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Two types of nanosecond spark discharges in atmospheric air

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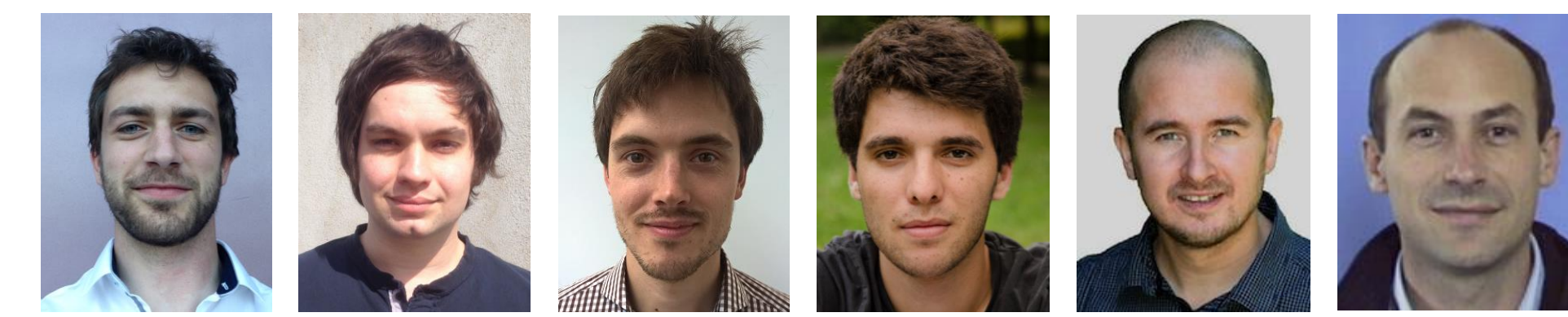
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Motivation

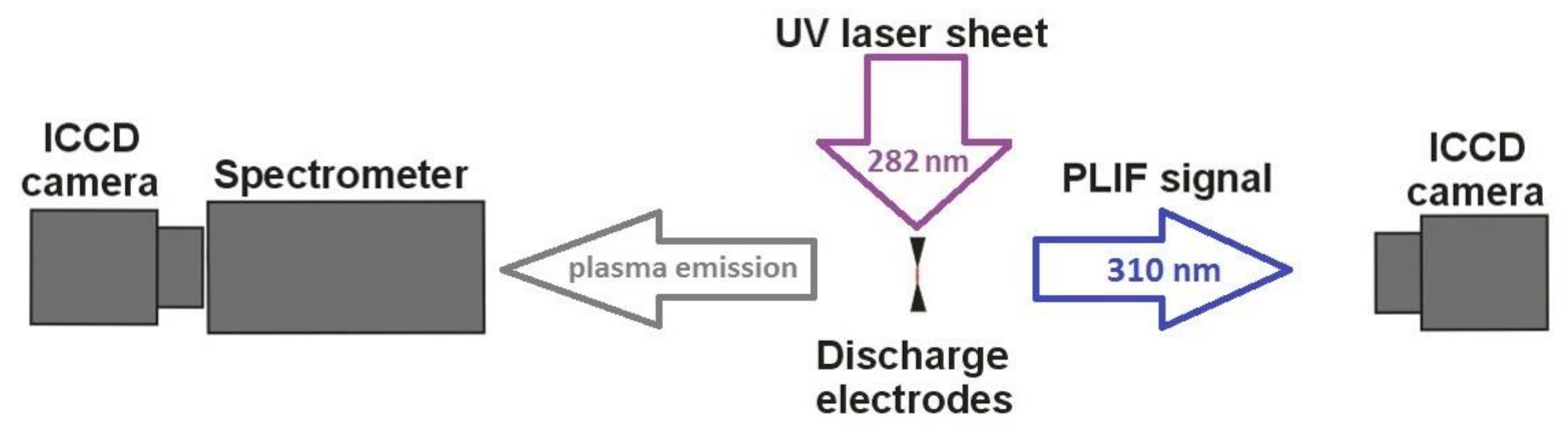
Repetitive nanosecond sparks have potential applications in combustion:

- Ignition & stabilization of lean/diluted flames
- Control of thermo-acoustic instabilities
- Reduction of pollutant emission (soot, NO_x)

Fully ionized sparks in air were predicted [1] and recently observed [2] in nanosecond discharges. This is in contrast with the partially ionized sparks of [3, 4].



