



Hydrodynamic effects induced by nanosecond sparks

Nicolas Minesi, Sergey Stepanyan, Erwan Pannier, Gabi-Daniel Stancu,
Christophe O. Laux

► To cite this version:

Nicolas Minesi, Sergey Stepanyan, Erwan Pannier, Gabi-Daniel Stancu, Christophe O. Laux. Hydrodynamic effects induced by nanosecond sparks. 6th Aerospace Thematic Workshop, Fundamentals of Flow and Combustion Control by Plasmas, Oct 2017, Saint-Petersburg, Russia. hal-01866537

HAL Id: hal-01866537

<https://hal.science/hal-01866537>

Submitted on 20 Feb 2020

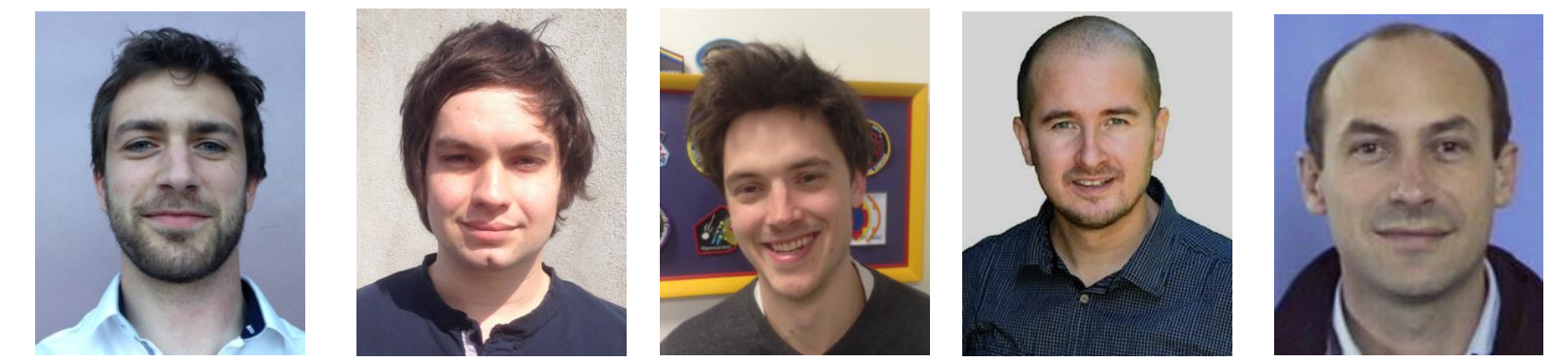
HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

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.

Hydrodynamic effects induced by nanosecond sparks

N. Minesi, S. Stepanyan, E. Pannier, G.D. Stancu, C.O. Laux

Laboratoire EM2C, CNRS, CentraleSupélec, Université Paris-Saclay, Grande Voie des Vignes, 92295 Châtenay-Malabry cedex, France



