Using lasers to create cleaner engines

Accurate laser-based thermometry techniques are a fascinating academic challenge and are helping to design the next generation of fuel-efficient internal combustion engines.

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Measuring temperature accurately inside internal combustion engines is, understandably, difficult. At the centre of a typical cylinder, temperatures can reach 2000K - enough to melt any invasive probe. But Prof. Paul Ewart's research has a solution: using the latest laser spectroscopy techniques to measure the temperature of burning gases.

Knowing the temperature before and after ignition is crucial if researchers are to fully understand the complex chemical reactions that occur when fuel burns. Using those temperature measurements, engine and fuel manufacturers hope to exploit the phenomenon of evaporative cooling to make engines more efficient. When gaseous fuel is injected into engine cylinders, it cools the air present, causing it to contract and draw more air into the cylinder. By tuning the air-fuel mix to take advantage of this effect, engineers can improve an engine's efficiency.

But current laser measurement techniques are accurate to within 5-10% – which is not enough to precisely measure the effects of evaporative cooling. So University of Oxford physicists, led by Prof. Ewart, have been working on a method to measure temperature in hostile environments with unprecedented accuracy, called Laser Induced Grating Spectroscopy (LIGS). LIGS uses three laser beams, crossing at the same point. Two of those beams are designed to interfere with each other and the resulting optical interference pattern acts as a grating, causing the third to be diffracted.

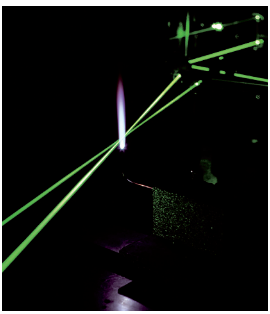

Image: P. Ewart

When the first two beams are pulsed, molecules illuminated within the bright regions of the interference pattern are rapidly heated, creating a thermal grating that matches the optical grating. The slight temperature, and density, change creates sound waves which modulate the intensity of the diffracted beam. Analysing the resulting modulation, the physicists can measure the speed of the sound waves and hence the temperature to within 0.1% – two orders of magnitude better than existing technologies.

The technique is being used in projects supported by major international oil companies and automobile manufacturers to study both the fundamental physics of combustion and to aid the design of the next generation of smaller, cleaner and more efficient internal combustion engines. By exploiting and optimizing the evaporative cooling effect engineers hope to improve engine efficiency by up to 5% – which will reduce the load on fossil fuel supply and cut CO_2 emissions.

The team now plan to combine the LIGS technology with more conventional 2D laser temperature measurements in a plane, to create accurate temperature maps of the entire engine cylinder. In the world of non-invasive thermometry, that's pretty hot stuff.

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