Experimental setup

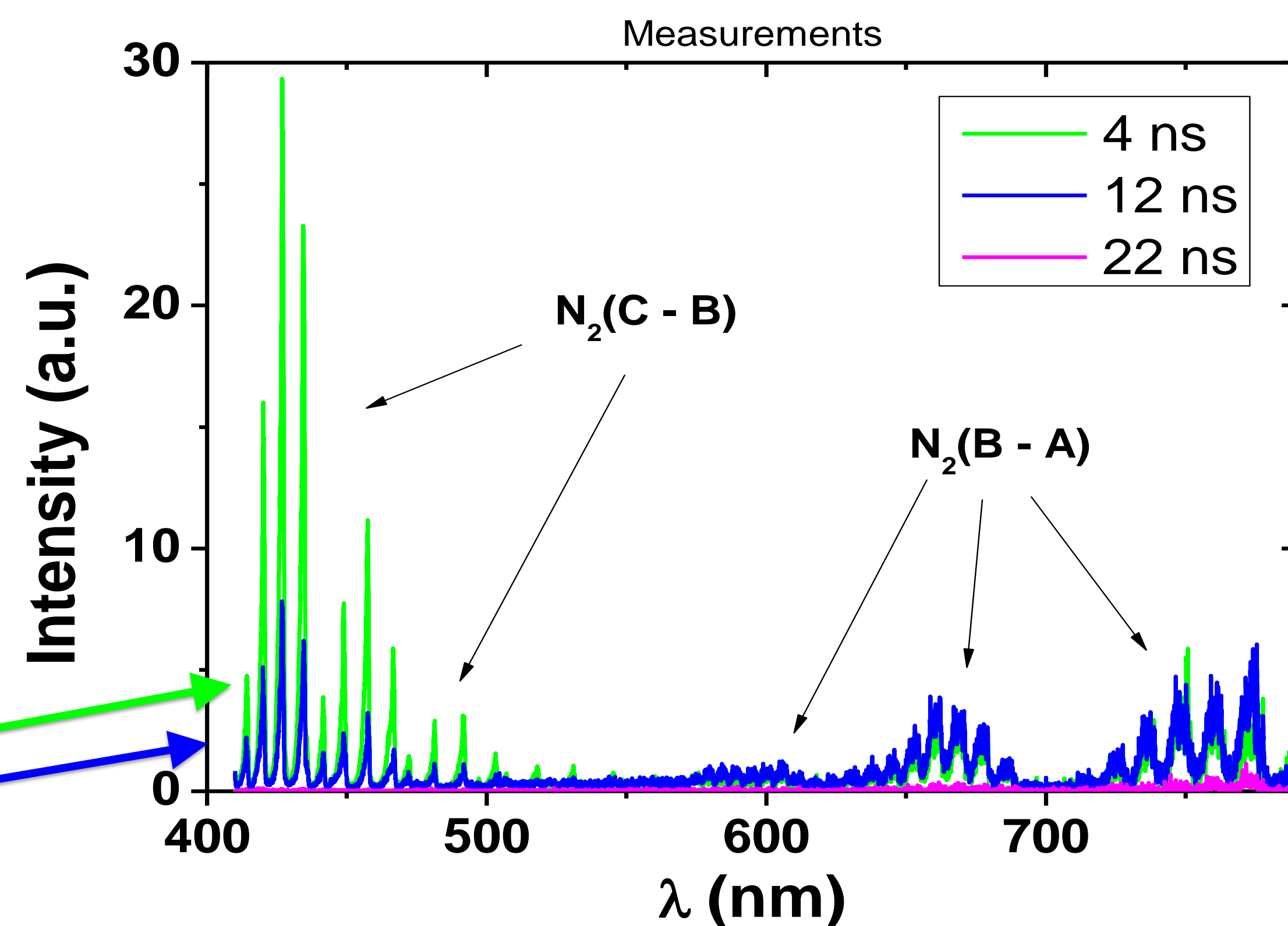
