Spray A experimental efforts

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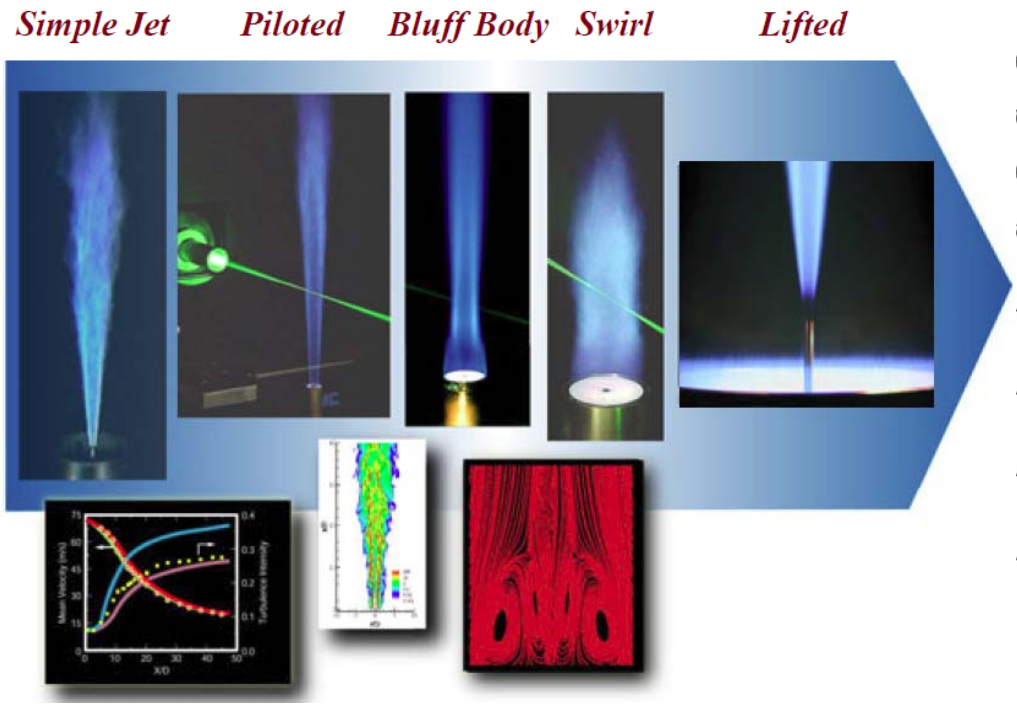
IFPEN

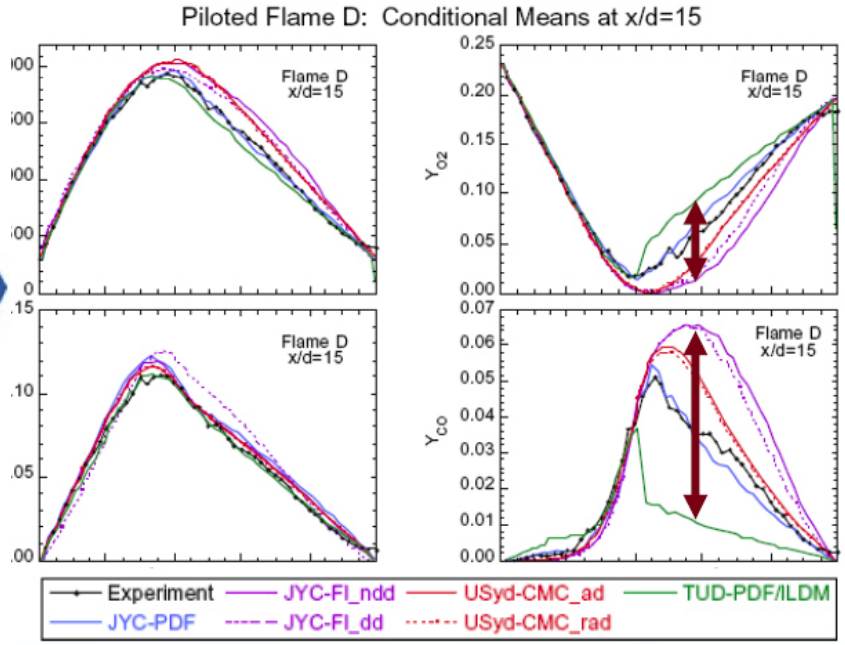
Spray A session

- Context
  - ECN/Spray A
- Objectives
- Organization
- Topics of interest / Contributing institutions

ECN idea modeled after the Turbulent Non-Premixed Flame (TNF) Workshop.