Motivation

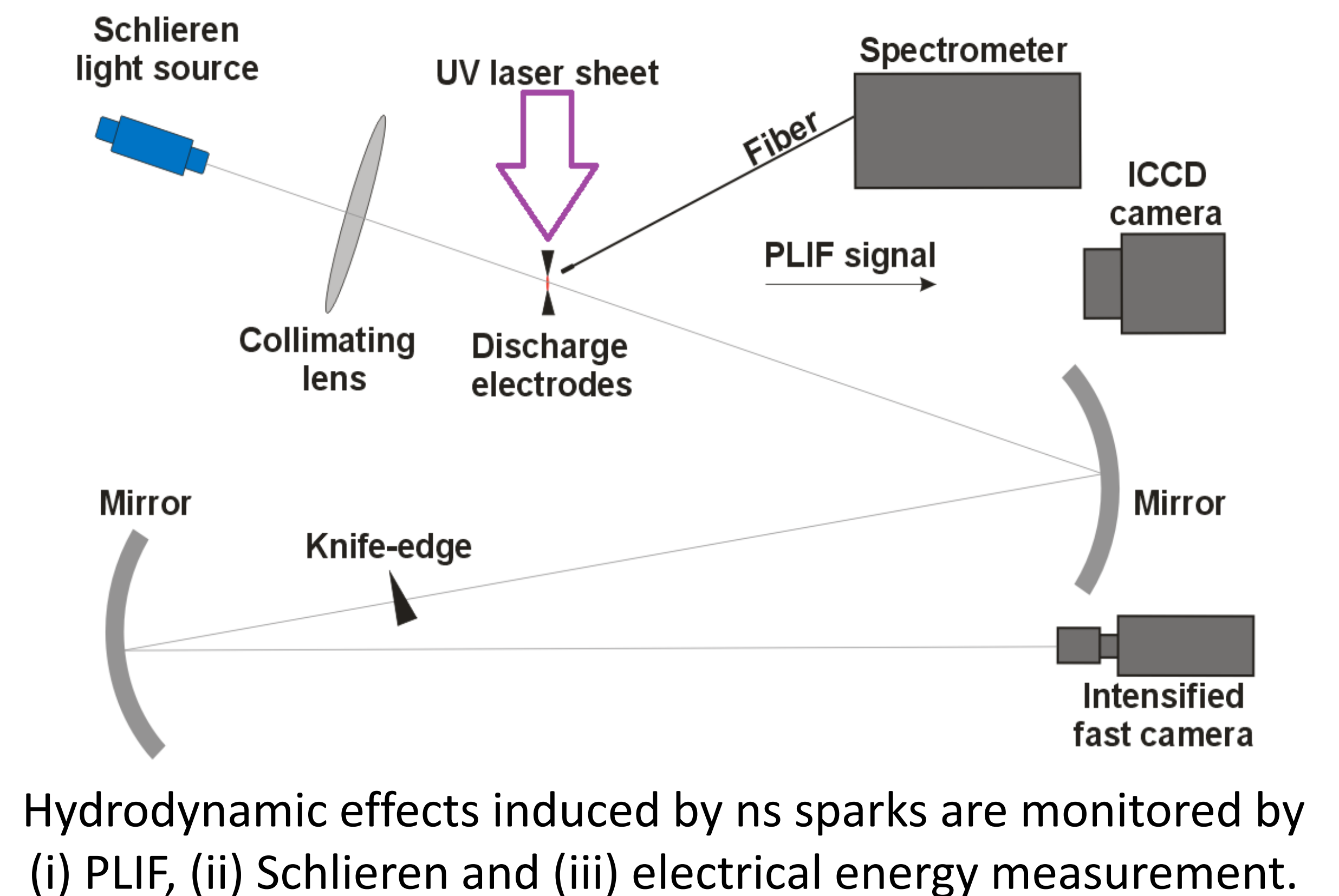
Repetitive nanosecond sparks have numerous applications in combustion :

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

We believe that the hydrodynamic effects induced by ns sparks [1,2] coupled with the production of active species [3] can bring a significant improvement for the applications mentioned above.