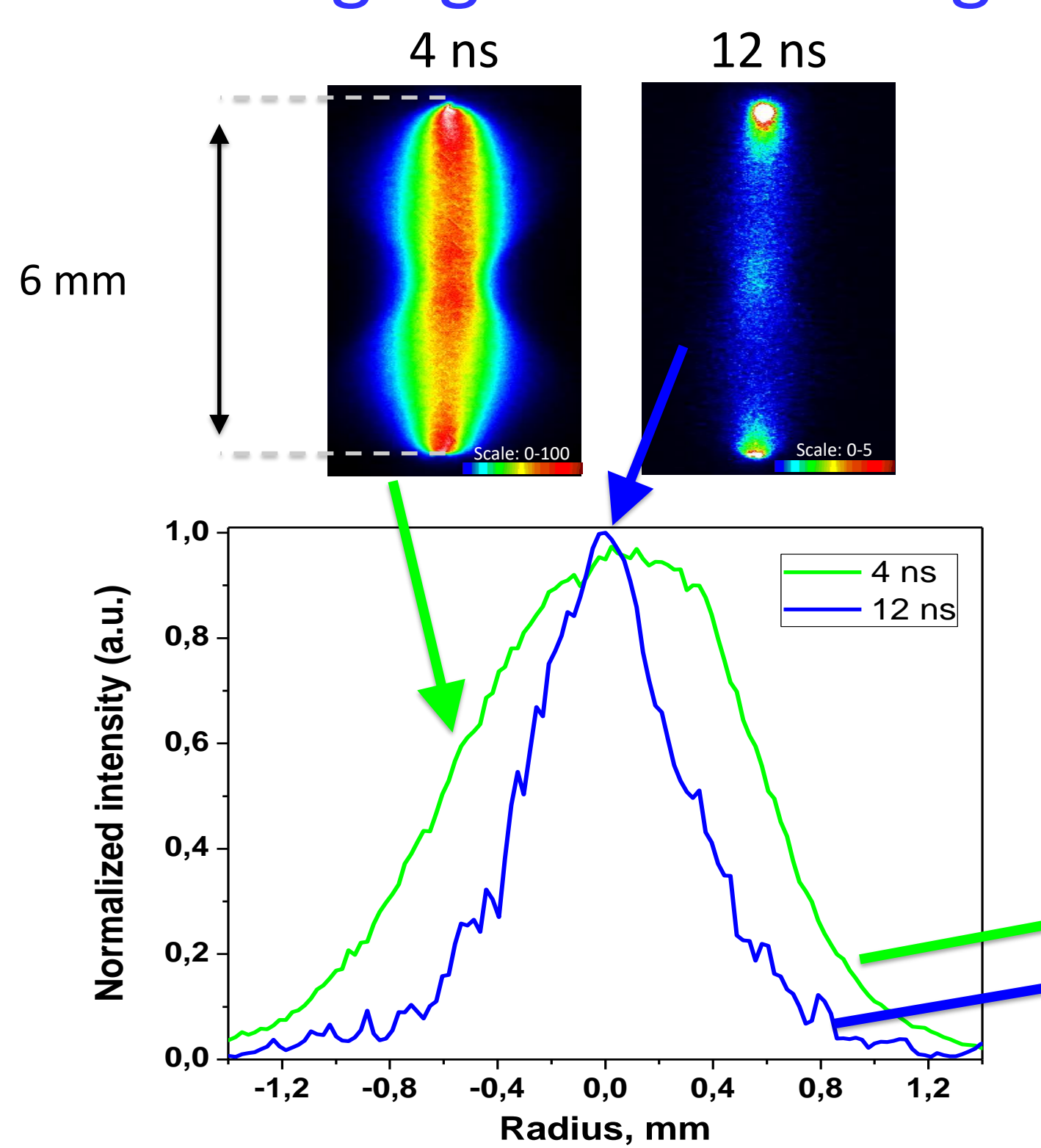


