Cross-Cutting Technologies to Enable Clean Energy Manufacturing

CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov

Connection to AMO Mission

Distributed energy systems improve energy efficiency, reduce carbon emissions, optimize fuel flexibility, lower company operating costs, and facilitate market opportunities for U.S. electricity generating capacity, enabling U.S. manufacturers to be cost-competitive and energy-independent.

Opportunity

Cross-cutting technology could generate several gigawatts of distributed electricity worldwide.

Goals

- Develop engine/generator systems with high efficiency at high power output, that emit very low exhaust emissions while maintaining excellent durability, at a low installed cost.
- Technical end goals include 50% brake thermal efficiency (BTE) and 0.1 g/bhp-hr NO_x emissions.

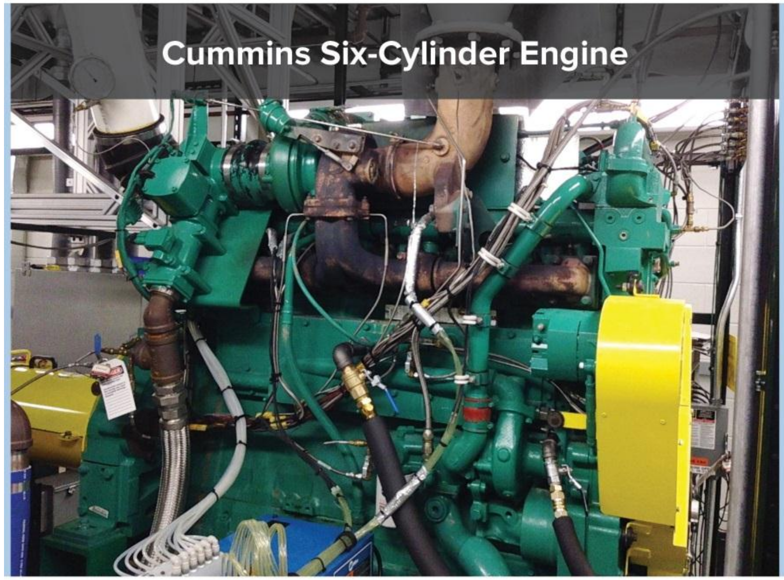
This presentation does not contain any proprietary, confidential, or otherwise restricted information.

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc

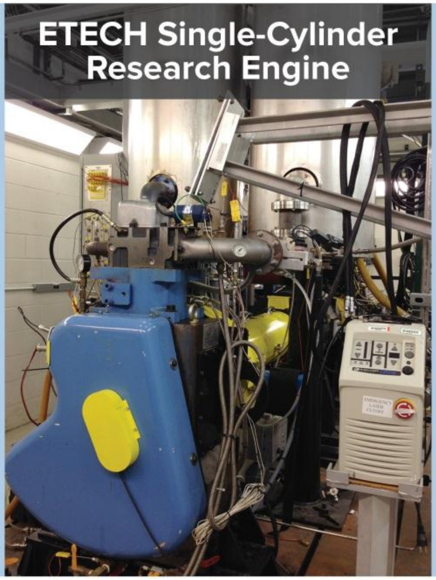
Argonne NATIONAL LABORATORY

Cross-Cutting Technologies to Enable Clean Energy Manufacturing

CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov



Cummins Six-Cylinder Engine



ETECH Single-Cylinder Research Engine

Distributed Energy Research Center (DERC)

Cummins · Capstone · PRINCETON OPTRONICS · altronic HOERBIGER Engine Solutions · DENSO · U.S. DEPARTMENT OF ENERGY

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc

Argonne NATIONAL LABORATORY

Cross-Cutting Technologies to Enable Clean Energy Manufacturing

CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov

3rd Laser Ignition Conference

April 27-30, 2015 | Argonne National Laboratory, USA

- 45 presenters from 12 different countries
- Luminaries in the field delivered 16 invited and 3 plenary lectures
- Well attended by engine manufacturers, Tier-I suppliers, research organizations and academia.
- Showcased state-of-the-art in lasers and high-power laser delivery technologies.

Cummins Capstone PRINCETON OPTRONICS altronic HOERBIGER Engine Solutions DENSO U.S. DEPARTMENT OF ENERGY

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc

Cross-Cutting Technologies to Enable Clean Energy Manufacturing

CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov

Micro-Lasers for Ignition in Engines

Overview

- Natural gas engine operation is optimized between efficiency, NO_x emissions and specific power. Even better performance requires the use of combustion modes that mandate the use of advanced ignition systems.
- Laser ignition has proven unparalleled in performance as it enables
  - Lean ignition limit extension;
  - Better ignition stability;
  - Faster rate of heat release;
  - Higher efficiency; and
  - Lower emissions.

Objectives

- To determine the extent of performance benefits that one obtains with Laser Ignition.
- By working with laser designers, develop laser ignition systems deployable in production engines.