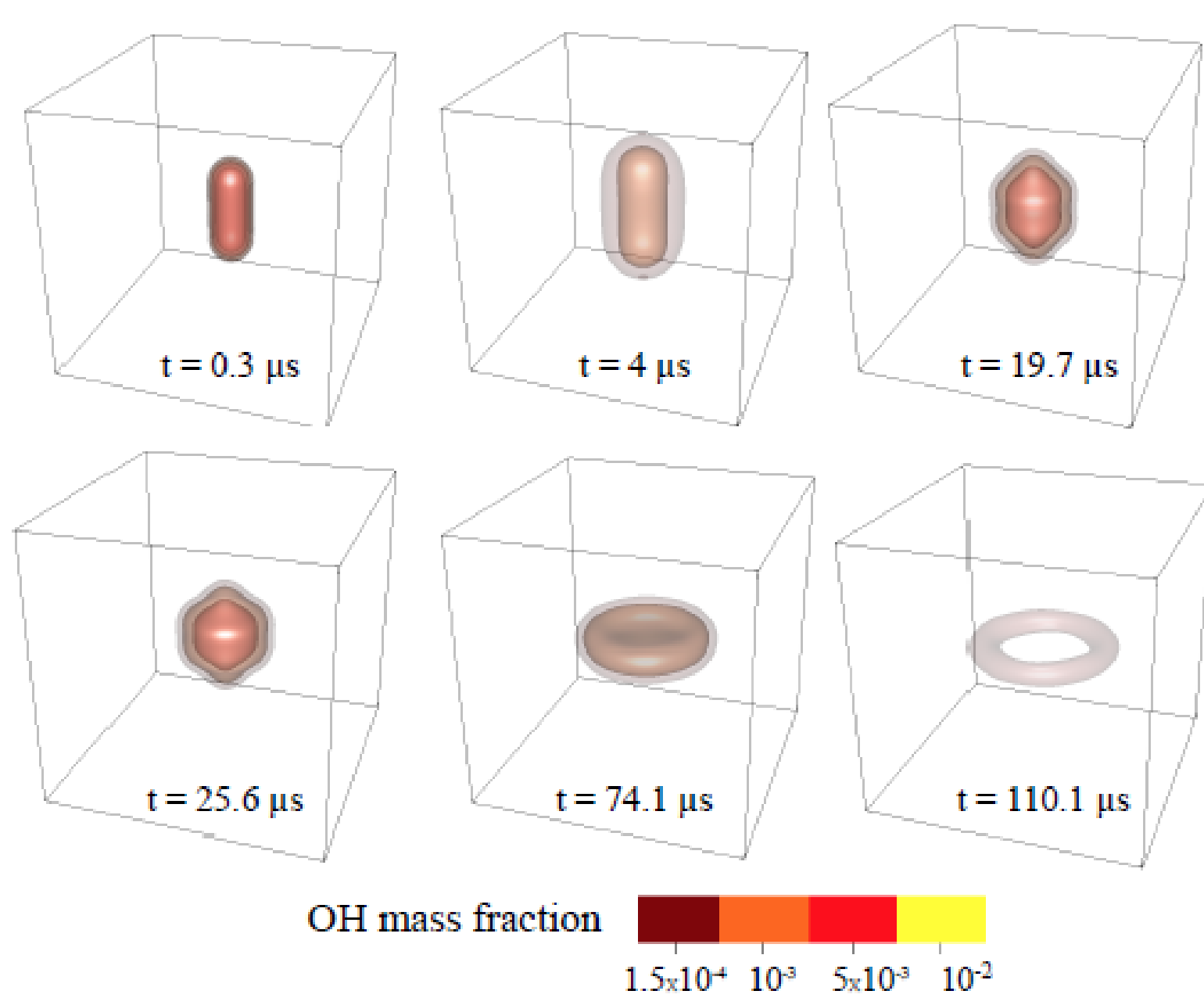
Experimental setup



Spatial redistribution of energy

Mechanism of energy redistribution