Nanosecond sparks are investigated in air (300 K, 1 atm) by (i) OH planar LIF and (ii) Optical Emission Spectroscopy

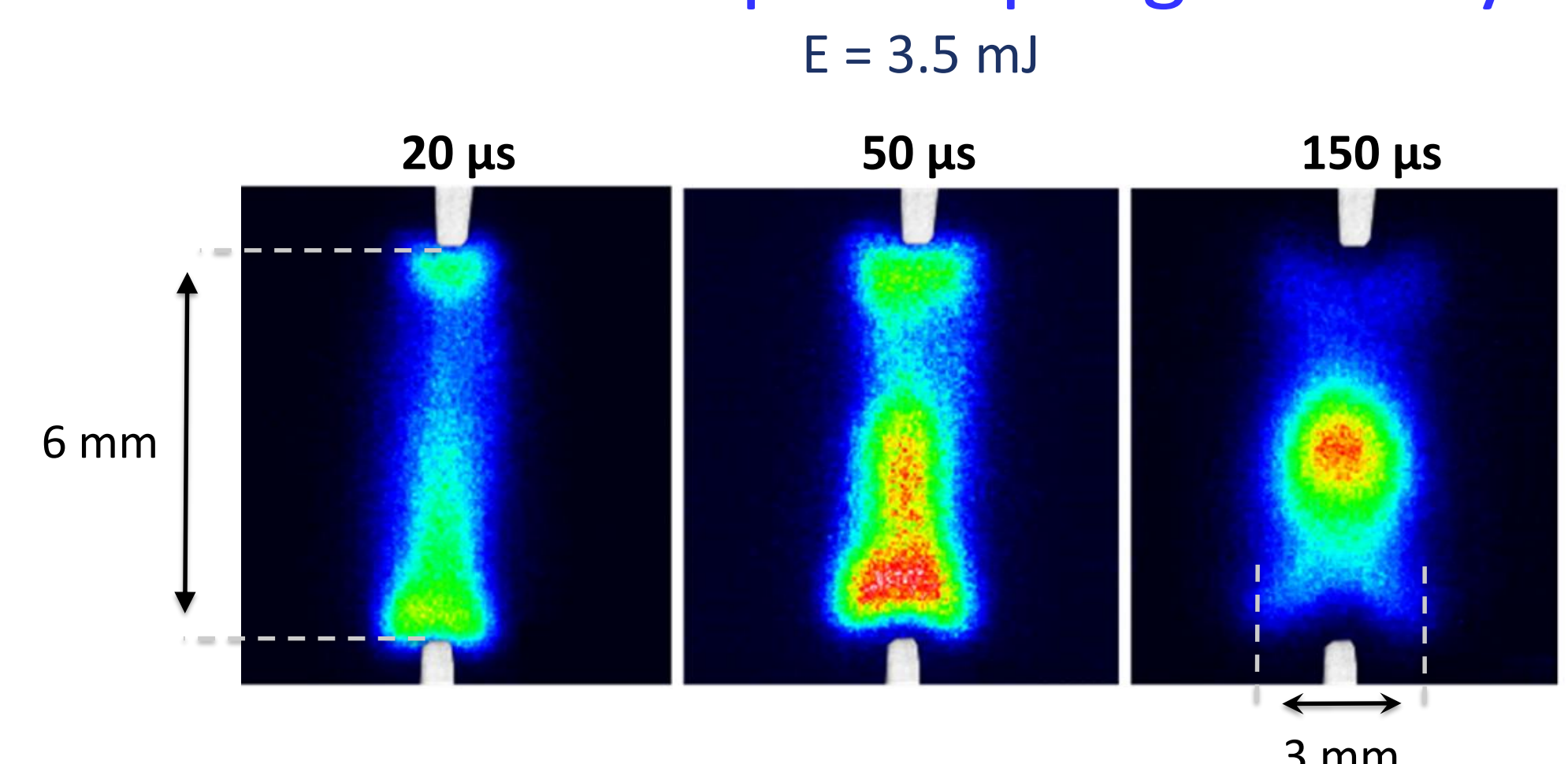
Non-contracted spark ($E/N = 200 \text{ Td}$)

($P = 1 \text{ bar}$, 6-mm gap, single pulse of 10 ns)

