Development of Modelling and Optical Diagnostics at Birmingham

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School of Mechanical Engineering

Acknowledgement

- Work contribution from

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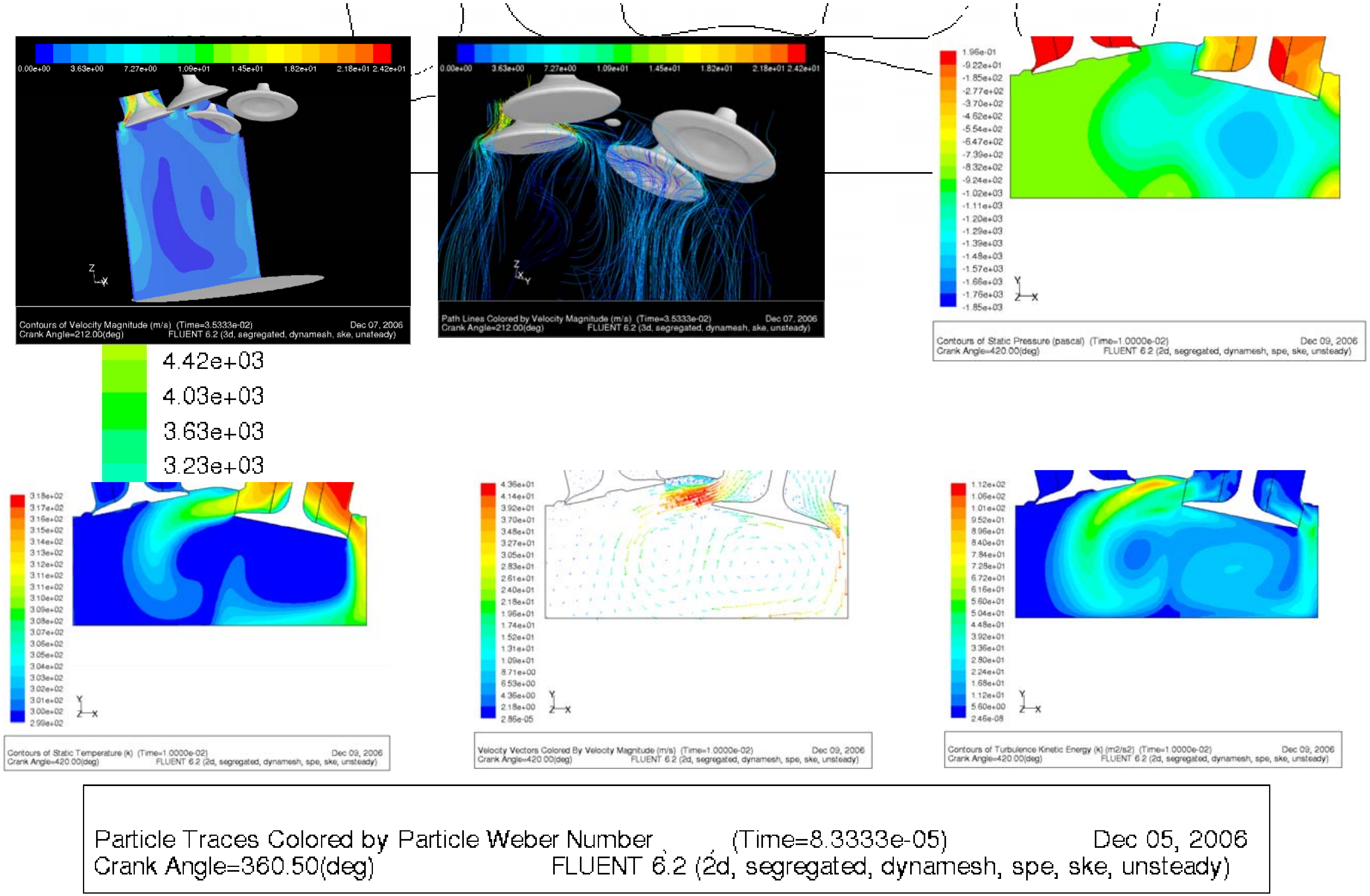
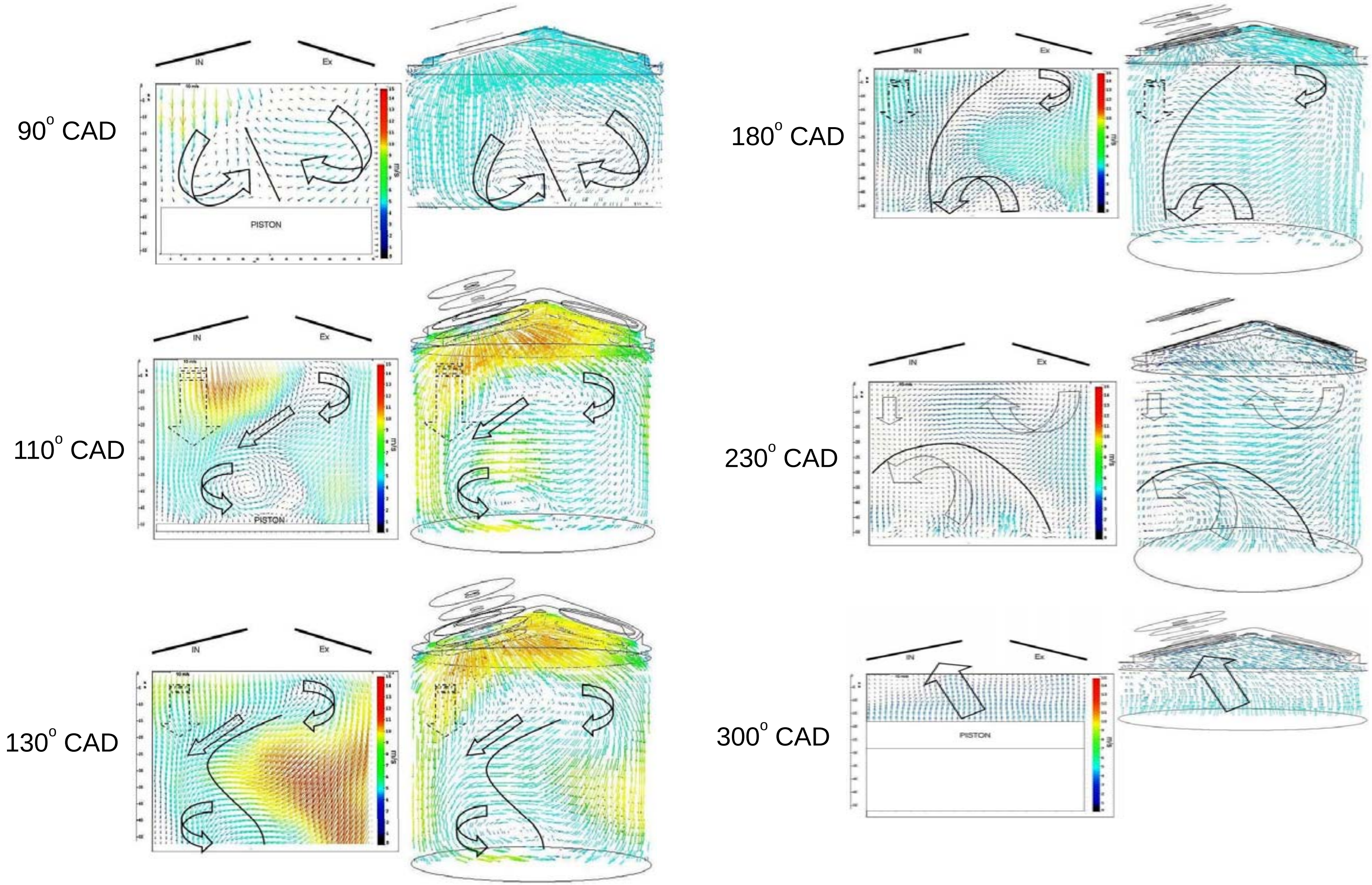
Presentation outline

1. Activities of CFD modelling
2. Activities of optical diagnostics
3. Research on a new bio-fuel candidate
4. Some results and discussion
5. Summary

In-Cylinder Flow

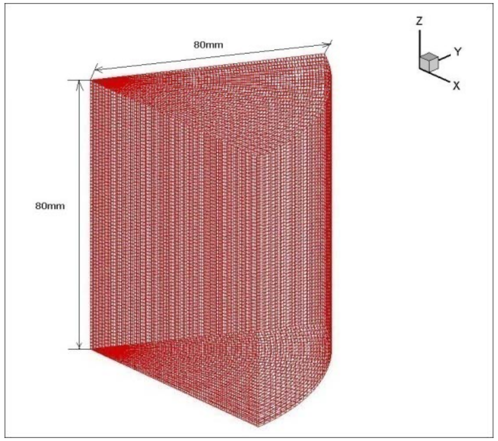


Compare PIV measurement and CFD

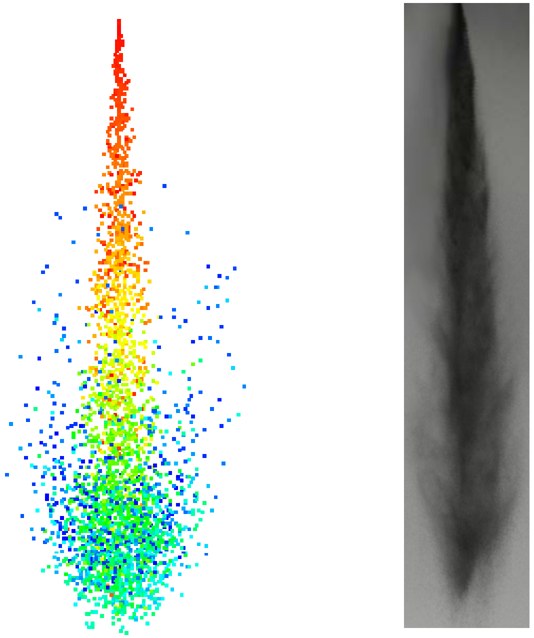


Left: PIV Experiment, Right: CFD Prediction

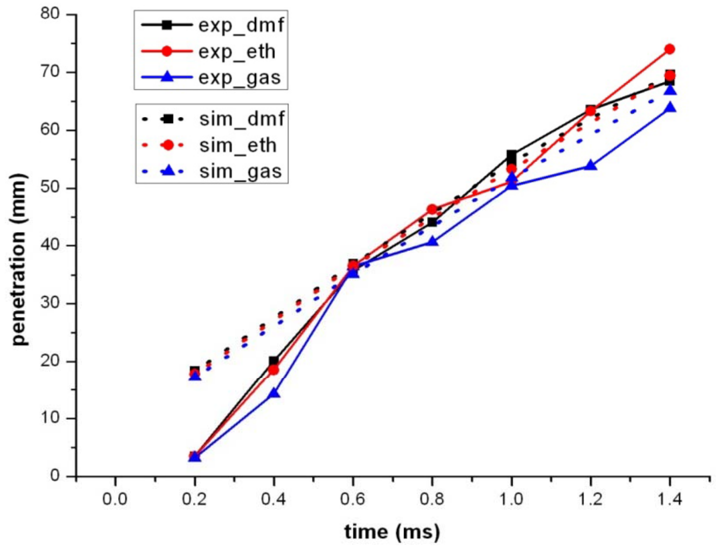
Penetration of biofuel spray



Ambient Pressure	0.99bar
Ambient Temperature	20ºC
Injection Duration	1.6ms
Injection Pressure	100bar
Injection mass	From injector calibration test
Nozzle exit velocity profile	From PDPA

