Physical Sciences

Dual-Laser-Pulse Ignition

This scheme provides a more reliable ignition source and more efficient energy delivery than a single-pulse format.

Marshall Space Flight Center, Alabama

A dual-pulse laser (DPL) technique has been demonstrated for generating laser-induced sparks (LIS) to ignite fuels. The technique was originally intended to be applied to the ignition of rocket propellants, but may also be applicable to ignition in terrestrial settings in which electric igniters may not be suitable. Laser igniters have been sought as alternatives to such conventional devices as electrical spark plugs and torch igniters for the following main reasons:

1. A typical electric spark igniter generates sparks at its electrode near a wall, which potentially quenches combustion. Hence, more spark energy is needed to ensure ignition. A large combustion chamber would require a torch igniter, which comprises an electric-spark source, a premixing chamber, and propellant valves. In contrast, the laser igniter is capable of creating sparks directly in a main chamber at specific optimal locations, which can be out away from the chamber walls, and without the need of other subsystems.
2. Laser igniters can generate LIS with very precise timing, on the order of nanoseconds. This accurate timing precision may be helpful in certain ignition applications. Furthermore, this ignition generates significantly less electromagnetic emission noise than electrical igniters. Such noise can interfere with other electronic signals of engine sensors and control components.

Years of research on laser ignition have produced viable single-pulse laser ignition concepts; however, the transmission of high laser energy through fiber optics required by these single-pulse schemes has been problematic due to potential fiber damage and reduction in transmission efficiency. In comparison, optical energy for the DPL method can be stretched out and transmitted through multiple fiber lines, effectively reducing the energy intensity. In addition, the lifetime of the plasmas generated by use of the DPL exceeds those of plasmas generated by single-laser pulses, which increases their efficacy as an ignition source.

In the present DPL technique, the first pulse is used to generate a small plasma kernel. The second pulse is subsequently used to irradiate the plasma kernel. The transfer of laser energy into the kernel is much more efficient because the radiation-absorption characteristics of the plasma kernel are greatly enhanced, relative to the single-pulse approach. Consequently, the kernel can develop into a more effective ignition source.

Comparative experiments on single- and dual-pulse laser ignition were performed in a small test-bed rocket thrust chamber, at Marshall Space Flight Center, using gaseous oxygen and kerosene. Sapphire windows were used for optical access to the chamber. In the tests, the DPL technique was found to provide a repeatable ignition source for combustion with an optimal energy level.

This work was done by Huu Trinh of **Marshall Space Flight Center***, James W. Early of Los Alamos National Laboratory, Matthew E. Thomas of CFD Research Corp., and John A. Bossard, formerly of CFD Research Corp. Further information is contained in a TSP* *(see page 1).*
MFS-31922

Enhanced-Contrast Viewing of White-Hot Objects in Furnaces

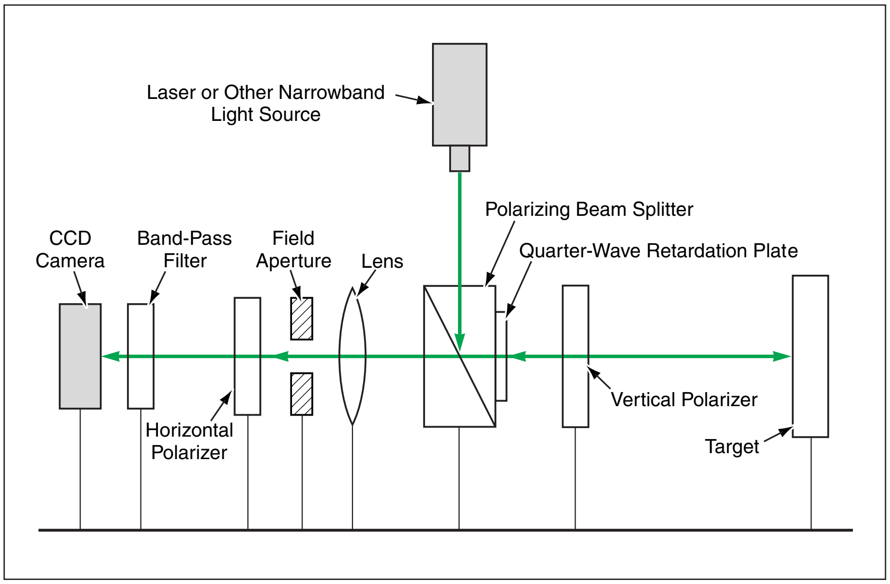
Band-pass- and polarization-filtered laser light exceeds polarization-suppressed blackbody light.

