Nanoparticle Diagnostics Collaborative Task

Soot LII signal variation by multiple laser pulse irradiance

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In Laser-Induced Incandescence soot particle heating plays a fundamental role.

- **Peak temperatures are in the range from 3000 to more than 4000 K**
- **The temperature rise is on the order of ns**
- **Morphological modifications are possible and have been previously observed**
- **Understanding these changes is fundamental for a correct modeling of LII signals**

Aim of the work

✓**To gain some insights on morphological modifications of soot nanoparticles under laser irradiation**

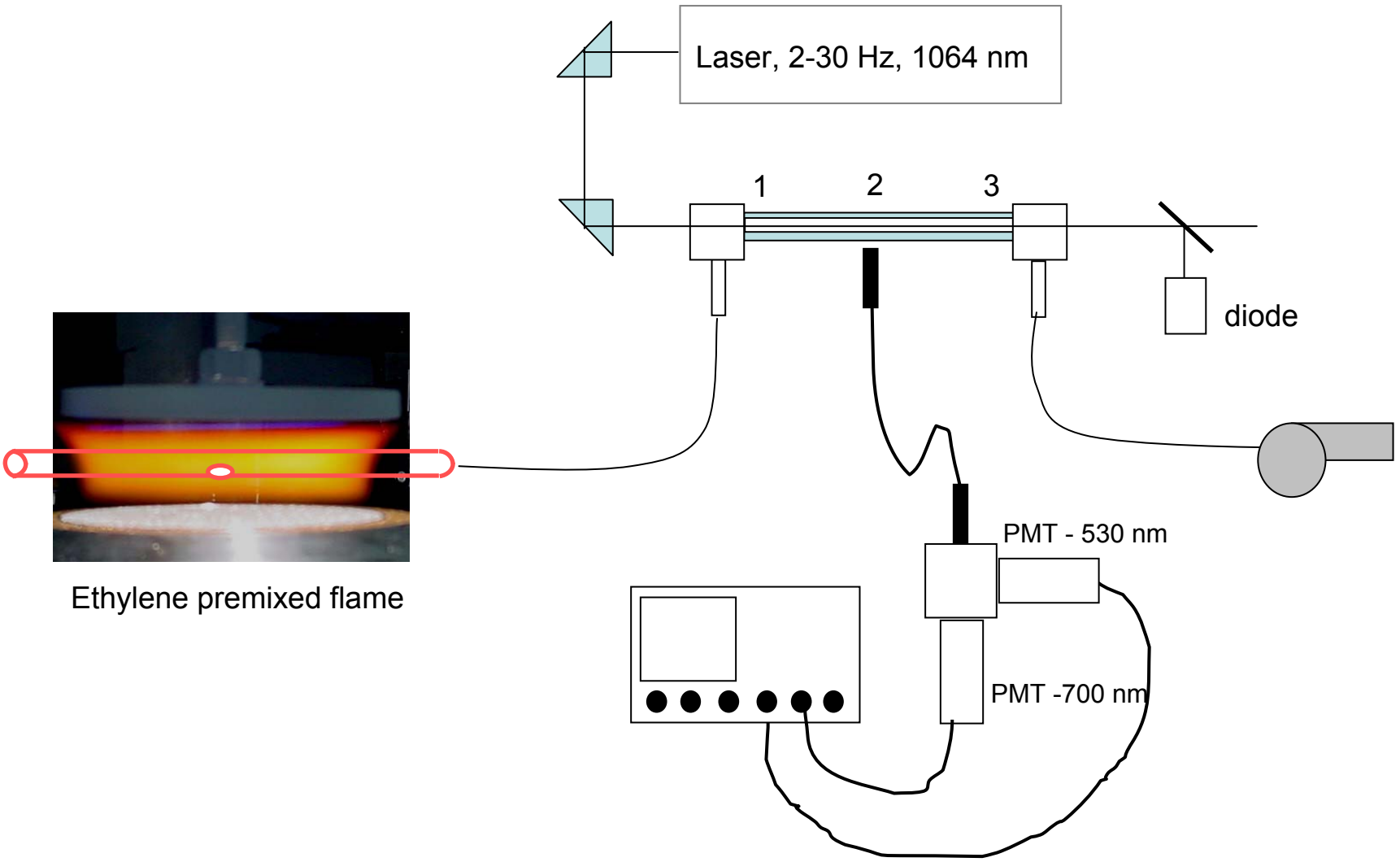
✓**To understand how these modifications affect the LII signals**

Methodology

✓**Two-color LII signals on a cell with a pulsed laser with variable frequency and with different fluences**

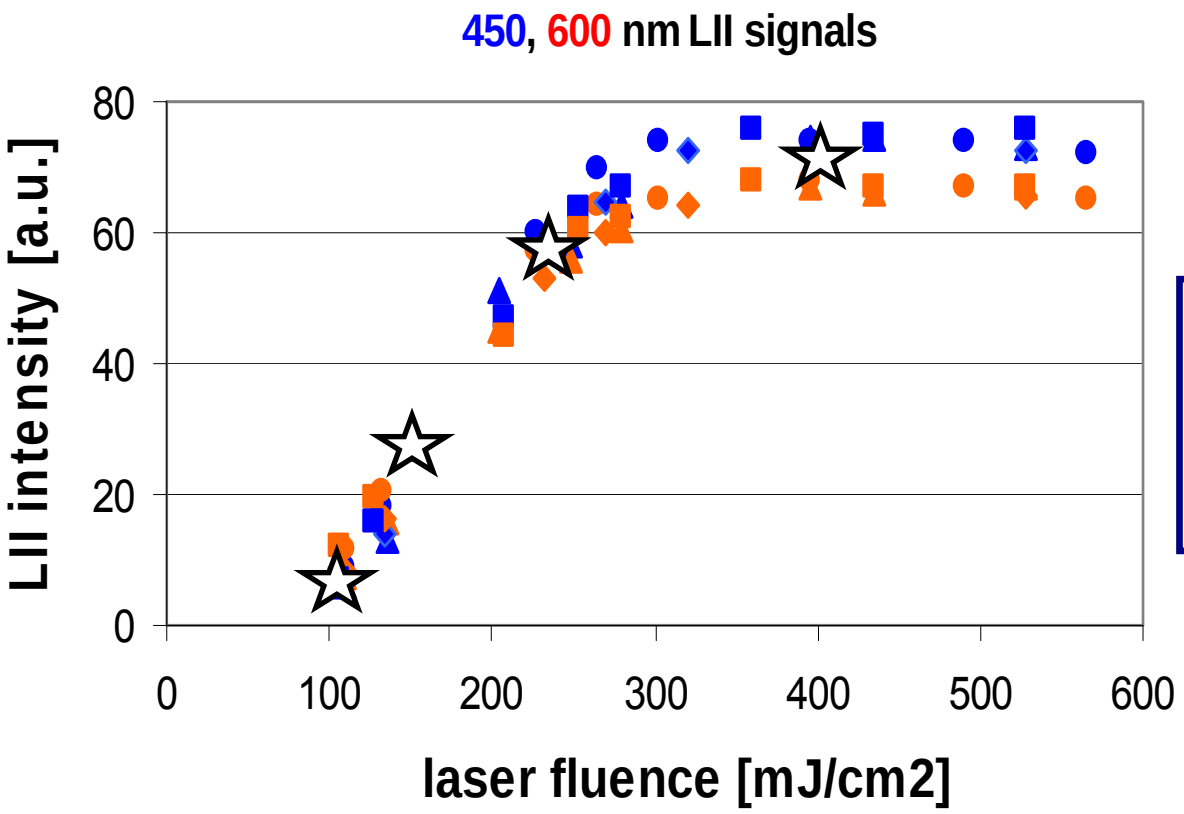
✓**TEM analysis of collected soot samples under different laser irradiance conditions**