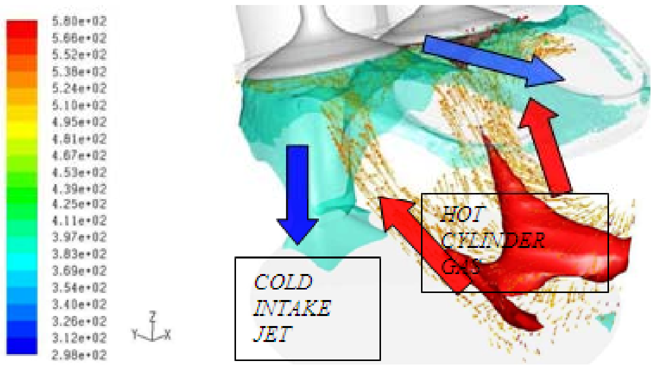


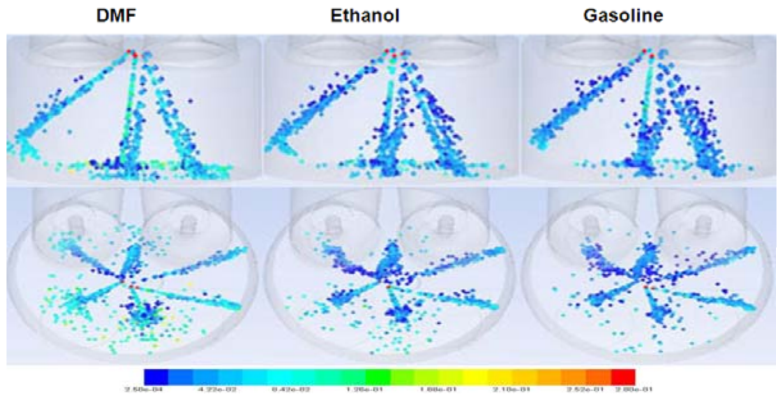
Numerical Results and Image Taken of Spray



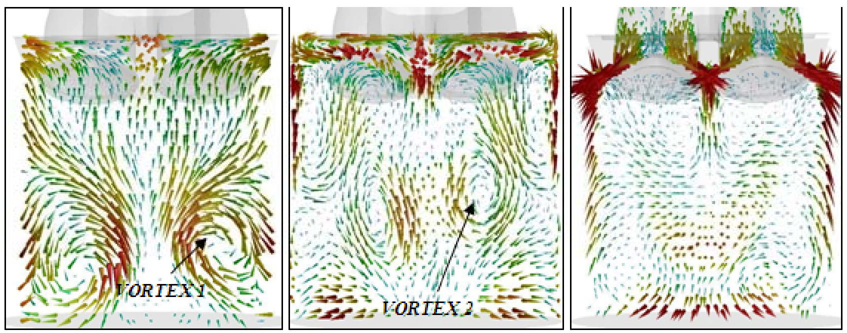
Comparison of Numerical and Experimental Results

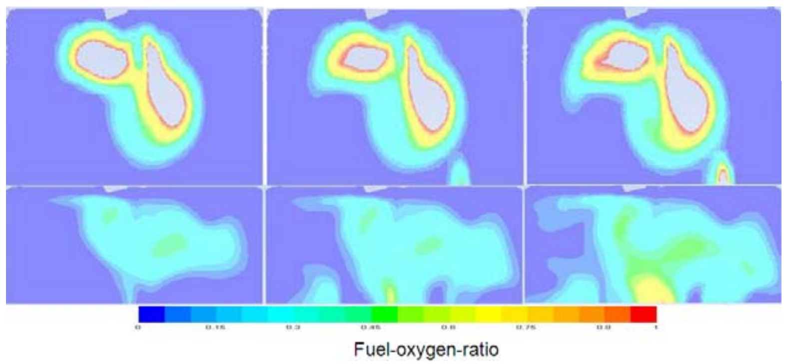
CFD modeling of spray of biofuels





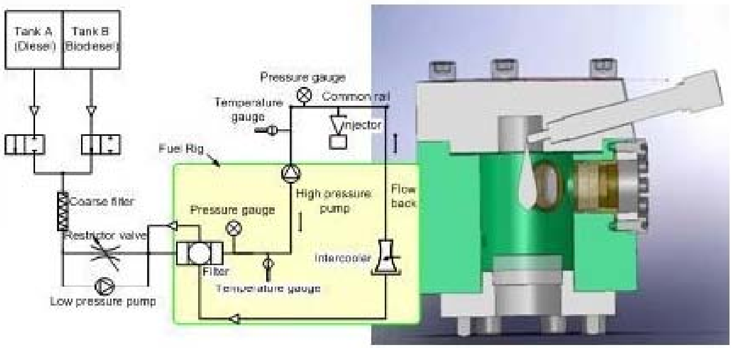
Particle Traces Colored by Particle Diameter (mm)



