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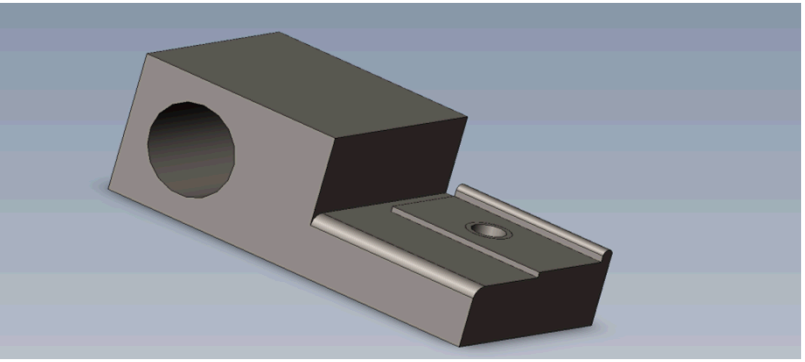
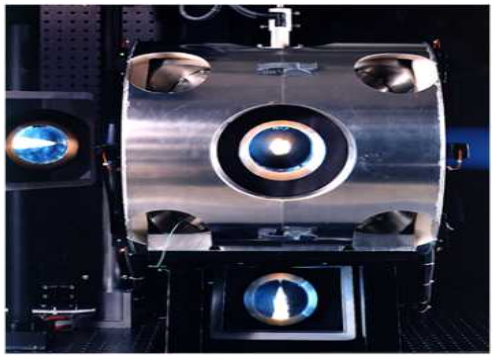
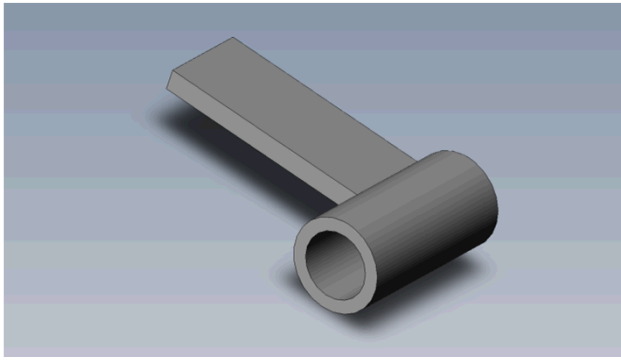

Ducted Fuel Injection:

A Technique for Preventing Soot Production in Diesel Engines

Christopher Nilsen and Charles Mueller

U.S. DEPARTMENT OF ENERGY | National Nuclear Security Administration

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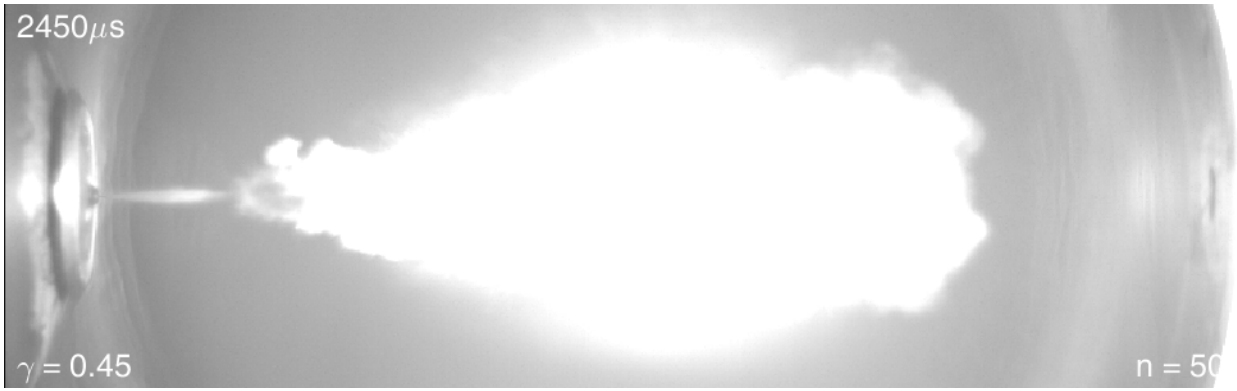
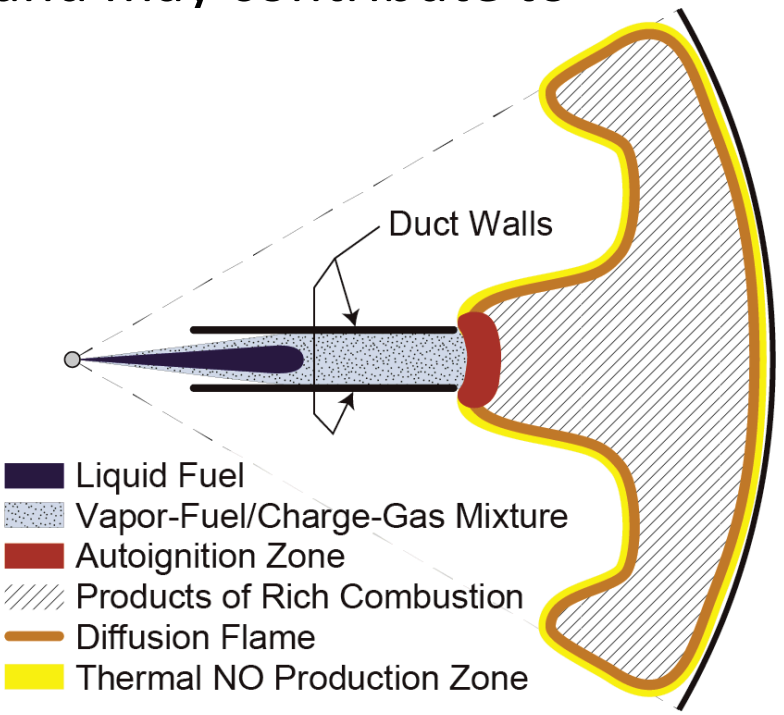
Project Purpose

- Soot is a significant component of smog in the Earth's atmosphere
- Currently soot is removed from the exhaust after it is created in the engine
  - Particulate filters are large, heavy, expensive, and require management and maintenance
- A burning condition known as Leaner Lifted-Flame Combustion (LLFC) significantly reduces soot production in a Diesel engine
  - LLFC is achieved by having an equivalence ratio less than 2 in the autoignition zone
  - Equivalence ratio is the $\frac{actual\ fuel\ to\ air\ ratio}{stochimetric\ fuel\ to\ air\ ratio}$

