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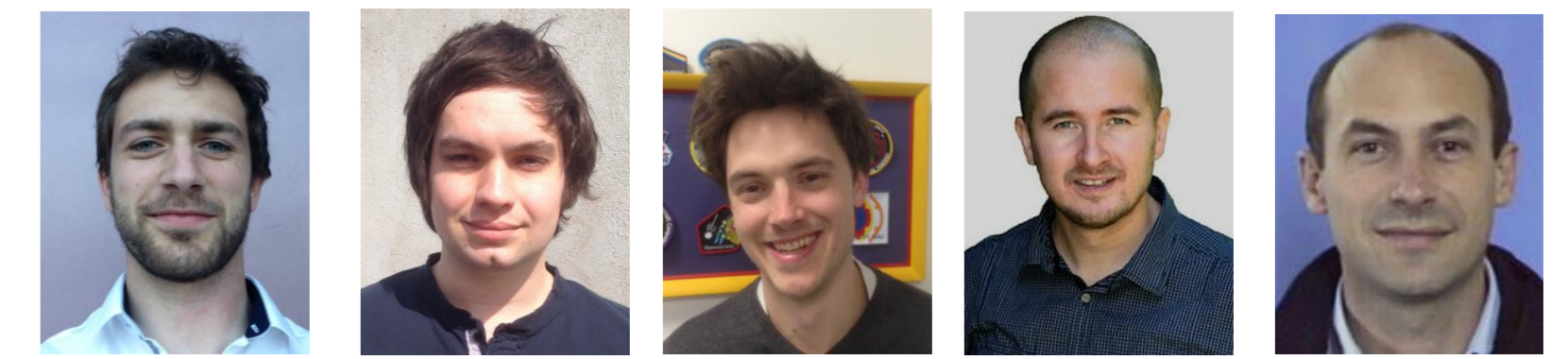
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Hydrodynamic effects induced by nanosecond sparks

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Motivation

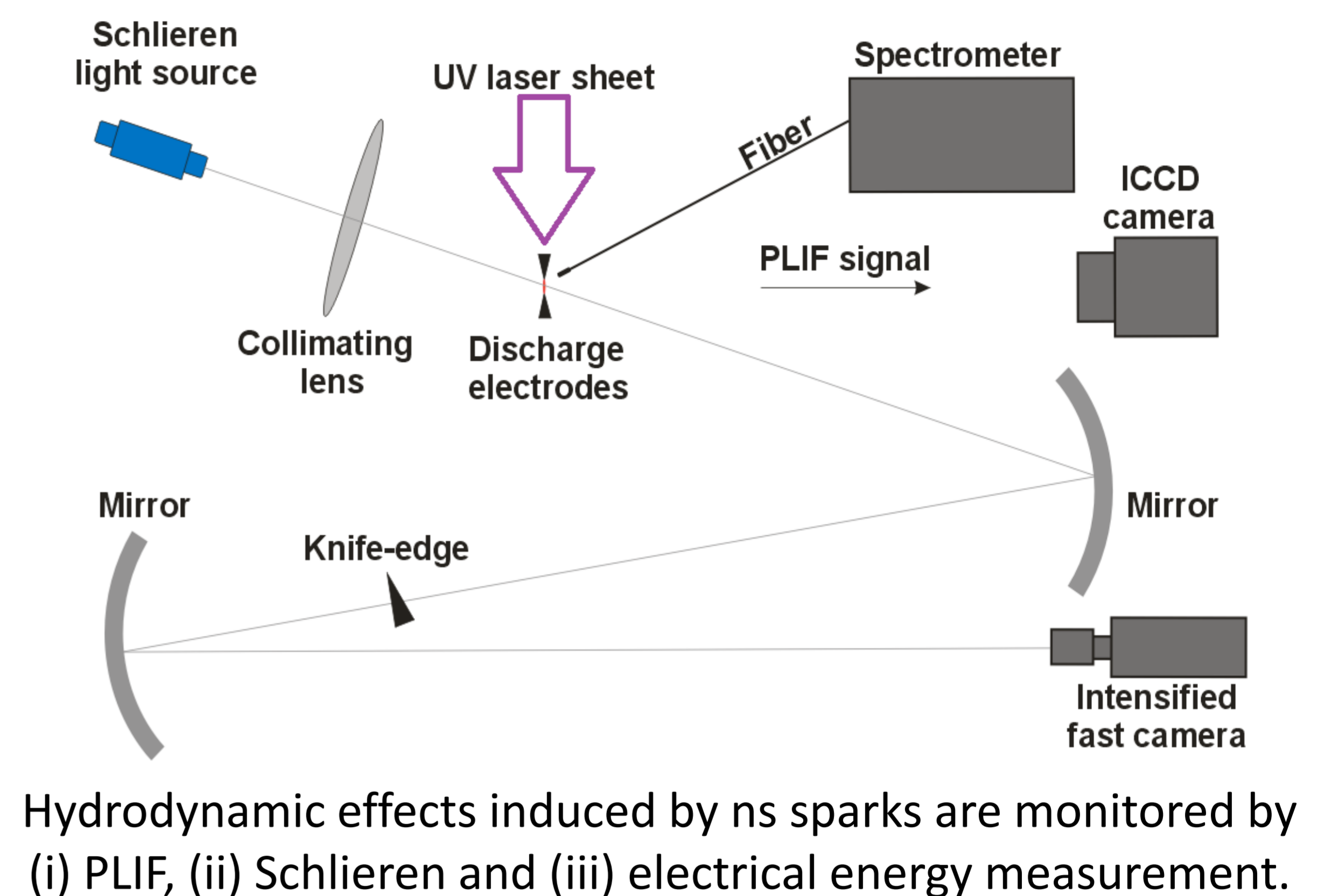
Repetitive nanosecond sparks have numerous applications in combustion :