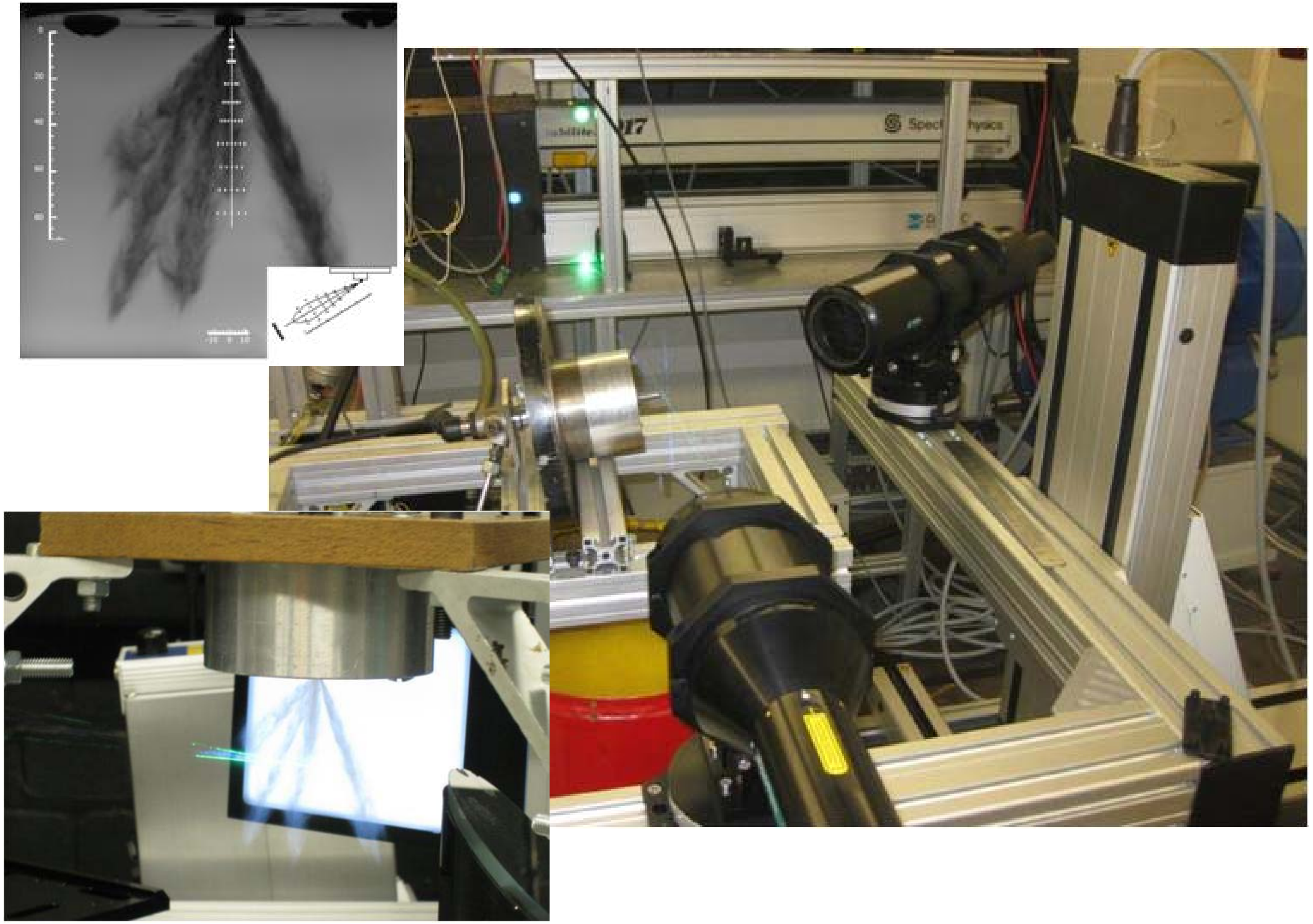


Particle Trace and Fuel-O_2 Ratio

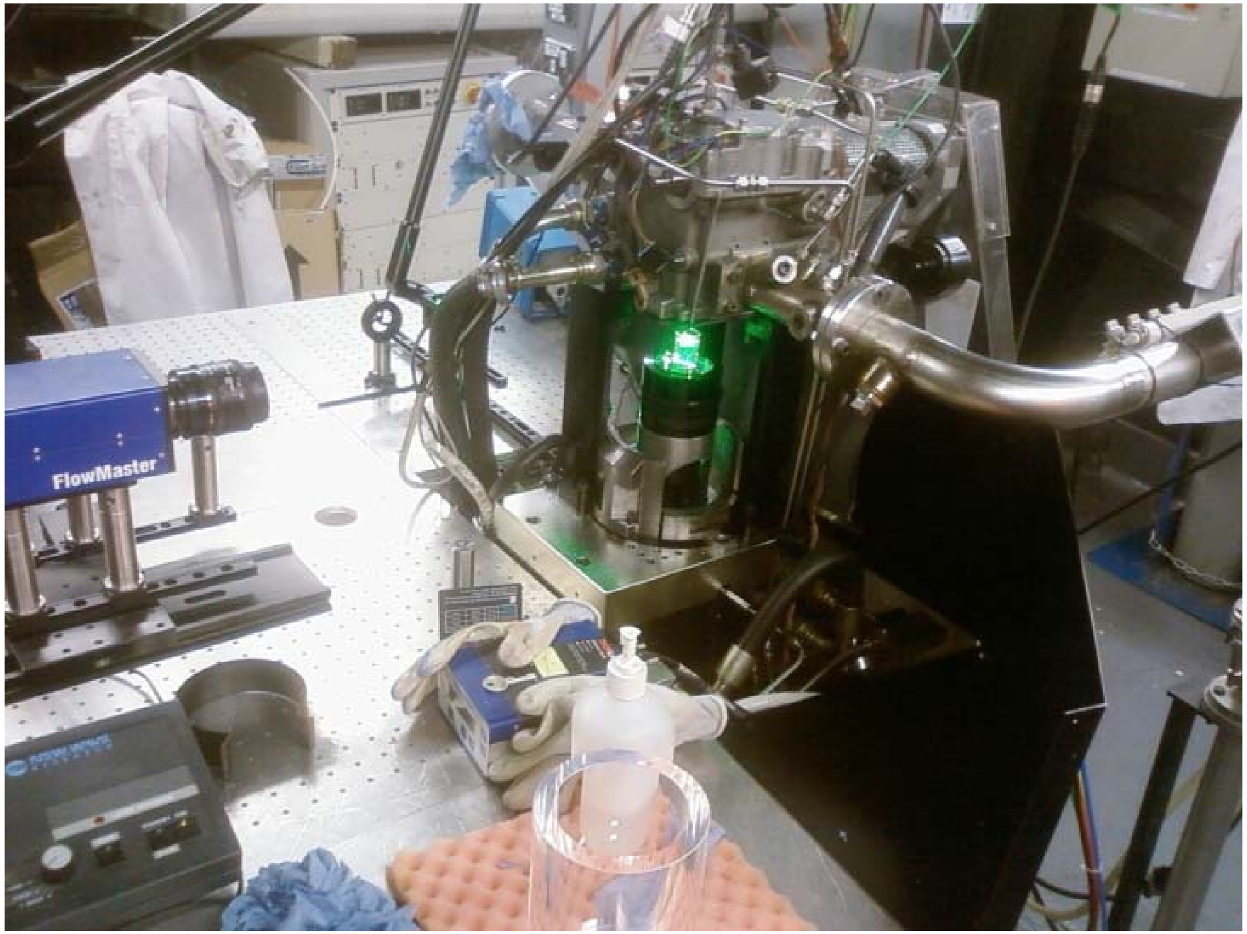
Spray measurements



Spray characteristics by 3D PDPA

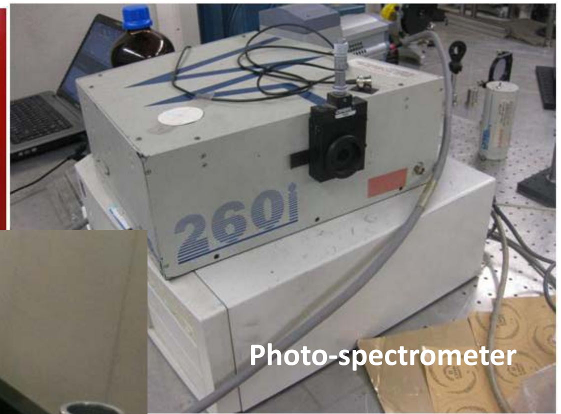


Jaguar optical engine

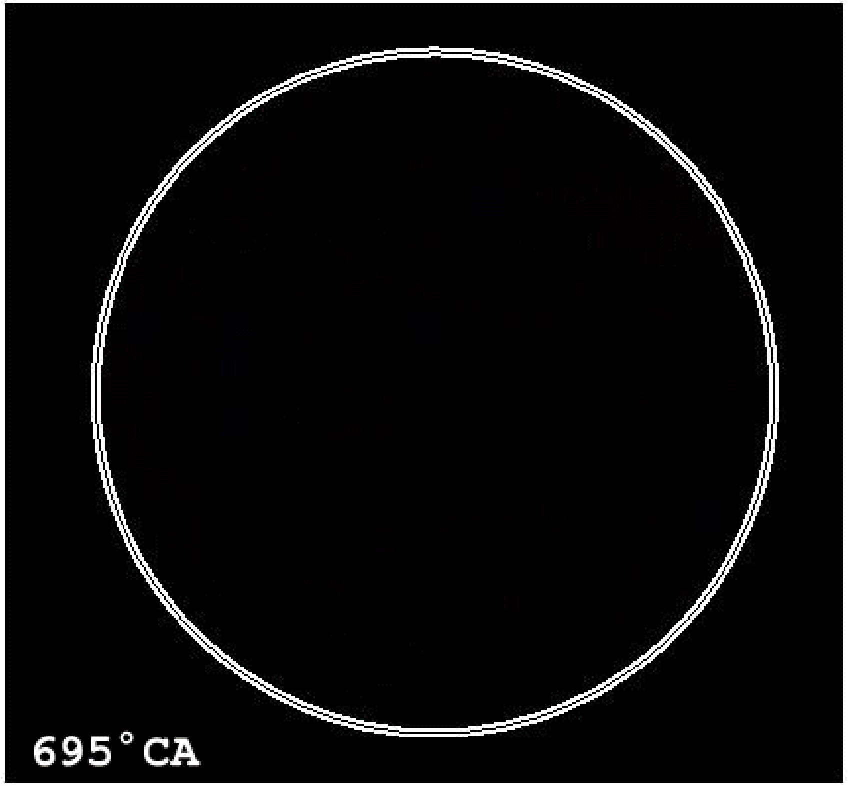


- AJ133 cylinder head with 2nd gen GDI or PFI
- Short and full quartz liner
- Capable of HCCI
- Flexible intake temperature control