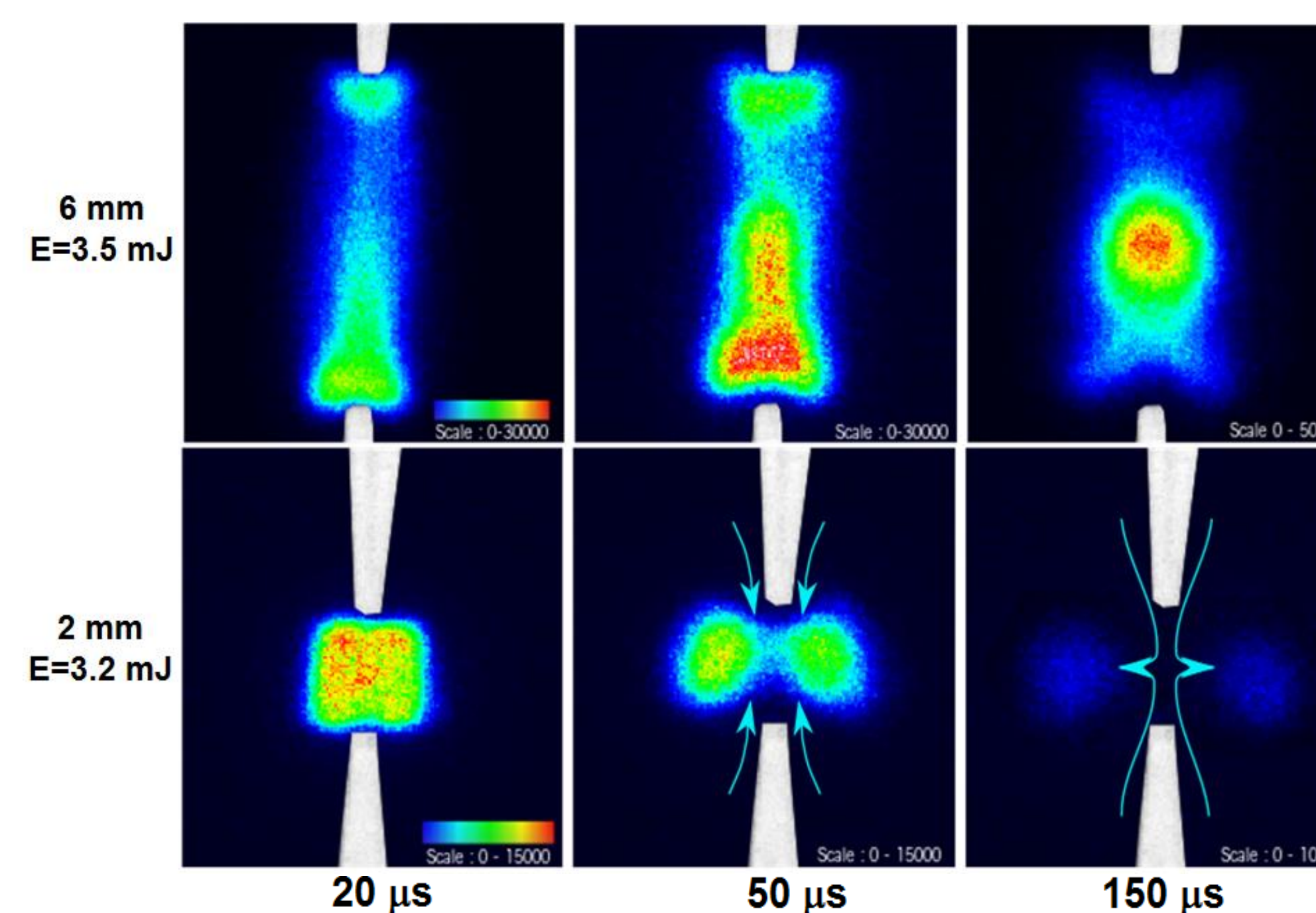
Simulations from [4]
($P=1$ bar, single pulse, $E=1.8$ mJ)



