2019 ERC SYMPOSIUM

Argonne NATIONAL LABORATORY

LASER IGNITION IN RECIPROCATING ENGINES

SREENATH GUPTA
Distributed Energy Research Center
Argonne National Laboratory, USA

5-6 June, 2019

ACKNOWLEDGMENTS

Argonne Contributors

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Industrial Partners

- Princeton Optronics Inc. (prime to an SBIR-Phase II)
- DENSO
- BOSCH

Academic Partners

- University of Central Florida
- Syracuse University

Funding Agencies

- DOE-VTO & DOE-AMO

THERE ARE TWO POTENTIAL APPLICATIONS

Stationary Natural Gas Engines
0.5 – 2 MW, are Used for
Distributed Power Generation
Lean-burn: $\phi < 1$; T/C
(ARES program)

HD Natural Gas Engines
~350 hp., 6-cyl
Rich-burn: $\phi = 1$; T/C+EGR+3-wat cat

THE DRIVERS

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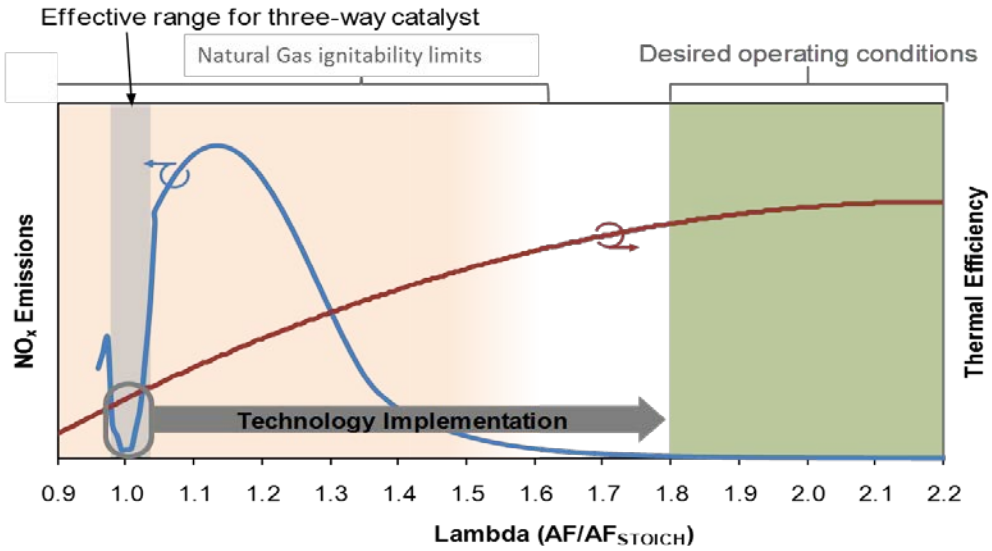
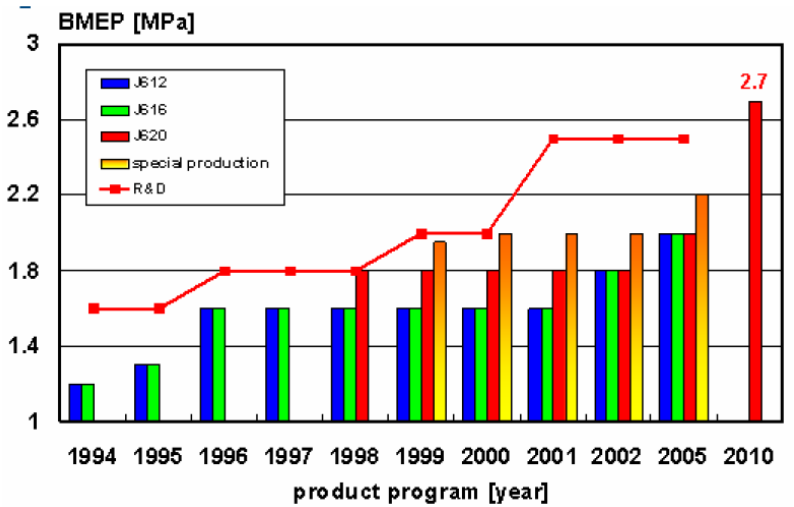
DEMANDS ON FUTURE NATURAL GAS ENGINES





Higher efficiency, and lower NOx emissions through a shift to lean-burn combustion

