



**HAL**  
open science

## Two types of nanosecond spark discharges in atmospheric air

Nicolas Minesi, Sergey Stepanyan, Erwan Pannier, Pierre Mariotto, Gabi D. Stancu, Christophe O Laux

### ► To cite this version:

Nicolas Minesi, Sergey Stepanyan, Erwan Pannier, Pierre Mariotto, Gabi D. Stancu, et al.. Two types of nanosecond spark discharges in atmospheric air. 70th Gaseous Electronics Conference, Nov 2017, Pittsburg, United States. hal-01866390

**HAL Id: hal-01866390**

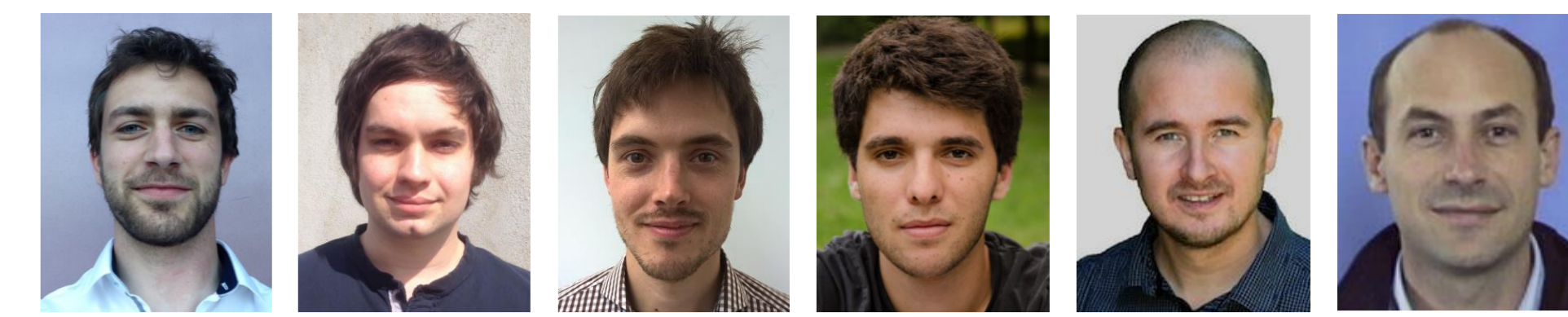
**<https://hal.science/hal-01866390>**

Submitted on 24 Feb 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.





## Motivation

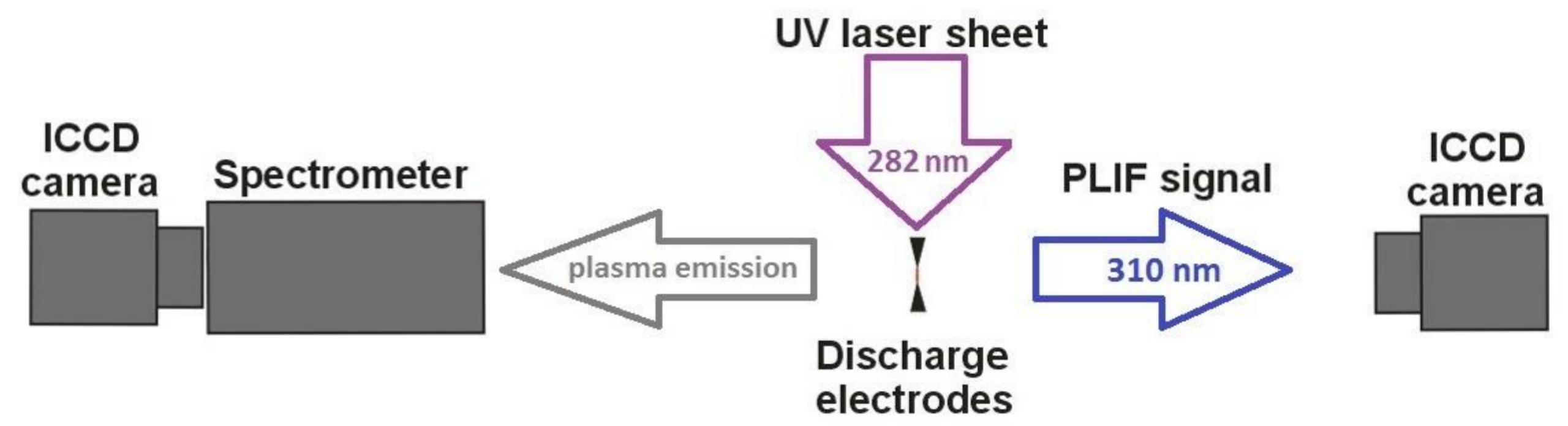
Repetitive nanosecond sparks have potential applications in combustion:

- Ignition & stabilization of lean/diluted flames
- Control of thermo-acoustic instabilities
- Reduction of pollutant emission (soot,  $\text{NO}_x$ )

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

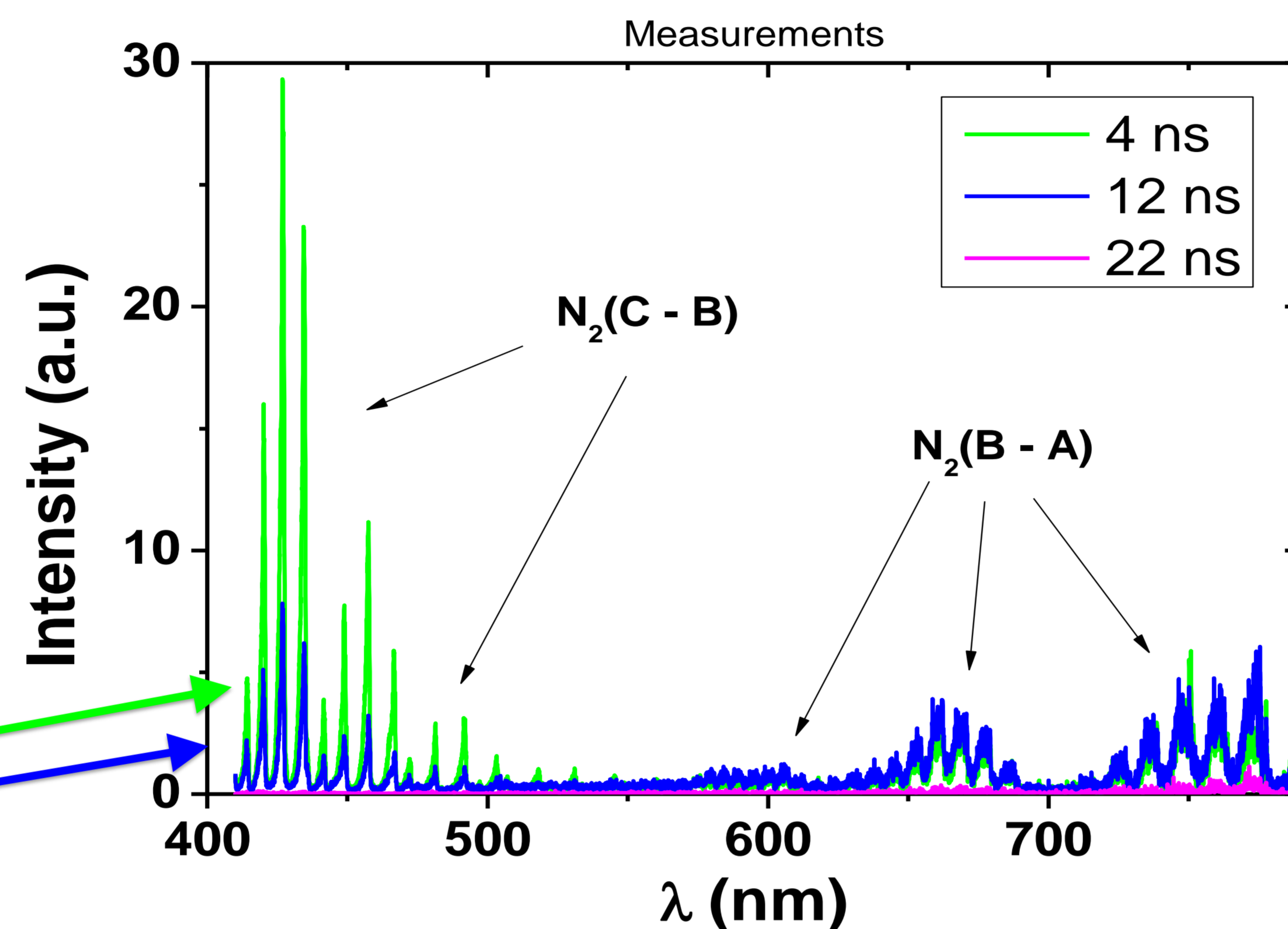
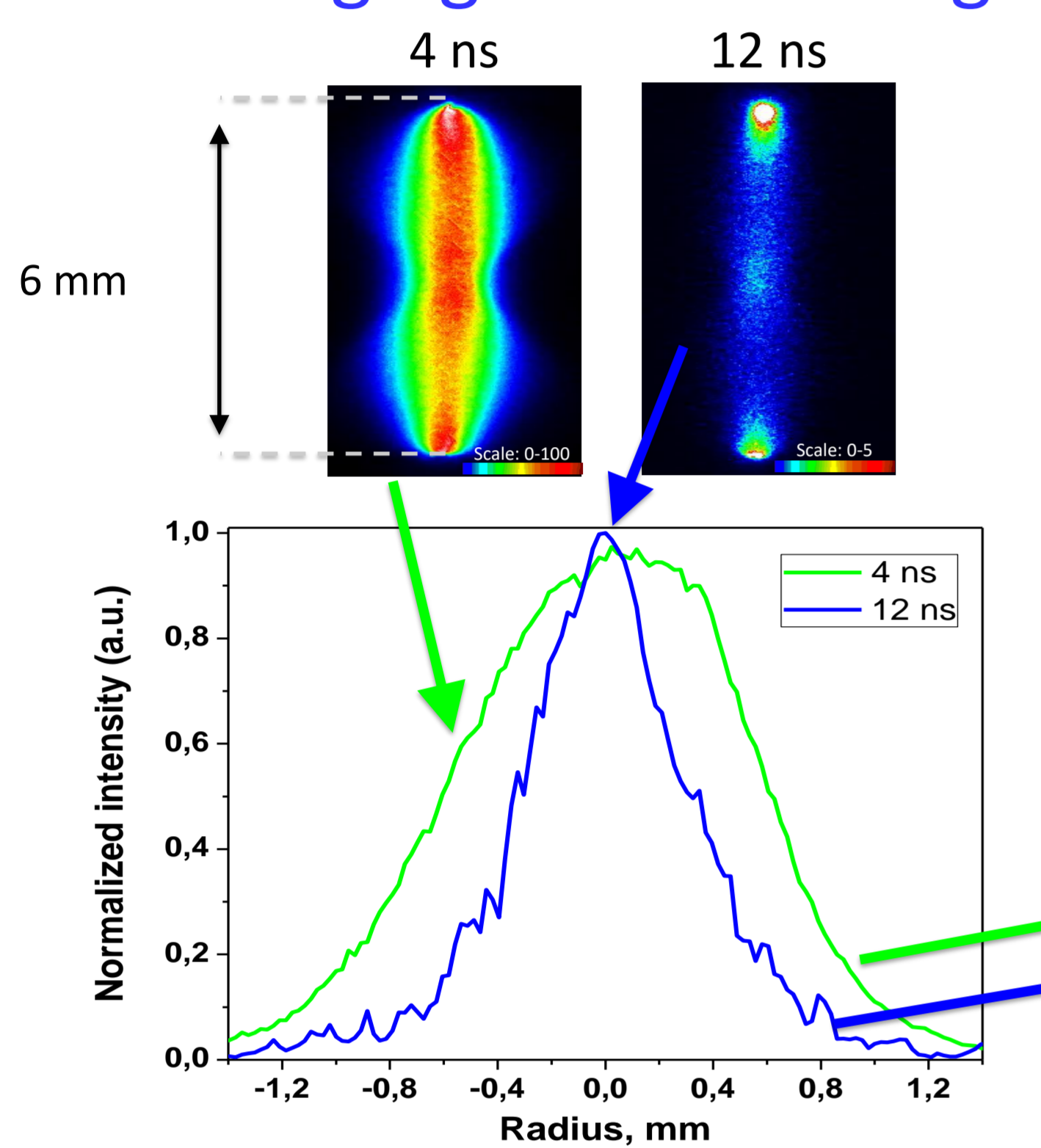


