Single-shot, time-resolved planar laser-induced incandescence (TiRe-LII) for soot primary particle sizing in flames

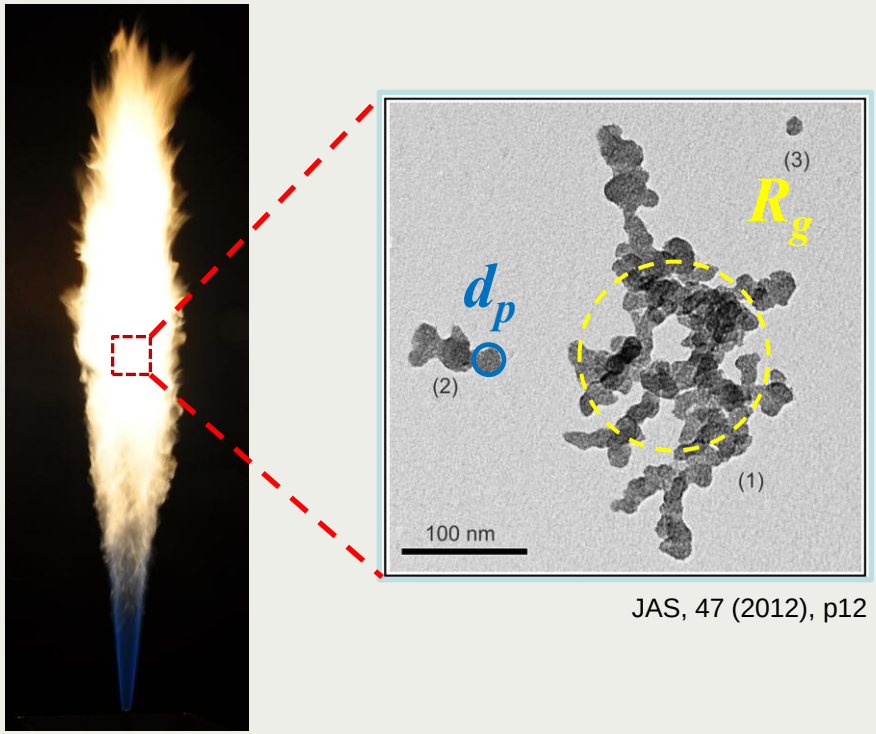
Mr. Dahe Gu
Prof. Graham J. Nathan
A/Prof. Zeyad T. Alwahabi
Prof. Bassam B. Dally

Zhiwei Sun

Centre for Energy Technology
School of Mechanical Engineering
The University of Adelaide, SA, Australia

Aim:

Measure soot primary particles diameters (d_p) in ***turbulent*** flames, with ***temporal*** and ***spatial*** resolution.



JAS, 47 (2012), p12

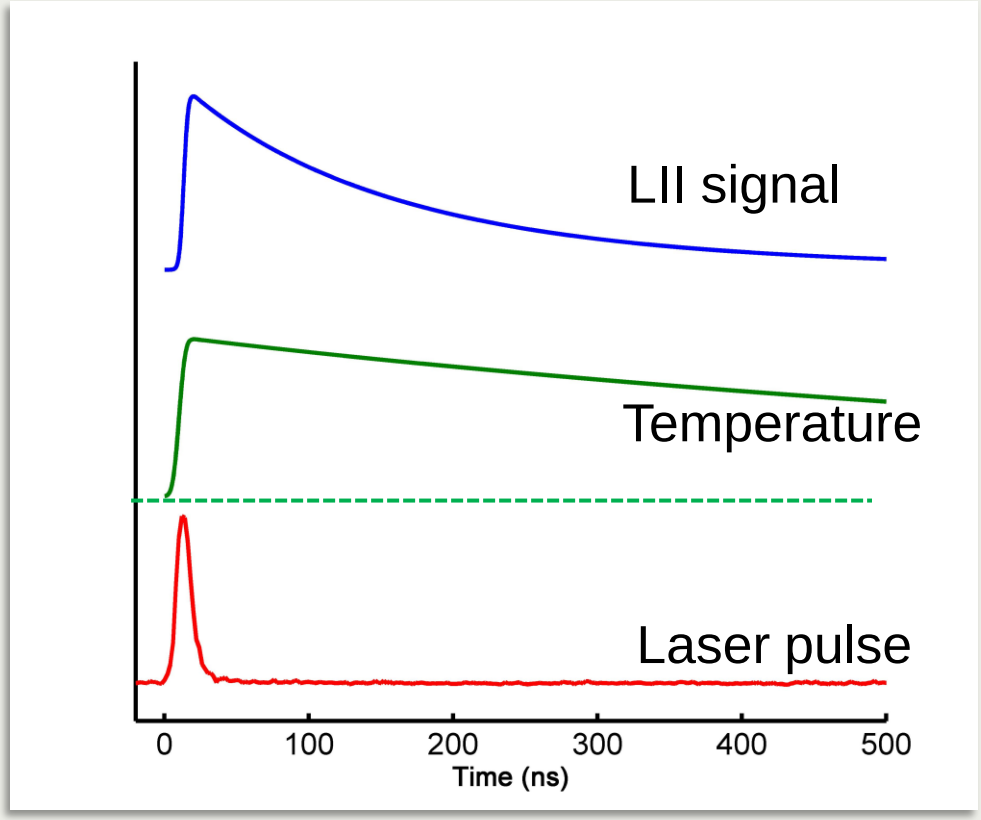
The heat conduction:

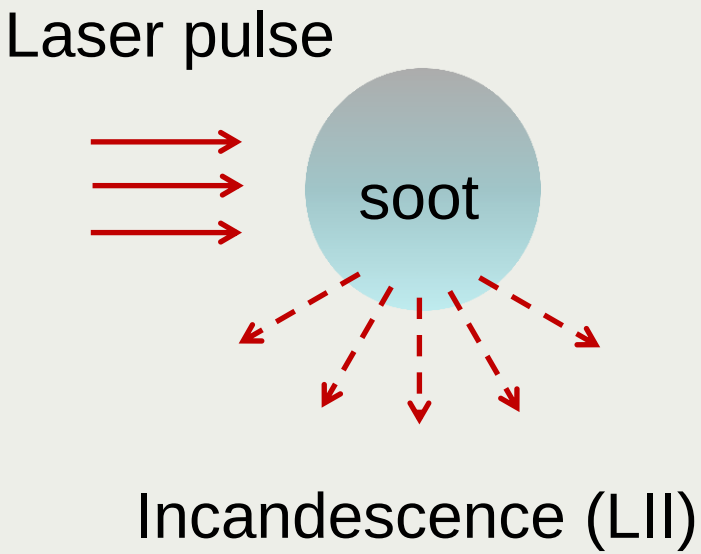
$$\dot{Q}_{cond} \propto (d_p)^2$$

The radiation:

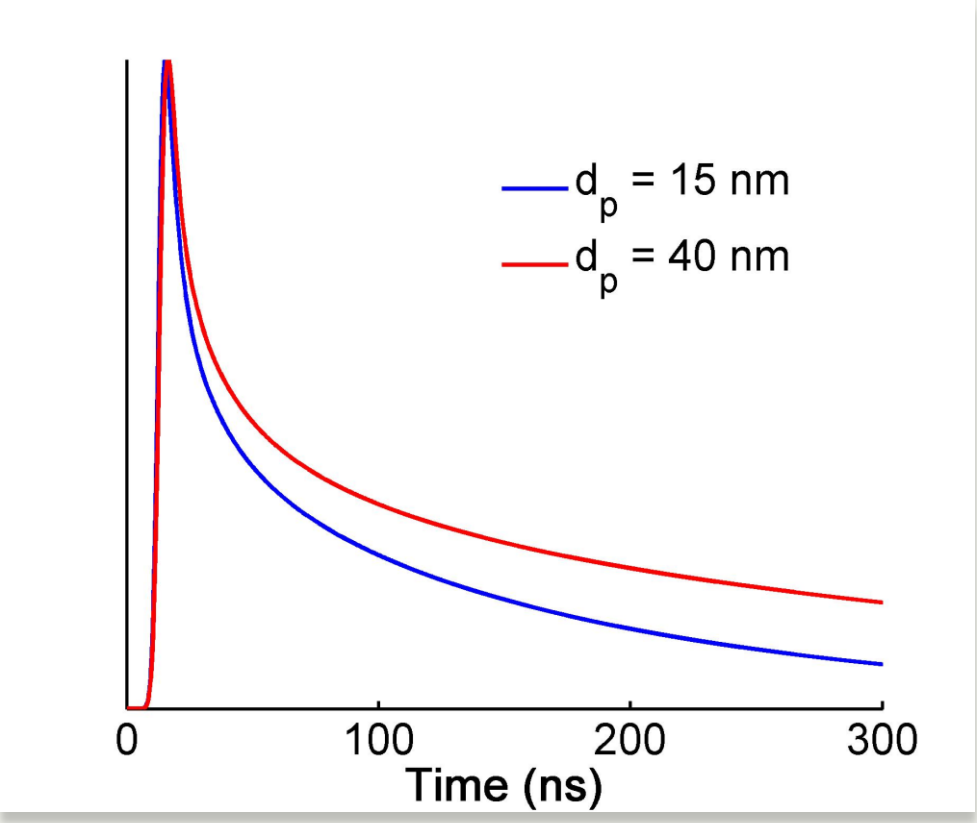
$$\dot{Q}_{rad} \propto (d_p)^3$$

Laser-induced incandescence (LII)



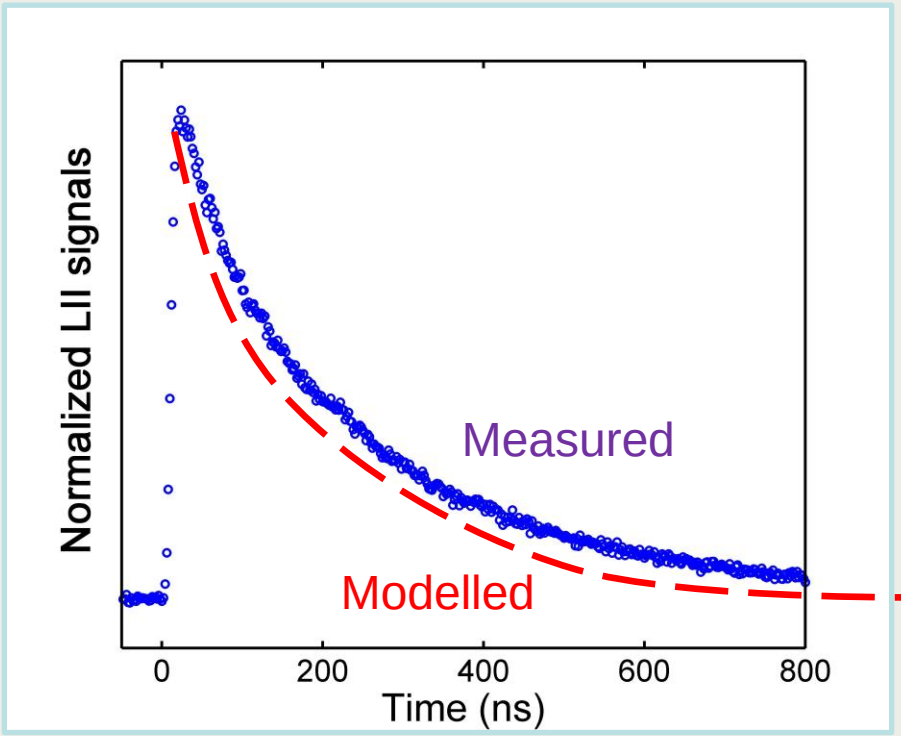


The decay time is a proxy of d_p



$d_p \uparrow$, decay time $\uparrow$.