- Simulations of [4] predicted toroidal expansion of ns sparks

Effect of gap distance : for fixed energy

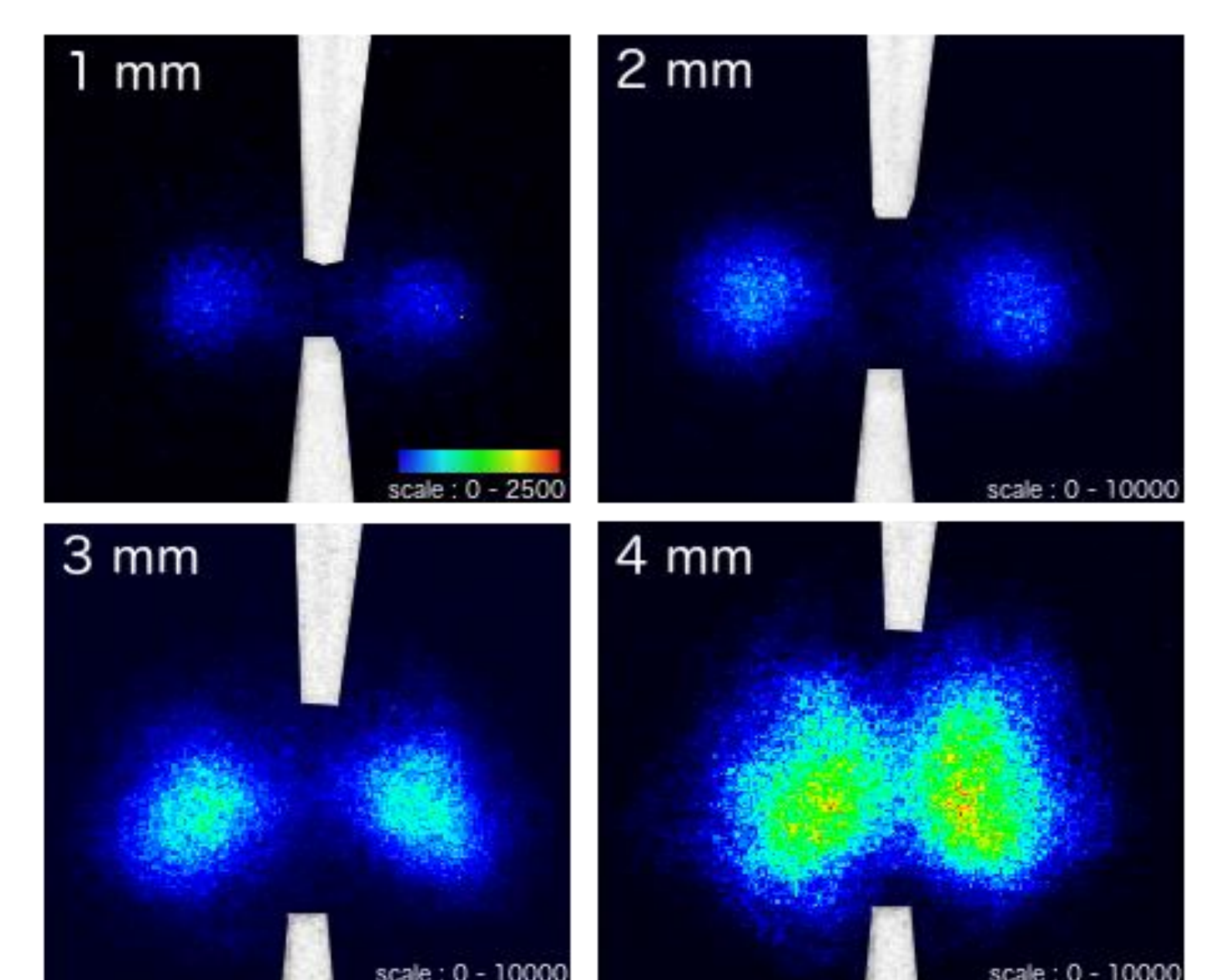
OH PLIF in pin-to-pin geometry
($P=1$ bar, single pulse of 10 ns, $U=30$ kV)



- 6 mm: cylindrical expansion
- 2 mm: toroidal expansion due to fresh gas recirculation