- 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.



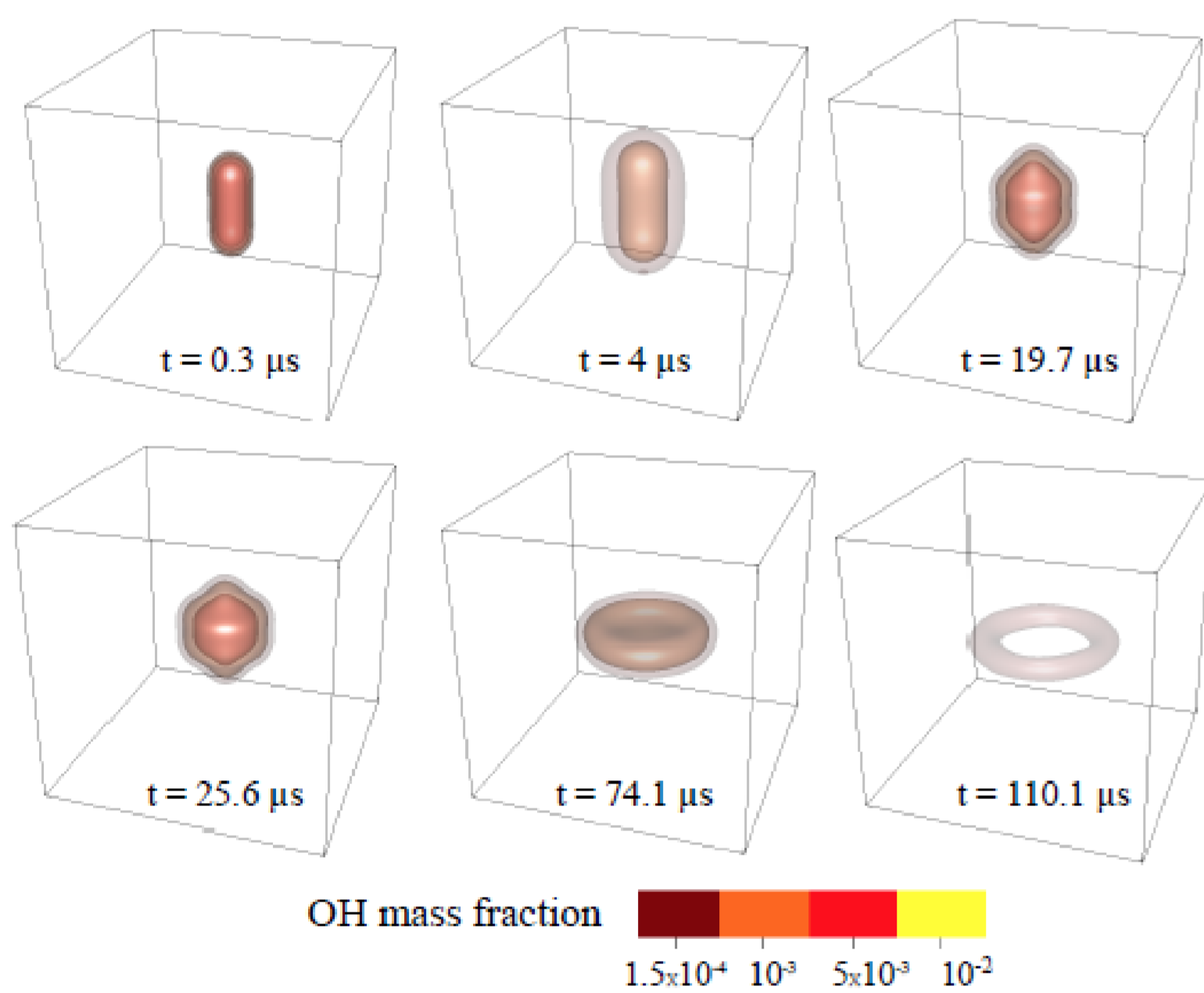
Experimental setup



Spatial redistribution of energy