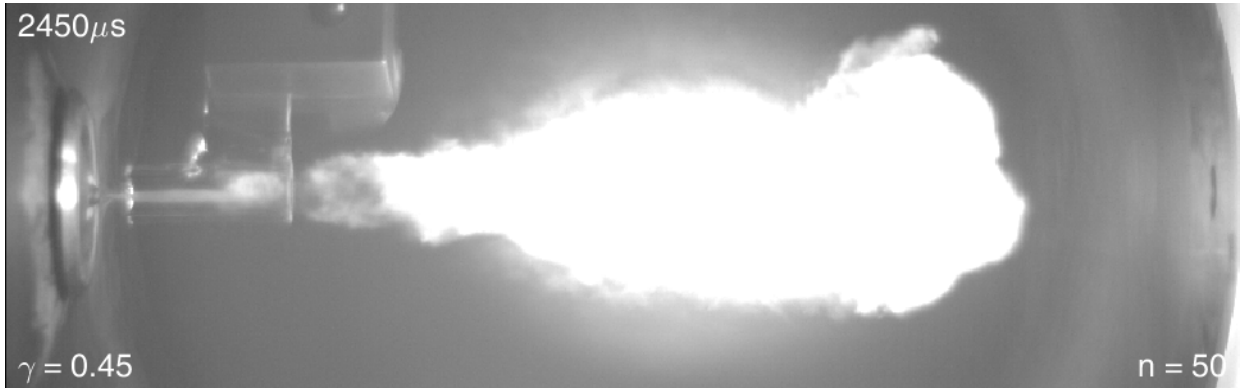


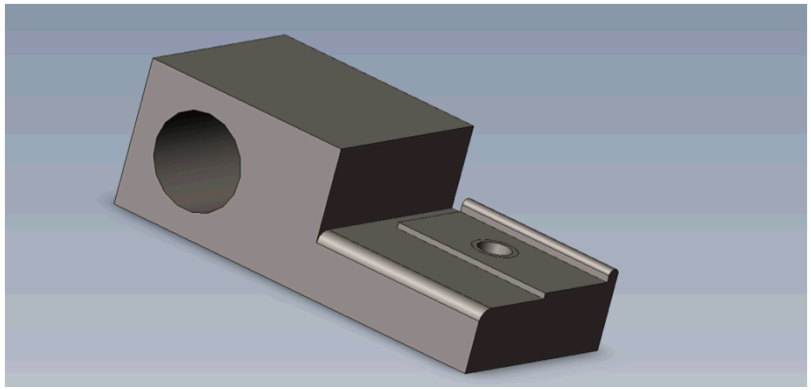
Ducted Fuel Injection (DFI) Concept

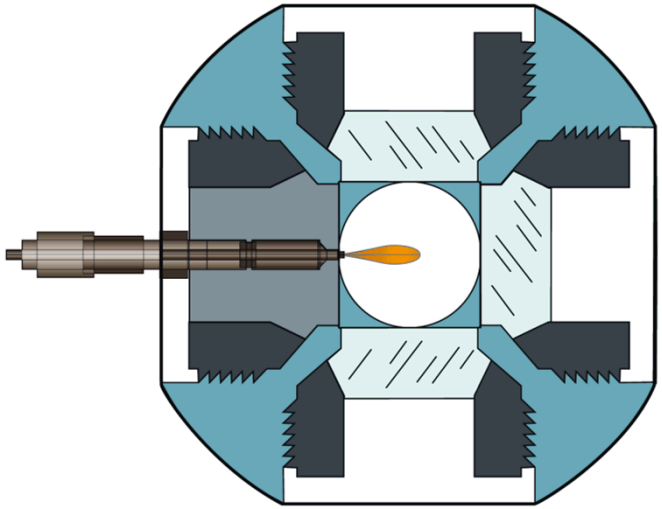
- The flow of the air and fuel through the duct will be turbulent
  - Turbulent flow enhances mixing of fuel and air
- Cooler temperatures inside the duct will reduce heat transfer from the ambient gas to the fuel and may contribute to increased ignition delay
  - Lower equivalence ratios in the autoignition zone have been shown to occur with longer ignition delays



Experiment Setup







Constant Volume-Combustion Chamber

Experiment Conditions

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Variables	
Ambient Gas Temperature	800 K, 850 K, 900 K, 950 K, and 1000 K
Duct Material	Steel and Quartz
Duct Location	1, 2, 4, 6, 7, 10, and 12 mm
Duct Length	7, 14, and 21 mm
Duct Diameter	3, 5, and 7 mm

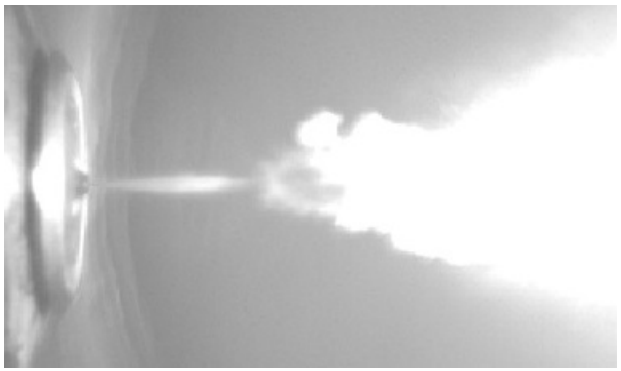
Constants	
Ambient Gas Pressure	~6.0MPa
Ambient Gas Density	22.8 kg/m^3
Ambient Gas Oxygen	21 mol%
Fuel Injection Pressure	150 MPa
Fuel	n-dodecane