Effect of gap distance : for fixed energy density

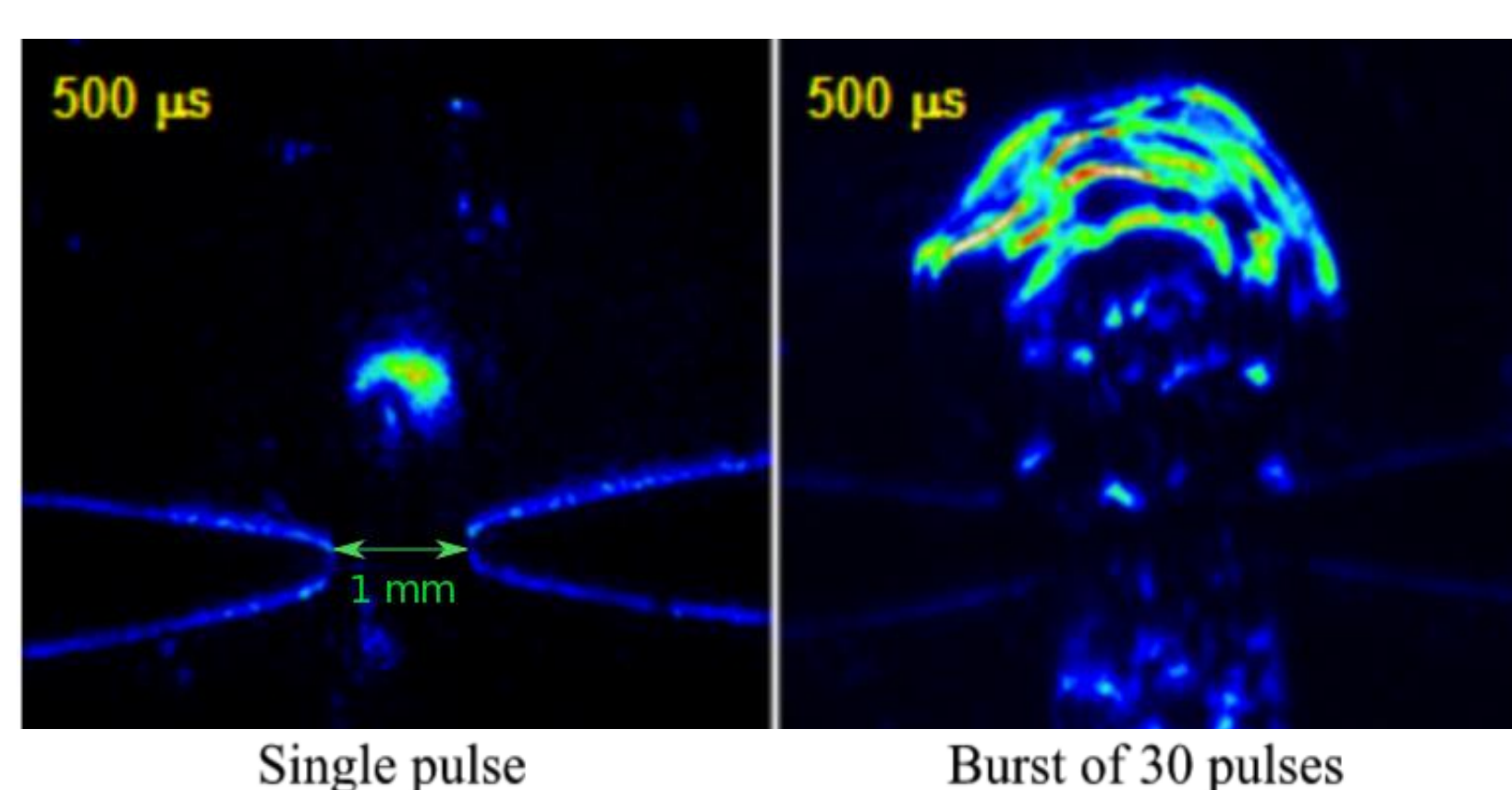
OH PLIF in pin-to-pin geometry
($P=1$ bar, single pulse of 10 ns, $U=30$ kV)



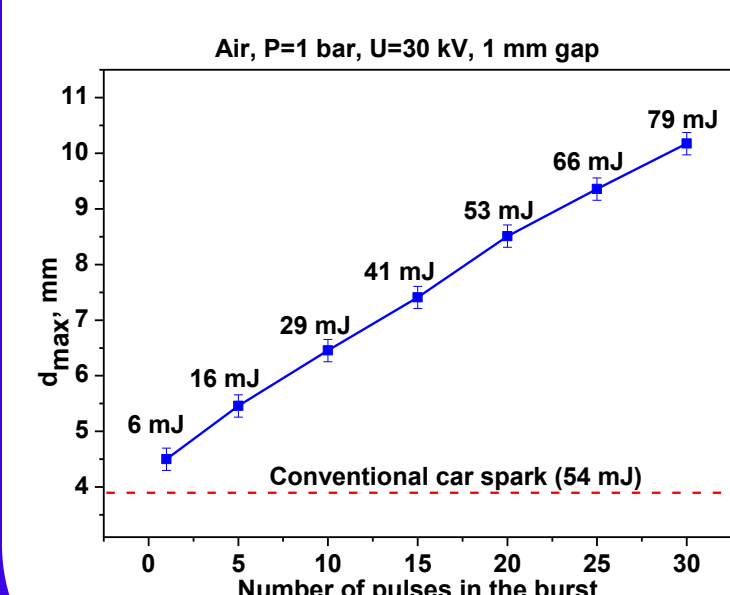
- Same energy density (1.5 mJ/mm) but a different redistribution of radical species

Effect of multiple sparks

Schlieren
($P=1$ bar, pulse(s) of 10 ns, $U=30$ kV)



