand tensions in excess of 400 lbf. Nevertheless, considerable data were obtained during the deployment.

The most significant result is that the satellite drew current from the ionospheric plasma three to five times more efficiently than current models had predicted; hence it holds greater potential for auxiliary power. The increase stems from a hitherto unsuspected plasma instability near the satellite, where the electrons are heated to many times their normal temperature of 2,000 K.

Recent experiments at Phillips Lab used a chemical oxygen-iodine laser (COIL) to cut aluminum and steel. A 10-kW device was used with a N₂ or O₂ gas assist. A comparison with Nd:YAG and CO₂ lasers demonstrates a comparable cutting speed with Nd:YAG, and 3 times the speed of CO₂ with N₂ and 9 times with O₂. Equally important, a CO₂ beam cannot be transmitted through a fiber optic, while the Nd:YAG beam is limited to a 5-kW continuous wave. A 40-kW COIL beam has been transmitted through a fiber optic.

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CORRECTION: The last paragraph of the entry on Plasmadynamics and Lasers in the December issue (page 19) should read as follows: "Recent experiments at Phillips Lab used a 10-kW class chemical oxygen-iodine laser (COIL) to cut thick aluminum and steel. A comparison of COIL with Nd:YAG and CO₂ lasers demonstrates a comparable cutting speed with Nd:YAG, and 3 times the speed of CO₂. Another advantage of COIL is the ability to scale to large powers; Phillips Lab has demonstrated a 40-kW COIL, while the highest demonstrated pseudo-continuous Nd:YAG power is 5 kW. The CO₂ beam cannot be transmitted through fiber optics, while TRW has demonstrated the transmission of 5 kW of pseudo-continuous Nd:YAG power through a fiber optic and the Japanese have transmitted a 1-kW COIL beam through a fiber. The future potential to transmit a high power, short wavelength COIL beam through a fiber optic is very intriguing for industrial applications."

GRAPHIC: Diagram, The satellite is deployed upward from the Shuttle, which flies with a velocity V in an inverse airplane mode. The magnetic field B is directed into the page. Current I collected from the ionosphere by the engine bells flows through the tether to the satellite and back to the ionosphere. Dashed lines represent the potential sheaths around the satellite and Shuttle.

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