Nanosecond sparks are investigated in air (300 K, 1 atm) by (i) OH planar LIF and (ii) Optical Emission Spectroscopy

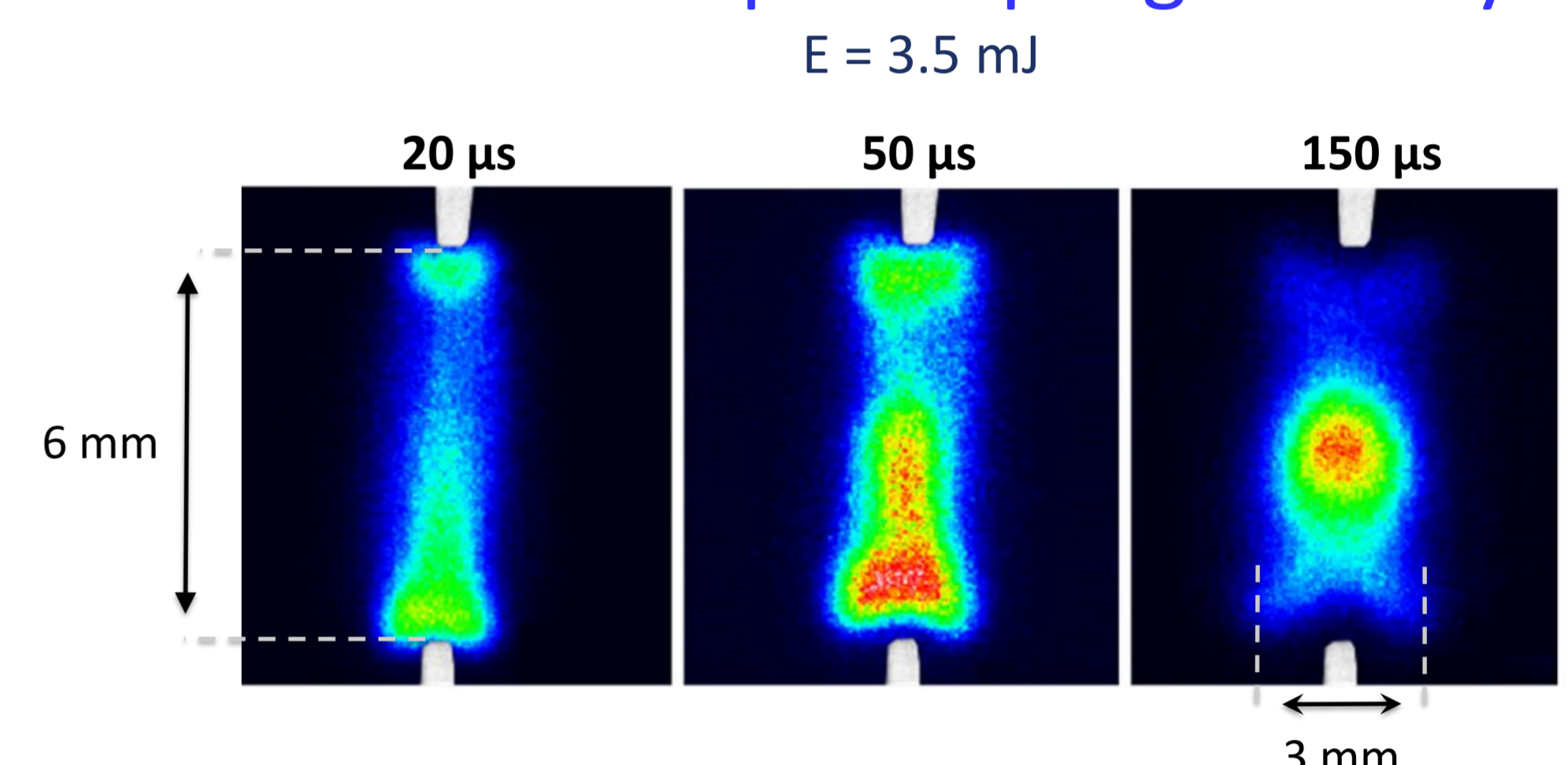
## Non-contracted spark ( $E/N = 200 \text{ Td}$ )