Lean-burn combustion

Market demands a gradual increase in Engine Specific Power

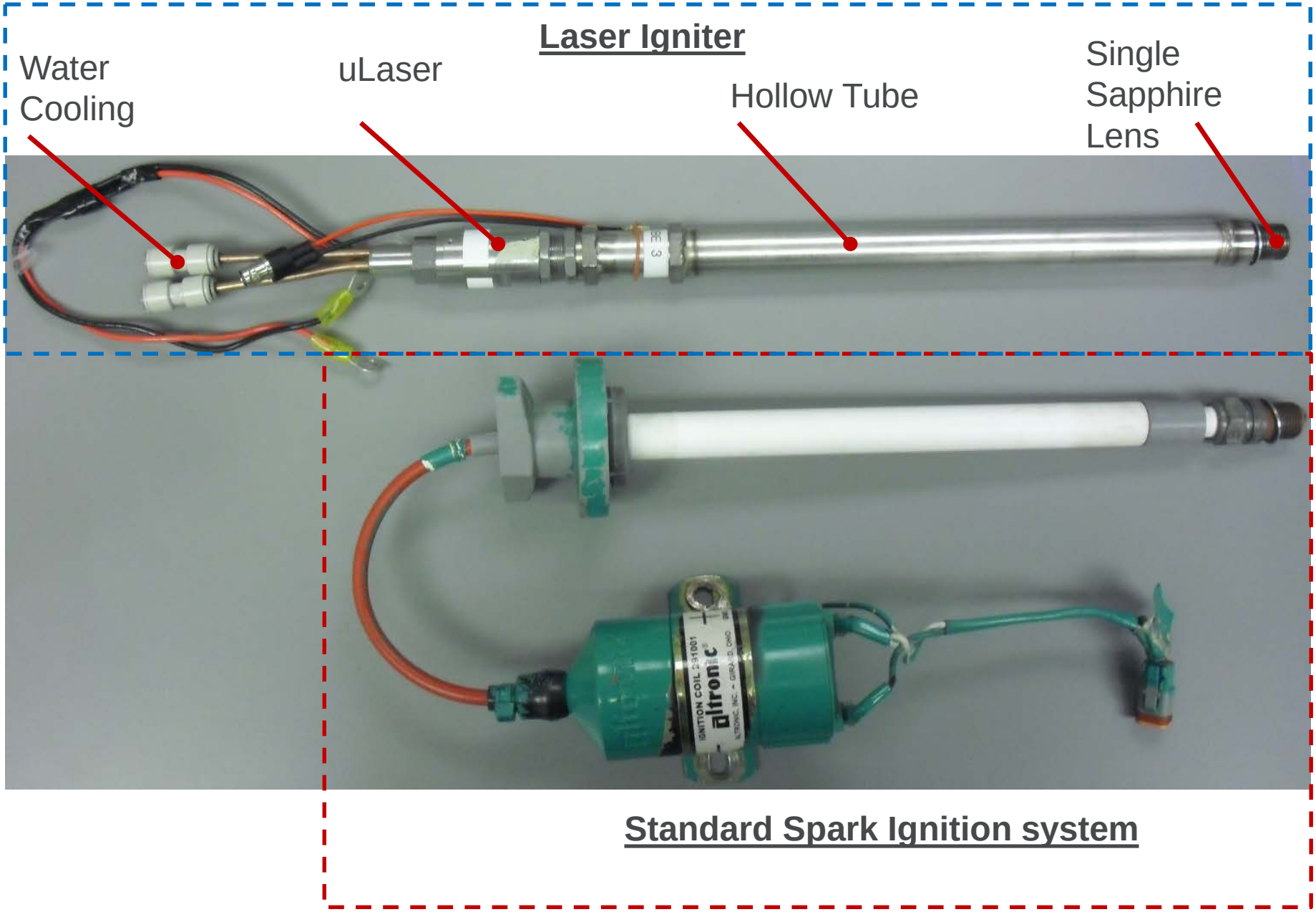
Turbocharged operation

ADVANTAGES WITH LASER IGNITION

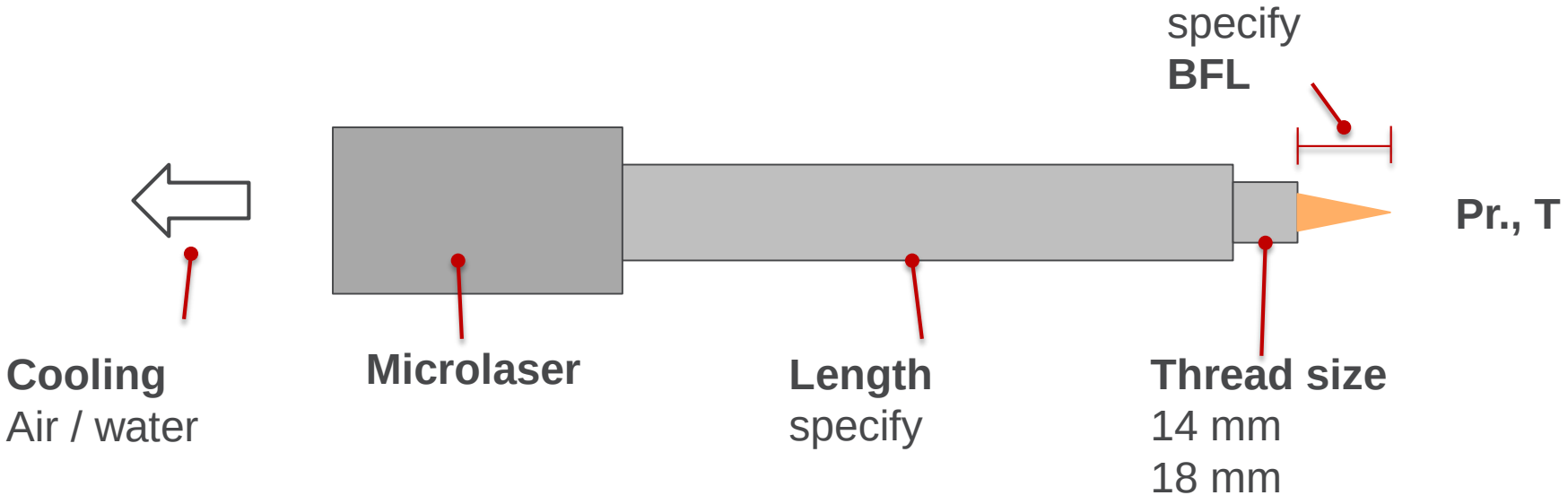
LASER IGNITION = BETTER IGNITION

- large ignition kernel
  - Improved ignition stability
- Ignition at higher pressures
  - Higher the pressure it becomes easier to ignite
- Ignition of very dilute mixtures
  - Higher EGR tolerance
  - Leaner mixtures
  - Low-quality fuels
- Avoid flow field perturbation

EFFORTS TO REDUCE LI TO PRACTICE


Laser Igniter
Water Cooling
uLaser
Hollow Tube
Single Sapphire Lens
Standard Spark Ignition system

THROUGH NUMEROUS ITERATIONS A LASER IGNITER WAS DEVELOPED



ISSUES ADDRESSED

- packaging
- small-size
- sealing
- cost
- longevity
- ruggedness
- power draw
- Safety
- temperature resistance
- vibration resistance
- thermal management (cooling)

RESULTS

- On engine tests have shown improved engine efficiency

  $\Delta\eta \sim 3\%$ points

  Could result in considerable fuel savings
  - Stationary engines: $15,000/MW/ year
  - NGVs: ~$2000/year/ HD vehicle

- Current design has shown continuous on-engine operation up to 830 hrs.
  - Efforts are being pursued to extend it up to 2000 hrs.

RELEVANT PUBLICATIONS