Measure d_p through the LII signal decays



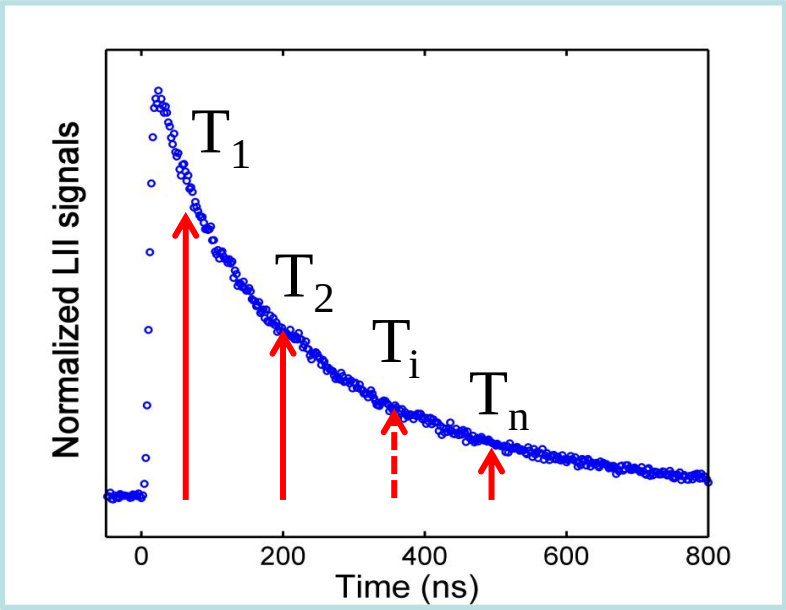
However, most works are

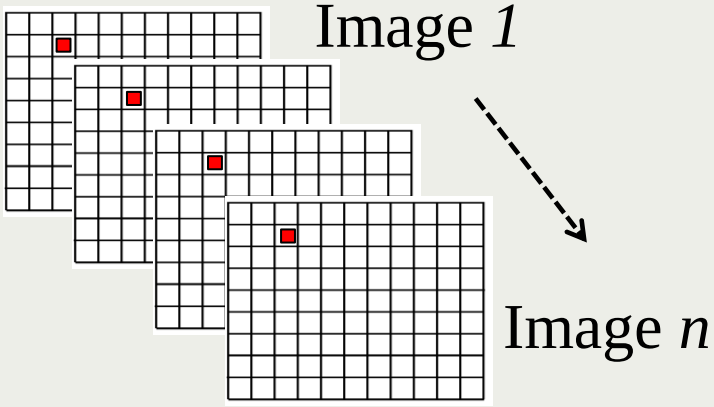
- Point-measurements
- Time-averaged measurements in steady laminar flames.

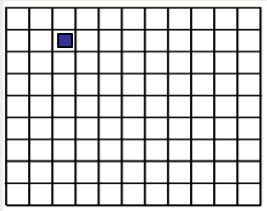
In turbulent flames, it needs

Single-shot, time-resolved planar laser-induced incandescence (TiRe-LII) for soot primary particle sizing in flames

Planar time-resolved LII







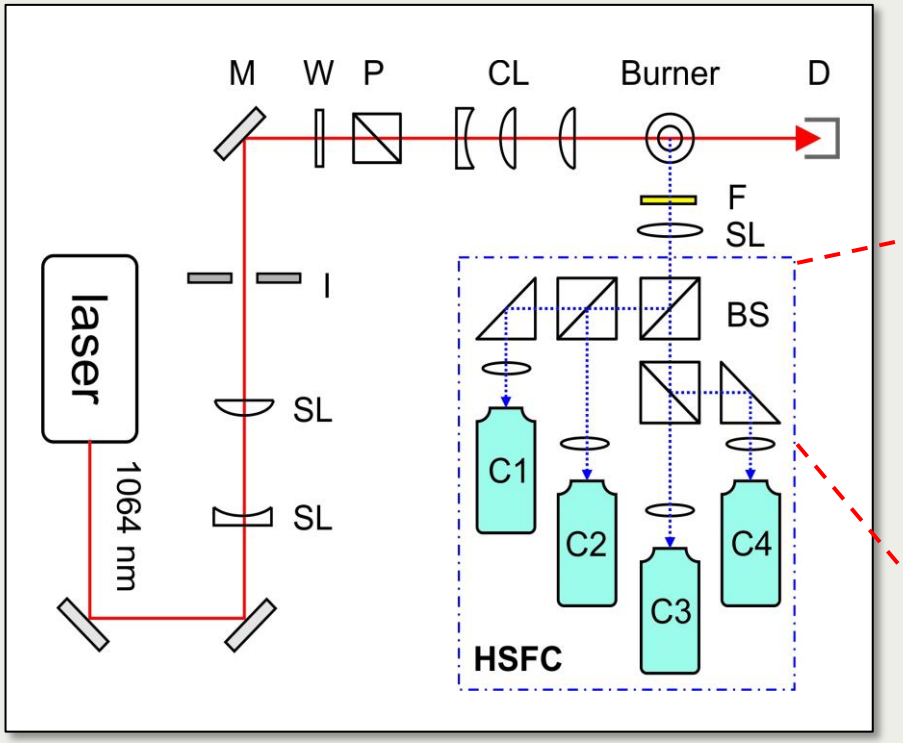
Size Image

Does TiRe-LII work? Does it work well?