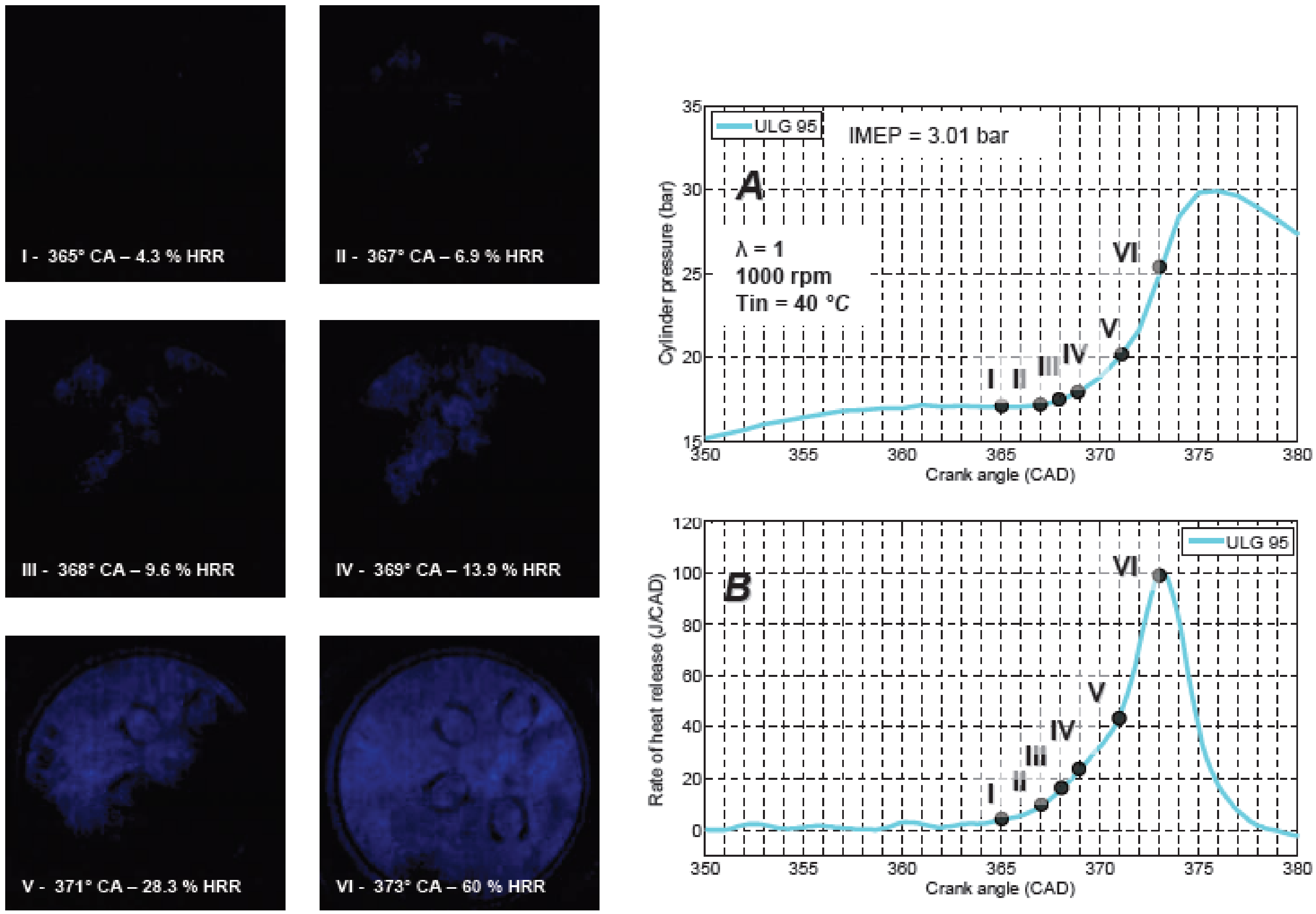
DANTEC PIV/(tuneable)PLIF/LII system



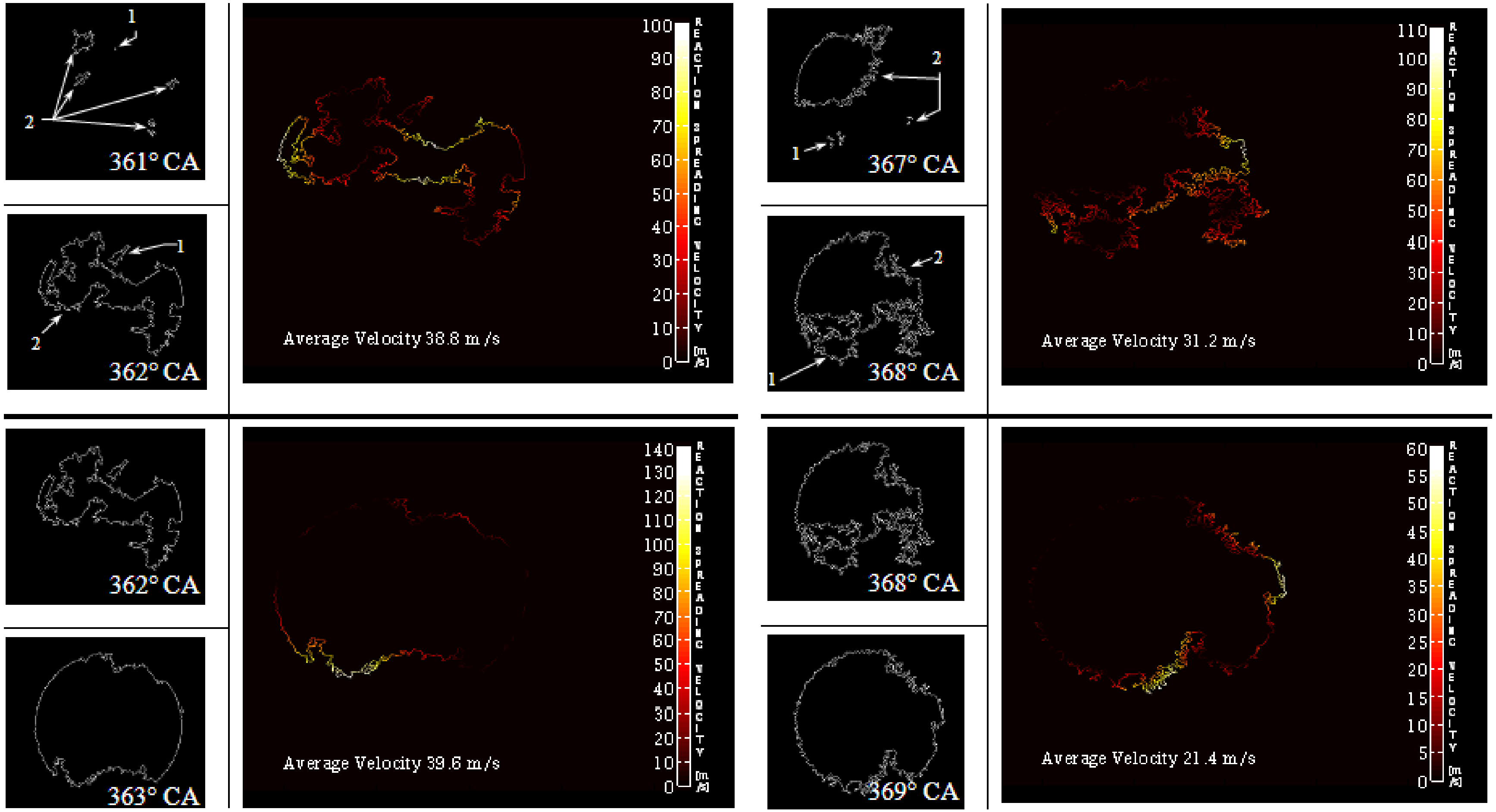
SI/HCCI flame development imaging



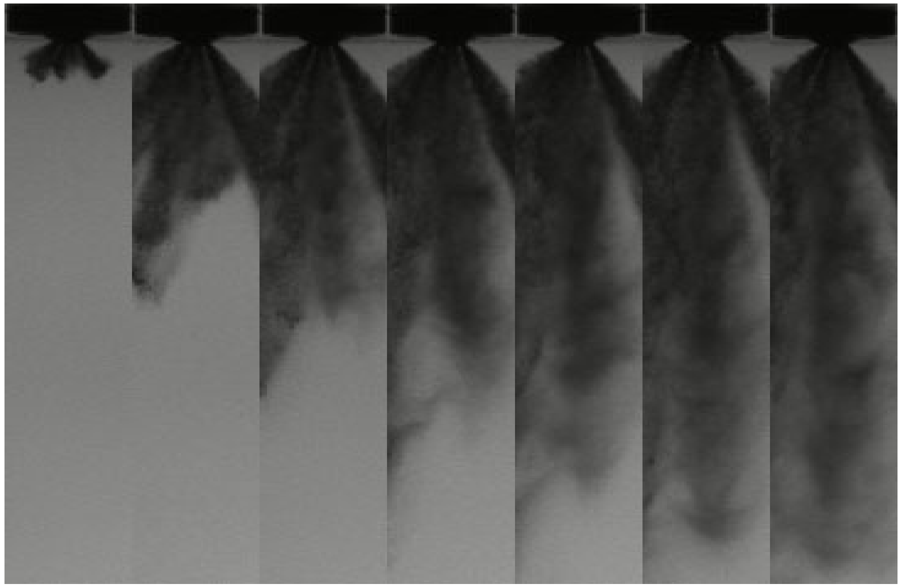
Flame propagation imaging

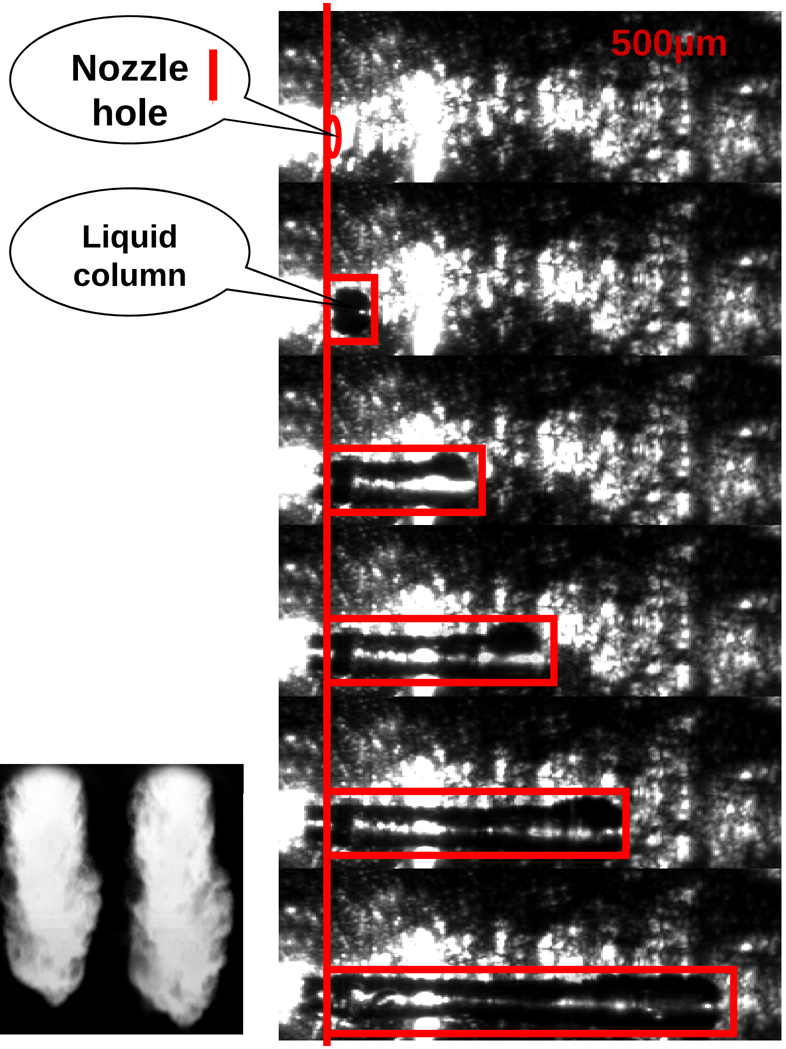


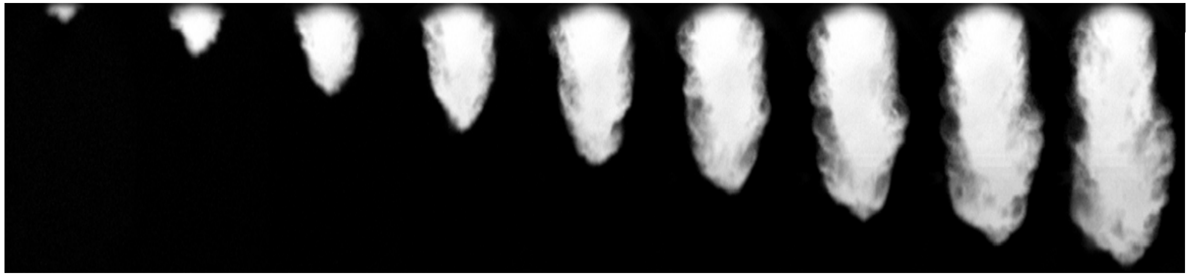
Flame development characteristics



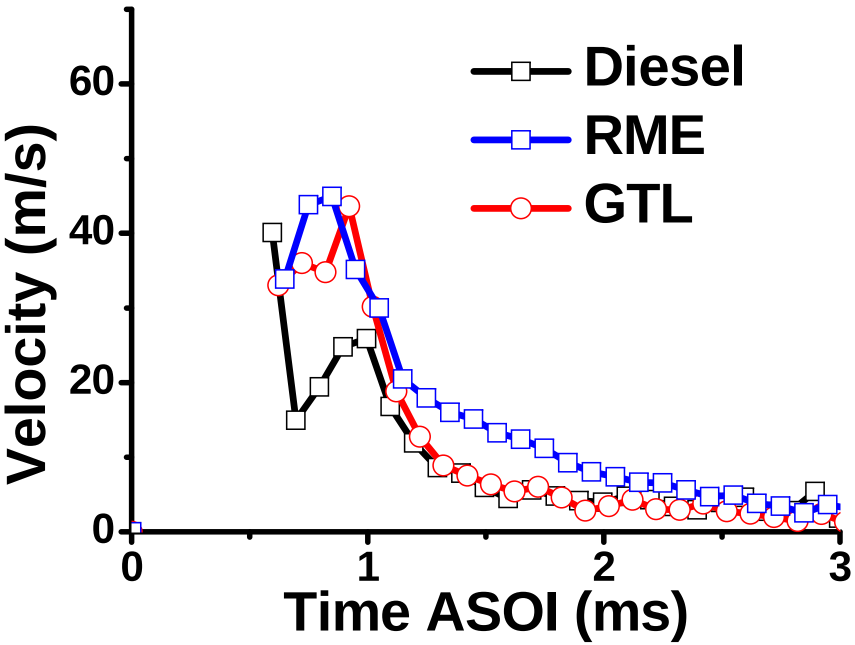
Ultra-high speed CCD Imaging >1m f/s



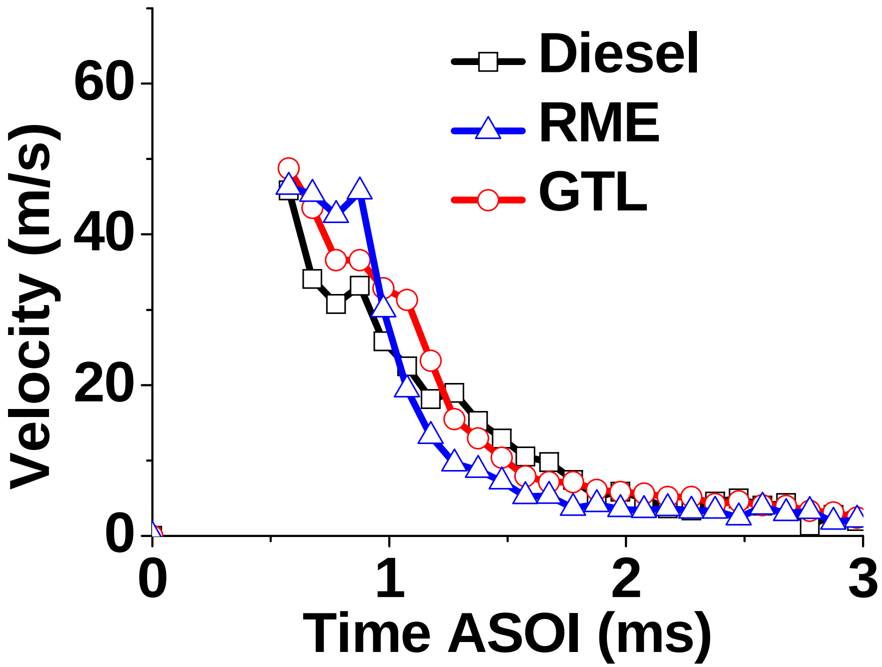




Diesel type of fuel spray characterisation

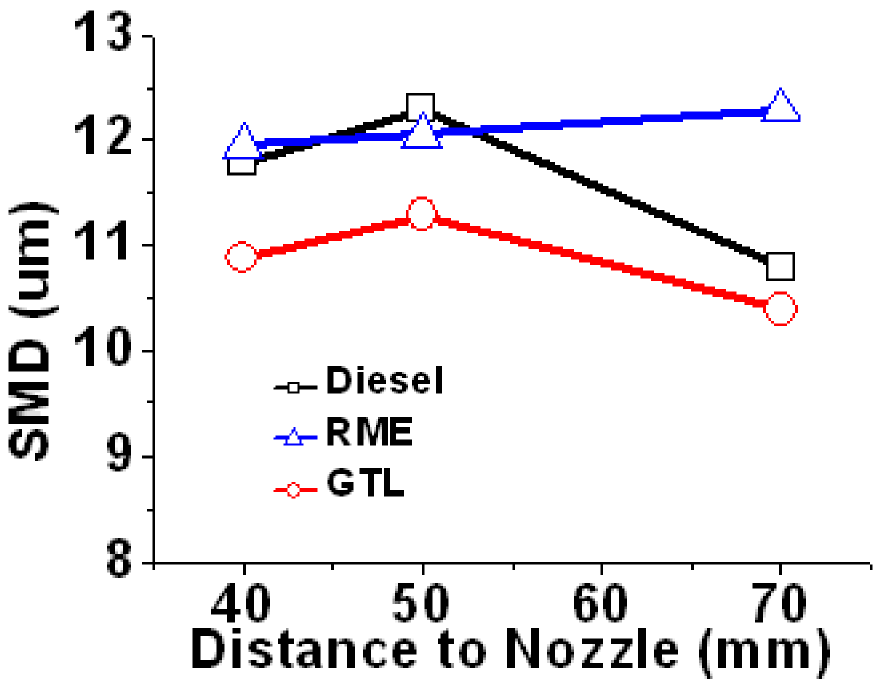


800 bar injection pressure

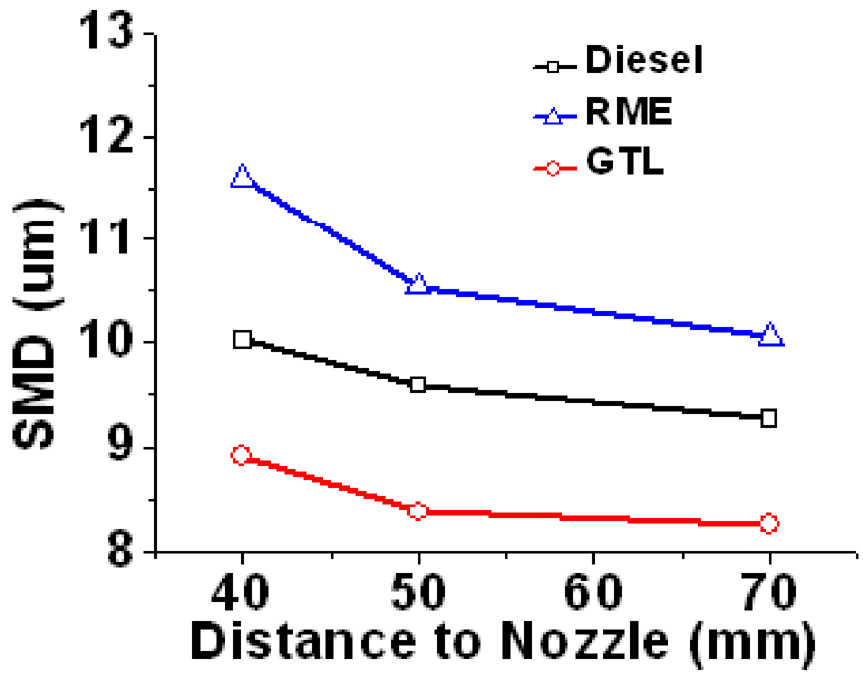


1200 bar injection pressure

Spray characteristics of biodiesels



800 bar injection pressure



1200 bar injection pressure

Collaborative Research Sponsored by EPSRC

Impact of DMF on Engine Performance and Emissions as a New Generation of Sustainable Biofuel

Feb 2009 — August 2012

EPSRC Engineering and Physical Sciences Research Council

EP/F061692/1.

Research Councils UK Energy For a Low Carbon Future

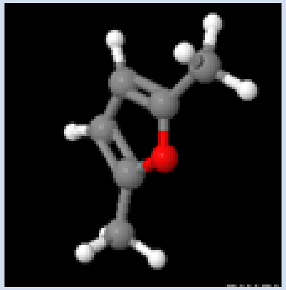
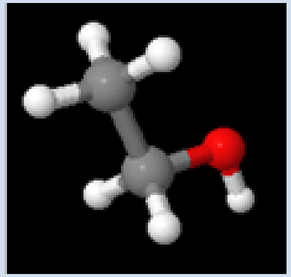
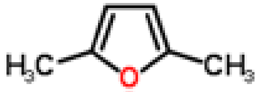
To study the characteristics of combustion and emissions of a newly proposed generation of Biofuel for gasoline (SI) engines with bench-marking to ethanol, involving modelling and experimental study of fuel spray, direct injection mixture preparation, combustion and emissions (regulated and unregulated)