- Gupta, S. B., Akih-Kumgeh, B., “Interferometric imaging of laser initiated spark kernel,” 7th Laser Ignition Conference, Yokohama, Japan, April 22-26th, 2019.
- Bader Almansour, Subith Vasu, Sreenath B. Gupta, Qing Wang, Robert Van Leeuwen, Chuni Ghosh, “Prechamber Equipped Laser Ignition for Improved Performance in Natural Gas Engines,” J. Eng. Gas Turbines Power. 2017; 139(10):101501-101501-6, GTP-17-1042, doi: 10.1115/1.4036291
- Bader Almansour, Subith Vasu, Sreenath B. Gupta, Qing Wang, Robert Van Leeuwen, Chuni Ghosh, “Performance of a Laser Ignited Multi-Cylinder Lean Burn Natural Gas Engine,” J. Eng. Gas Turbines Power. 2017; GTP-16-1480, doi: 10.1115/1.4036621
- Klett, G. M., Gupta, S. B., Bihari, B., and Sekar, R. R., “Ignition Characteristics of Methane-air Mixtures at Elevated Temperatures and Pressures,” ICES2005-1064, *ASME Spring Technical Conference*, Chicago, IL, 2005.

PATENTS

- “Laser igniter with integral optimal geometry prechamber,” US Patent 10,180,124
- “Laser Based Ignition System for Natural Gas Reciprocating Engines, Laser Based Ignition System Having Capability to Detect Successful Ignition Event, And Distributor System for use with High-Powered Pulsed Lasers,” US Patent 7114858.
- “A Method to Distribute High-Energy Laser Pulses to Multiple Channels,” US patent 7,699,033.

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