Mechanism of energy redistribution

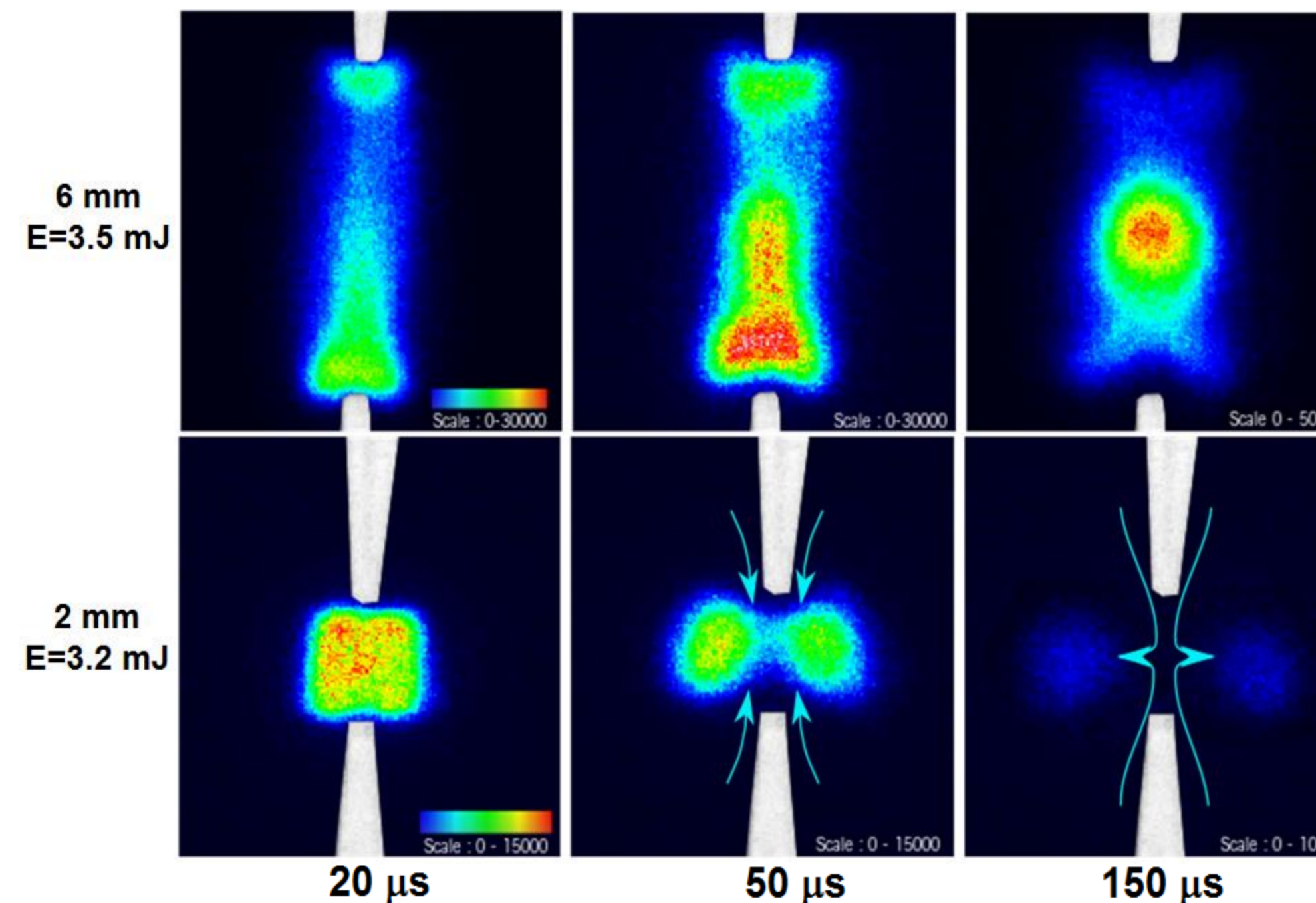
Simulations from [4]
($P=1$ bar, single pulse, $E=1,8$ mJ)