Outline

- ✓ The model of laser-induced incandescence
- ✓ Experimental setup
- ✓ Selection of the laser fluence
- ✓ Evaluation of soot particle size
- ✓ Results:
  - in a laminar flame
  - in an unsteady flame
- ✓ Conclusion and discussion

Experimental setup

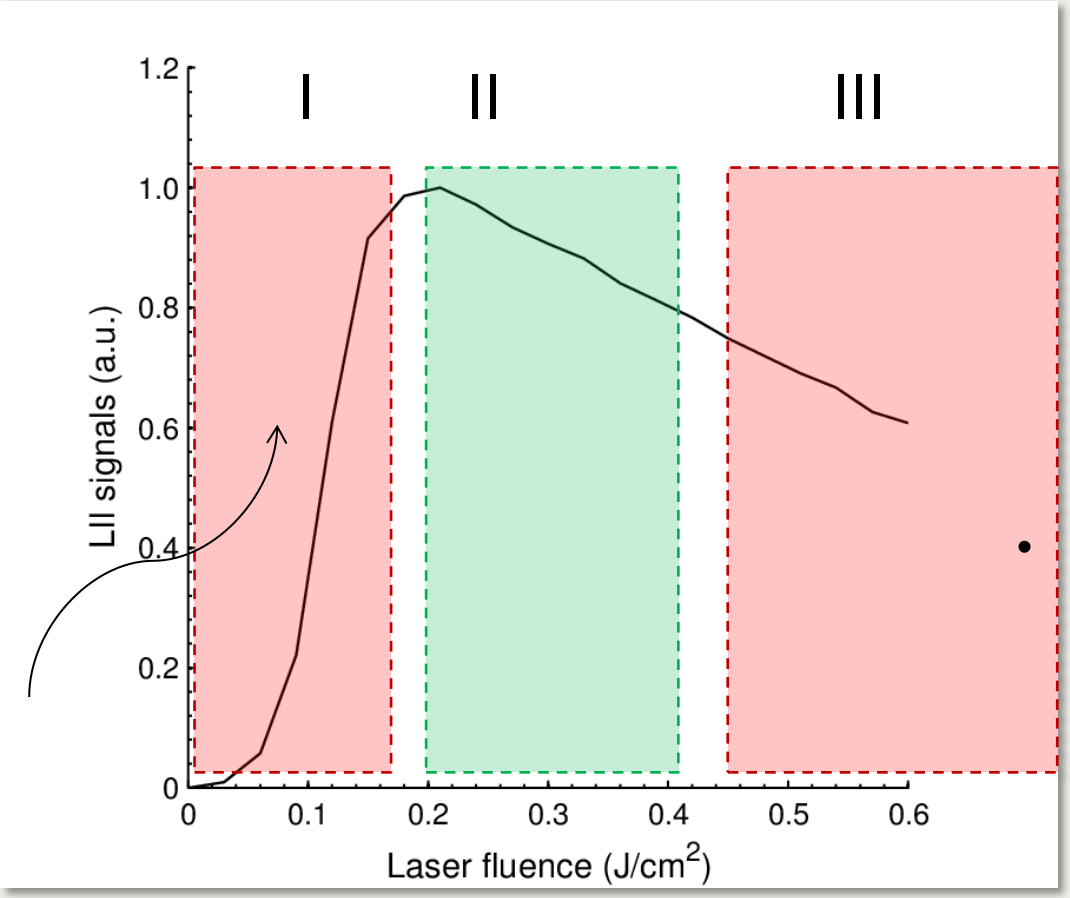


The schematic diagram

- The detector (HSFC pro camera)
- The band-pass filter (510-590 nm)
- Negligible C_2 emission

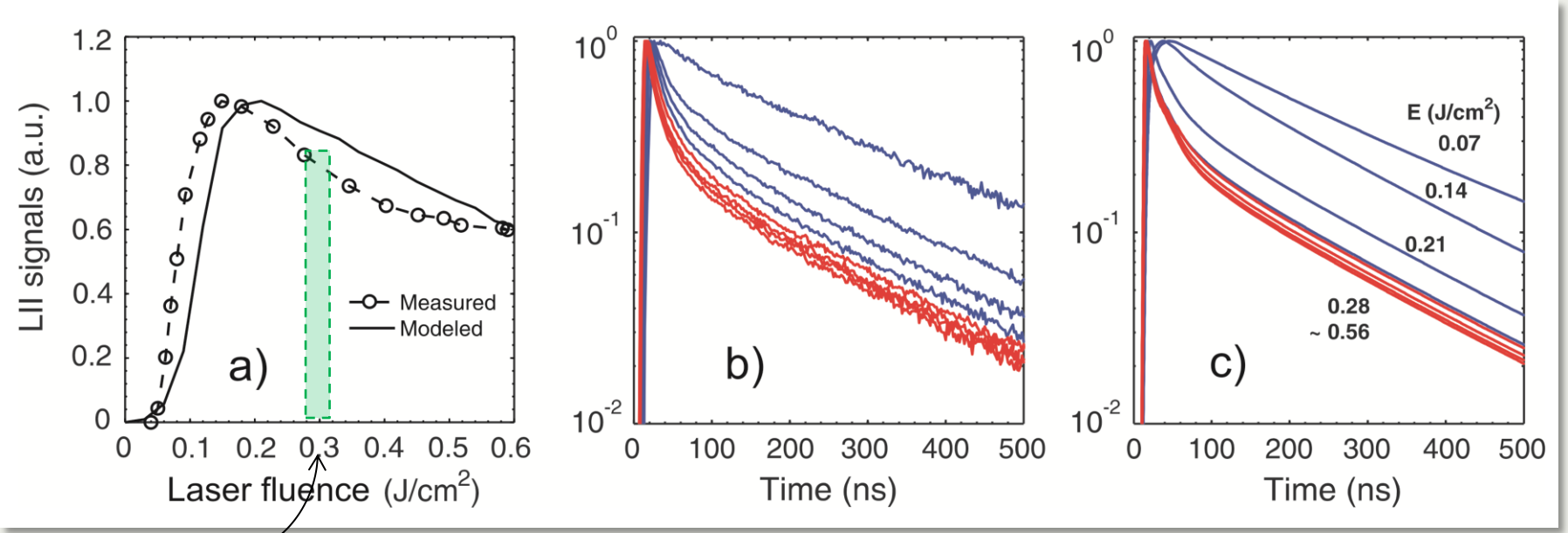
Selection of the laser fluence (1)