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

### Imaging of ns discharge



### OH PLIF in pin-to-pin geometry

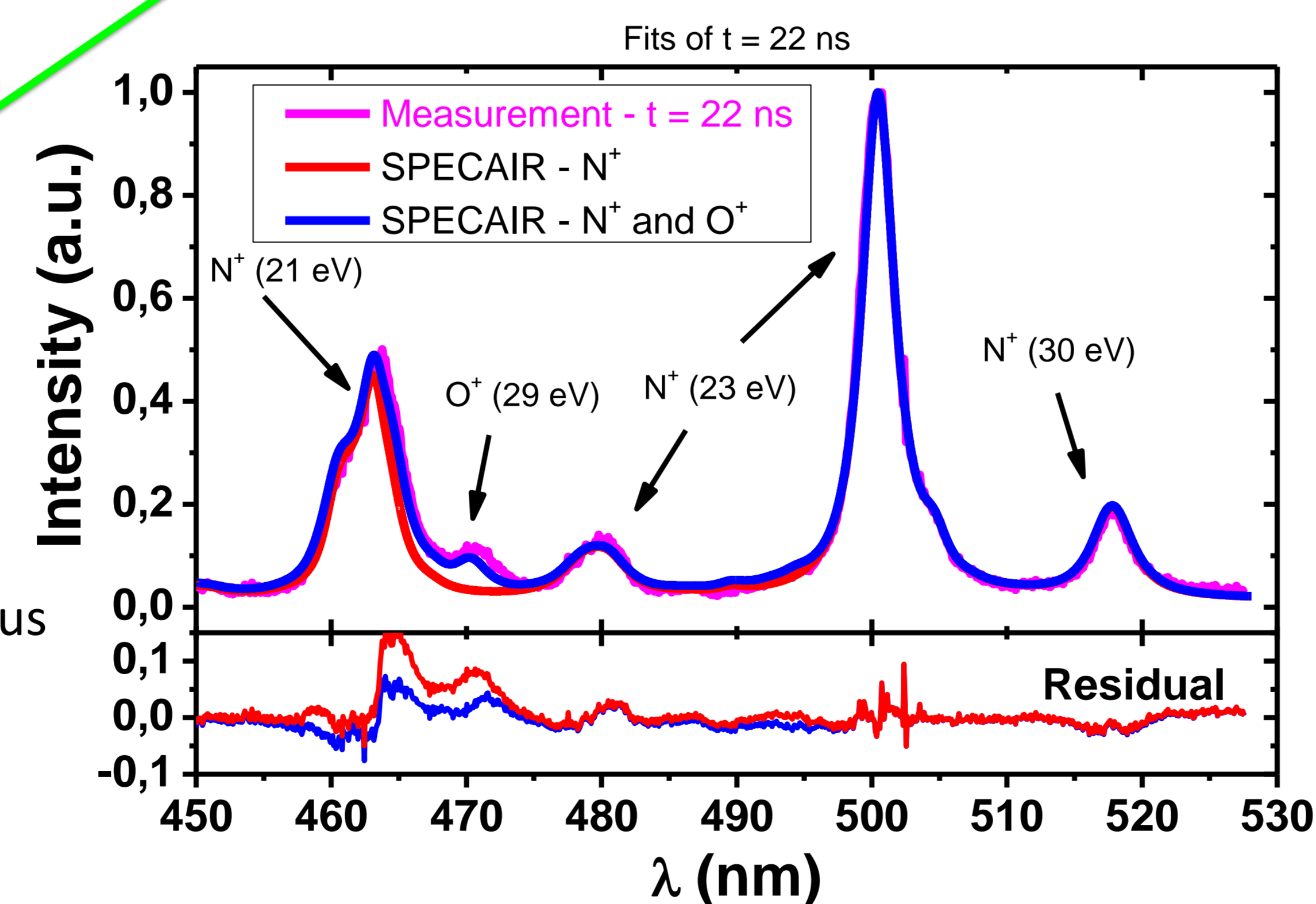
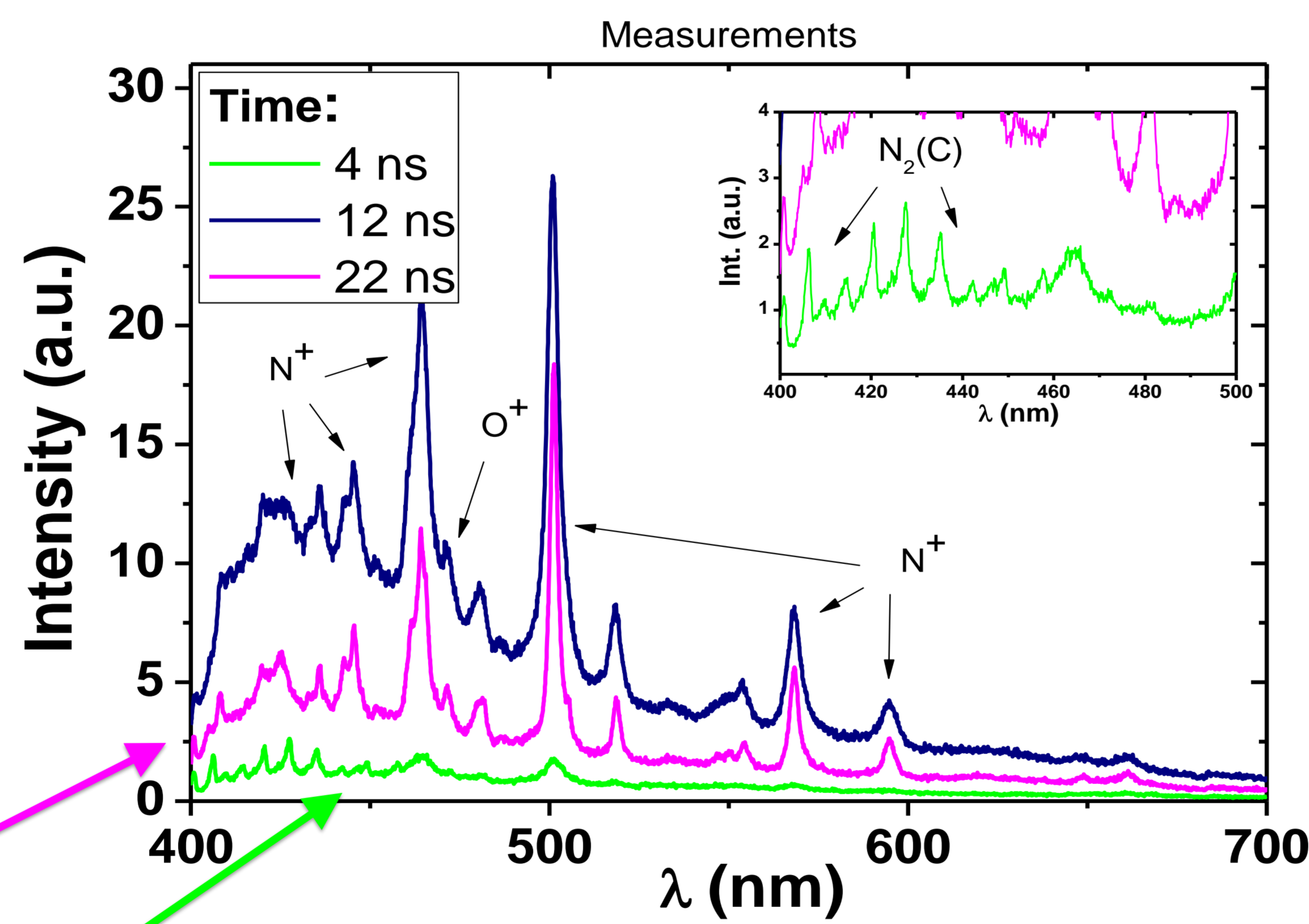
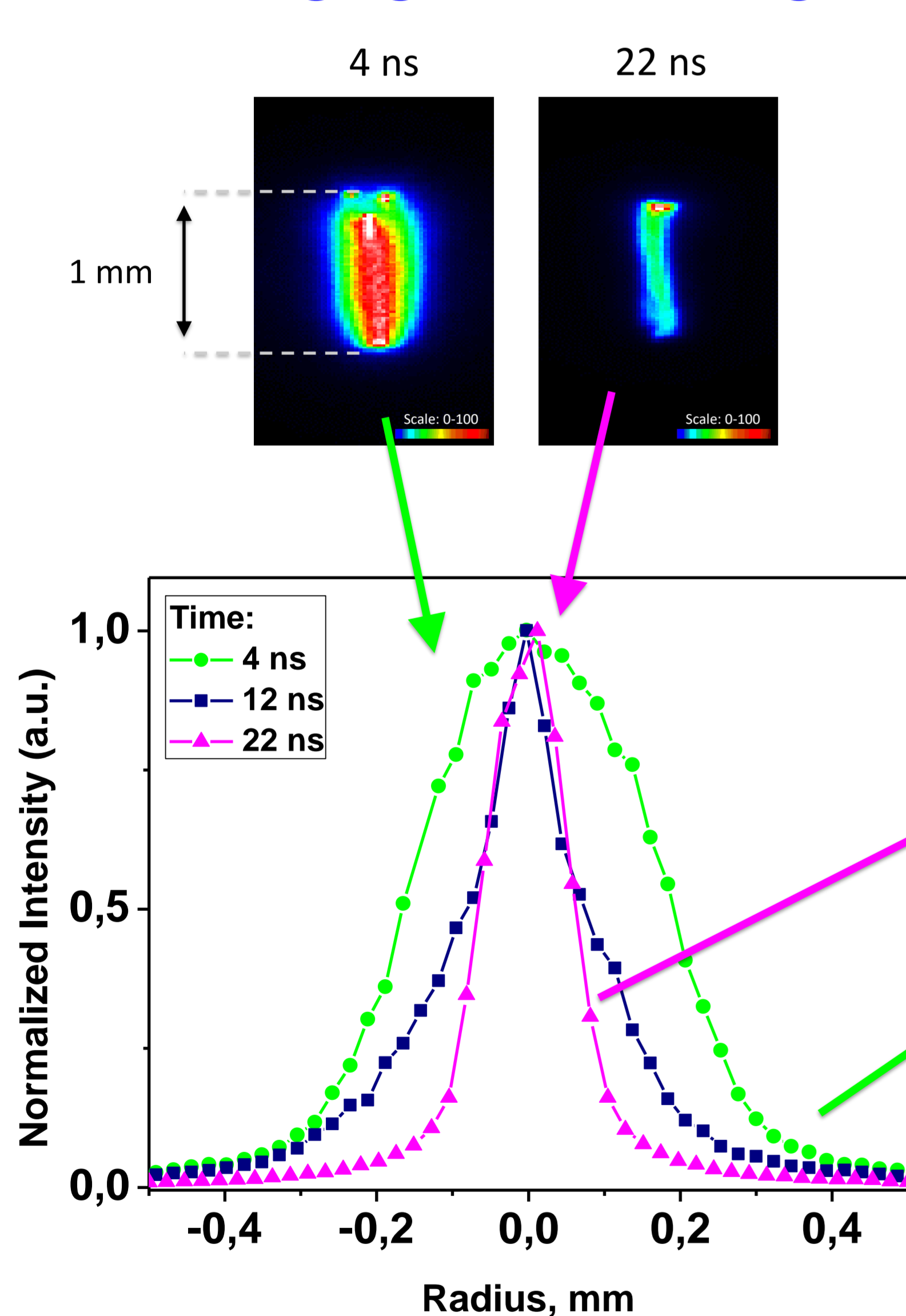