Experimental set-up LII measurements



Choice of the fluence

Old results, diffusion flame



Conf 1 = 400 mJ/cm2

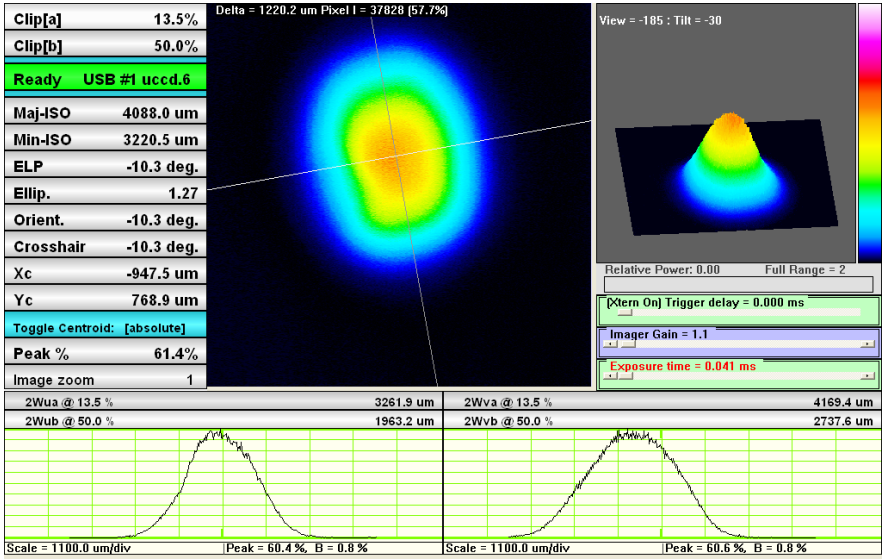
Conf 2 = 240 mJ/cm^2

Conf 3 = 146 mJ/cm2

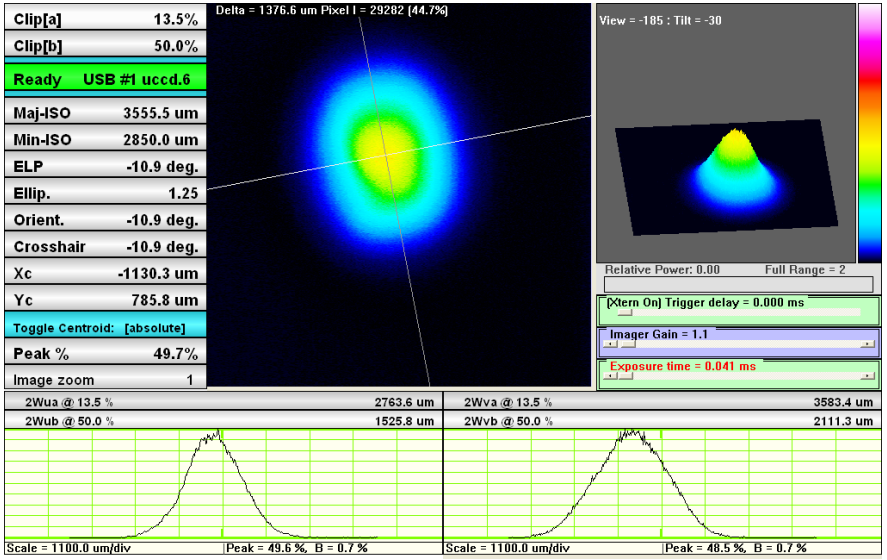
Conf 4 = 106 mJ/cm^2

Beam profile

(Gentec – Focus I)