UNIVERSITY OF BIRMINGHAM

partners

JAGUAR · LAND ROVER · Shell · innospec · green fuels · 1896 · TSINGHUA UNIVERSITY 1911

What is DMF

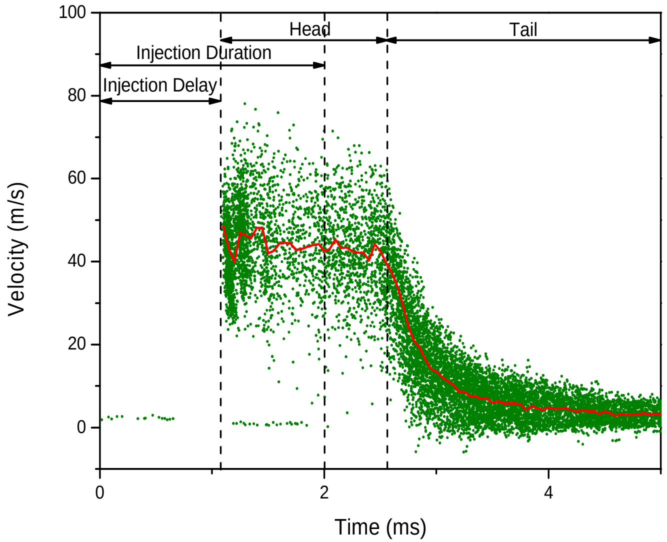
Name(s)[i,ii]	2,5 Dimethylfuran	Ethanol	Gasoline
Linear Structure Formula[i]	$(CH_3)_2C_4H_2O$	CH_3OCH_3	Variable
Molecular Formula[i]	C_6H_8O	C_2H_6O	C_2 to C_{14}
Molecule 3D View[iv]			Variable
Molecule Schematic[iv]			Variable
BP, Boiling Point (1atm)[i]	$93.0°C$	$77.3°C$	
Enthalpy of Vaporization[iv] ($20°C$)	$31.91 kJmol^{-1}$	$43.2496 kJmol^{-1}$	
Enthalpy of Combustion[iii]	$42.0 kJmol^{-1}$	$26.9 kJmol^{-1}$	$43.4 kJmol^{-1}$
ρ, Density of Liquid [i]	$0.8954 kgm^{-3}$ @$20°C$	$0.79363 kgm^{-3}$ @$15°C$	
Research Octane Number (RON)[v]	119	110[vii]	95[iv]
Auto Ignition Temperature[vii]	$285.85°C$	$423°C$	$257°C$

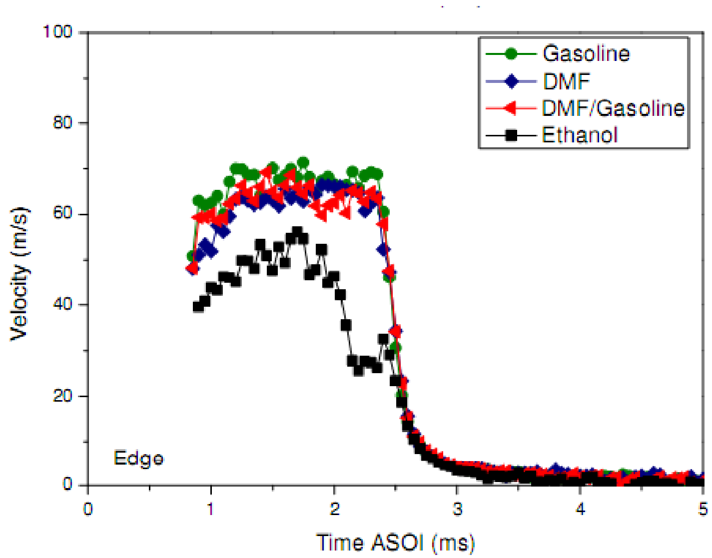
Why DMF is good?

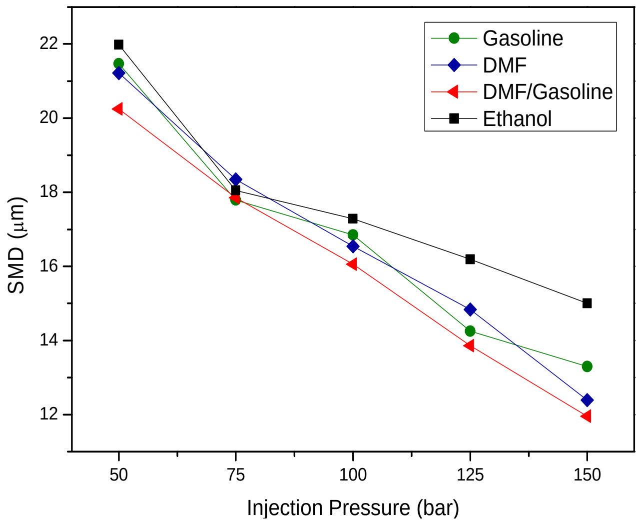
- DMF has physical properties very close to gasoline, but it has a very high octane number (RON=119) and relatively low volatility.
- Compared to ethanol, it has an energy density higher by 60 per cent in volume and by 40% in mass.
- DMF is stable in storage and not soluble in water and therefore it cannot become contaminated by absorbing water from the atmosphere.
- It consumes only one-third of the energy in the evaporation stage of its production, compared with that required to evaporate a solution of ethanol produced by fermentation for biofuel applications.