- Emission:  $\text{N}_2$  first and second positive system
- Cylindrical expansion of the active medium
- $n_{e, \text{max}} = 2 \times 10^{15} \text{ cm}^{-3}$  [3]
- $T_{\text{max}} = 2500 \text{ K}$  [3]

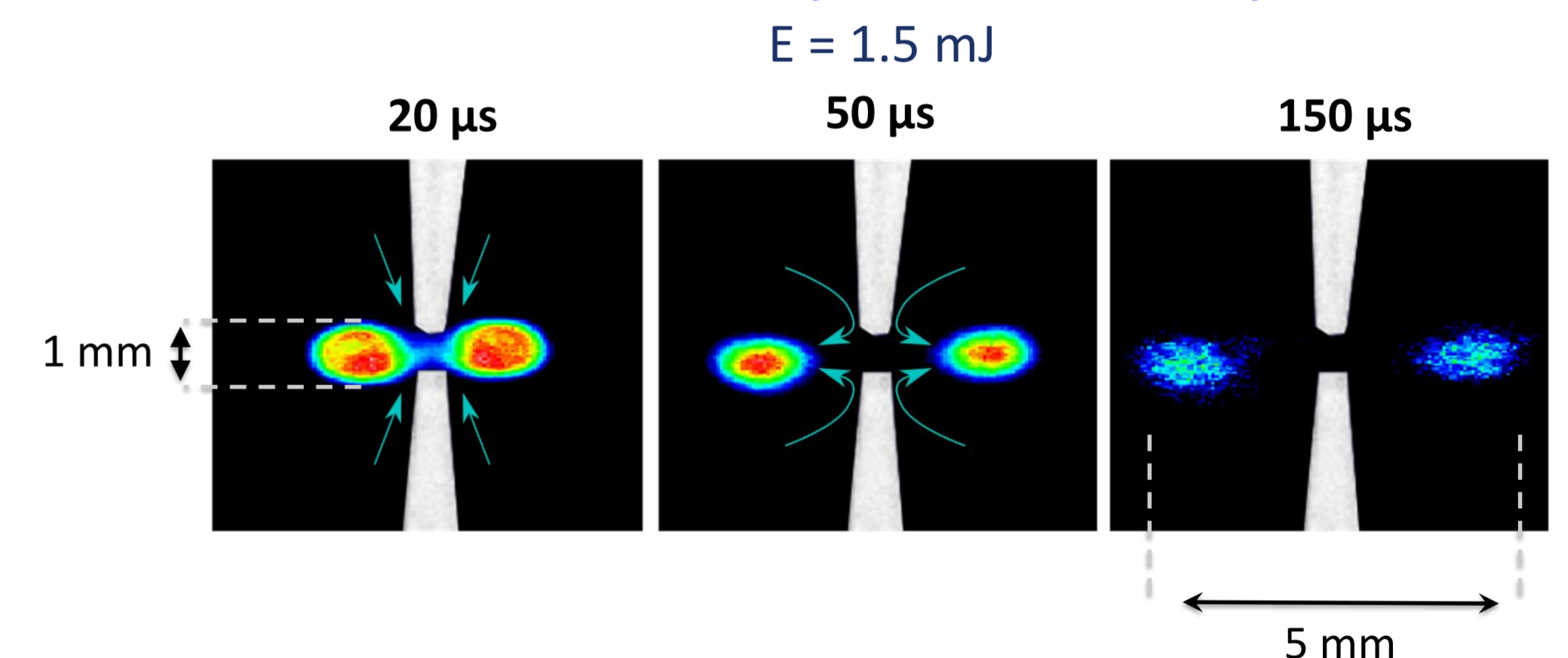
## Transition to contracted spark ( $E/N = 440 \text{ Td}$ )