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc

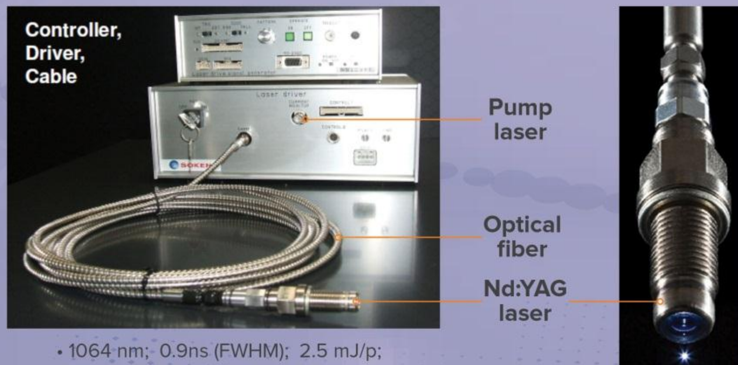
CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov

Argonne NATIONAL LABORATORY

Cross-Cutting Technologies to Enable Clean Energy Manufacturing

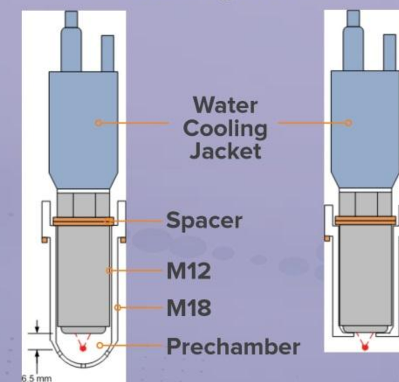
Argonne's Approach:

A fiber coupled DPSS laser end-pumping a Nd:YAG / Cr:YAG composite - A LI system previously developed by DENSO for cars.



- 1064 nm; 0.9ns (FWHM); 2.5 mJ/p; up to 11 pulses; 80 µsec apart

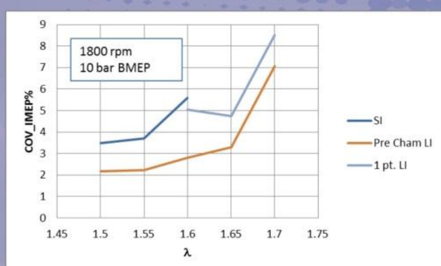
Spark plug geometry was optimized for two configurations

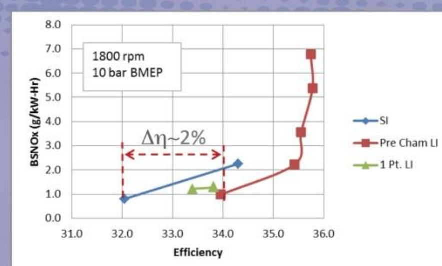


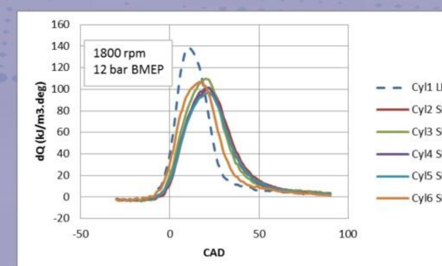
Type A
Multi-point ign. ~300X Ign. energy

Type B
Single point ign.

Test Results: from tests conducted in single-cylinder and 6-cylinder engines







- LI leads to lean ignition limit extension
- Pre-chamber LI leads to better ignition stability
- Improved efficiency (2% points)
- Faster rate of heat release

It appears that flamejets also contribute to NO_x formation → further optimization required

Cummins Capstone PRINCETON OPTRONICS altronic HOERBIGER Engine Solutions DENSO U.S. DEPARTMENT OF ENERGY

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc

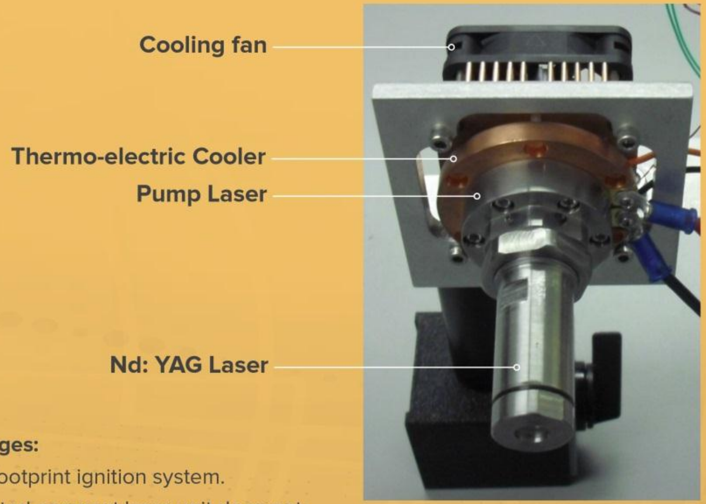
Cross-Cutting Technologies to Enable Clean Energy Manufacturing

CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov

Argonne's Approach:

Develop cost-effective, durable VCSEL pumped micro-lasers.