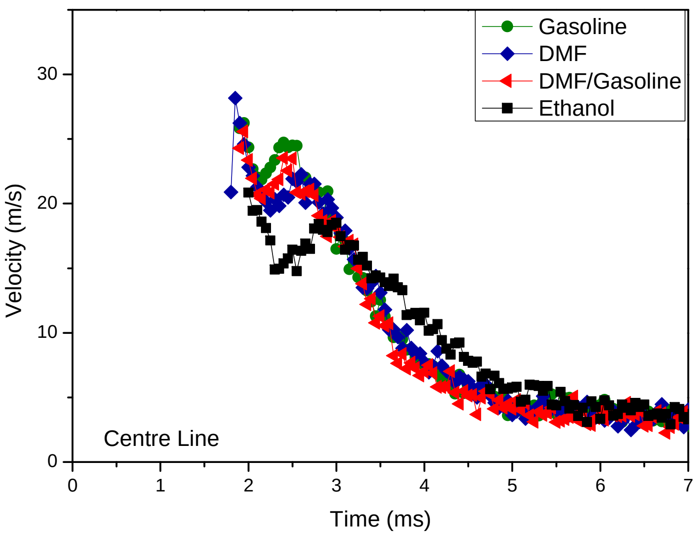
The most attractive advantage is that making DMF will not compete with land and food, and therefore it can be an ideal candidate for a new generation of sustainable bio-fuel!

Gasoline type of fuel spray characterisation

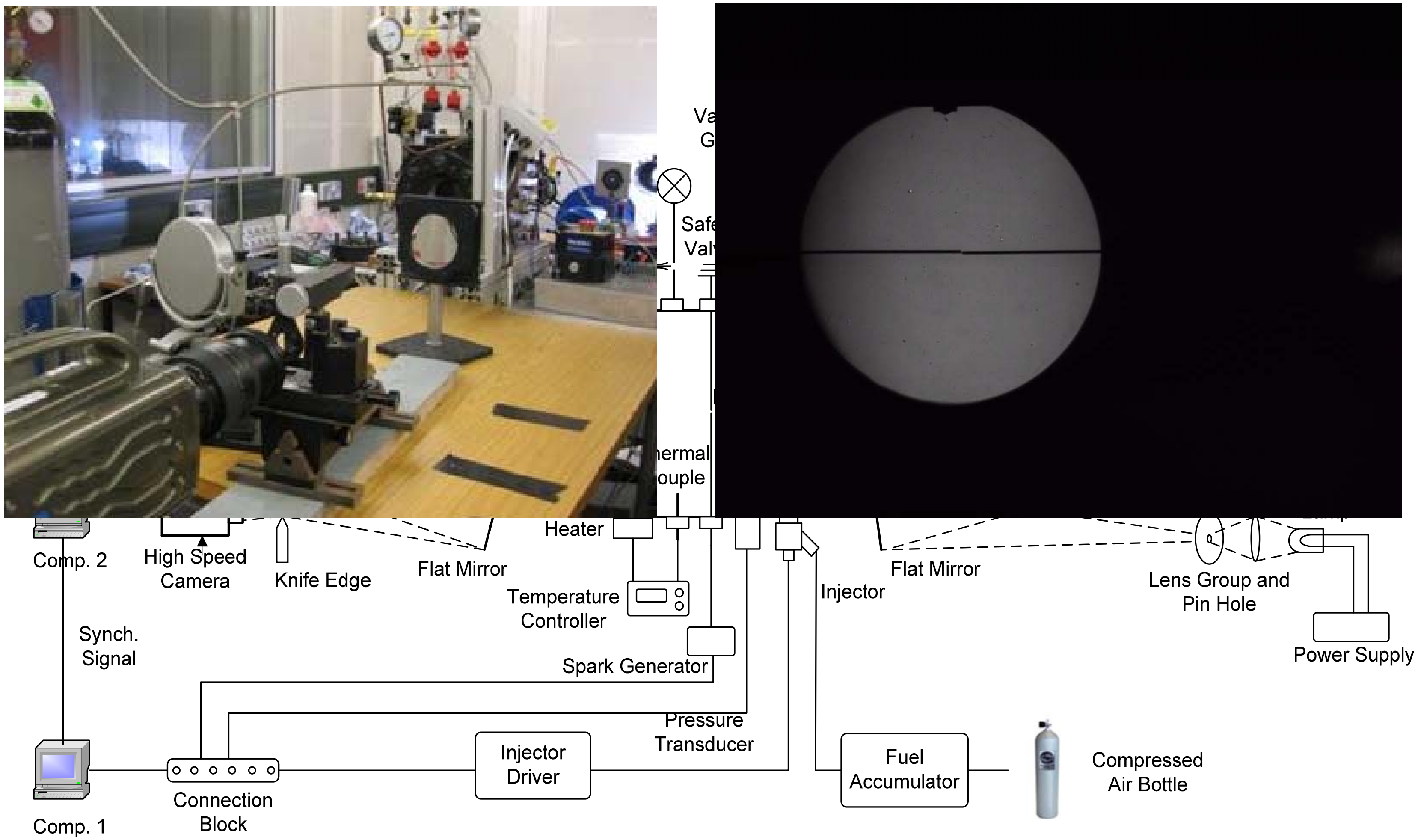




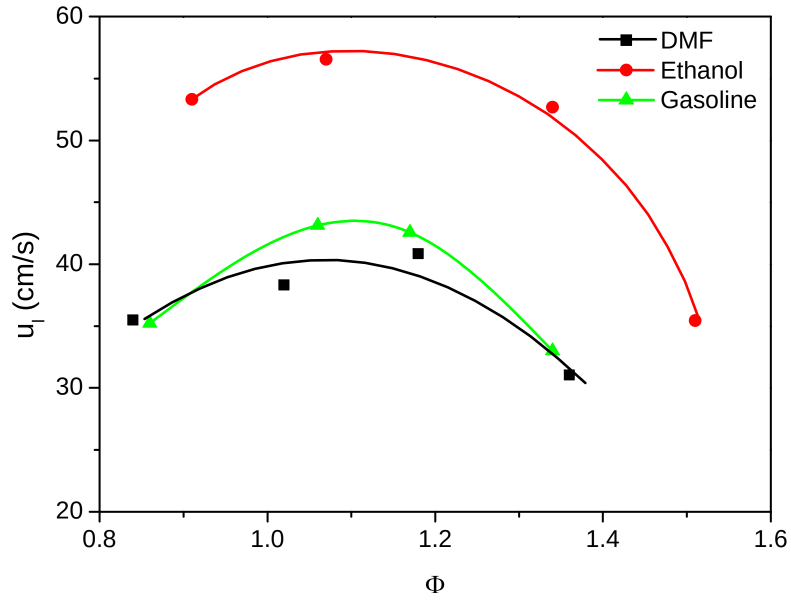




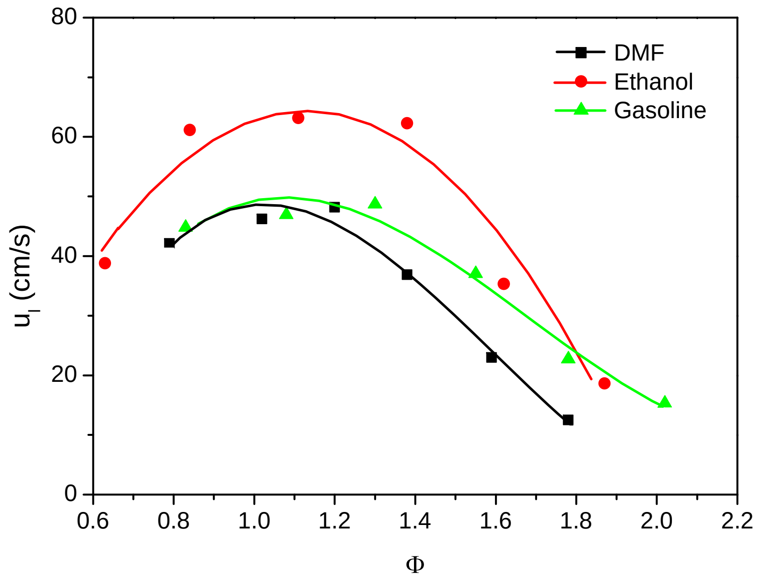
Ignition, flame propagation and speed



Laminar burning velocity of biofuels



50°C initial temperature

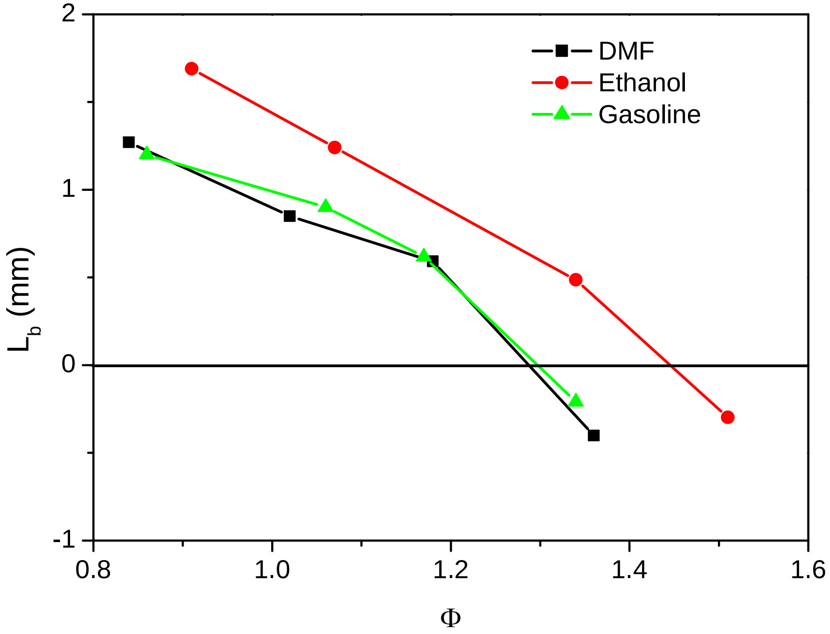


100°C initial temperature

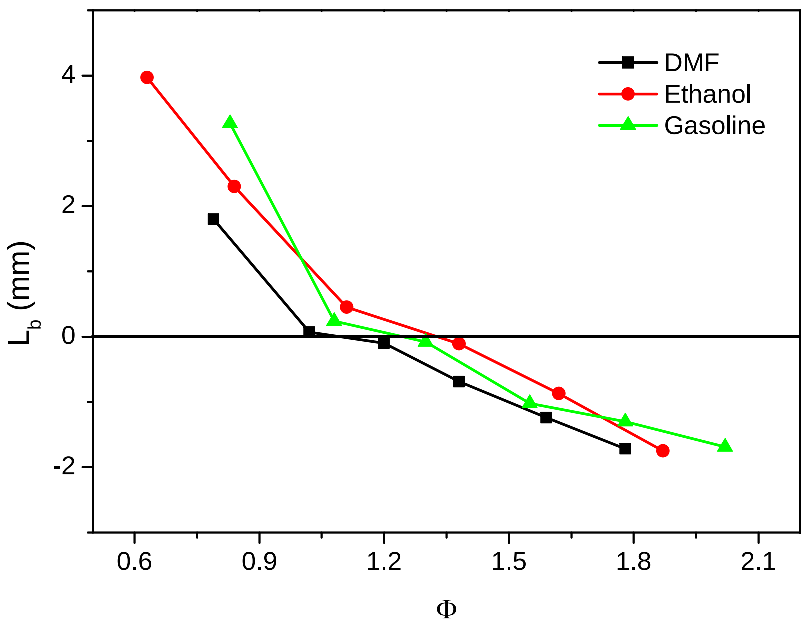
•The laminar burning velocity of DMF is closer to gasoline than ethanol for given initial test conditions.