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

Effect of gap distance : for fixed energy

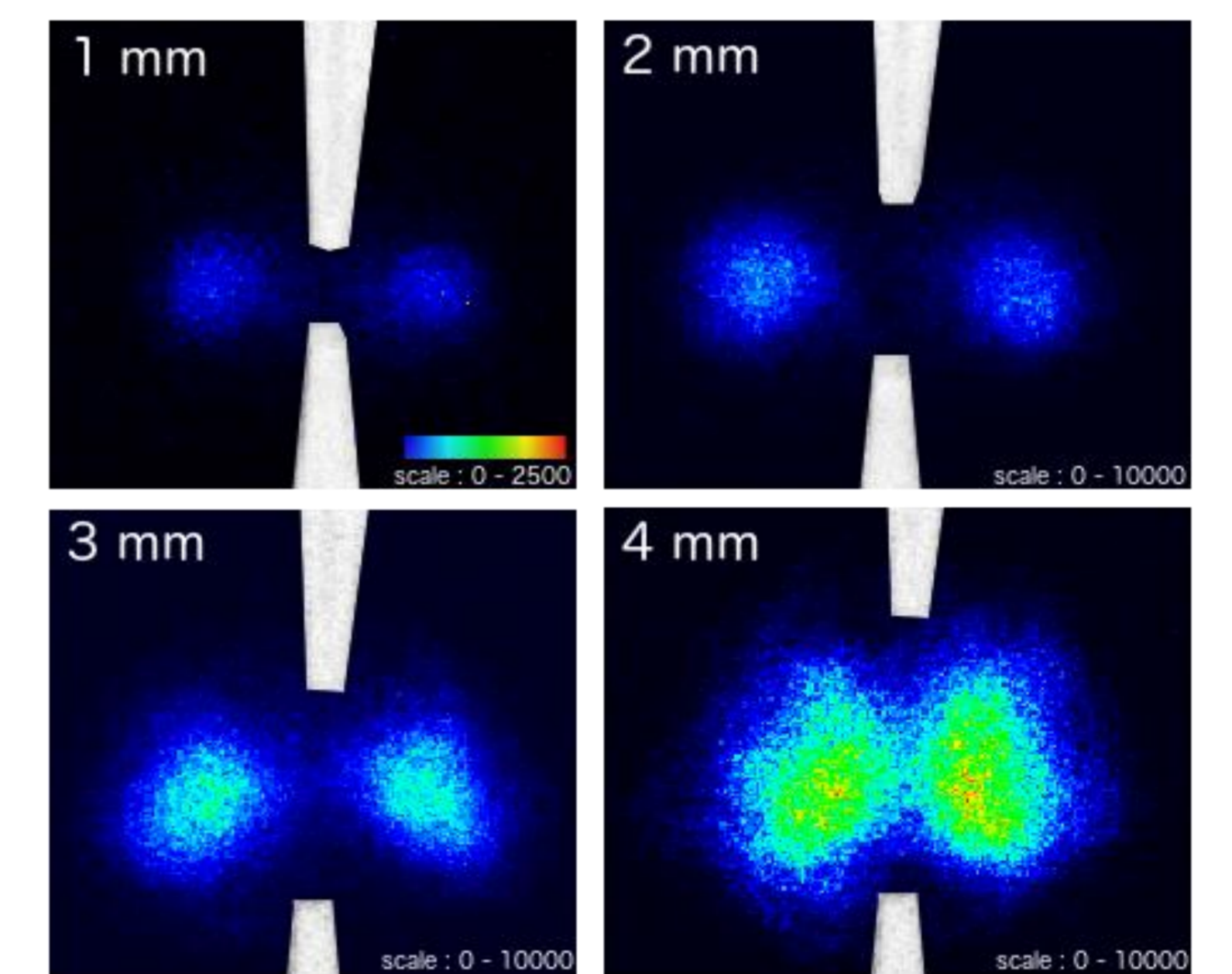
OH PLIF in pin-to-pin geometry
($P=1$ bar, single pulse of 10 ns, $U=30$ kV)