- Use a series of well-defined, canonical flames to promote model development applicable to turbulent combustion.





90 participants at last workshop.

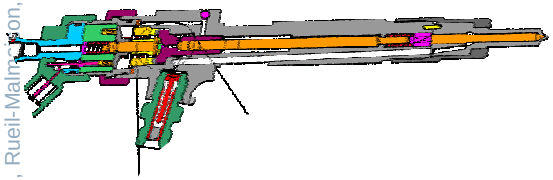
- This type of dataset and focused modeling effort does not exist for engine conditions!
- We need to (and can) delve deeper to understand the workings of engine sprays.

ECN goals

- Establish an international experimental database for model validation in realistic engine conditions
- Provide a framework for collaborative comparisons of measured and modeled results
- Identify priorities for further experimental and computational research

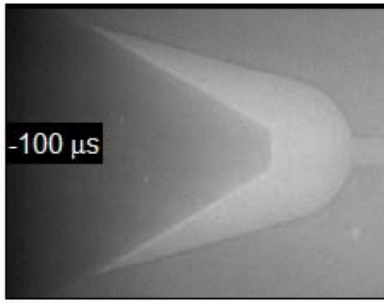
Spray A database

Bosch
Donates 10 "identical" common-rail injectors



Argonne (x-ray source)
Internal needle movement
Near-nozzle liquid volume

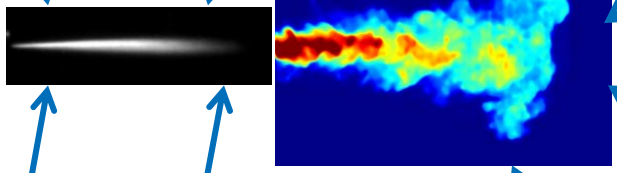
Blowup of needle motion



General Motors
Mixing
Droplet sizing

Michigan Tech. Univ.
Vessel temperature composition

IFP (France)
Spray velocity
Combustion



CMT (Spain)
Rate of injection
Spray momentum

Caterpillar
Lift-off length
nozzle shape

Sandia
Liquid and vapor mixing
Combustion diagnostics

Meiji (Japan)
Soot formation

Definition of “Spray A” conditions

- Spray A:
  - A common condition for all the institutions contributing to the database
  - common???

Ambient gas temperature	900 K
Ambient gas pressure	6 MPa
Ambient gas density	22.8 kg/m^3
Ambient gas composition	15% O_2, 0% O_2
Common rail fuel injector	Bosch solenoid-activated, generation 2.4
Fuel injector nozzle outlet diameter	0.090 mm
Nozzle K factor	1.5 { $K = (d_{inlet} - d_{outlet})/10$ [use μm] }
Nozzle hydro-erosion	Discharge coefficient = 0.86 with 100 bar ΔP.
Spray full included angle	0° (1 axial hole)
Fuel injection pressure	150 MPa
Fuel	n-dodecane
Fuel temperature at nozzle	363 K (90° C)
Common rail volume/length	22 cm^3/ 28 cm (Use GM rail model 97303659)
Distance, injector inlet to common rail	24 cm
Fuel pressure measurement	7 cm from injector inlet / 24 cm from nozzle
Injection duration	1.5 ms
Approximate injector driver current	18 A for 0.45 ms ramp, 12 A for 0.345 ms hold

Spray A challenges

- Provide a standard case common to all the participating institutes
  - Difficulties related to boundary conditions control
    - ambient conditions
    - injection conditions…
  - Difficulties related to the verification of the main characteristics
    - optical diagnostics set up configurations
    - data processing methods...