Before the cell

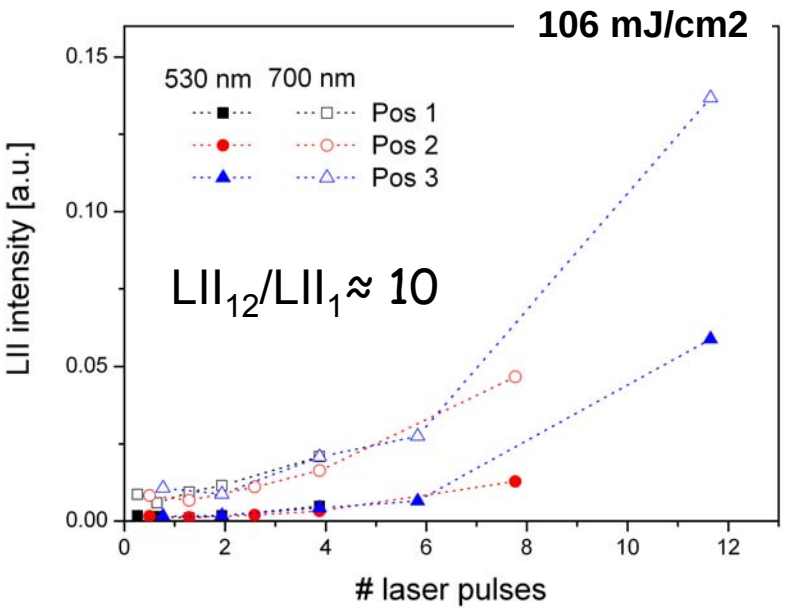


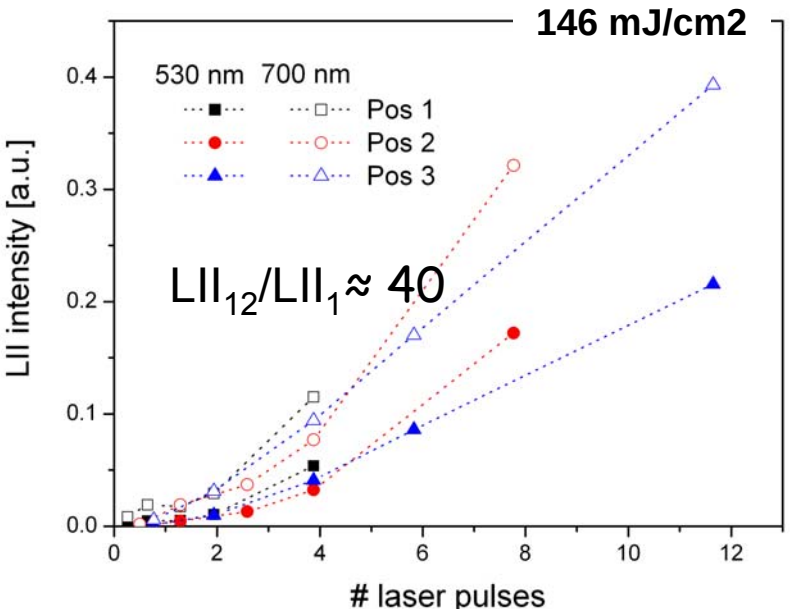
After the cell

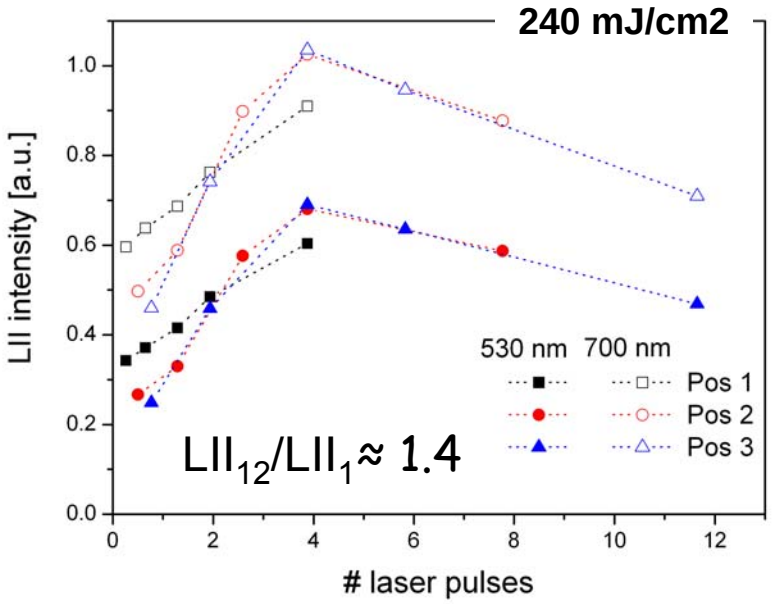
of pulses before the LII signal

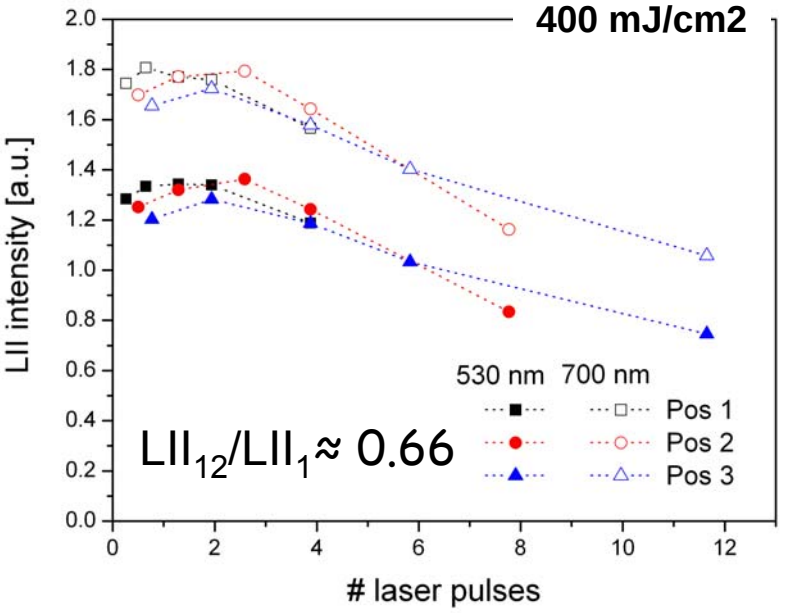
	cm	time [s]	1 Hz	2 Hz	3 Hz	5 Hz	6 Hz	10 Hz	15 Hz	30 Hz
	1	0.021587	0.021587	0.043175	0.064762	0.107936	0.129524	0.215873	0.323809	0.647619
	2	0.043175	0.043175	0.086349	0.129524	0.215873	0.259048	0.431746	0.647619	1.295238
	3	0.064762	0.064762	0.129524	0.194286	0.323809	0.388571	0.647619	0.971428	1.942857
	4	0.086349	0.086349	0.172698	0.259048	0.431746	0.518095	0.863492	1.295238	2.590476
	5	0.107936	0.107936	0.215873	0.323809	0.539682	0.647619	1.079365	1.619047	3.238094
Pos. 1	**6**	0.129524	0.129524	**0.259048**	0.388571	**0.647619**	0.777143	**1.295238**	**1.942857**	**3.885713**
	7	0.151111	0.151111	0.302222	0.453333	0.755555	0.906666	1.511111	2.266666	4.533332
	8	0.172698	0.172698	0.345397	0.518095	0.863492	1.03619	1.726984	2.590476	5.180951
	9	0.194286	0.194286	0.388571	0.582857	0.971428	1.165714	1.942857	2.914285	5.82857
	10	0.215873	0.215873	0.431746	0.647619	1.079365	1.295238	2.15873	3.238094	6.476189
	11	0.23746	0.23746	0.474921	0.712381	1.187301	1.424762	2.374603	3.561904	7.123808
Pos. 2	**12**	0.259048	0.259048	**0.518095**	0.777143	**1.295238**	1.554285	**2.590476**	**3.885713**	**7.771427**
	13	0.280635	0.280635	0.56127	0.841905	1.403174	1.683809	2.806349	4.209523	8.419046
	14	0.302222	0.302222	0.604444	0.906666	1.511111	1.813333	3.022222	4.533332	9.066665
	15	0.323809	0.323809	0.647619	0.971428	1.619047	1.942857	3.238094	4.857142	9.714283
	16	0.345397	0.345397	0.690793	1.03619	1.726984	2.07238	3.453967	5.180951	10.3619
	17	0.366984	0.366984	0.733968	1.100952	1.83492	2.201904	3.66984	5.504761	11.00952
Pos. 3	**18**	0.388571	0.388571	**0.777143**	1.165714	**1.942857**	2.331428	**3.885713**	**5.82857**	**11.65714**
	19	0.410159	0.410159	0.820317	1.230476	2.050793	2.460952	4.101586	6.15238	12.30476
	20	0.431746	0.431746	0.863492	1.295238	2.15873	2.590476	4.317459	6.476189	12.95238