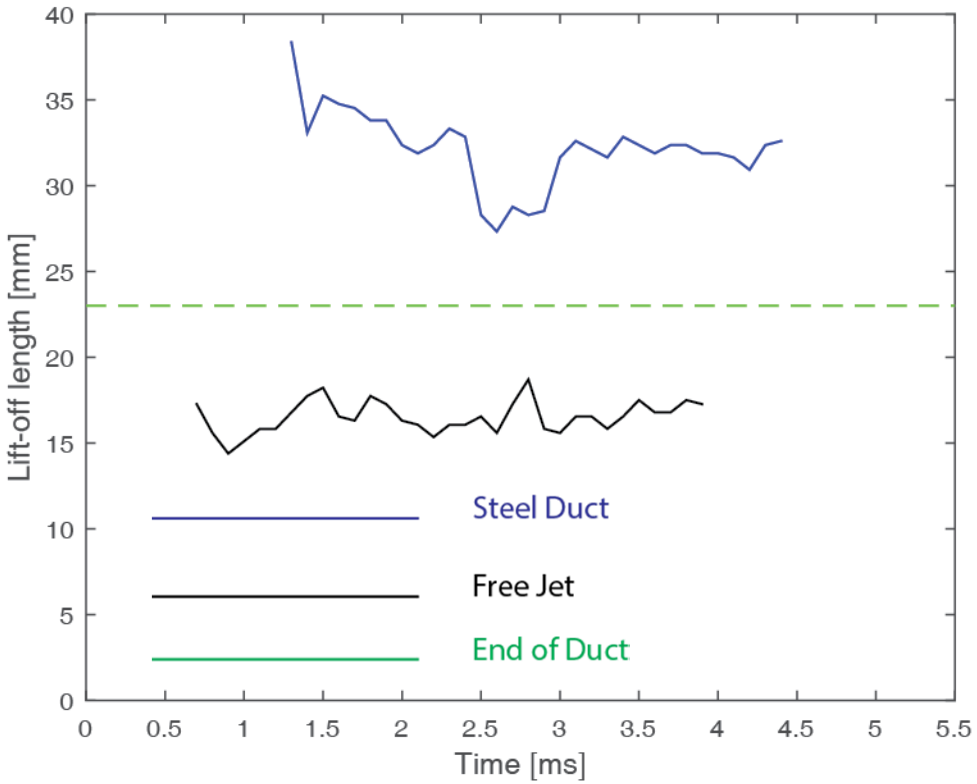
Conditions are based on those used in Spray A research