Spray A standard diagnostics

- Set up specifications
  - Injection system geometry (rail, tube length, pressure acquisition..)
  - Nozzle tip temperature
- Ambient temperature distribution (thermocouple)
- Spray characterization
  - Liquid penetration (fast Mie scattering)
  - Vapor penetration (fast Schlieren)
- Combustion characterization
  - Ignition (fast direct visualization/fast Schlieren)
  - Lift off length (filtered direct visualization)
  - Soot luminosity (fast direct visualization)
  - pressure rise (precombustion vessels)

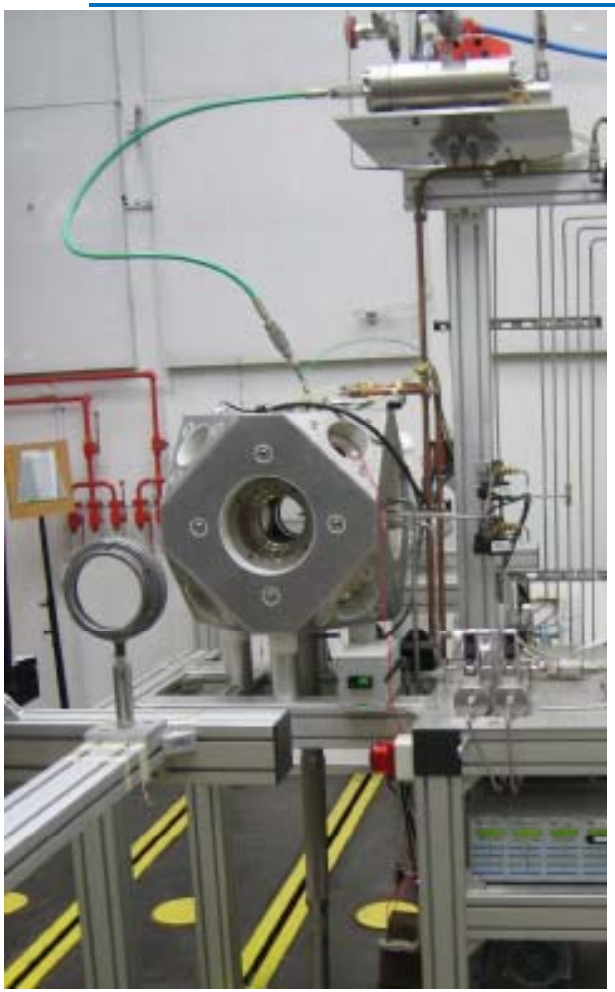
Spray A session objectives

- Communicate on Spray A conditions
- Compare results between contributing institutions
  - Serve as discussion platform to propose guidelines for the institutions that are willing to perform spray A conditions experiments and modeling
- Present the past and future experiments of each contributing institution

Spray A session organization

- Topics of interest
  - Vessel temperature
  - Ambient composition
  - Nozzle and injector temperature
  - Nozzle geometry
  - Hydraulic characterization
  - Liquid length
  - Vapor penetration (non reacting/reacting)
  - Combustion (Lift off length/soot luminosity/pressure rise)
- Working groups lead by the contributing institutions
  - Presentation of the synthesis of data comparison (15min)
  - Open discussion during the session (10min)
  - Recommendation for the “best” experimental and post-processing methods