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

Effect of gap distance : for fixed energy density

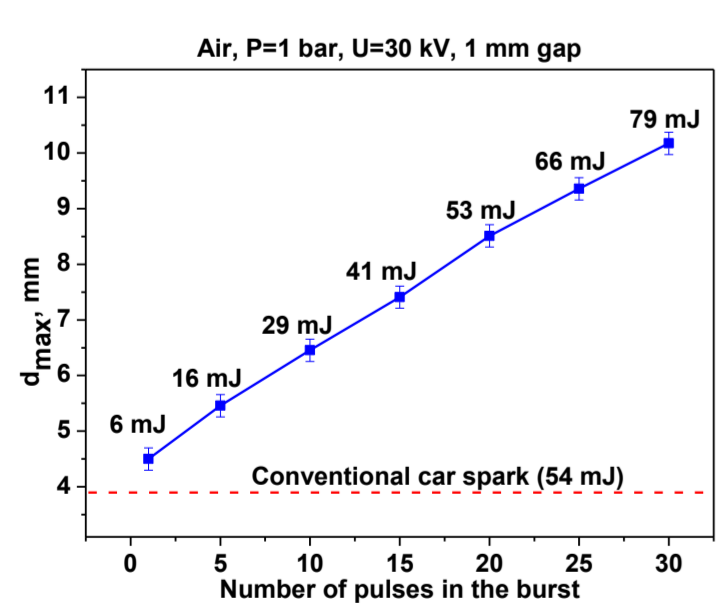
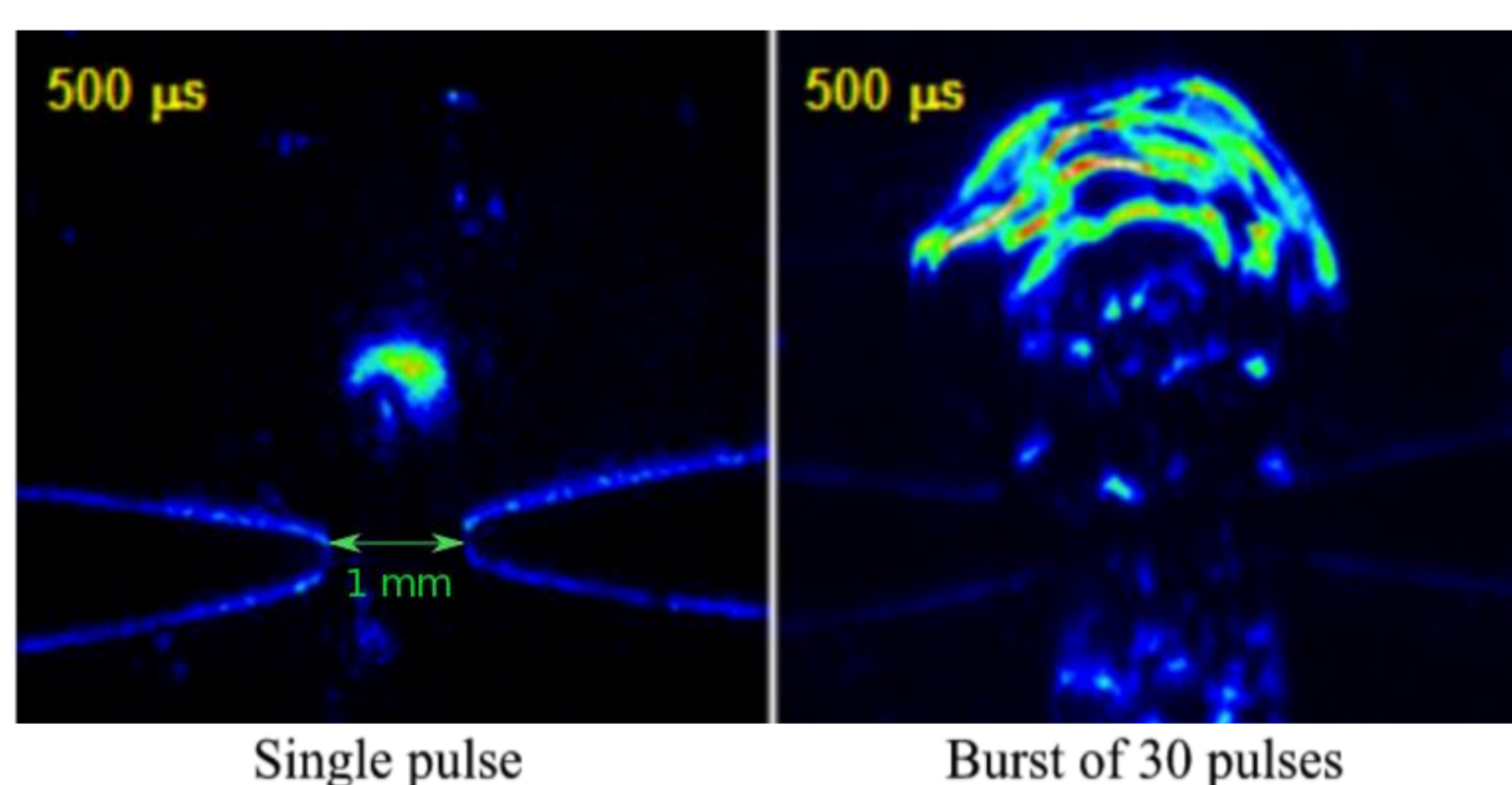
OH PLIF in pin-to-pin geometry
($P=1$ bar, single pulse of 10 ns, $U=30$ kV)