Video 950 K

Lift-off Length

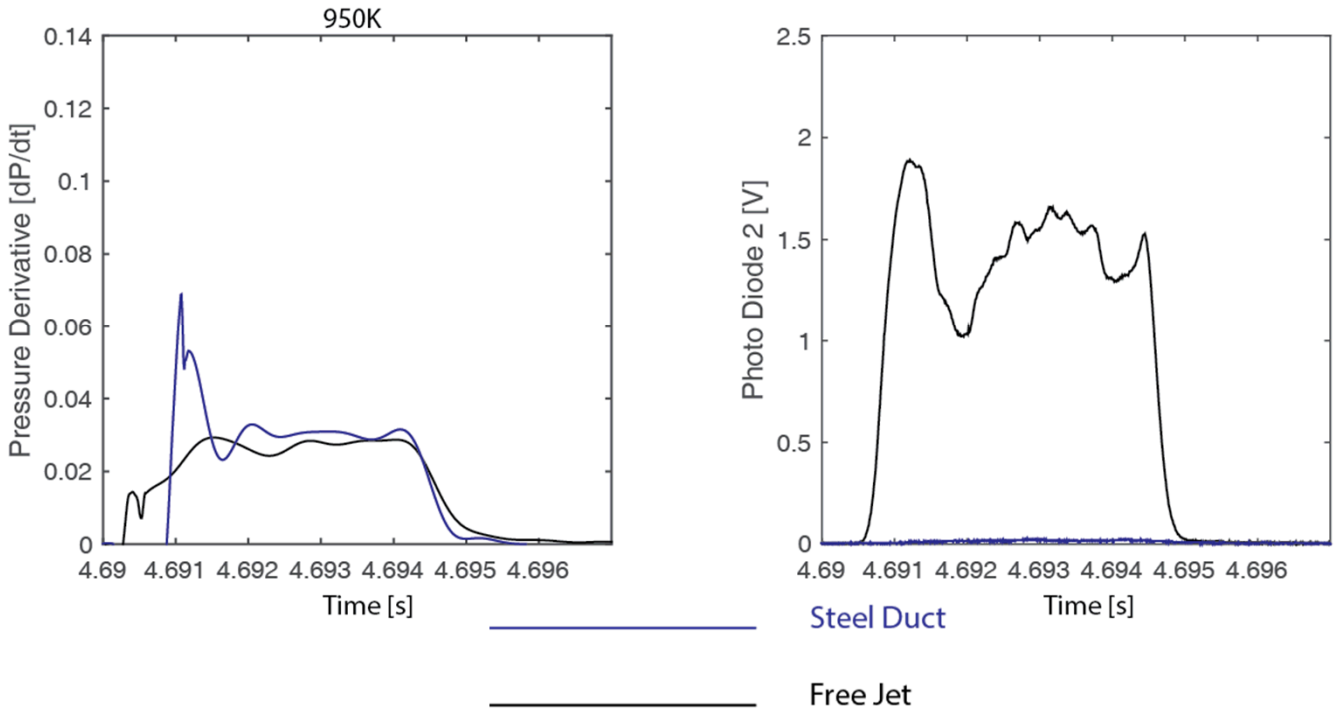
- Longer lift-off length corresponds to longer ignition delay
- The effect of the duct on the total amount of oxygen entrained before autoignition isn't clear
  - Lower soot may be due to duct-enhanced local mixing



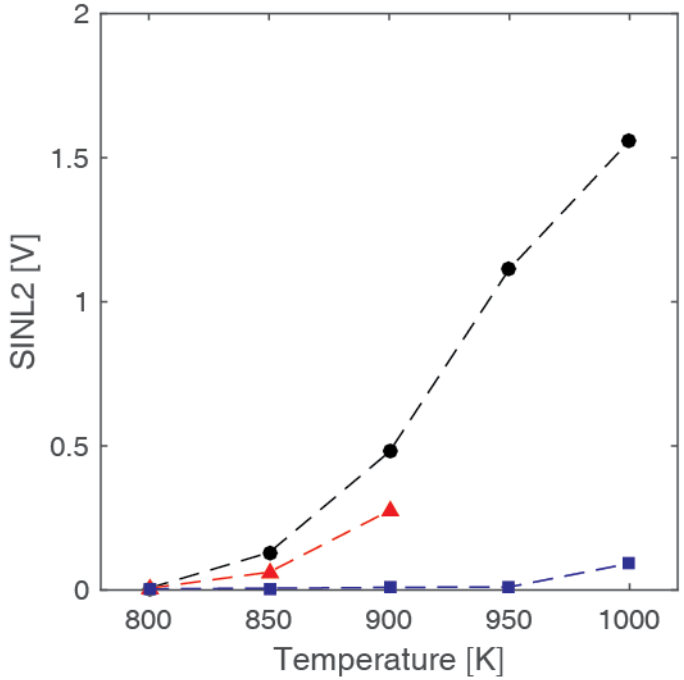


Pressure Derivative and Photodiode Signal

- Pressure derivative shows the start of combustion
- Photodiode shows the relative amount of light produced in each case