Results - LII signals

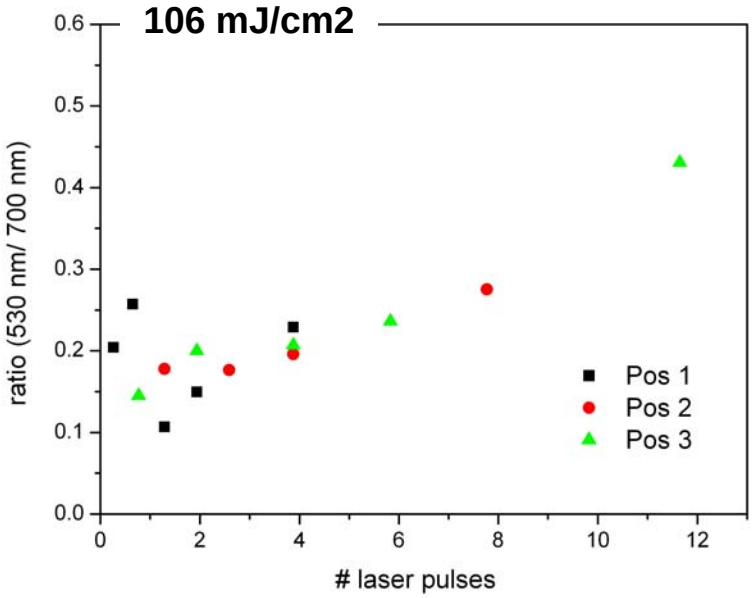


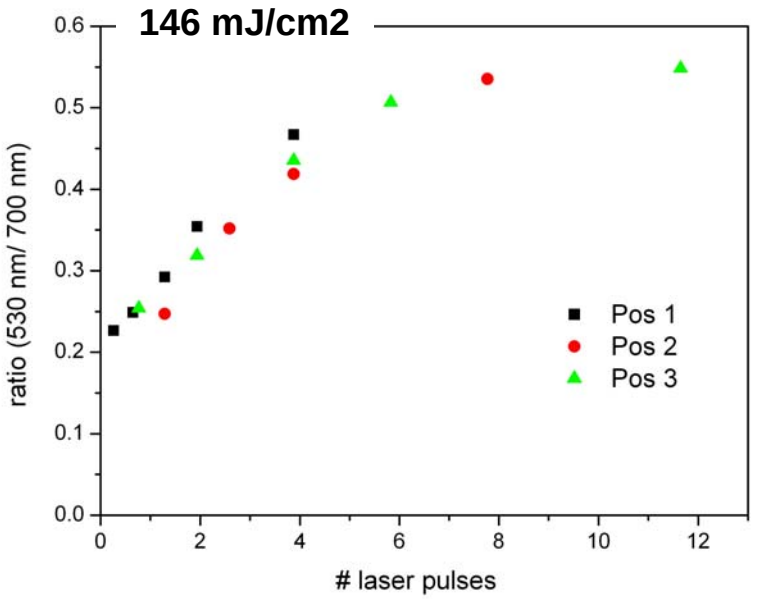


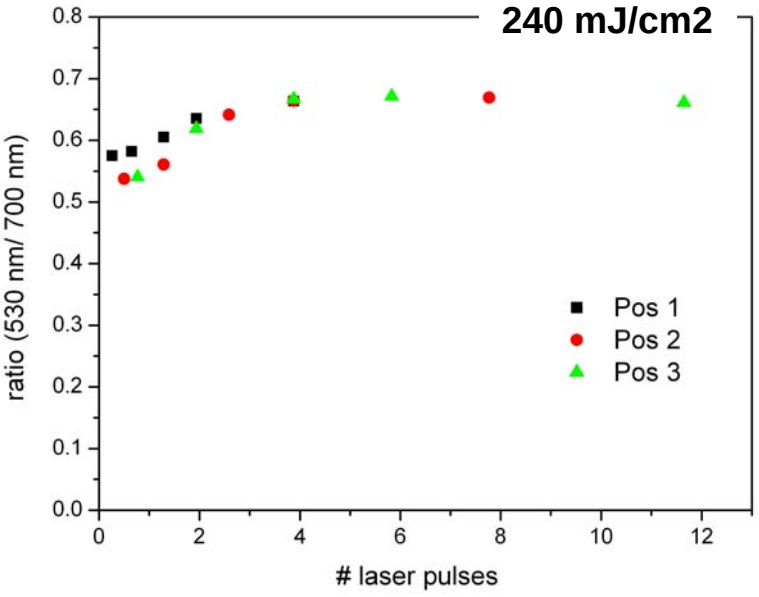


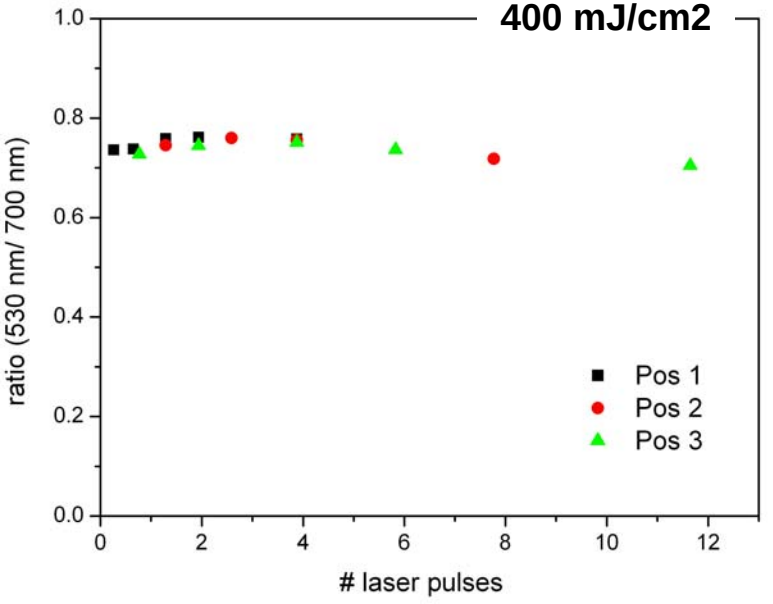


LII signal ratio ≈ T_{soot}

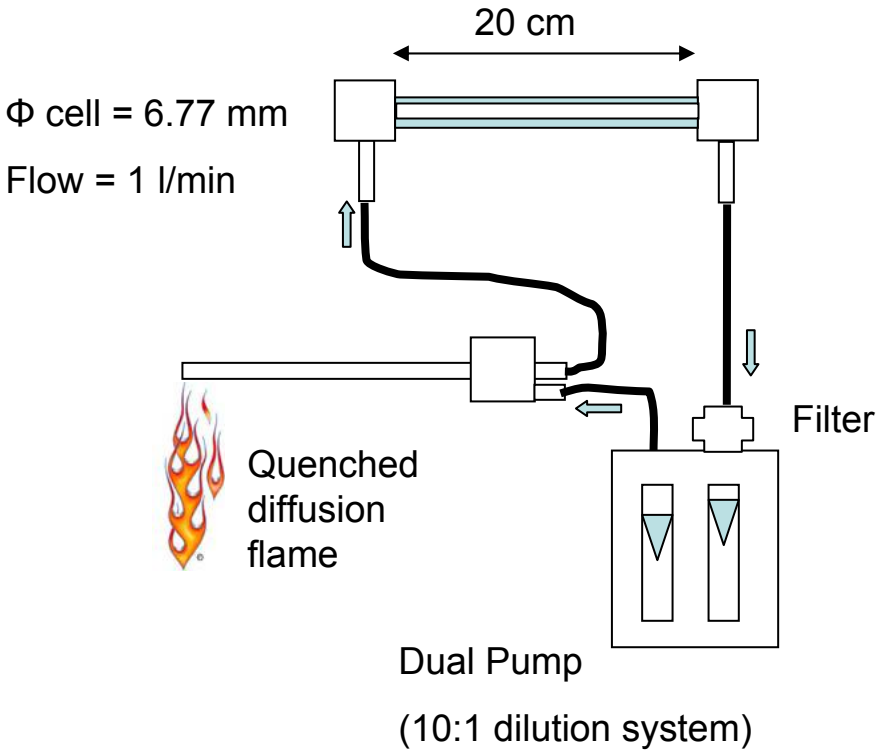




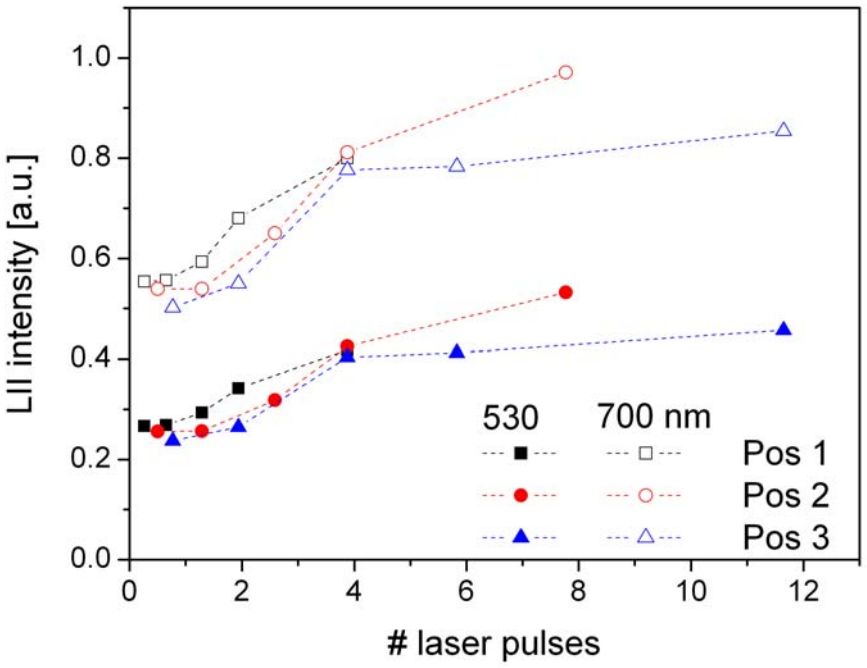


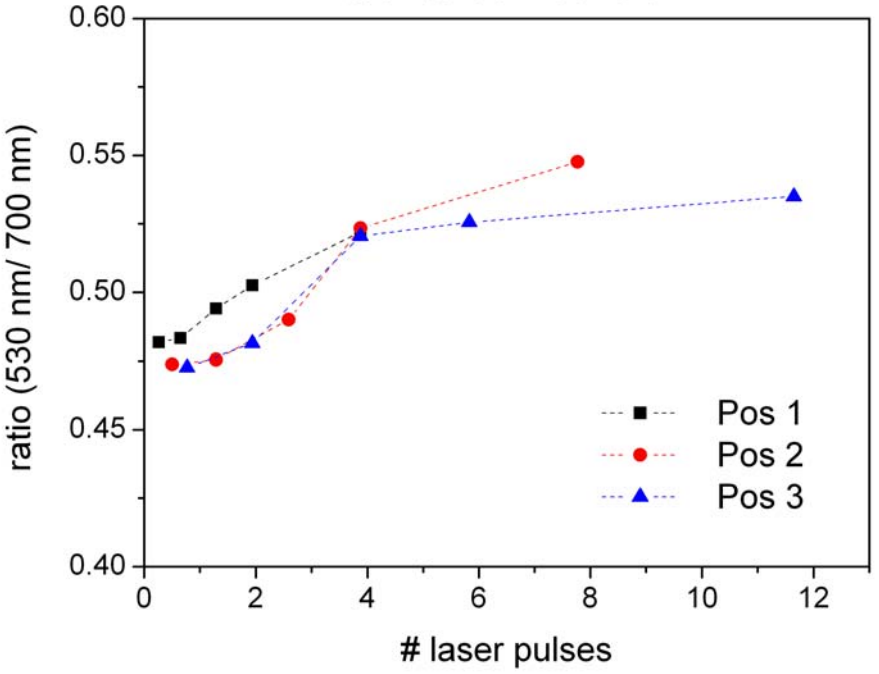


Experimental set-up - Quenched diffusion flame



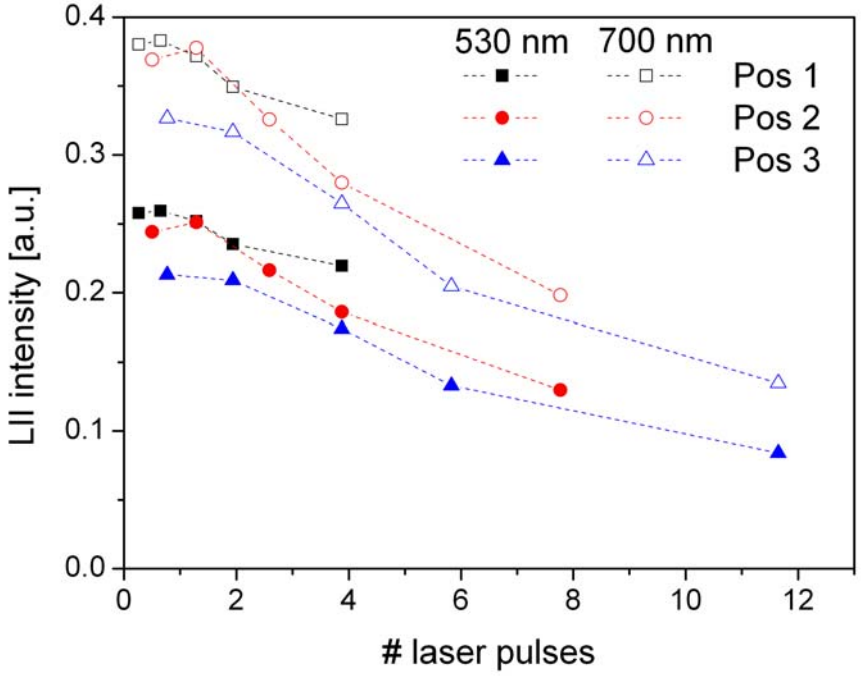
Diffusion flame – Laser fluence = 106 mJ/cm²