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

Effect of multiple sparks

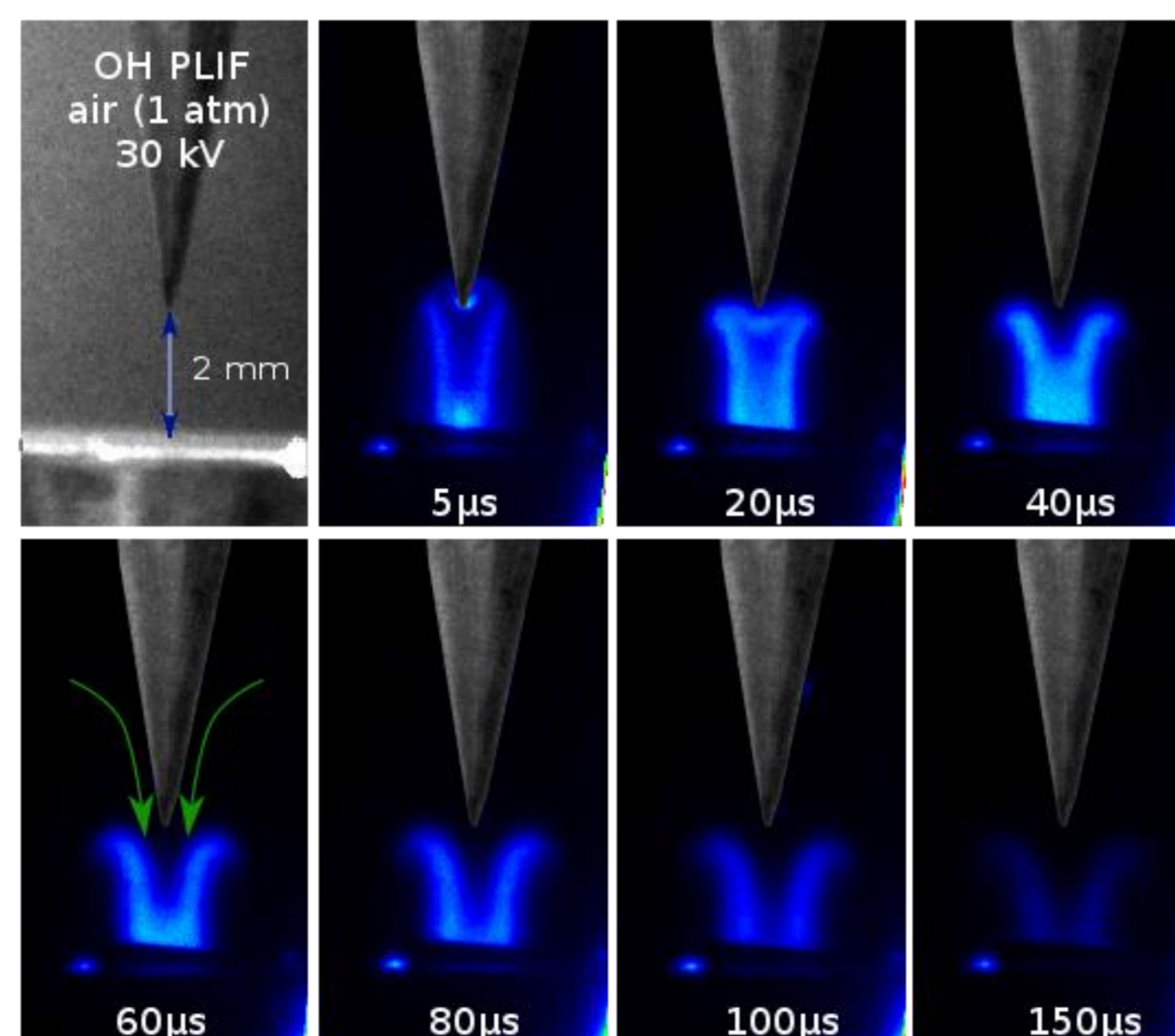
Schlieren
($P=1$ bar, pulse(s) of 10 ns, $U=30$ kV)