Vessel Temperature
Technical University Eindhoven - Precombustion vessel

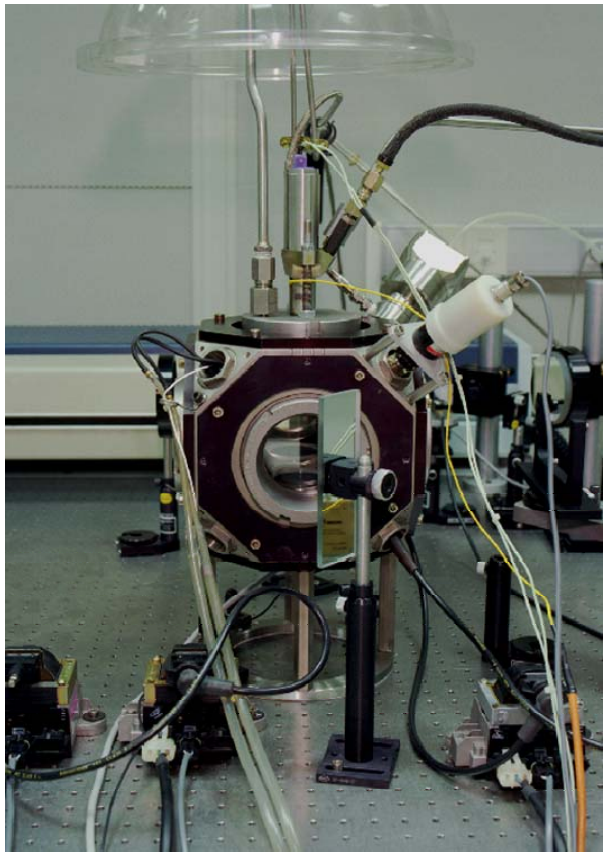


- Team
  - M. Meijer, R.J. Christians, L.M.T. Somers
- Characteristics of apparatus
  - Precombustion vessel:
    C_2H_2, N_2, 0_2, Ar $\longrightarrow$ H_2O, CO_2, N_2 , 0_2 , Ar
  - up to 300bar, 2200K, 60kg/m^3
  - 3 optical access: 5*10cm sapphire windows
  - Injection system: hydro-pneumatic pump, 4000bar max
- Diagnostics/Schedule
  - Past, Mie Scattering, Schlieren, LOSA
  - 2011, Toluene PLIF, TLIF, phospor seeding
  - 2012, Formulation of a diesel surrogate fuel, Soot diagnostics for PCCI combustion

Ambient composition
Michigan Technological University – Precombustion Vessel

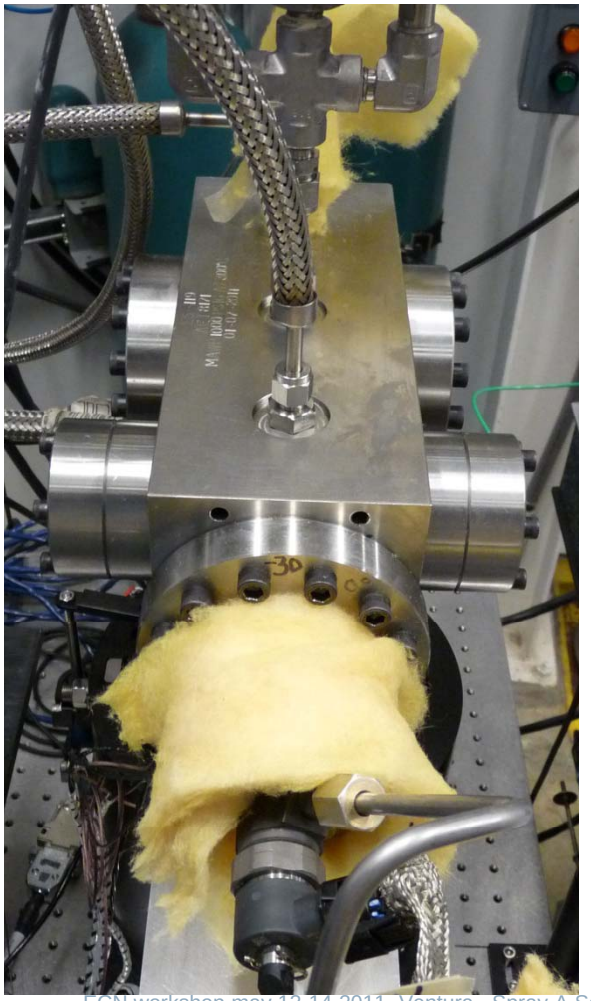
- Team
  - Jeffrey Naber, Seong-Young Lee, Jaclyn Nesbitt, Seung Hyun Yoon, Anqi Zhang, Khanh Cung
- Characteristics of apparatus
  - Precombustion vessel:
    H_2, CH_4, C_2H_2, N_2, O_2, $CO_2 \rightarrow H_2O$, CO_2, N_2, O_2
  - Up to 350bar, 1800K+, 60kg/m^3
  - Optical access: up to 5 sapphire windows (4” diameter, 1.875” thickness)
  - Fuel Injection systems: Piezo & Solenoid, Air-driven liquid pump, 4140 bar max
- Diagnostics/Schedule
  - Back Mie Scattering, Laser Scattering, Schlieren, CH*, PIV – Done 2009 / 2010
  - LDV/PDPA, LII - 2011