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

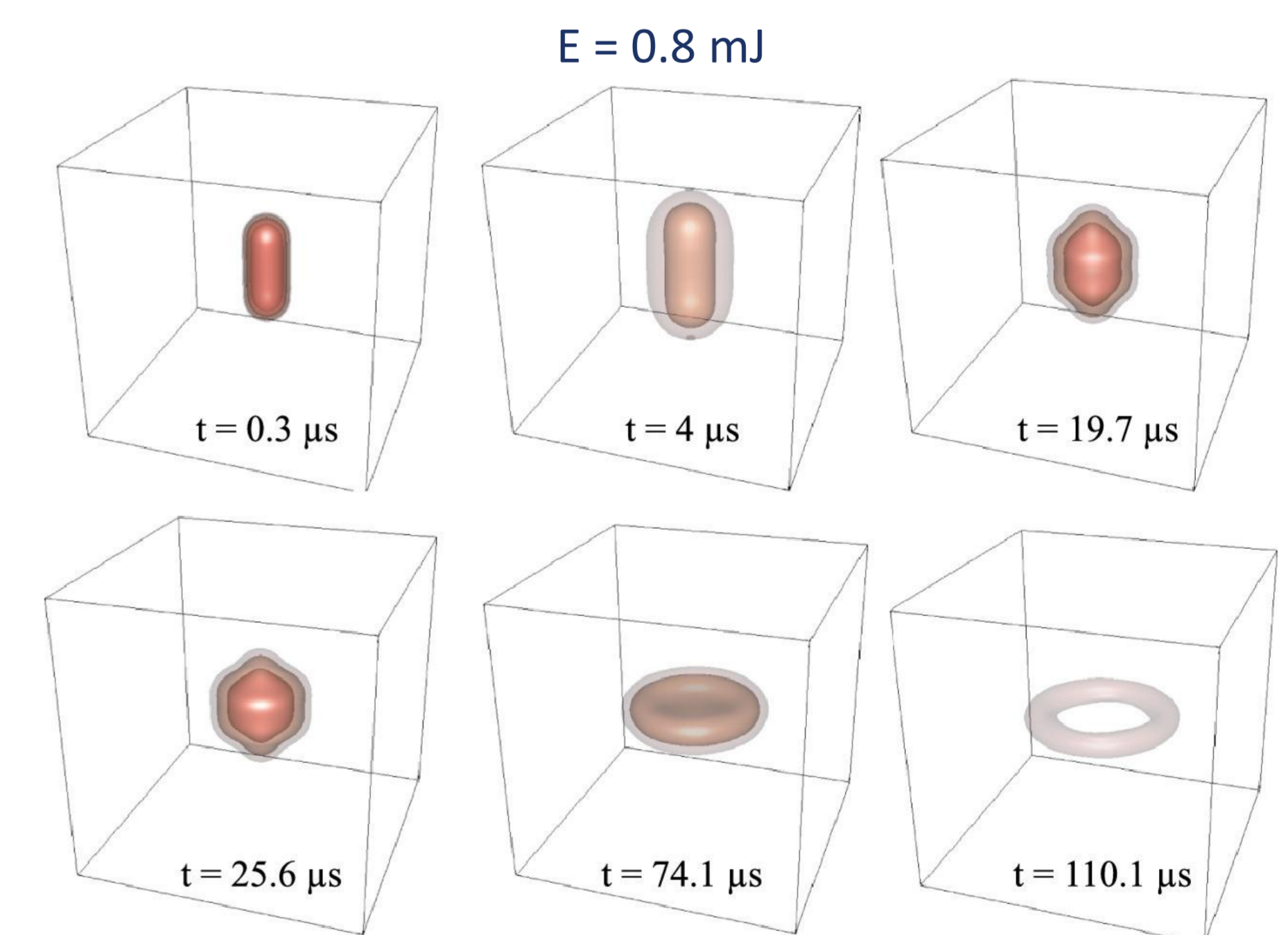
### Imaging of ns discharge



### OH PLIF (ambient air)



### OH simulations



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

- Emission:  $\text{N}^+$ ,  $\text{O}^+$ , 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
- [4] D Z Pai, D A Lacoste, C O Laux, 2010, *PSST*, 19 065015
- [5] H L Olsen, R B Edmonson, E L Gayhart, 1952, *J. Appl. Phys.*, 23 1157
- [6] S Stepanyan, J Hayashi, A Salmon, G D Stancu, C O Laux, 2017, *PSST*, 26 04LT01

## Conclusions

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