Prototype Air-Cooled Micro-Laser



Lasing Medium:	**Nd: YAG**
Passive Q-Switching:	**Cr: YAG**
Pulse Energy:	**16 mJ/p**
Lasing Wavelength:	**1064 nm**
Pulse Width:	**4.2 ns**

Advantages:

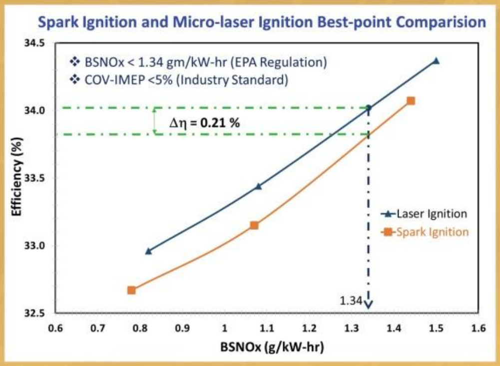
- Small footprint ignition system.
- Integrated compact laser unit does not require external water cooling.
- VCSELs are manufactured using well established semiconductor processing.
- Cost-effective mass manufacturing is possible.

Future Prospects:

Micro-laser development for laser-ignition, micro-machining, and R&D applications.

Results & Accomplishments:

- A prototype air-cooled VCSEL pumped micro-laser was designed.
- The prototype withstood engine temperature (95°C) and vibration (16g).
- Single-cylinder engine tests showed:
  - Lean operation extension from λ=1.58 to λ=1.613, and
  - Efficiency gain of 0.21% while meeting EPA regulated BSNOx of 1.34 gm/kW-hr.
- Optimizing optics and laser parameters will:
  - Improve energy coupling into the plasma kernel
  - Result in better efficiency gains.



Cummins | Capstone | PRINCETON OPTRONICS | altronic HOERBIGER Engine Solutions | DENSO | U.S. DEPARTMENT OF ENERGY

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc

Cross-Cutting Technologies to Enable Clean Energy Manufacturing

CONTACT:
Doug Longman
Argonne National Laboratory
dlongman@anl.gov

Visualization of Natural Gas Combustion in Engines

Objective: To evaluate advanced ignition systems and study the effect of flame kernel influence on engine performance using visualization techniques

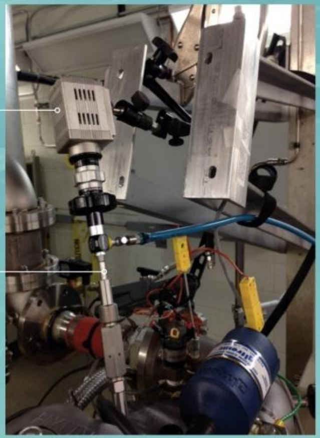
Opportunity: Engine efficiency, emissions, and power density demands push the ignition system performance to new challenging levels. In-cylinder combustion visualization enables evaluation and development of advanced ignition systems for engines

Advanced Ignition Systems:

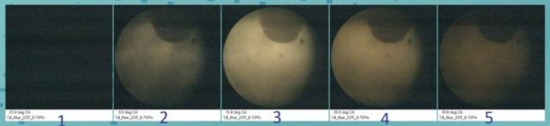
- Laser Ignition
- Turbulent Jet Ignition
- High energy ignition
- Corona discharge, micro-wave ignition,
- Pilot fuel ignition

Benefits of Imaging ignition events enables detailed study of:

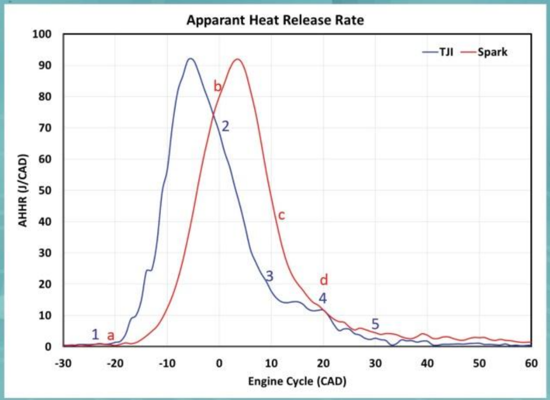
- Flame kernel characterization
- Spark properties
- Laser spark:
  - Flux intensity, repeatability, and performance
  - Influence of multiple sparks and distance (from fire deck) on combustion

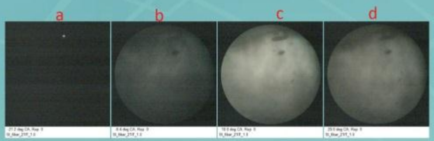


Turbulent Jet Ignition: BMEP-6bar; Spk-23bTDC; Φ: 0.75



Pre-chamber with 5 holes





J type Spark Plug

Baseline Spark Ignition: BMEP-6bar; Spk-21bTDC; Φ: 1.0

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. AMO2015_poster_rc