- **Beam attenuation**
- **Decay time is sensitive to laser fluence**



- **Sublimation effect**

Selection of the laser fluence (2)



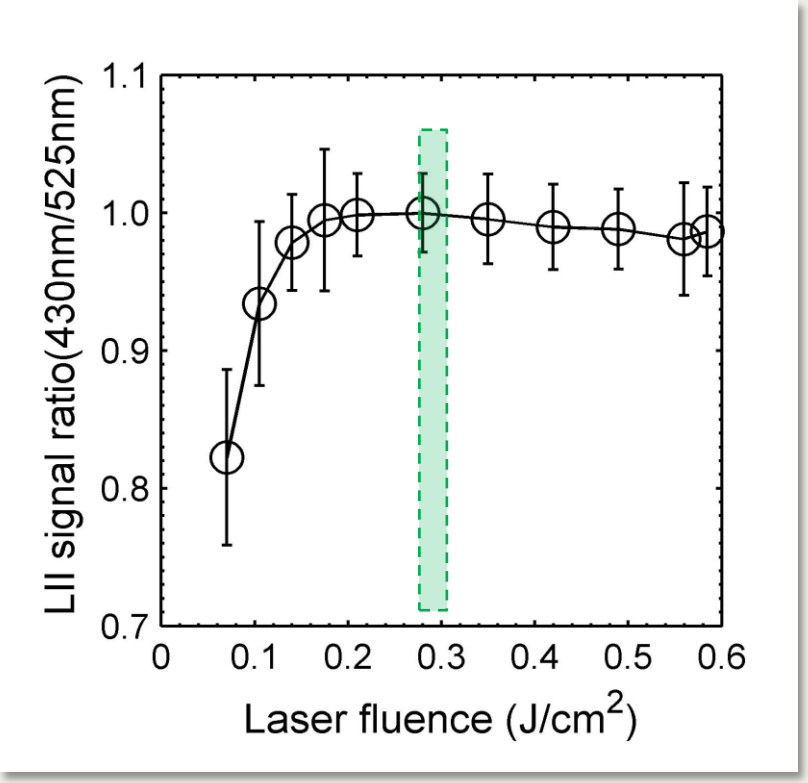
Measured LII decays

Modelled LII decays

0.3 J/cm^2 was selected.

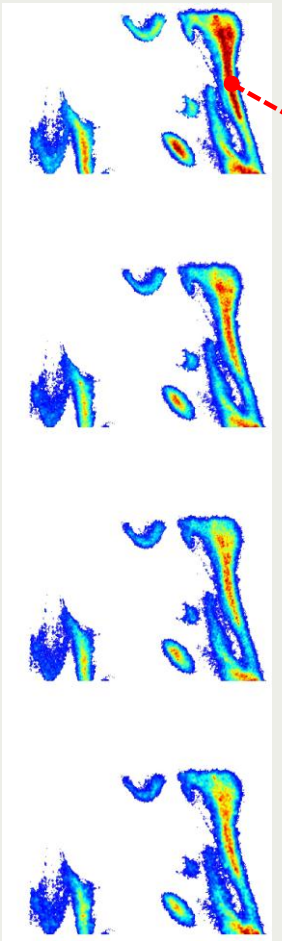
Selection of the laser fluence (3)

At the selected fluence 0.3 J/cm^2 , soot has its ‘maximum’ temperature.

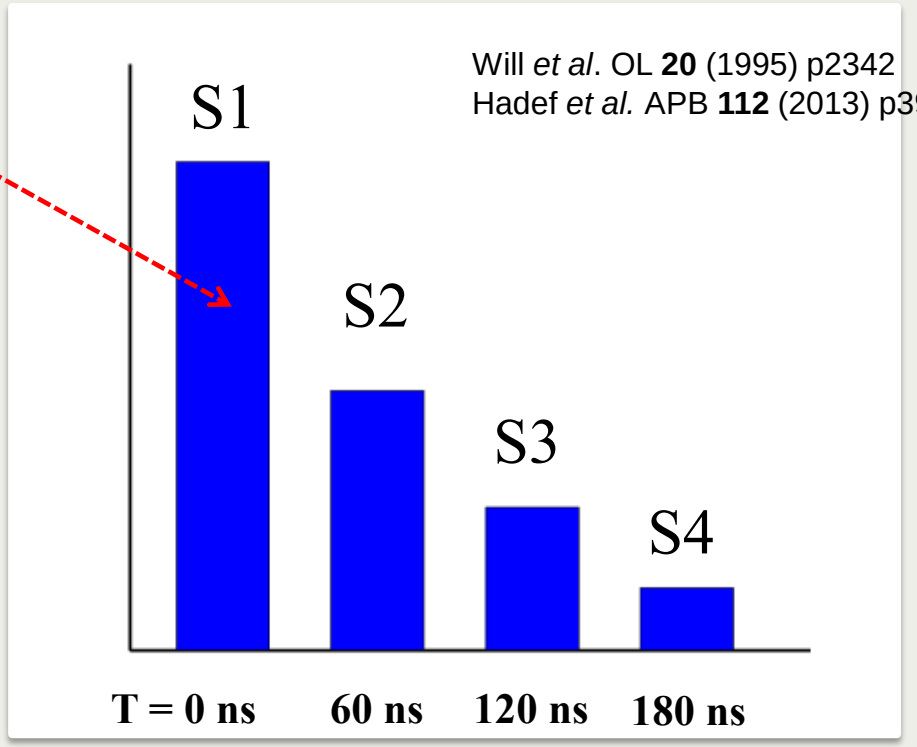


Ratio of two-colour prompt-LII signals: at 430 nm and 525 nm

Evaluation of soot particle size (1)