Imaging of ns discharge



OH PLIF in pin-to-pin geometry

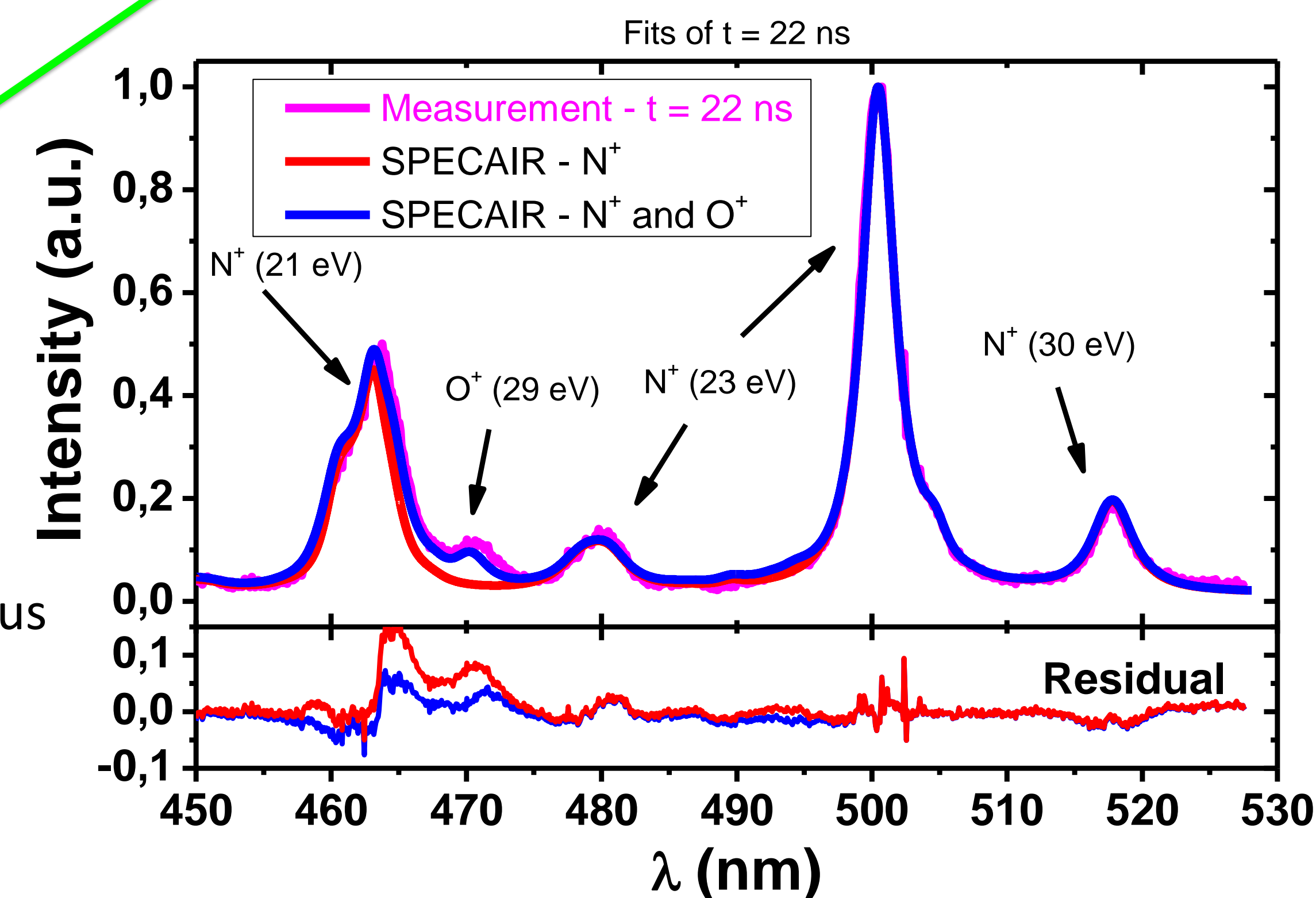
