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.

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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