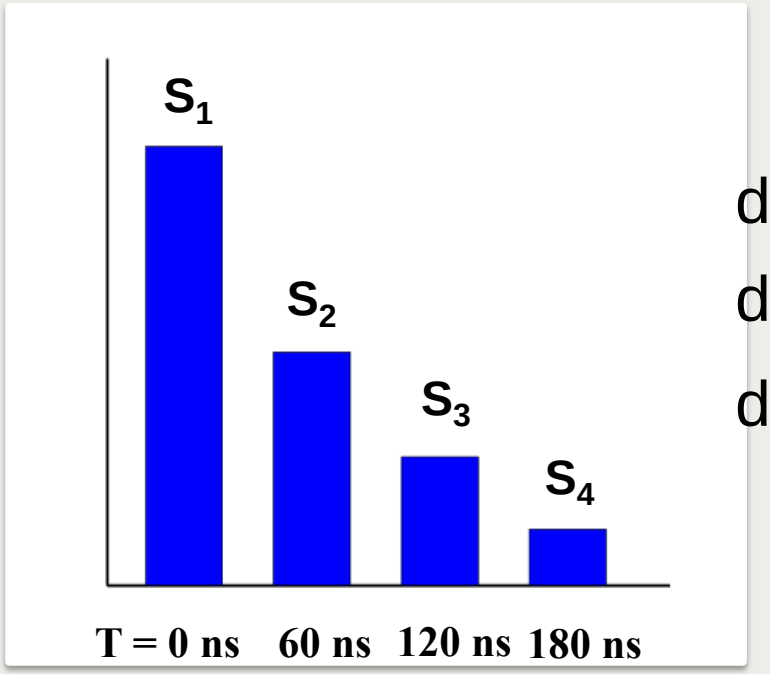


d_p is derived from the ratio of gated images



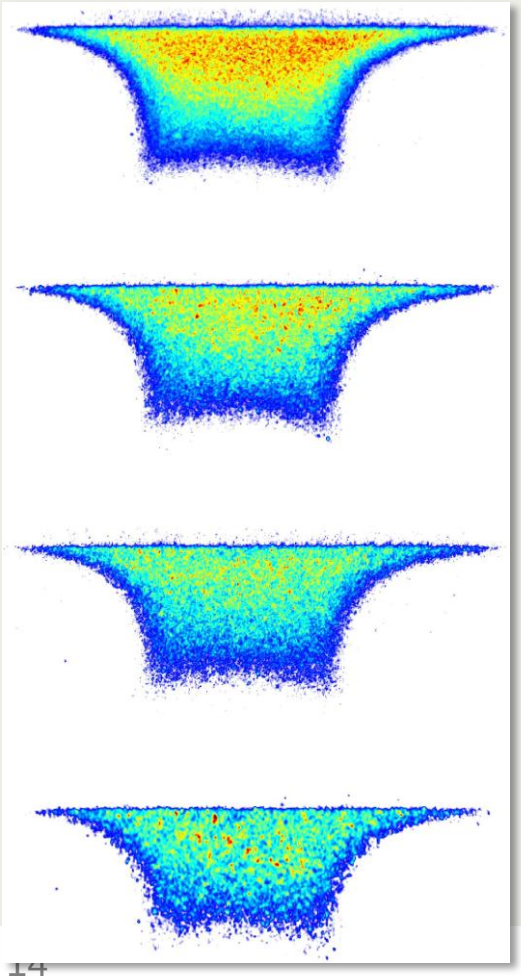
Evaluation of soot particle size (2)