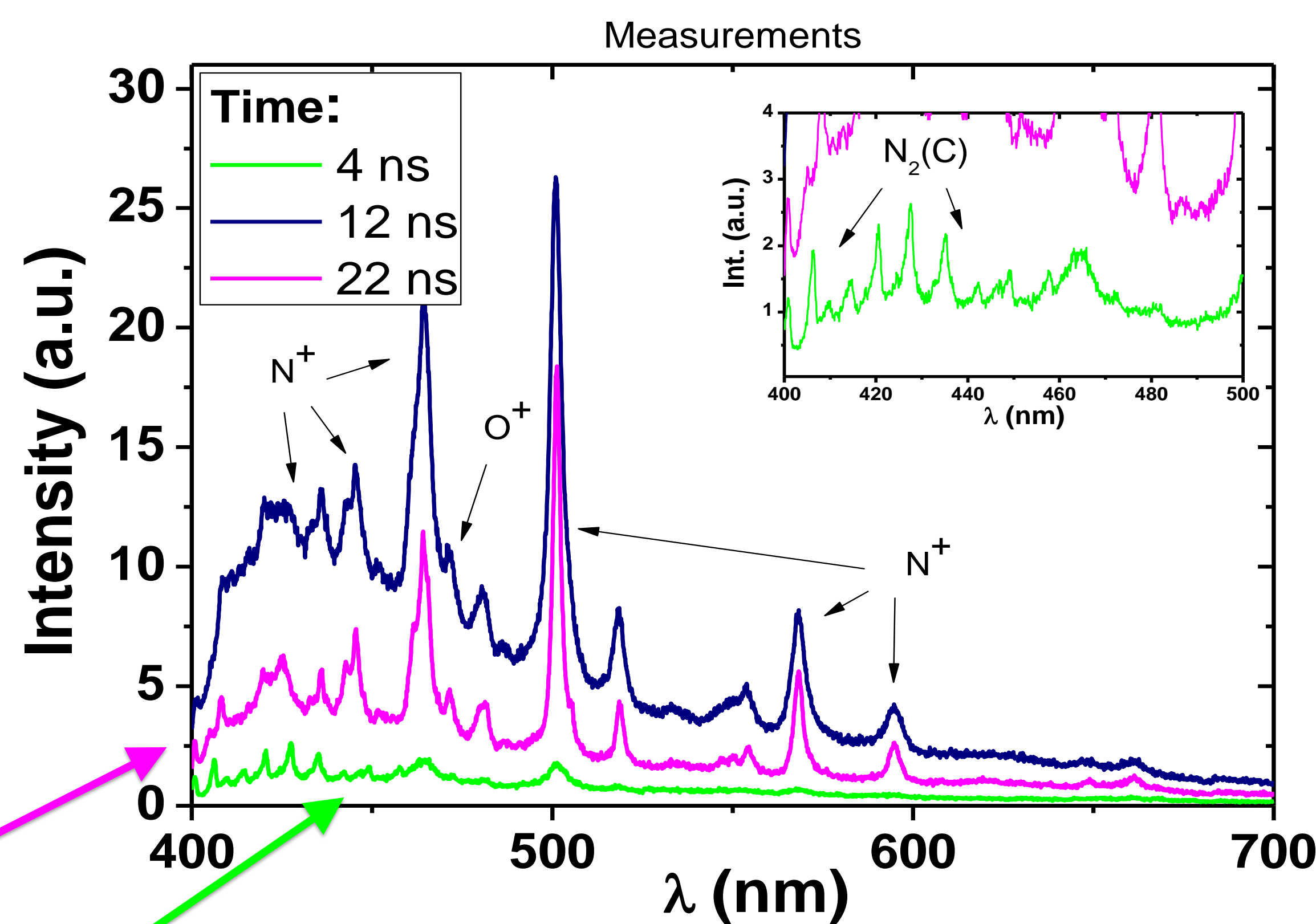
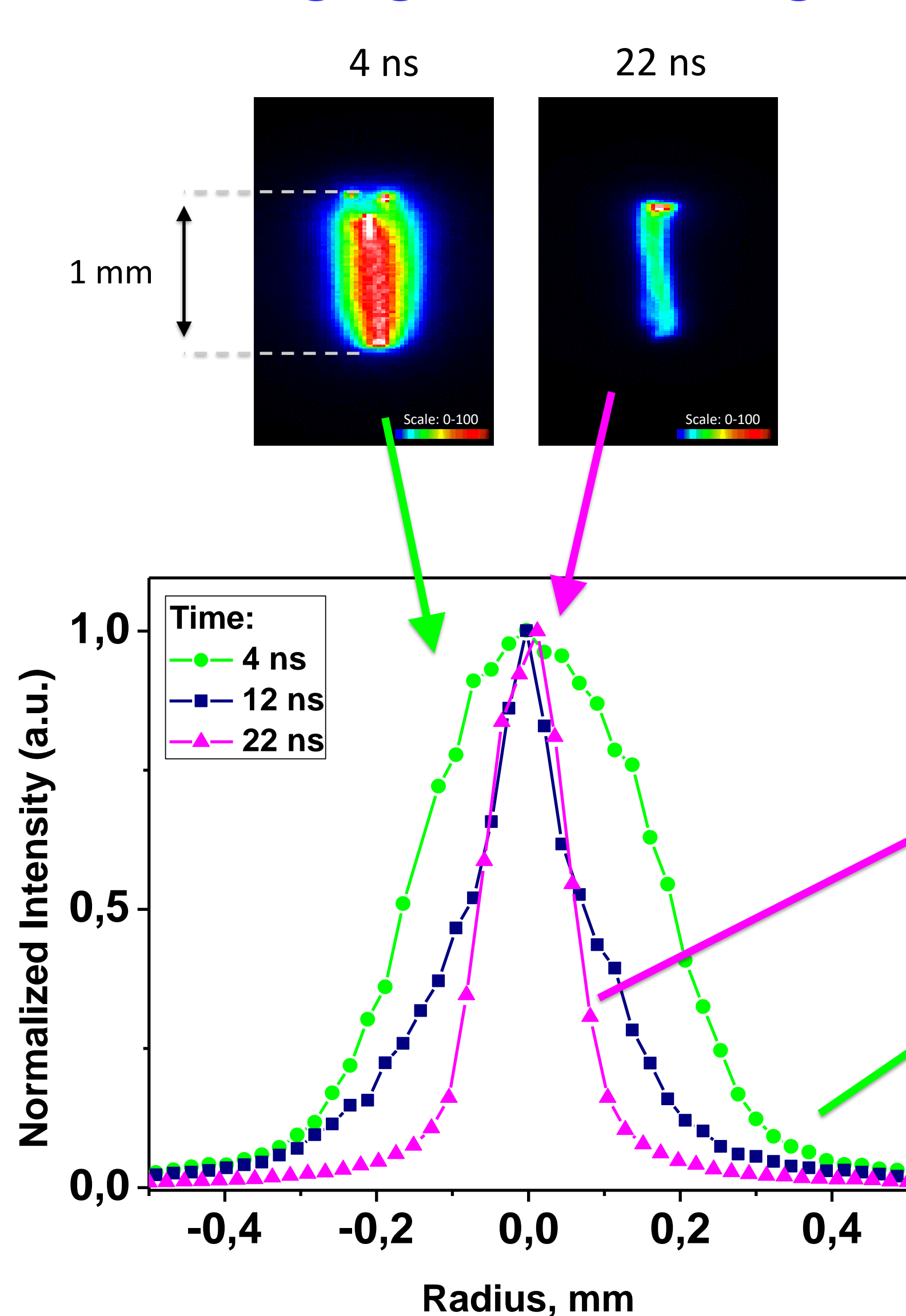