•Ethanol's laminar burning velocity is the highest amongst the three fuels for the test conditions studied with respect to temperature and equivalence ratio, and it is approximately 30-40% faster compared with DMF.

Markstein length as a function of T_i and Φ



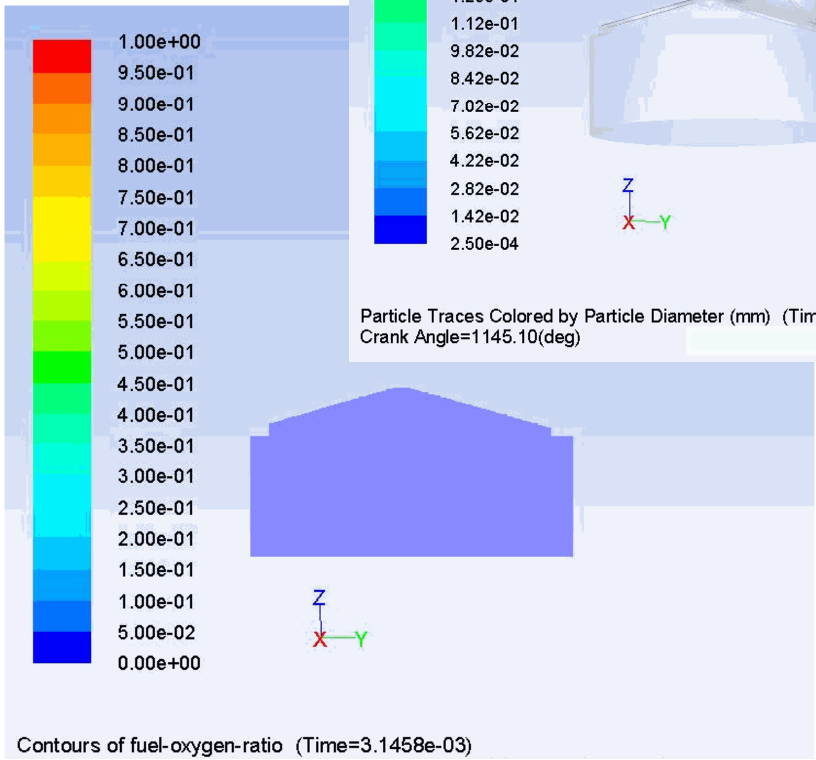
50°C initial temperature

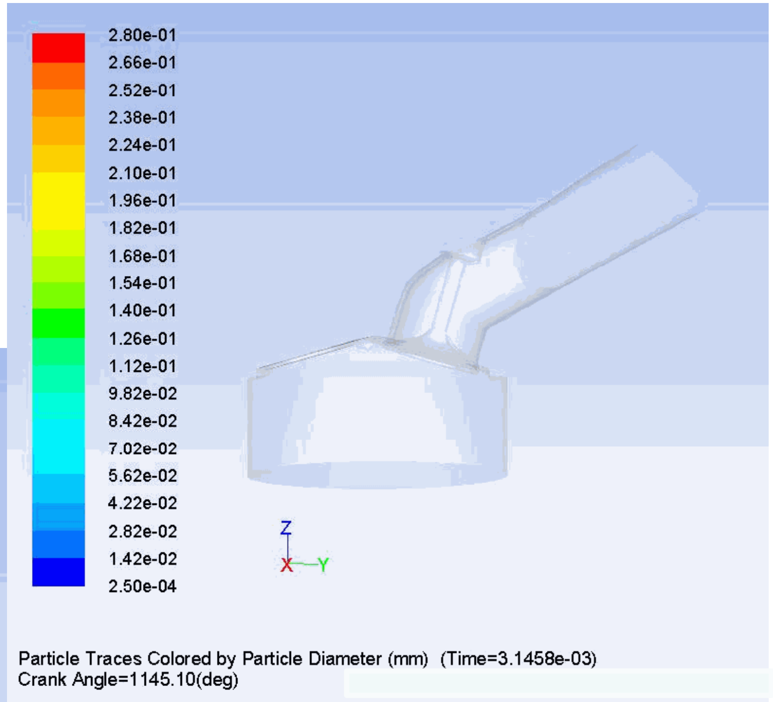


100°C initial temperature

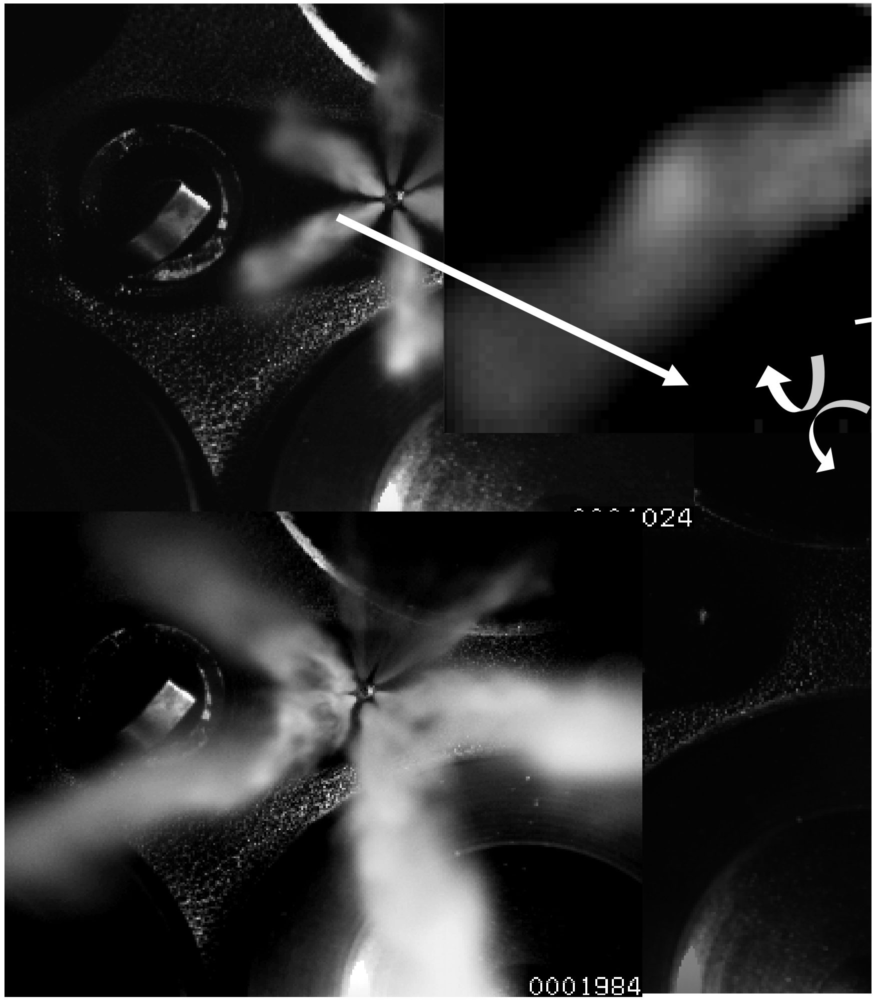
Positive Markstein lengths indicate that the flame speed is decreased with the increase of the stretch rate, while a negative Markstein length indicates that the flame speed is increased with the increase of the stretch.

DMF- biofuel spray modeling and validation

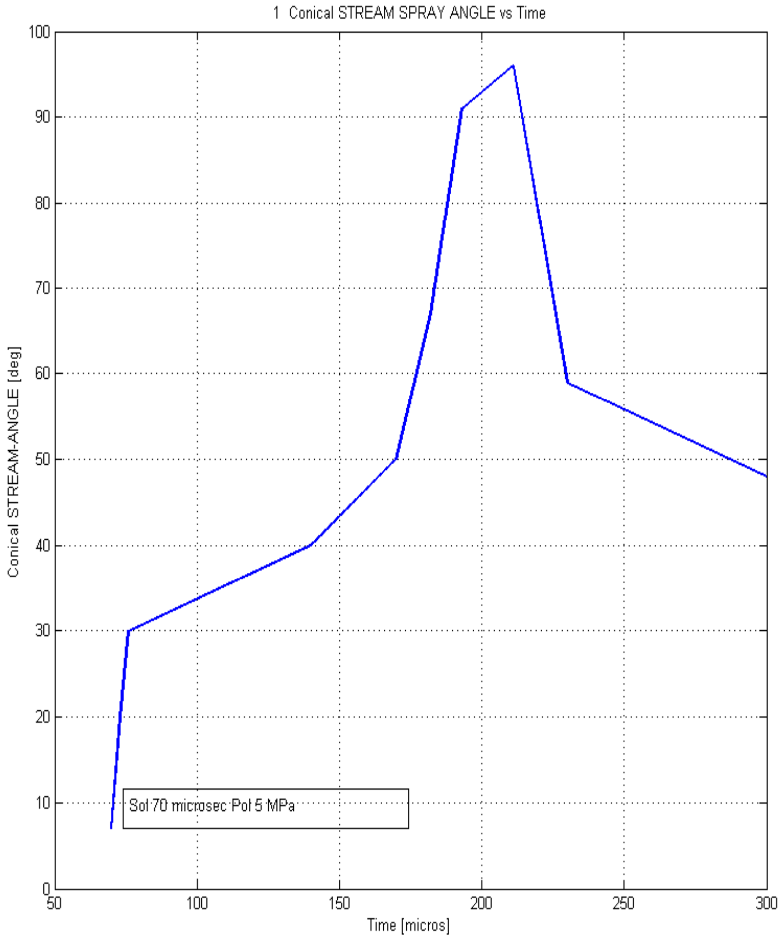




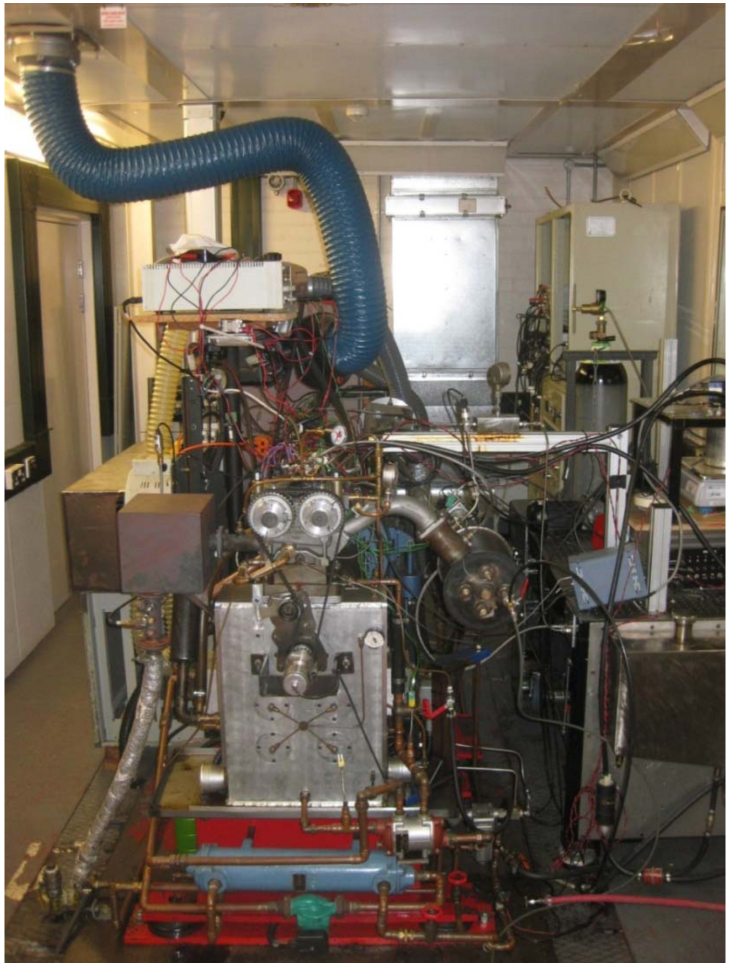
Imaging fluctuation of direct injection spray