Marshall Space Flight Center, Alabama

An apparatus denoted a laser image contrast enhancement system (LICES) increases the contrast with which one can view a target glowing with blackbody radiation (a white-hot object) against a background of blackbody radiation in a furnace at a temperature as high as ≈1,500 °C. The apparatus utilizes a combination of narrowband illumination, along with band-pass filtering and polarization filtering to pass illumination reflected by the target while suppressing blackbody light from both the object and its background.

In a typical application, the target is about 1 cm in size and located as far as 30 in. (≈76 cm) into the furnace. In the absence of this or another contrast-enhancing apparatus, a white-hot target in a furnace is nearly or totally indistinguishable from the white-hot background. Unlike a prior contrast-enhancing apparatus that utilizes two intersecting optical axes for viewing and illumination of the target and requires a furnace opening as wide as 3 in. (≈8 cm) the LICES provides for both illumination and viewing of the target along the same path. Hence, the LICES makes it possible to utilize a narrower opening into the furnace: the LICES can function with an illumination/viewing tube only about half an inch (≈1.3 cm) wide.

The LICES (see figure) includes a laser aimed perpendicularly to the optical path to the target. (Optionally, another source of narrowband illumination could be used.) The laser light impinges on a polarizing beam splitter that turns the light onto the optical path to the target. The laser light passes through a quarter-wave retardation plate, which causes the light to become



Only One Optical Path is used for both illuminating and viewing the target with laser light. Blackbody radiation from the target is suppressed by the crossed (horizontal and vertical) polarizers.

circularly polarized. The circularly polarized laser light passes undisturbed through a vertical polarizer, then travels along the optical axis to the target. Reflection from the target reverses the circular polarization. The reflected laser light passes again through the vertical polarizer and then through the quarter-wave retardation plate, which converts the reverse circular polarization to horizontal polarization.

The polarizing beam splitter passes the horizontally polarized reflected laser light, which then passes through a lens, a field aperture (which helps to increase contrast by blocking background light), a horizontal polarizer, and a filter having a 20-nm-wide wavelength pass band. The reflected laser light ultimately comes to focus in a charge-coupled-device (CCD) camera. At the same time, the crossed polarizers and the band-pass filter discriminate the wideband, randomly polarized blackbody light from both the target and the background.

Because the intensity of blackbody radiation is proportional to the fourth power of absolute temperature, it could be necessary to increase the laser power to maintain adequate contrast at higher temperatures. A prototype LICES has been found to yield high-contrast images at temperatures 1,500 °C.

This work was done by William K. Witherow and Richard R. Holmes of **Marshall Space Flight Center** *and Robert L. Kurtz of Pace & Waite, Inc.*

This invention has been patented by NASA (U.S. Patent No. 6,366,403). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31561-1.

Electrically Tunable Terahertz Quantum-Cascade Lasers

These devices would supplant gas lasers as far-infrared sources.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved quantum-cascade lasers (QCLs) are being developed as electrically tunable sources of radiation in the far infrared spectral region, especially in the frequency range of 2 to 5 THz. (Heretofore, the wavelengths of QCLs have been adjusted by changing temperatures, but not by changing applied voltages or currents.) In comparison with gas lasers now used as far-infrared sources, these QCLs would have larger wavelength tuning ranges, would be less expensive, and would be an order of magnitude less massive and power-hungry. It is planned to use the improved QCLs initially as the active components of local oscillators in spaceborne heterodyne instruments for studying infrared spectral lines of molecules of scientific interest. On Earth, the QCLs could be used as far-infrared sources for medical glucose-monitoring and heart-monitoring instruments, chemical-analysis and spectral-imaging systems, and imaging instruments that exploit the ability of terahertz radiation to penetrate cloth and walls for detection of contraband weapons.

The structures of QCLs and the processes used to fabricate them have much in common with those of multiple-quantum-well infrared photodetectors described in numerous previous *NASA Tech Briefs* articles. In one of four approaches being followed in the present development effort, the focus is upon designing and fabricating the structures to obtain heterogeneous cascades for different electric fields and different wavelengths in order to enable electrical tuning of laser emission wavelengths. Both the variation of the emission wavelength and the targeted range of the electric-field strength for each cascade would be kept small so the spectral gains of adjacent cascades at any given electric-field strength in the target range would overlap. This approach is expected to afford the desired variation of the gain maximum with electric-field strength, so that a change in applied bias voltage would result in a wavelength change.

In the second approach, layers of a QCL structure are to be graded to modify the shapes and depths of quantum wells, such that the electronic wave functions in the quantum wells and the transition energies between them would change with an intentional variation of the applied bias electrical field. A change of the bias applied to such a structure would result in a change in the energy and, hence, of the wavelength of the lasing transition.

In the third approach, the focus is on exploiting distributed-feedback and distributed-Bragg-reflector QCL architectures to achieve wavelength tuning through variation of applied electric current.

In the fourth approach, which is complementary to the other three, the focus