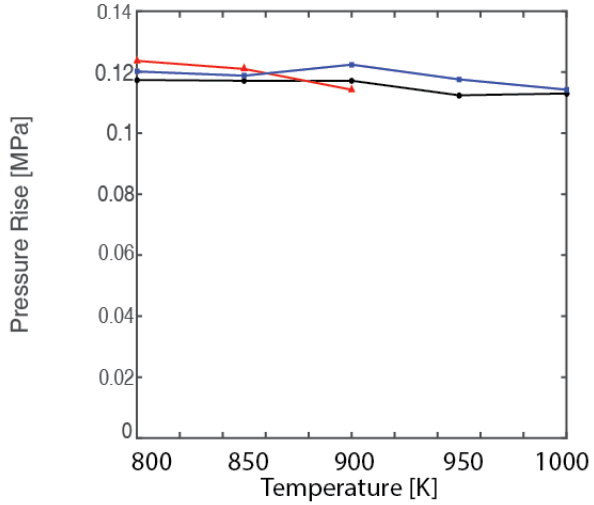
Scalar Data

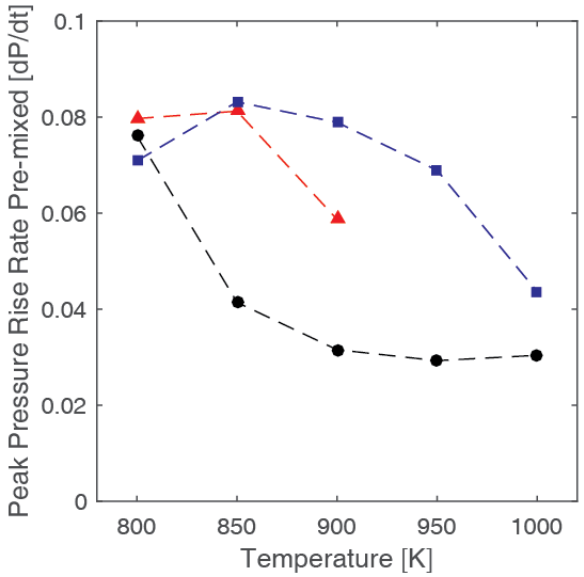


Steel Duct

Free Jet

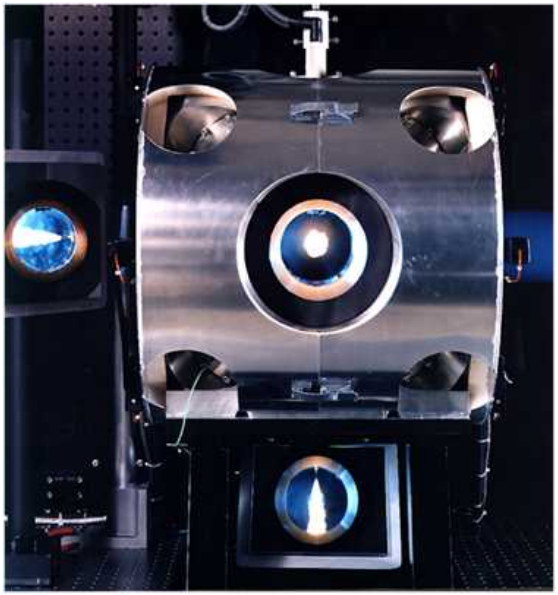
Quartz Duct

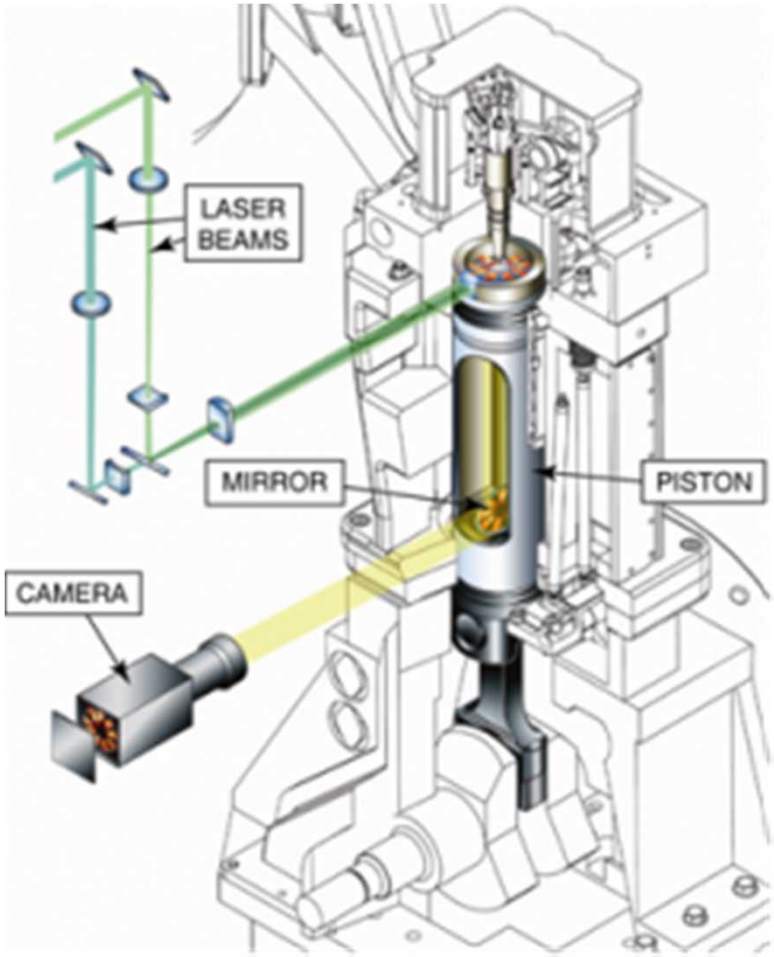




Future Plans

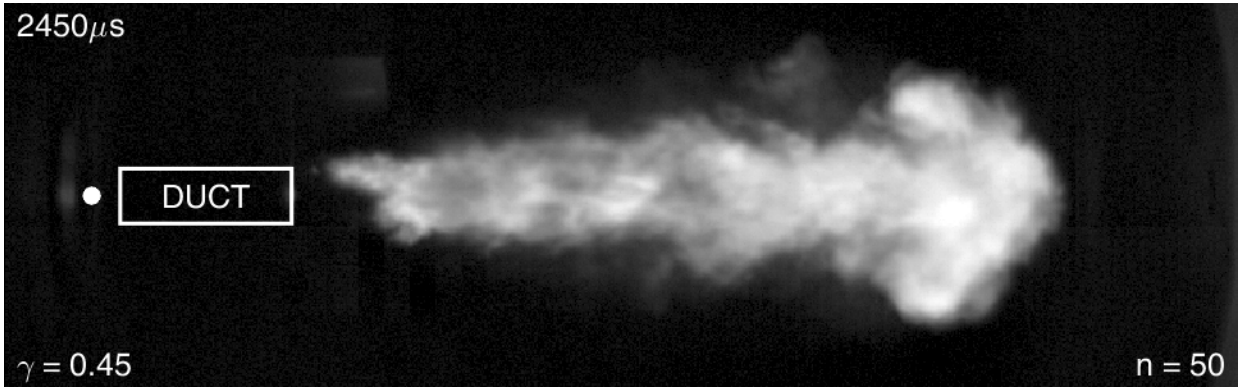
- Computer simulation
- Additional testing in the Constant Volume Combustion Chamber
- Perform experiments with duct inside engine





Conclusion

- The video and photodiode data indicate that less light intensity is seen in the ducted cases
- The consistent pressure rise indicates that the fuel was completely burned in all cases
- Higher heat release rates for the ducted cases suggest combustion is occurring at closer-to-stoichiometric conditions
- The duct appears to enable soot-free, efficient combustion (based on initial testing)



Questions?

Acknowledgment:

Thank you Lyle Picket and Scott Skeen for allowing us to use the Constant Volume Combustion Chamber in your lab to conduct these experiments.