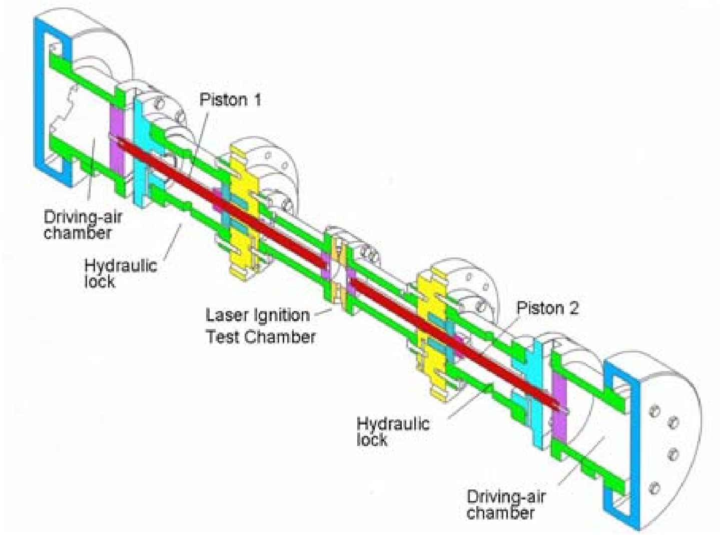
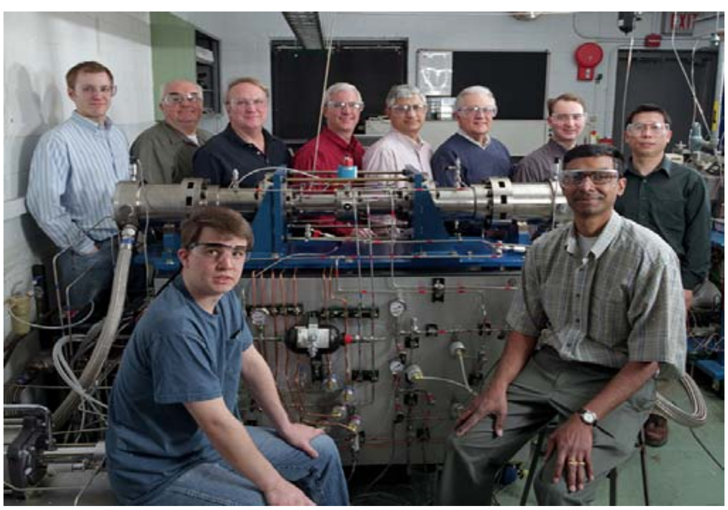
Ignition Studies in a Rapid Compression Machine

In accordance with US-DOE's ARES program, the performance and emissions targets for natural gas fired reciprocating engines are η > 50%, NOx < 0.1 g/bHp-Hr by year 2010. With such targets in mind, it is highly desirable to evaluate the possibility of extending the operation of modern lean-burn natural gas engines to even leaner operation. Such an operation promises improved efficiencies and reduced NOx emissions, however, sustaining reliable ignition is difficult. Addressing such an issue, DOE's ARES program is currently pursuing the development of various alternatives to conventional coil based ignition. One of the concepts that is being pursued, laser ignition, appears promising as it achieves reliable ignition at high pressures and under lean conditions relatively easily. To determine the extent of benefits that can be achieved with laser ignition over conventional ignition, Argonne National Laboratory has conducted comparative tests while very accurately simulating in-cylinder conditions in a Rapid Compression Machine (RCM).

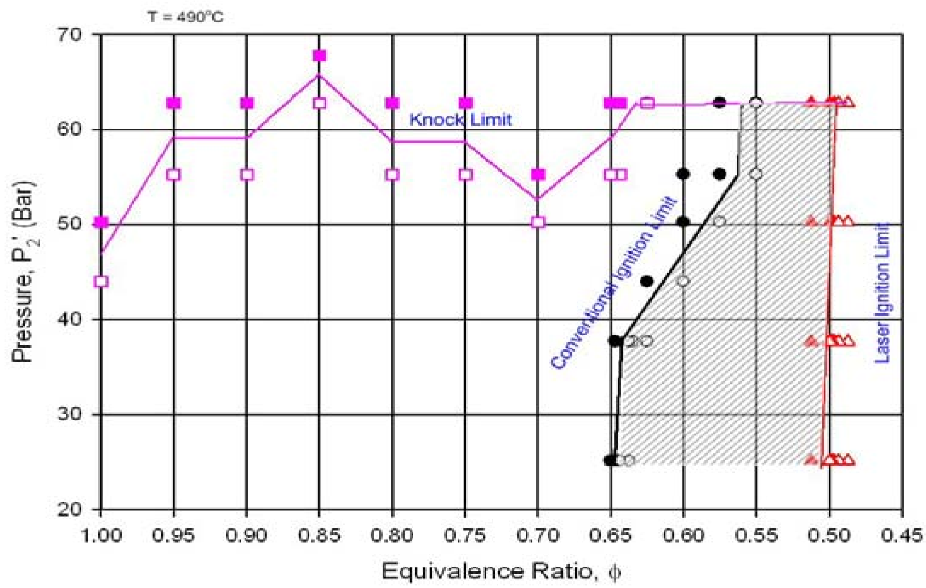


Schematic of Argonne's opposed piston rapid compression machine; designed for minimal vibration, compression ratio of 10.0 and maximum pressure of 362 bar.



Argonne's RCM Development Team

An initial design provided by MIT was significantly improved and an opposed piston RCM was developed to reproduce typical in-cylinder conditions of high temperature (~ 490 ^{o}C) and pressure (~ 80 Bar) at the time of ignition. The system driven by 300 psi compressed air releases two pistons in tandem that in-turn compress a premixed natural gas-air mixture to typical in-cylinder conditions. A hydraulic loop at 2400 psi provided a piston-locking mechanism that avoided the bounce of the pistons at the initiation of combustion. Experiments were performed comparing conventional coil based ignition (CDI) and laser ignition on methane-air mixtures while varying pressure and equivalence ratio systematically. It was observed that substantial gains are likely with the use of laser ignition as it extends the lean-ignition limit all the way to the flammability limit, i.e., φ = 0.5. On the other hand, conventional CDI ignition cannot ignite mixtures leaner than φ = 0.6. Also, faster combustion times and shorter ignition delays were observed in the case of laser ignition. Such combustion characteristics with laser ignition show a promise towards the achievement of ARES program goals while maintaining engine power density. These were confirmed through tests run on a single cylinder engine at SwRI.



Ignition limits of methane-air mixtures determined using Argonne's RCM

Reference: Gupta, S. B., Sekar, R. R., Klett, G. M., and Ghaffarpour, M., "Ignition Characteristics of Methane-air Mixtures at Elevated Temperatures and Pressures," SAE 2005-01-2189, *SAE Transactions Journal of Fuels and Lubricants*.

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