Nozzle and injector temperature
IFPEN – Precombustion vessel



- Team
  - L.M. Malbec, L. Hermant, G. Bruneaux
- Characteristics of apparatus
  - Precombustion vessel:
    $H_2, N_2, C_2H_6, 0_2 \longrightarrow H_2O, CO_2, N_2, 0_2$
  - up to 150bar, 1500K, 30kg/m^3
  - 5 optical access: 2*8cm sapphire windows
  - Injection system: hydro-pneumatic pump, 2750bar max
- Diagnostics/Schedule
  - Spray A standard – Done in 2010
  - PIV in reacting conditions - 2011
  - Formaldehyde and OH LIF - 2012

Nozzle geometry
Argonne – Cold-Flow X-Ray Measurements

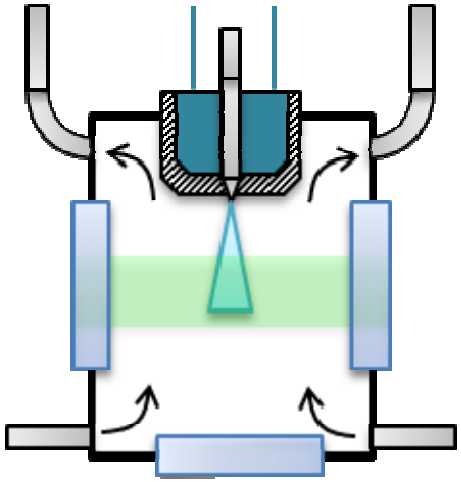


- Team
  - CF Powell, A Kastengren, J Wang
- Characteristics of apparatus
  - Cold-flow vessel with heated injector holder
  - N_2 up to 30 bar → 35 kg/m^3
  - Two custom polymer windows: x-ray transparent
  - Injection system: mechanical pump, 1600 bar max
- Diagnostics/Schedule
  - Injector geometry and needle motion – Done in March 2011
  - X-ray radiography of spray ongoing

Hydraulic characterization
CMT / UPV – Continuous flow vessel

- Team leaded by R. Payri
  - J.M. Garcia, J. Gimeno, J.J. Lopez
  - J. Manin, J.G. Nerva, M. Bardi
- Characteristics of apparatus
  - Continuous flow (either air, nitrogen or synthetic EGR)
  - From 10 to 150bar, From 300 to 1000K
  - 3 optical access with diameter 128 mm
  - High pressure CR Fuel Injection system
- Diagnostics/Schedule
  - Hydraulic characterization
  - Spray penetration in reacting and non reacting conditions (LL, LOL)
  - Vapor penetration
  - CH, OH chemiluminscence

