Longer laser pulses for practical LII

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To date nearly all LII is carried out using Q-switched, flashlamp pumped Nd/YAG lasers with pulse lengths ~10 ns. Although these lasers are well developed and readily available for use in the laboratory and in commercial instruments, they are bulky, inefficient and often the most costly part of an LII system. Cheaper, more compact lasers are becoming available, but very few are able to match the 10 ns pulse length and >100 mJ/pulse capability of Nd/YAG.

Background

The first published LII experiment [1] used a CO_2 TEA laser with microsecond pulses and some early work by Eckbreth [2] used a flashlamp pumped dye laser. However, since the expansion of the use of LII for combustion studies in the mid 1980s, the standard source has become the Q-switched, flashlamp pumped Nd/YAG operating at either 1064 or 532 nm. A picosecond lasers has been used to study the fundamental LII process [3], but very little attention has been given to the possibility of using longer pulse lasers.

Lasers for Practical Applications of LII

While the most common use of LII is the study of soot distribution in laboratory flames, there are commercial LII instruments in use for vehicle emission and atmospheric monitoring and at least three systems worldwide have been used to make in-situ measurements in aero-engine exhausts. The vehicle exhaust and atmospheric system perform LII on sampled gas within a light tight enclosure and so are not subject to laser safety constraints. However, the Nd/YAG laser is usually the largest, heaviest and most expensive part of these systems. It is very difficult to sample gas from an aero-engine exhaust and a major advantage of LII is that it can be applied in-situ. However, this involves irradiating the exhaust plume with a Class 4 laser, often at a wavelength of 1064 nm where eye safety is most difficult, and so its use is restricted to enclosed test beds or airfields which can be closed off. Lasers producing longer pulses and operating at longer wavelength (>1500 nm) would be subject to less stringent safety restrictions and could be used for in-situ measurement in a wider range of locations.

It may also be possible to combine LII with laser absorption spectroscopy using a mid or near IR laser to measure molecular species in an exhaust.

Developments in Lasers

New types of lasers which may be suitable for LII are becoming widely used, often in non-scientific applications, for example pulsed diode lasers in the printing industry and fibre lasers for welding and cutting applications. Both these types, which are lighter and more compact than their Nd/YAG equivalents can produce pulses with energies in the 10's of millijoules and pulse lengths of a few microseconds. Experiments with a fibre laser producing 5 mJ in 10 μs pulses which have an initial spike <1 μs are planned in an engine exhaust.

Conclusions

Model predictions show an increase in LII with longer pulses [4], perhaps because there is less competition with other processes such as sublimation, though annealing and ablative processes could be quite different with longer pulses. LII with lasers producing longer pulses than standard Q-switched Nd/YAG has been a neglected area of study, which may prove very useful for the advancement of the practical application of the technique in the future.

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[2] A.C. Eckbreth, J. Appl. Phys. 48, 4473 – 4479 (1977)

[3] H.A. Michelsen, Appl. Phys. B, 83, 443 – 448 (2006)

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International Discussion Meeting and Workshop 2006: Laser-induced Incandescence, Quantitative interpretation, modelling, application