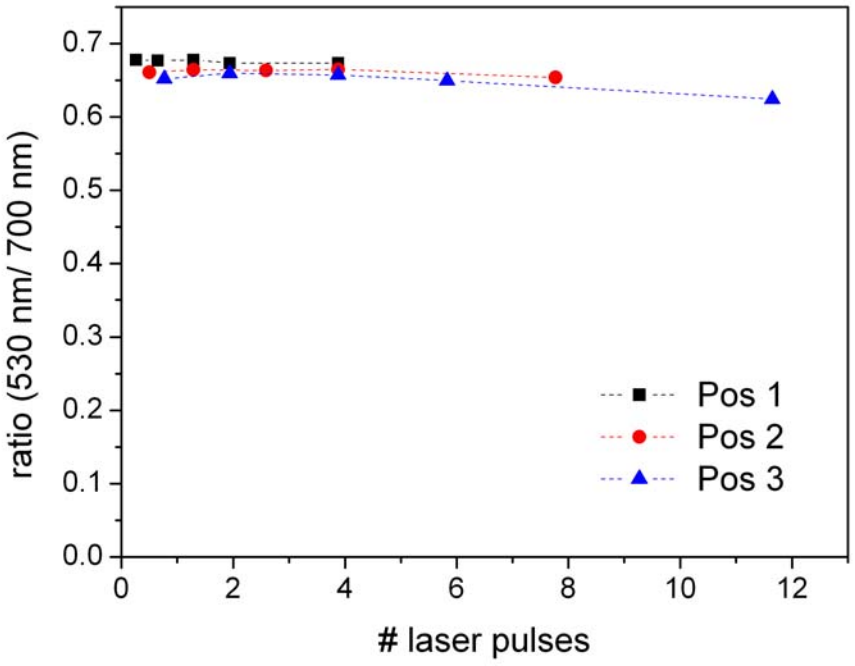




$LII_{12\ pulses}$ / $LII_{1\ pulse}$ ≈ 1.74

Diffusion flame – laser fluence = 240 mJ/cm^2



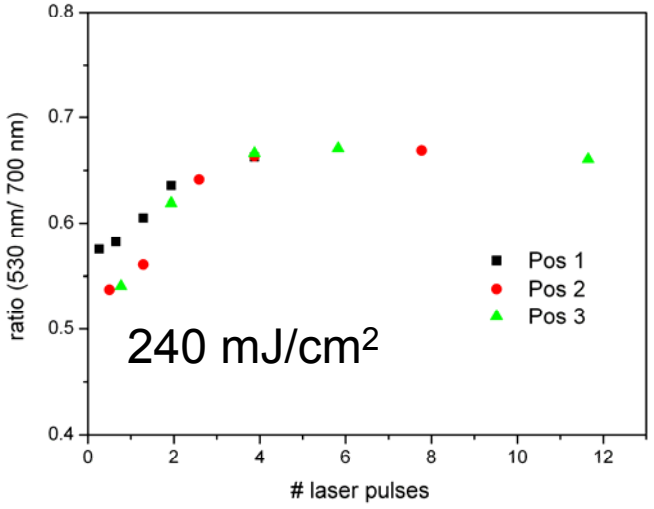


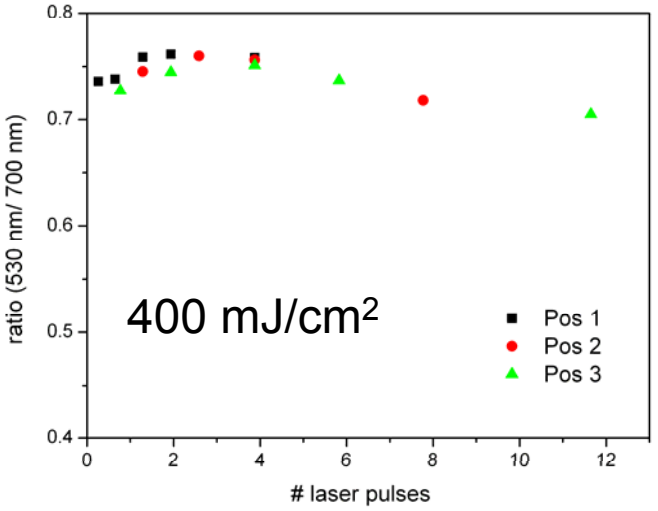
$LII_{12\ pulses} / LII_{1\ pulse} \approx 0.32$

$LII \propto f_v$ ⇨ Every pulse vaporizes about 6% of the mass

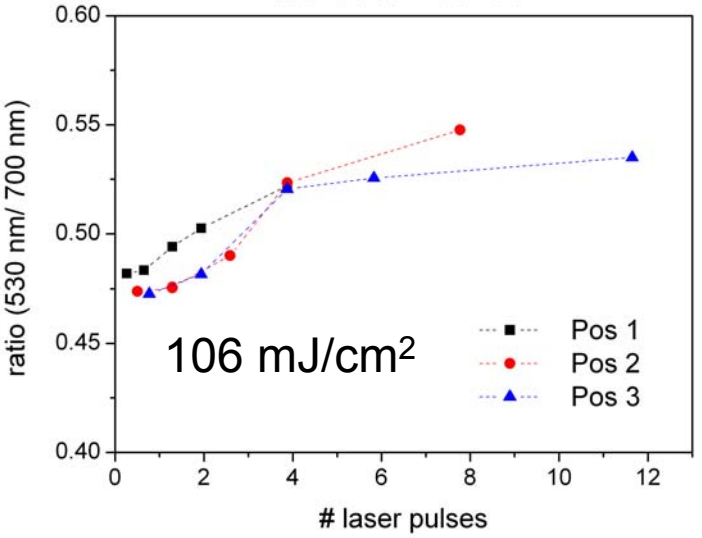
Comparison between premixed and diffusion flames