$$d_p = (d_1+d_2+d_3)/3$$



d_p	S_2/S_1	S_3/S_1	S_4/S_1
6.0000000e+000	2.8082006e-001	1.0656315e-001	4.4256627e-002
7.0000000e+000	3.1523523e-001	1.3437152e-001	6.1437892e-002
8.0000000e+000	3.4360674e-001	1.6029323e-001	7.9304531e-002
9.0000000e+000	3.6657006e-001	1.8333922e-001	9.6610010e-002
1.0000000e+001	3.8555878e-001	2.0392213e-001	1.1321340e-001
1.1000000e+001	4.0151869e-001	2.2233431e-001	1.2901835e-001
1.2000000e+001	4.1541072e-001	2.3915994e-001	1.4423468e-001
1.3000000e+001	4.2744753e-001	2.5430028e-001	1.5852560e-001
1.4000000e+001	4.3781744e-001	2.6771266e-001	1.7164593e-001
1.5000000e+001	4.4693350e-001	2.7981918e-001	1.8386540e-001
1.6000000e+001	4.5481476e-001	2.9047927e-001	1.9489641e-001
1.7000000e+001	4.6174071e-001	2.9999039e-001	2.0494542e-001
1.8000000e+001	4.6838231e-001	3.0928294e-001	2.1500271e-001
1.9000000e+001	4.7424353e-001	3.1759376e-001	2.2416064e-001
2.0000000e+001	4.7930729e-001	3.2485531e-001	2.3227100e-001
d_3 2.1000000e+001	4.8418770e-001	3.3197000e-001	2.4035219e-001
2.2000000e+001	4.8826761e-001	3.3796711e-001	2.4722080e-001
2.3000000e+001	4.9226843e-001	3.4388091e-001	2.5407630e-001
2.4000000e+001	4.9583698e-001	3.4922570e-001	2.6033376e-001
d_1 2.5000000e+001	4.9919294e-001	3.5432236e-001	2.6636434e-001
2.6000000e+001	5.0223426e-001	3.5898365e-001	2.7192254e-001
2.7000000e+001	5.0501204e-001	3.6323011e-001	2.7700808e-001
2.8000000e+001	5.0763225e-001	3.6722674e-001	2.8181575e-001
2.9000000e+001	5.1025315e-001	3.7125603e-001	2.8670278e-001
d_2 3.0000000e+001	5.1267825e-001	3.7496538e-001	2.9121433e-001
3.1000000e+001	5.1469613e-001	3.7805528e-001	2.9497951e-001
3.2000000e+001	5.1700518e-001	3.8146562e-001	2.9912215e-001
3.3000000e+001	5.1898241e-001	3.8448998e-001	3.0283759e-001
3.4000000e+001	5.2089814e-001	3.8742877e-001	3.0646197e-001
3.5000000e+001	5.2264973e-001	3.9003816e-001	3.0966518e-001
3.6000000e+001	5.2437600e-001	3.9263766e-001	3.1287654e-001
3.7000000e+001	5.2606516e-001	3.9518890e-001	3.1603506e-001
3.8000000e+001	5.2753233e-001	3.9740788e-001	3.1878523e-001
3.9000000e+001	5.2896037e-001	3.9957777e-001	3.2148703e-001
4.0000000e+001	5.3044313e-001	4.0179596e-001	3.2424191e-001
4.1000000e+001	5.3178715e-001	4.0385743e-001	3.2682170e-001
4.2000000e+001	5.3301932e-001	4.0571313e-001	3.2913925e-001

Results: in a laminar flame (1)



Prompt-

60 ns

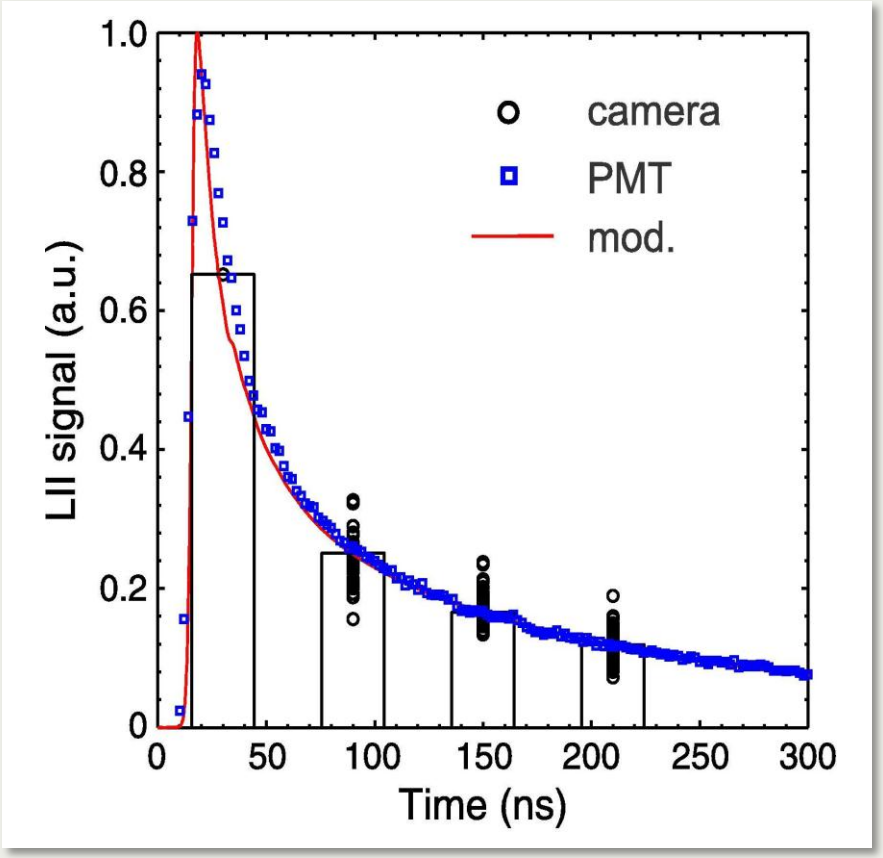
120 ns

180 ns

Four successive LII images:

- gate width = **30** ns.
- a photomultiplier tube was also used to record the LII signals at a single-point (HAB = 14 mm).

Results: in a laminar flame (2)