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

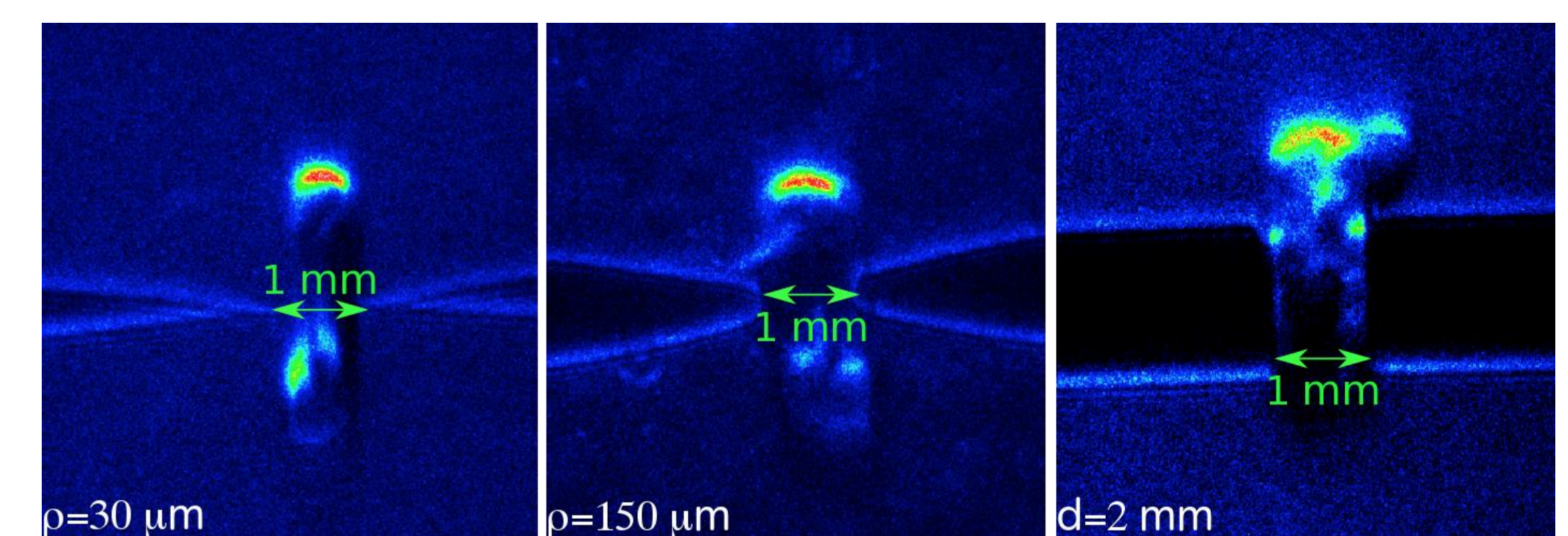
Asymmetric electrodes

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