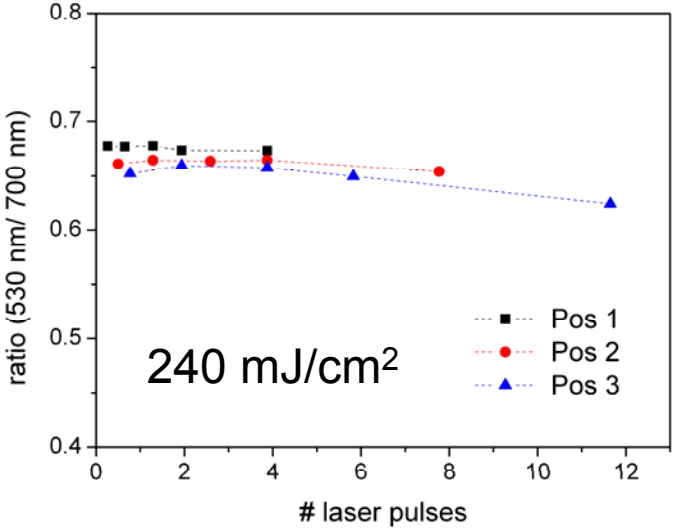
Premixed flame



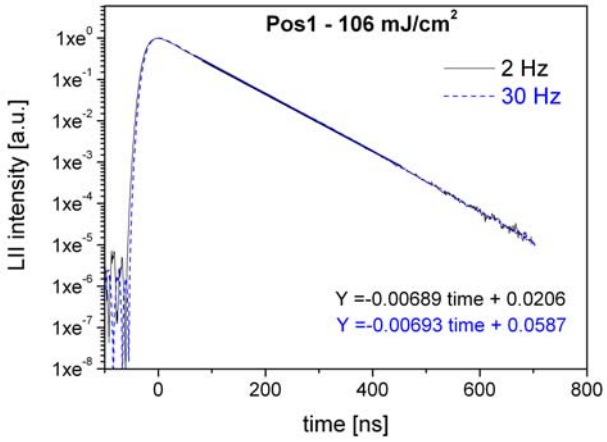


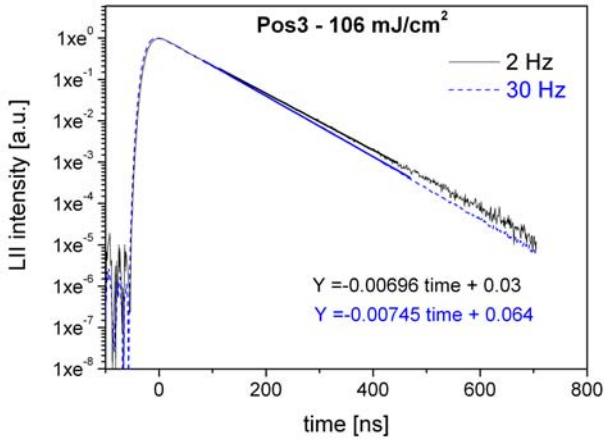
Quenched diffusion flame

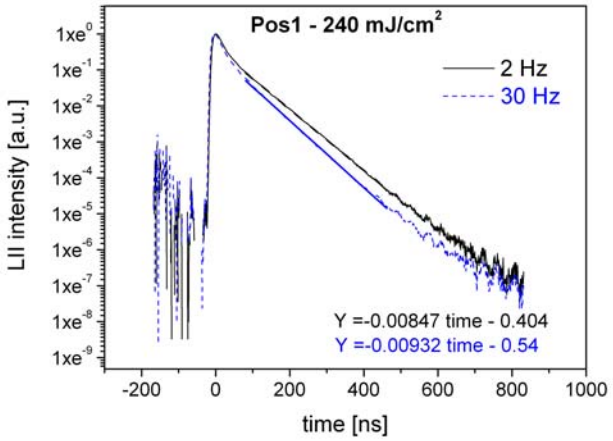


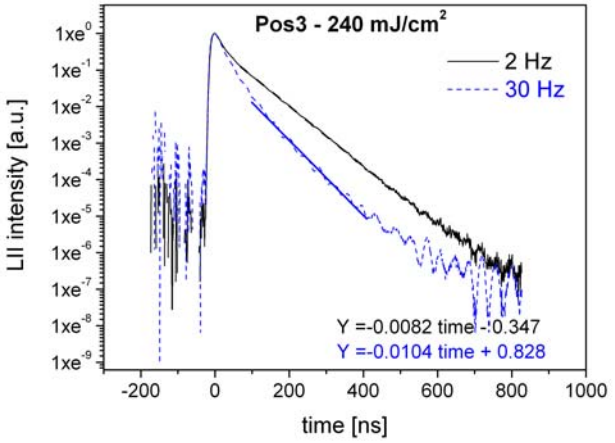


Diffusion flame - Comparison of LII decay curves



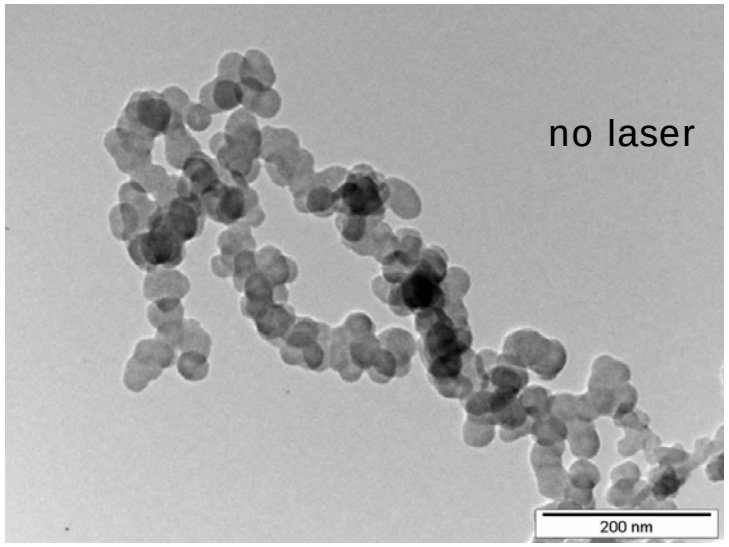


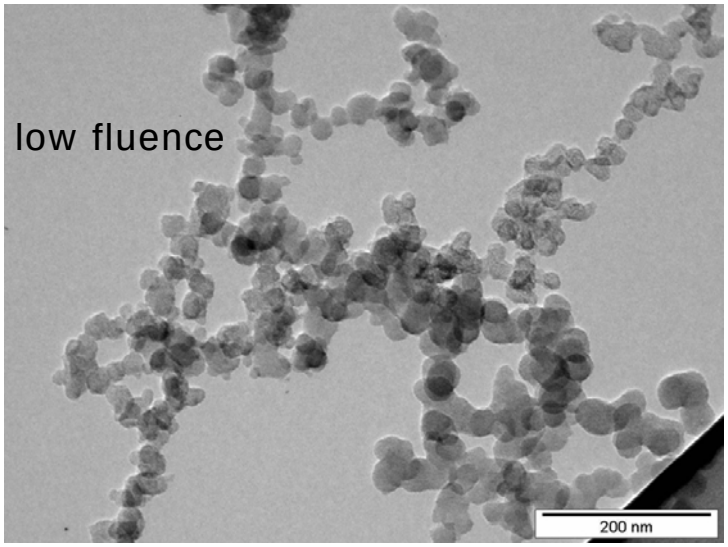


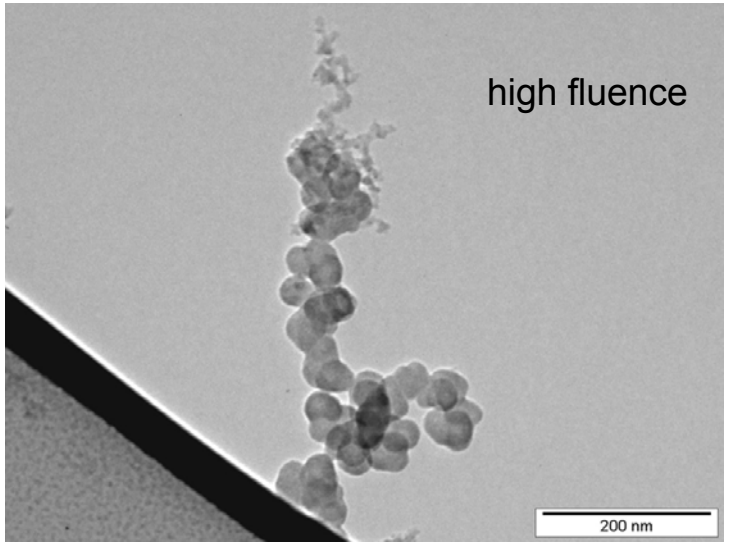


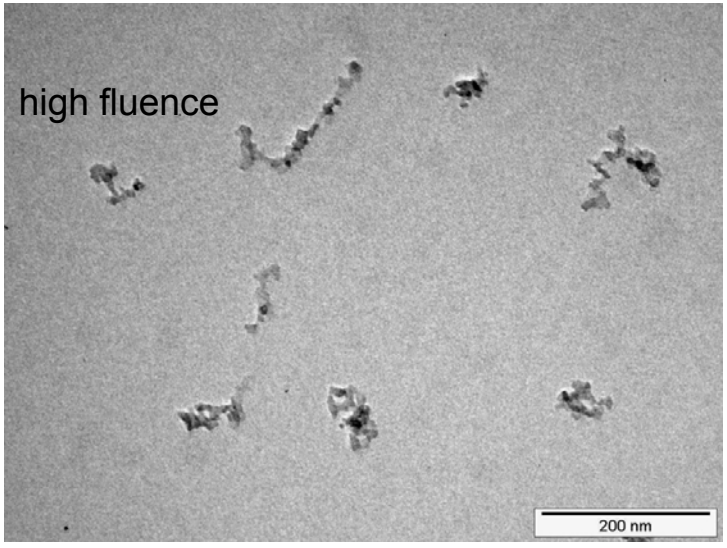
Laser Fluence	Laser (Hz)	Position 1		Position 2		Position 3	
		# pulses	slope,10^3	# pulses	slope,10^3	# pulses	slope,10^3
130 mJ/cm²	2	0.26	6.89	0.5	6.93	0.77	6.96
	30	3.88	6.93	7.77	7.11	11.65	7.45
350 mJ/cm²	2	0.26	8.47	0.5	8.37	0.77	8.2
	30	3.88	9.32	7.77	10.3	11.65	10.44