Angle Fluctuation of the spray plume in-cylinder



Single cylinder AJ133 Engine



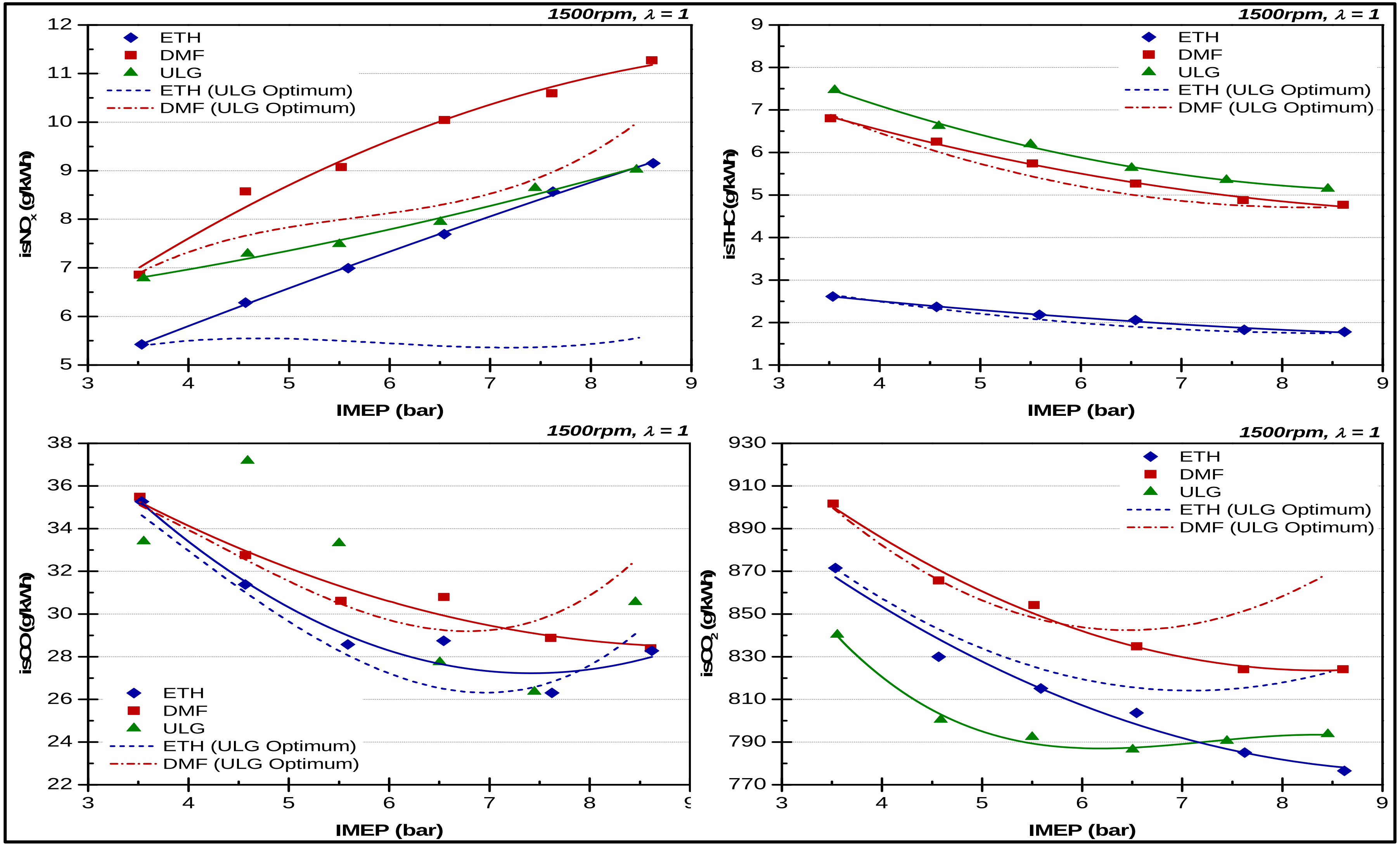
Compression ratio variable by changing the piston crown

Intake temperature variable between 25 – 350 C degree

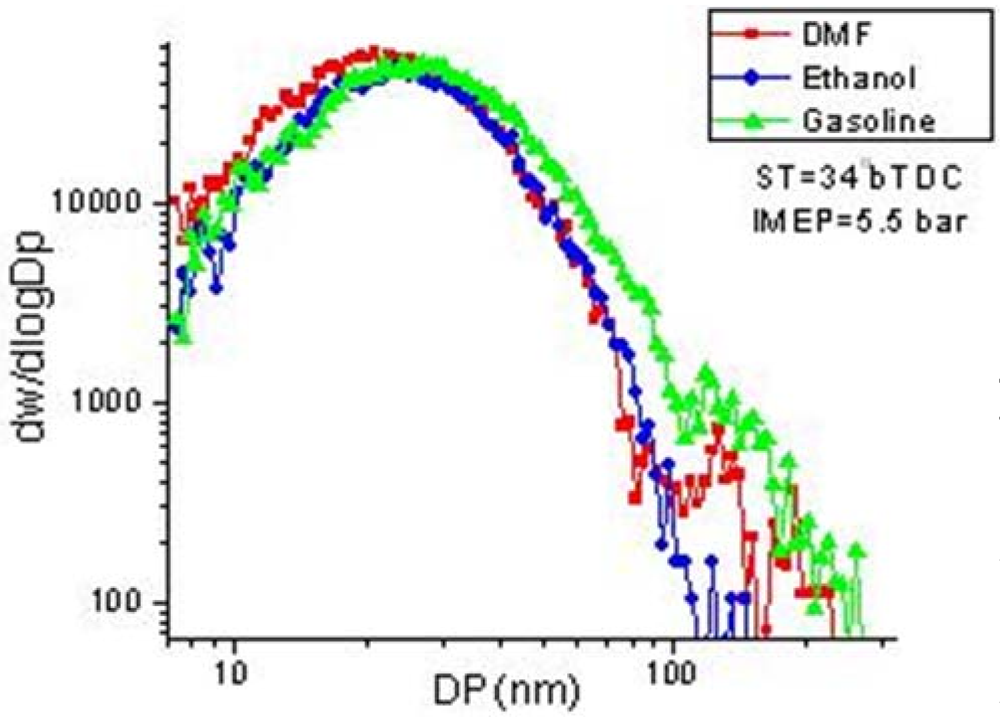
AJ133 2nd generation spray guided GDI

Variable valve timing for intake and exhaust

DMF - Comparison of emissions

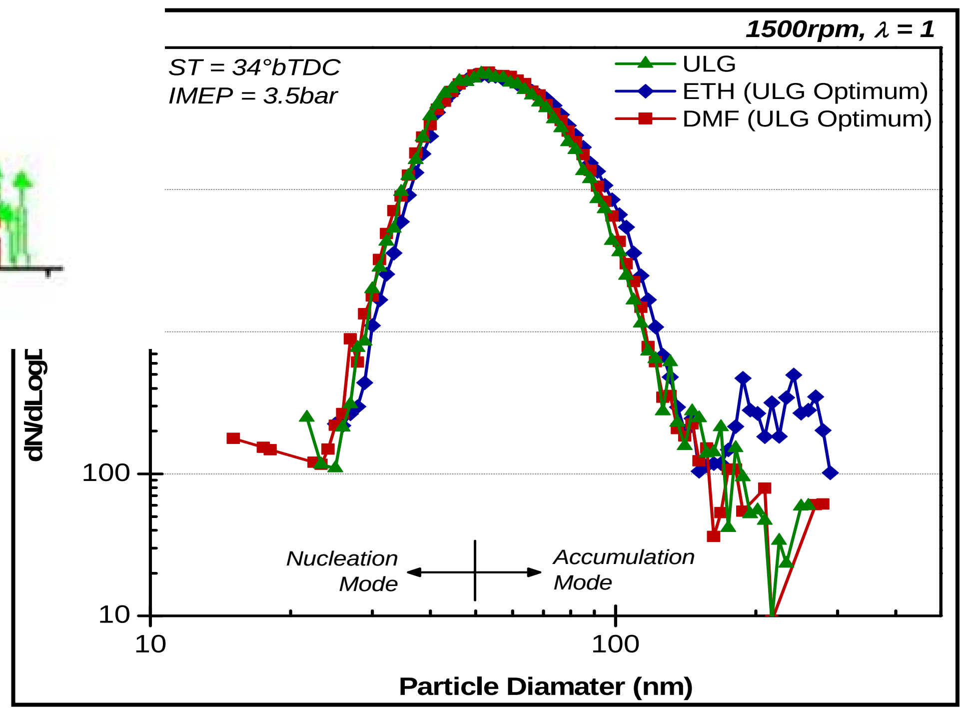


Particulate matter emissions



Higher loader load 5.5bar IMEP, 1500rpm

Lower load 3.5bar IMEP, 1500rpm



Summary

1. One key to the successful morden engine development is through the application of CAE /CFD modelling to provide tools for optimisation of the engine design.

2. CFD modelling requires necessary input parameters and validation, without which they mean very little to motor industry.

3. Optical diagnostics is the most effective technique to visualise the engine flow and combustion and supply required data to CFD models and their validation.

4. These tools and techniques have been developed and used to investigate the fuel spray, mixture formation and combustion for the reach of future fuels including new candidates for biofuels.

5. DMF has been shown a promising biofuel candidate but more research is required to complete the full investigation.

Thanks very much for your attention