- Emission: N_2 first and second positive system
- Cylindrical expansion of the active medium
- $n_{e, \text{max}} = 2 \times 10^{15} \text{ cm}^{-3}$ [3]
- $T_{\text{max}} = 2500 \text{ K}$ [3]

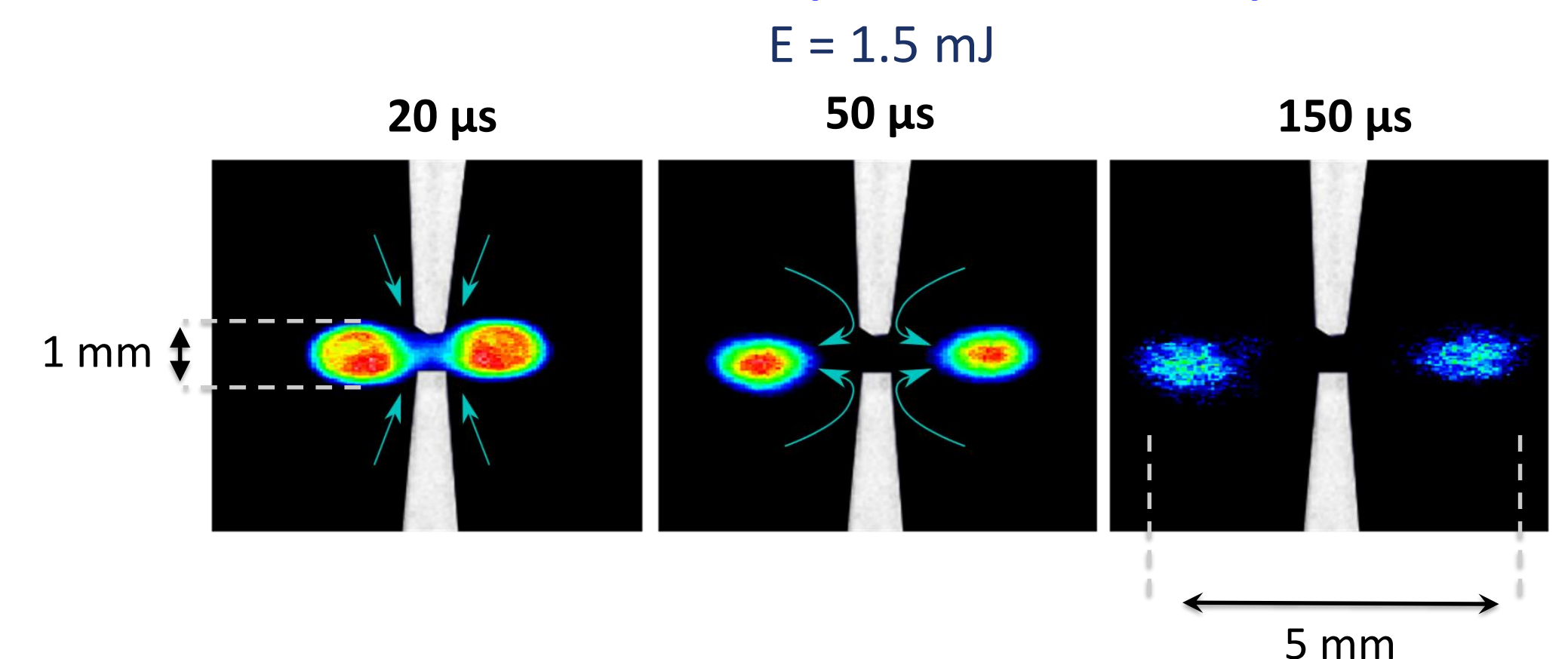
Transition to contracted spark ($E/N = 440 \text{ Td}$)

($P = 1 \text{ bar}$, 1-mm gap, single pulse of 10 ns)