TEM analysis

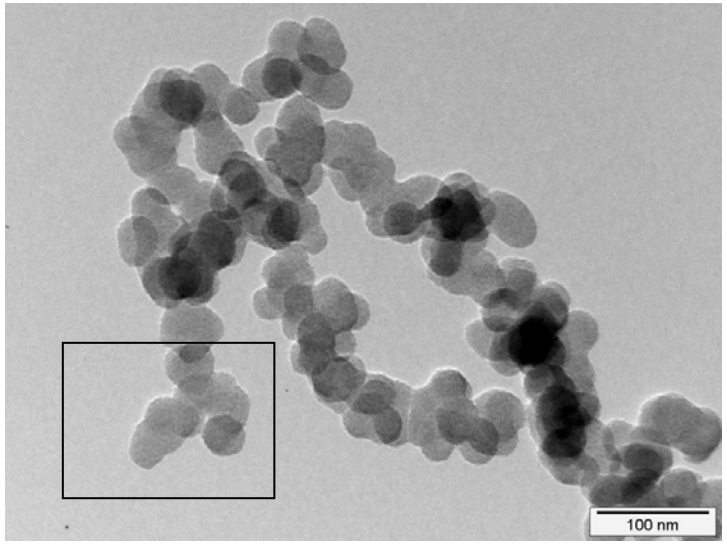


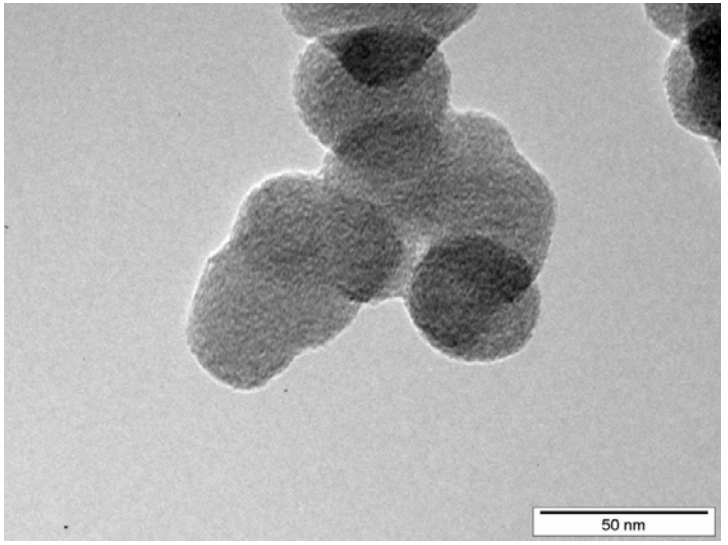


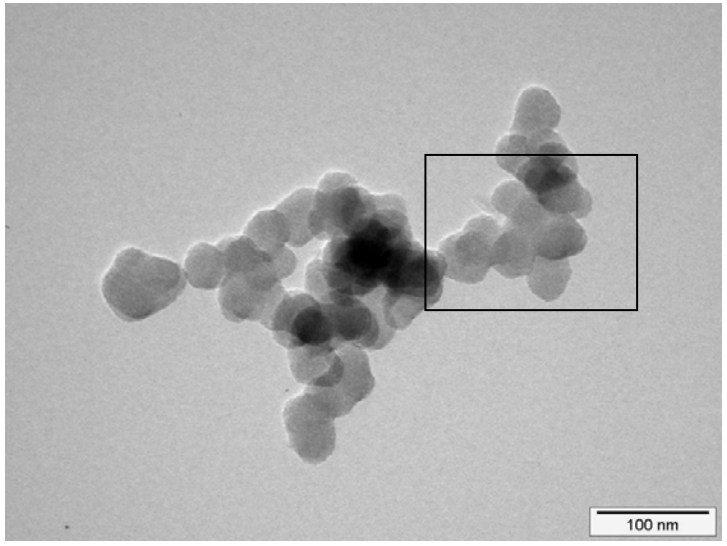


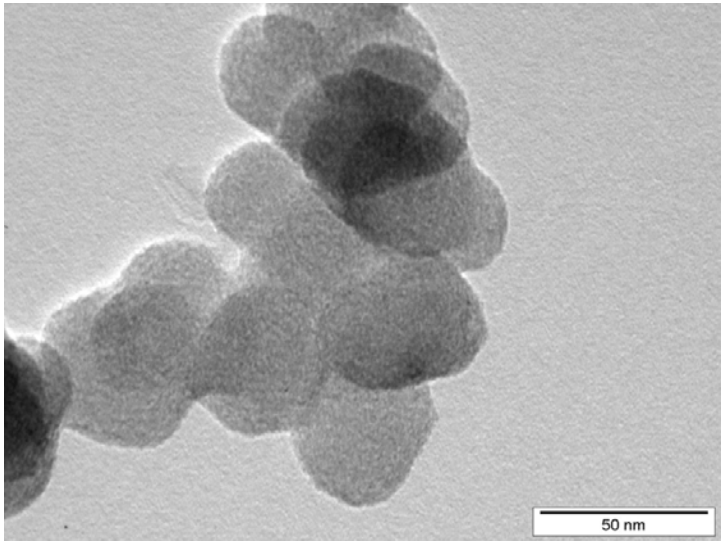


no laser

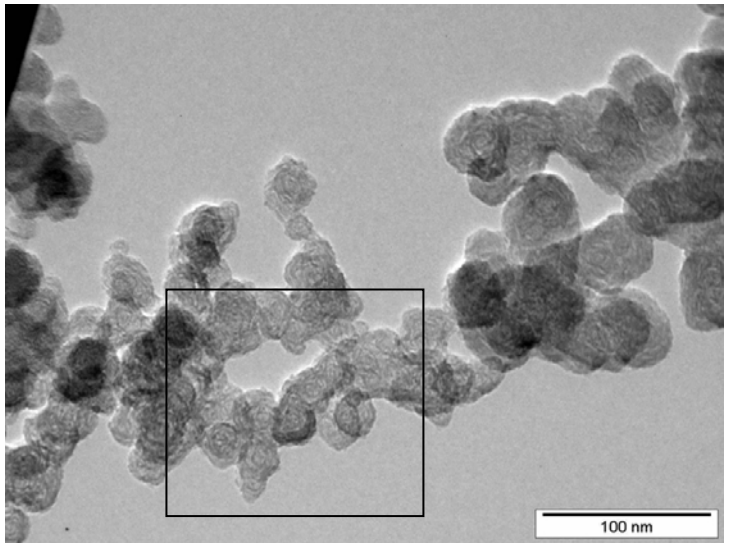


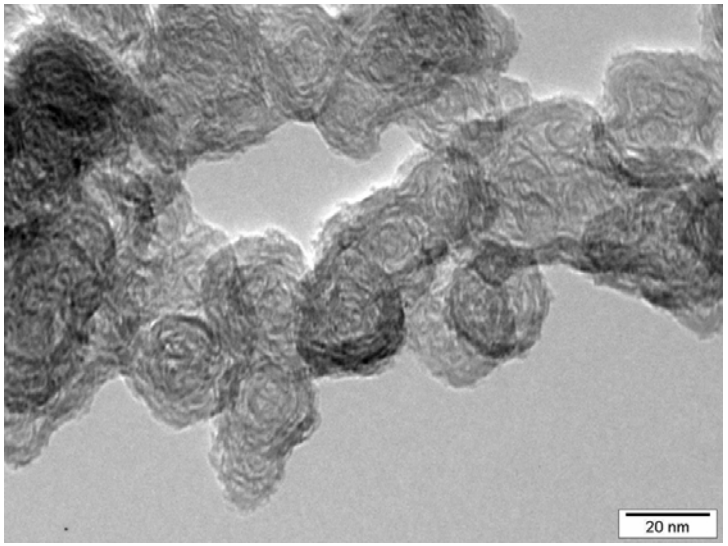


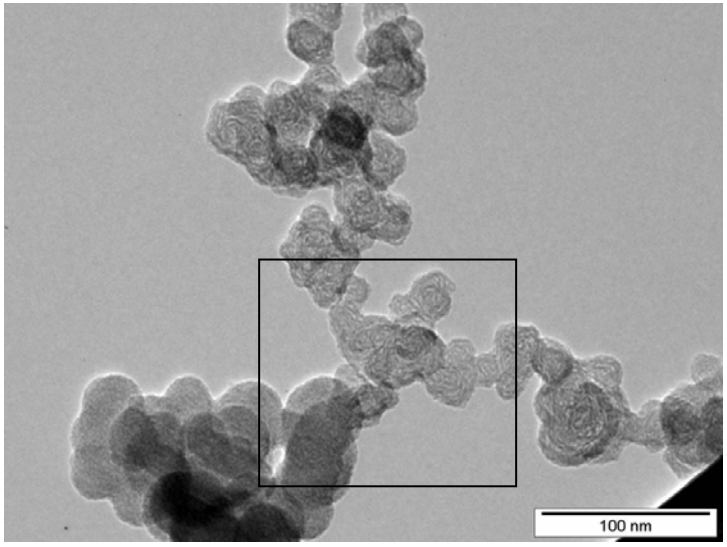


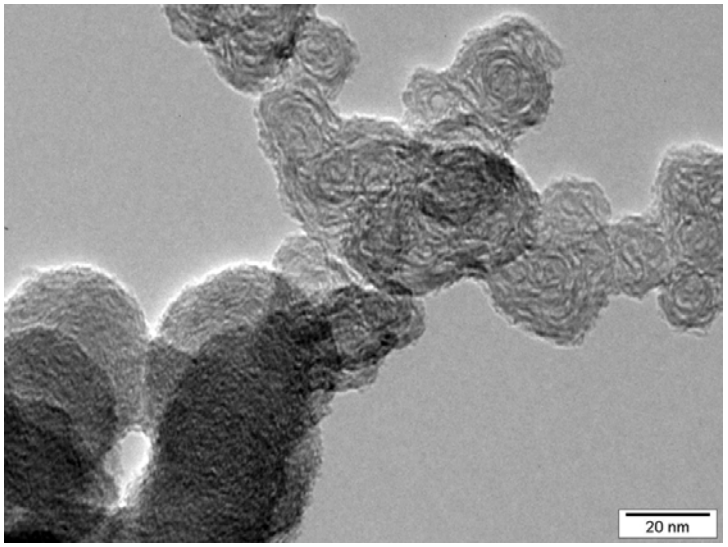


low fluence ~ 130 mJ/cm2

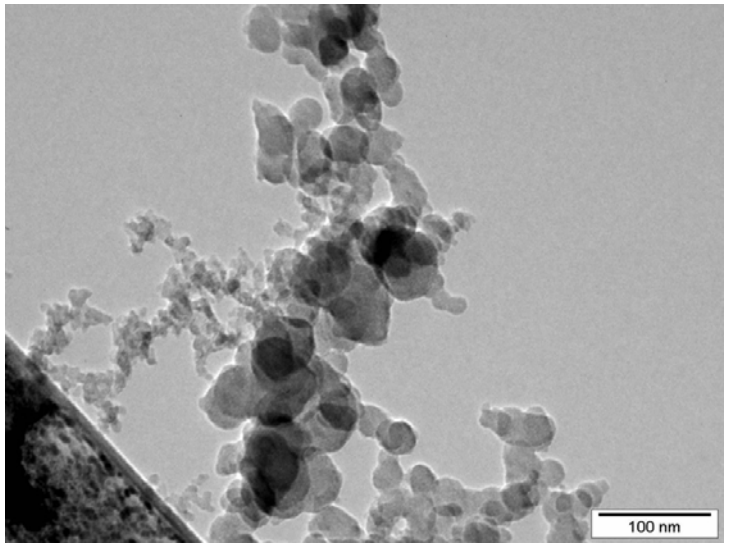


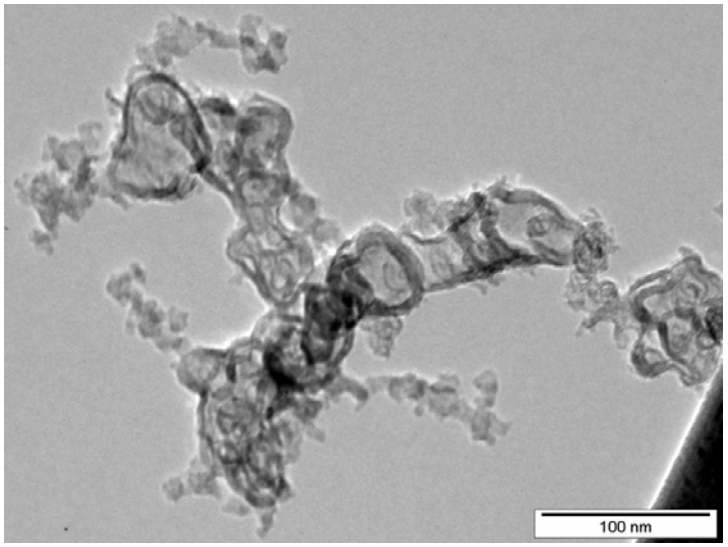


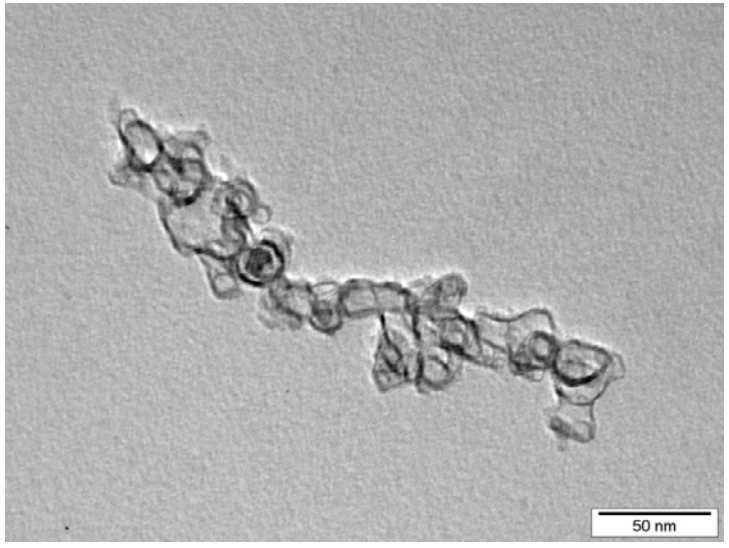


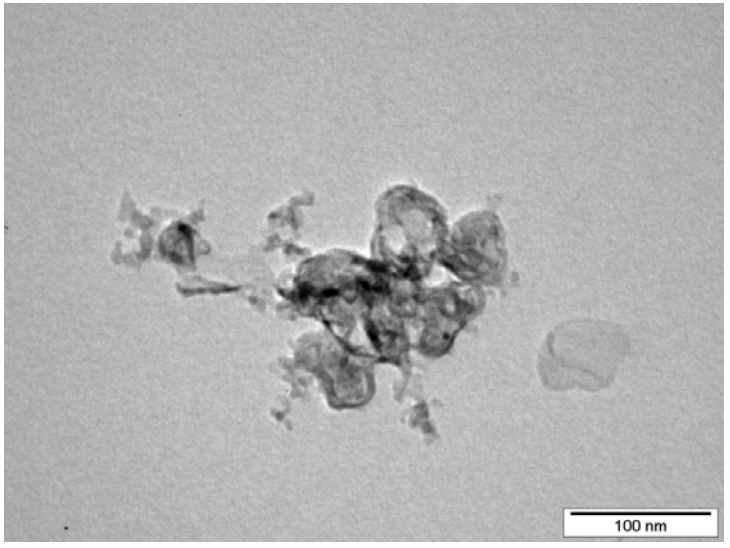


high fluence ~ 350 mJ/cm2









Conclusions and questions

✓Pulsed accumulation effects on soot from a premixed flame and a diffusion flame are similar but appear at higher fluences

✓At low laser fluence: pulse accumulation induces an increase in LII signals due to an increase in temperature. Why? Change in refraction index, graphitization?

✓At high laser fluence: the graphitization process is within the single laser pulse and the LII signal decreases due to vaporization. The aggregate dimensions are strongly reduced due to a breaking of the clusters.

Thank you for your attention