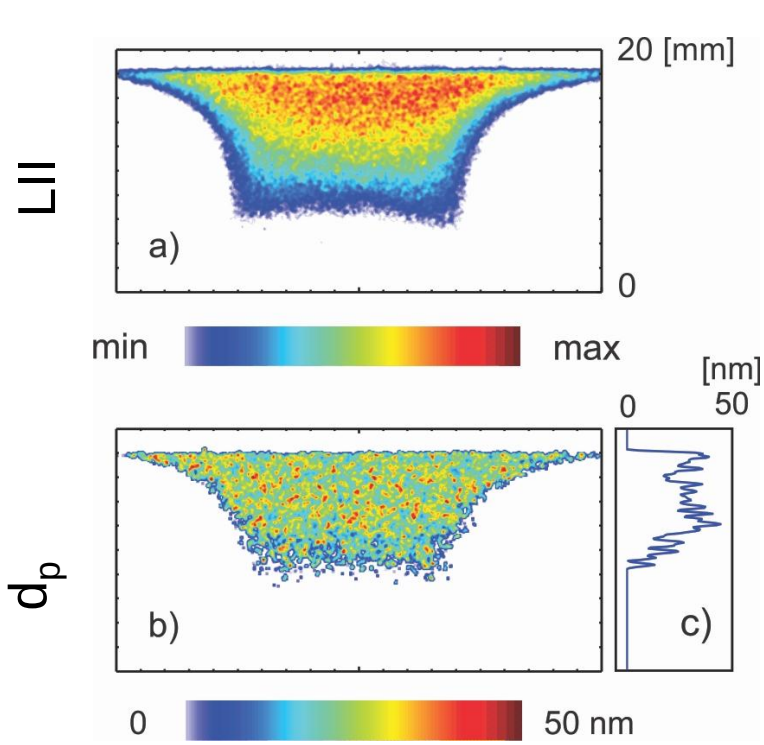


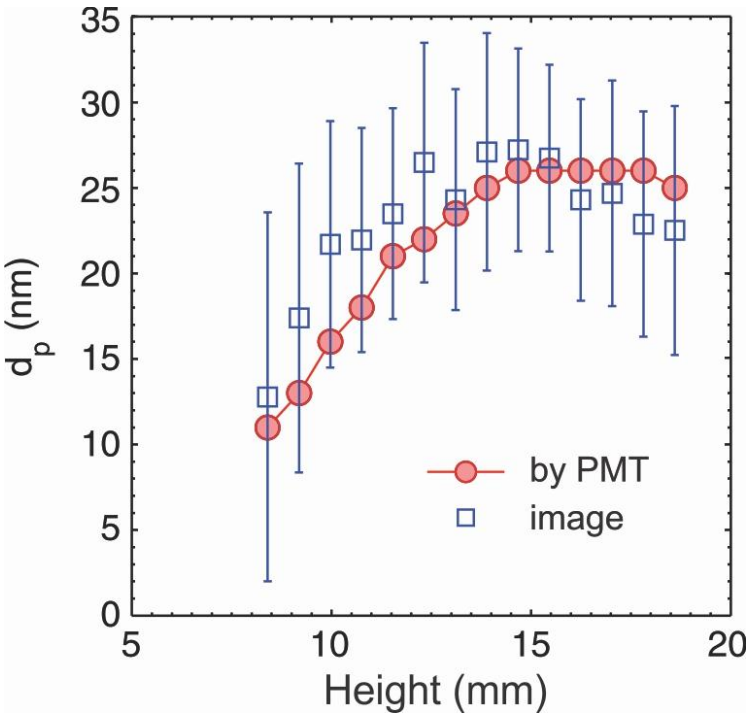
Three LII signals comparison

Results: in a laminar flame (3)

prompt LII and d_p

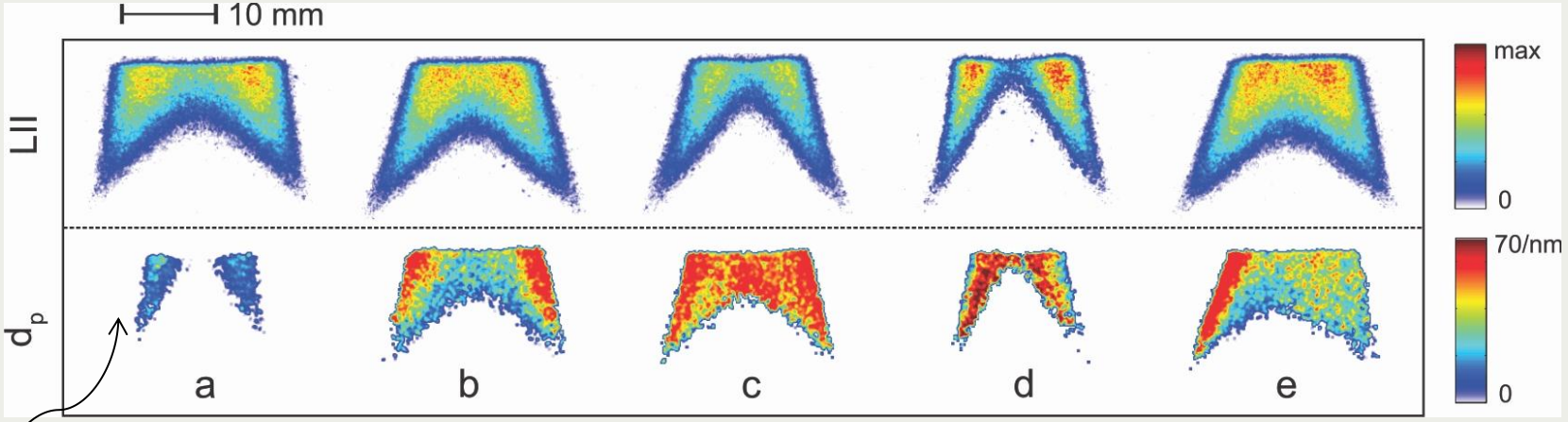
results and comparison





Results: in an unsteady flame

Instantaneous prompt-LII images and the corresponding d_p images



Weak signals in the delayed LII images

Conclusion and discussion

- The planar measurements of d_p using single-shot TiRe-LII are demonstrated.
- The results agree with that of single-point TiRe-LII.
- To improve the measurement accuracy, efforts must be made to:
  - ✓ flame temperature (currently assumed 1700K)
  - ✓ to use future more refined LII models
  - ✓ soot aggregate must be determined (using 2D scattering)
  - ✓ to use the full the distribution profile of d_p (i.e., σ) (currently only the mono disperesed was used)

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Thank You