Liquid length
Georgia Tech – Continuous Flow Vessel

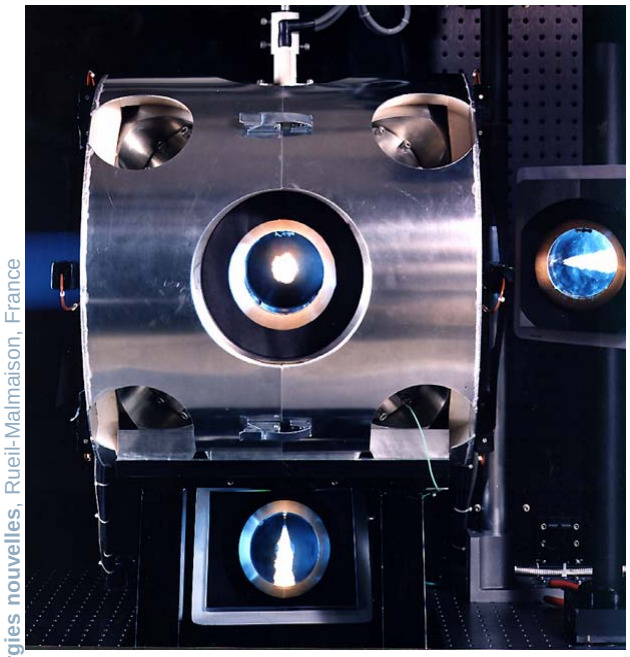


- Team
  - Caroline Genzale
  - Arriving in the Fall: Ben Knox, Mike Tree, Gina Magnotti
- Characteristics of apparatus
  - Lab build underway
  - Vessel design conditions: 150 bar, 1000 K
  - Injection system: air-driven pump, 4100 bar max
- Diagnostics/Schedule
  - Rate of momentum – Summer 2011
  - Spray A liquid and lift-off – 2012
  - Droplet sizing (non-vaporizing) – 2012
  - Droplet sizing and LVF (vaporizing) – 2013/14
  - Soot/LII – 2013/14

Vapor penetration (non reacting/reacting) Caterpillar - Continuous Flow Vessel

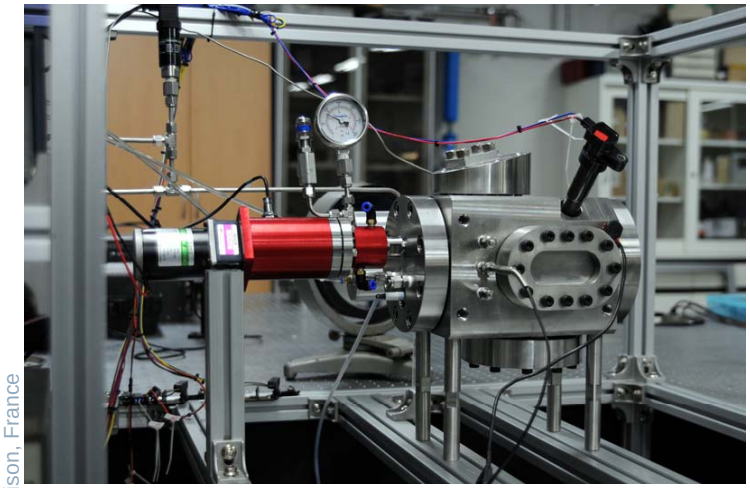
- Team
  - Tim Bazyn, Glen Martin
- Characteristics of apparatus
  - Continuous flow vessel:
    0-21% O_2 in N_2
  - up to 150bar, up to 1000K, up to 50+kg/m^3
  - 3 optical access: 125 mm FS windows
  - Injection systems:
    - Hydro-pneumatic pump 3000bar max
    - Common rail pump
    - Mechanical electronic injector
    - Hydraulic electronic injector
- Diagnostics/Schedule
  - Spray A standard + T and P sensitivity– Done in 2010