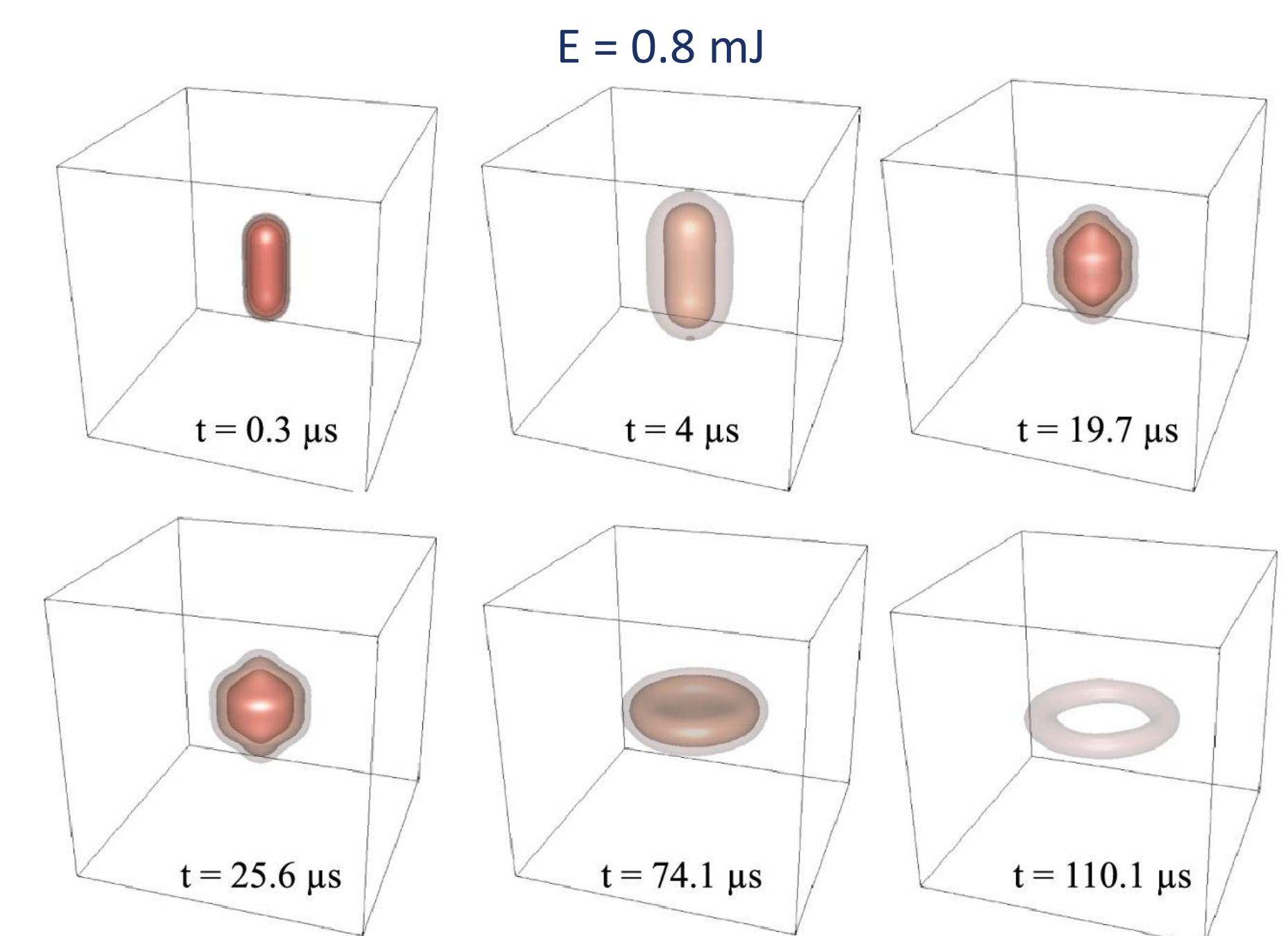
Imaging of ns discharge



OH PLIF (ambient air)



OH simulations



OH mass fraction 1.5×10^{-4} 10^{-3} 5×10^{-3} 10^{-2}
[Castela, Stepanyan, Fiorina, Coussment, Gicquel, Darabiha, Laux, 2017, Proc. Comb. Inst. 36 4095]

- Emission: N^+ , O^+ , free-free & free-bound continuum
- Toroidal expansion
- $n_{e, \text{max}} = 1.2 (\pm 0.2) \times 10^{19} \text{ cm}^{-3}$
- $T_e = T_{\text{N}^+} = T_{\text{O}^+} = 39,000 (\pm 4000) \text{ K}$

After transition ($t > 7 \text{ ns}$), we observe:

- Contraction of conductive channel radius
- Stark broadening
- $[\text{N}^+]/[\text{O}^+] = 4.1 (\pm 1.0)$
→ LTE @ 38,600K gives 3.8

References

- [1] E Sher, J Ben-Ya'ish, and T Krachvchik, 1992, *Combustion and flame*, 89 186
- [2] A Lo, A. Cessou, C Lacour, B Lecordier, P Boubert, D A Xu, C O Laux and P Vervisch, 2017, *PSST*, 26 045012
- [3] D L Rusterholtz, D A Lacoste, G D Stancu, D Z Pai, C O Laux, 2013, *J. Phys. D: Appl. Phys.*, 46 464010
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- [5] H L Olsen, R B Edmonson, E L Gayhart, 1952, *J. Appl. Phys.*, 23 1157
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Conclusions

Two regimes of spark discharges have been evidenced: contracted and non-contracted sparks. A correlation between spark contraction, emission of N^+/O^+ and toroidal expansion [5,6] has been found. In future work, we aim to determine which parameters trigger this transition.