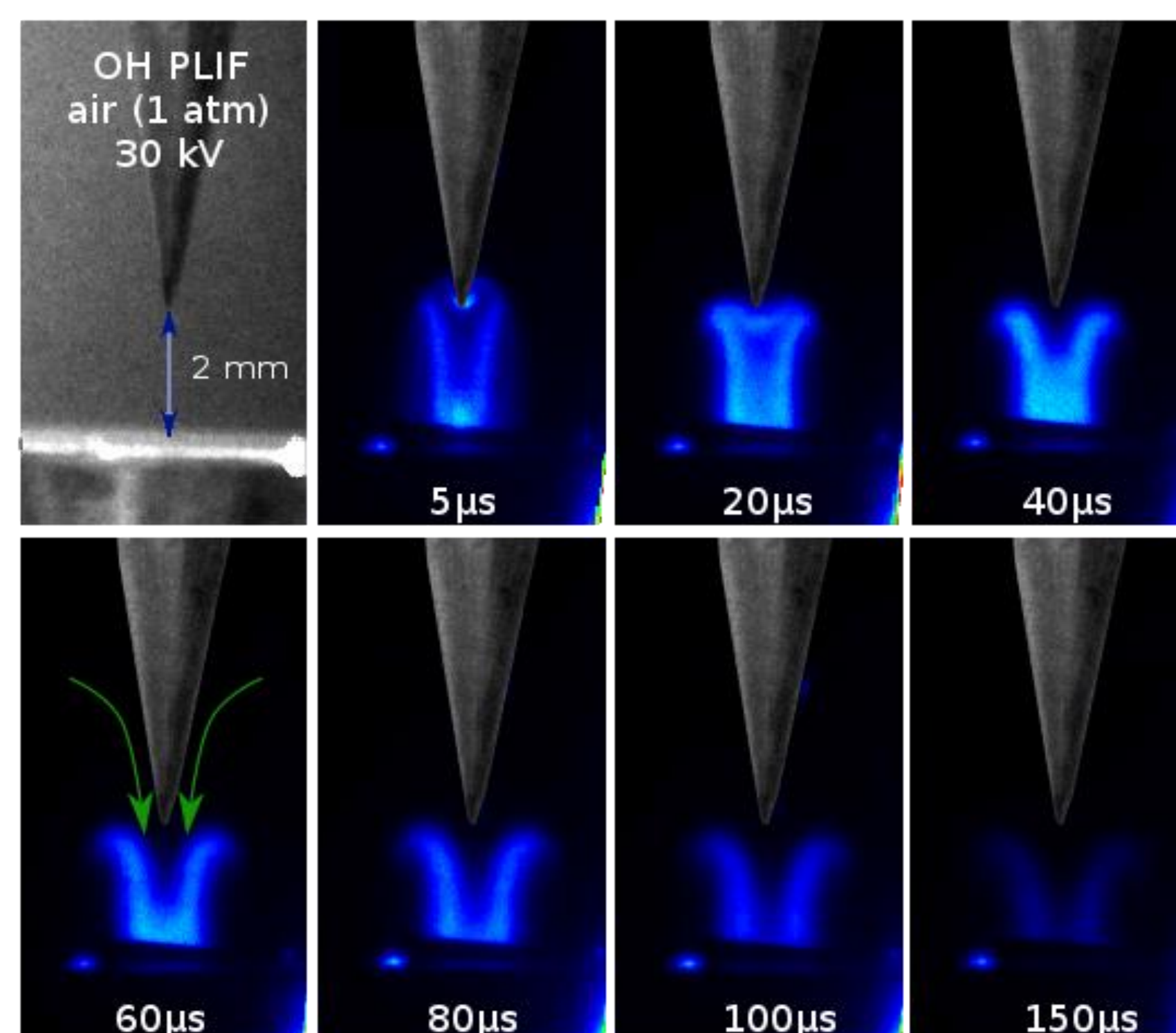
Single pulse Burst of 30 pulses



- Each new pulse is initiated in fresh gas
- Synergy promoting expansion

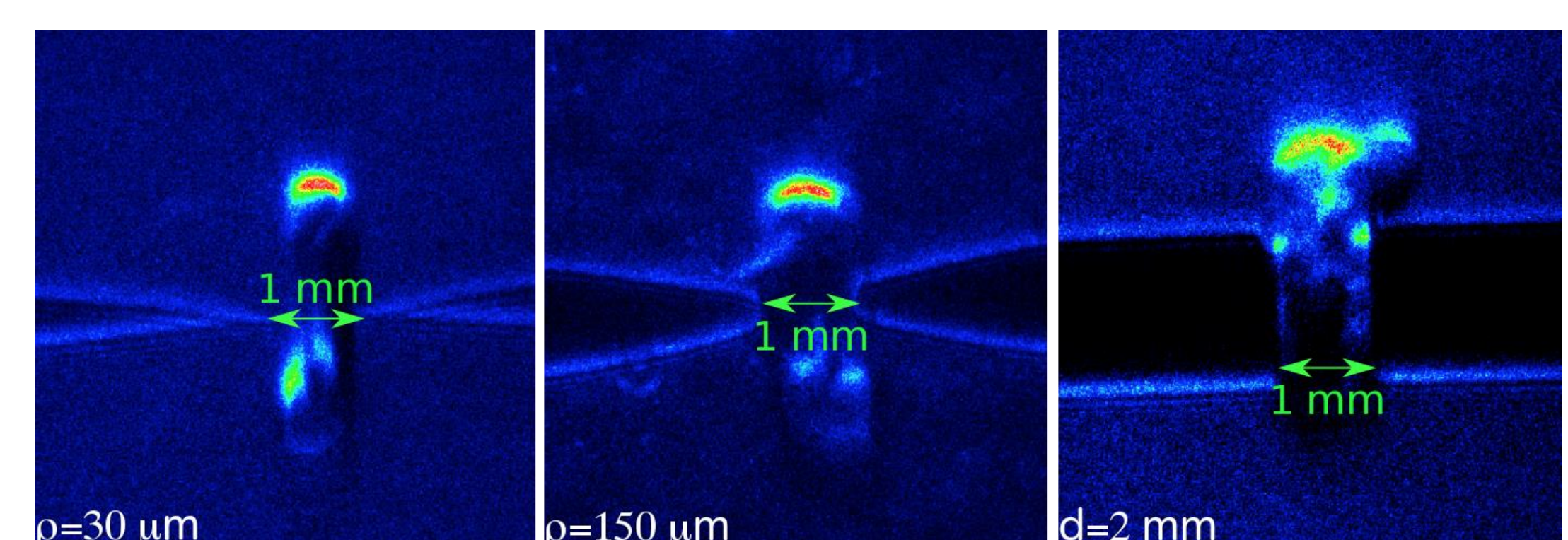
Asymmetric electrodes

OH PLIF in pin-to-plane geometry
($P=1$ bar, single pulse of 10 ns, $U=30$ kV)



Effect of electrode geometry

Schlieren
($P=1$ bar, single pulse of 10 ns, $U=30$ kV)



- No difference in expansion for symmetric electrodes
- A sufficiently thick electrode (plane) blocks the recirculation

Conclusions

- Ns sparks show fast spatial redistribution of the deposited energy (≈ 5 mm/100 μ s in a single pulse)
- One of the mechanisms of the spatial energy redistribution is the recirculation of hot gas
- Experiments in a pin-to-plane configuration demonstrate the influence of electrode geometry on HD effects
- Characteristic size of the active medium is proportional to the number of pulses (energy) in the burst due to synergy between the pulses
- Electrode distance is a key factor for tailoring radical species redistribution (rather than total energy or energy density)

References

- [1] Olsen H. et al, **1952**, "Microchronometric Schlieren Study of Gaseous Expansion from an Electric", *Spark Journal of Applied Physics* 23 1157
- [2] Kono M et al, **1989**, "Mechanism of flame kernel formation produced by short duration sparks", *22nd Symp. On Combustion* 22 1643-1649
- [3] Rusterholtz D et al, **2013**, "Ultrafast heating and oxygen dissociation in atmospheric pressure air by nanosecond repetitively pulsed discharges", *J. Phys.D: Appl. Phys* 46 464010
- [4] Castela M et al, **2016**, "Direct Numerical Simulations of plasma-assisted ignition in quiescent and turbulent flow conditions", PhD thesis