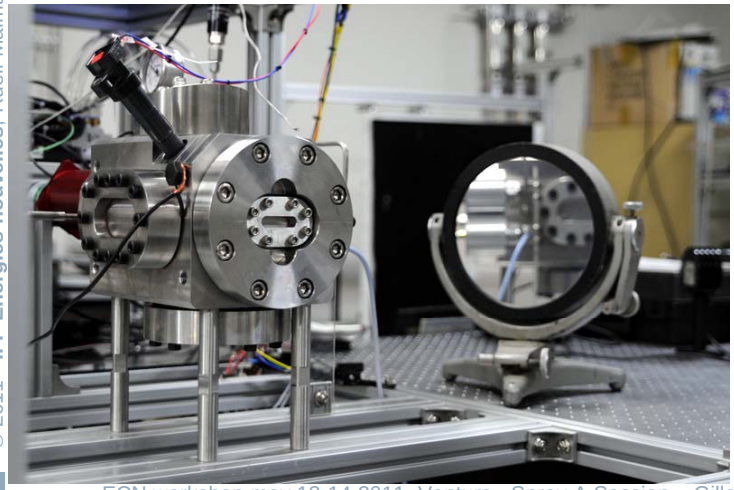
Combustion
Sandia– Precombustion vessel



- Team
  - J. Manin, P. Lillo, L.M. Pickett,
  - C. Genzale (now at GaTech)
- Characteristics of apparatus
  - Precombustion vessel:
    $H_2, N_2, C_2H_2, O_2 \longrightarrow H_2O, CO_2, N_2, O_2$
  - up to 350bar, 1500K, 60kg/m^3
  - 100 mm sapphire windows
- Diagnostics/Schedule
  - Spray A standard – Done in 2010
  - Rayleigh scattering- 2010
  - Liquid length quantification- 2011
  - Cool flame and soot- 2011

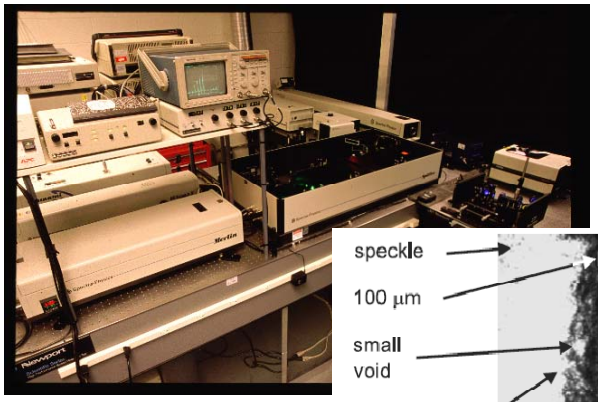
Institution SNU – Precombustion vessel

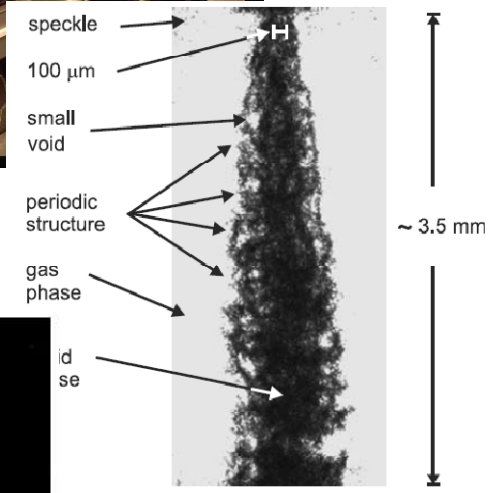


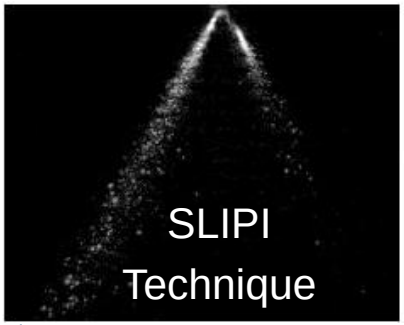


- Team
  - Junyong Lee, Namho Kim, Seunghyun Lee, Kyoungdoug Min
- Characteristics of apparatus
  - Dual-purpose : single-hole, multi-hole nozzle
  - Up to 150bar, 1500K
  - 4 optical access: 2 penetrating windows, 1 circular window, 1 laser window
  - Injection system: CR solenoid, Piezo
  - Mixing fan
- Diagnostics/Schedule
  - Automatic control system (ongoing)
  - Temperature distribution (2011)
  - Liquid and vapor penetration (2011)

Chalmers University & CORIA collaborating on diagnostics for dense sprays







Ballistic imaging

- Team
  - M. Linne & M. Rahm: Chalmers
  - J-B Blaisot, C. Rozé, S. Idlahcen & D. Sedarsky: CORIA
- Characteristics of apparatus
  - Two-pulse ballistic imaging for the liquid core and velocities
  - Structured laser induced planar imaging (SLIPI) for Mie and PLIF
  - Steady flow vessel (Chalmers):
    - up to 100bar, 900K
    - optical access