LUMINESCENCE BASED TEMPERATURE MEASUREMENTS IN MICRO CAVITATING FLOW

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Damien Colombet, Frédéric Ayela.

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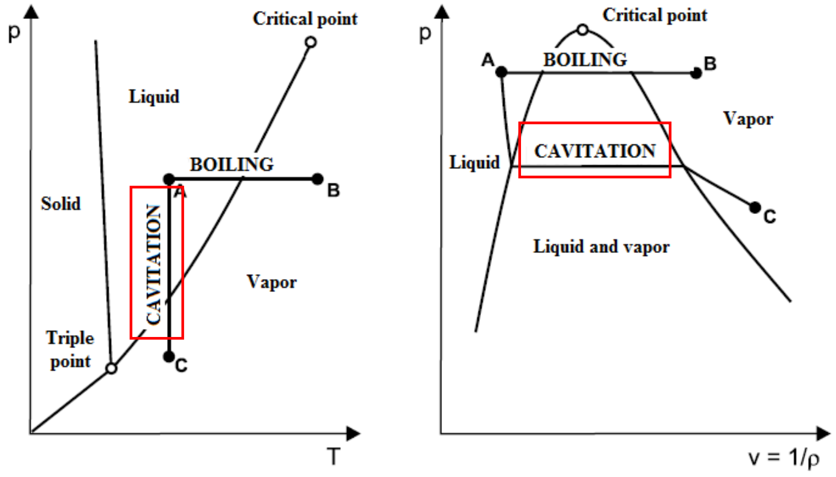
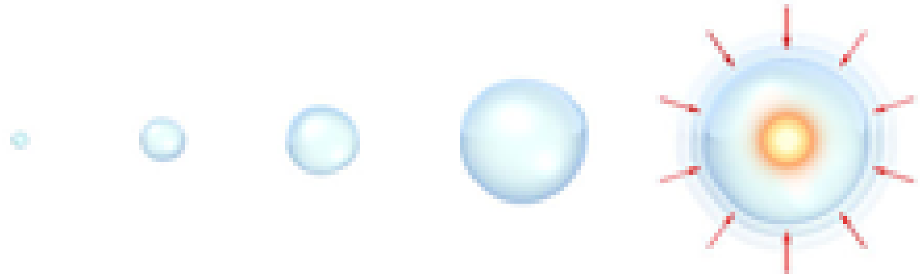
Cavitation

- Phase change transition (A→C): liquid → vapor.
- Related to boiling (A→B)
- Ambient pressure < liquid vapor pressure.



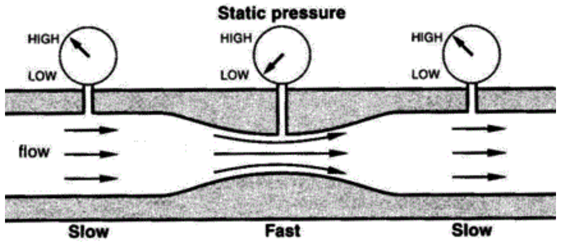


- Nucleation and growth of vapor bubbles
- Violent collapse → high temperatures & pressures in imploding bubble.

K. S. Suslick and Flannigan D.J., Annu Rev Phys Chem., 59, 659-83. (2008)

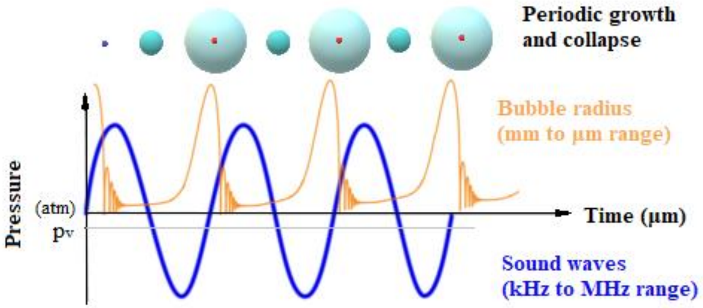
Cavitation

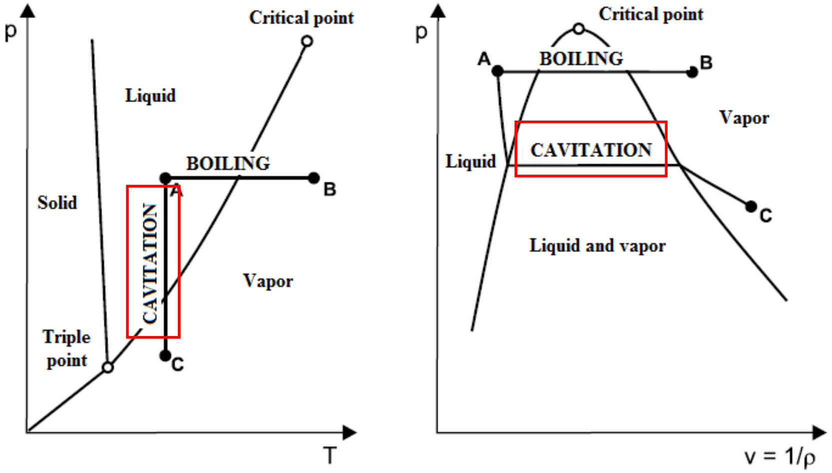
- Hydrodynamic cavitation → Bernoulli's principle



https://en.wikipedia.org/wiki/Cavitation

- Acoustic cavitation → rarefactions in soundwaves

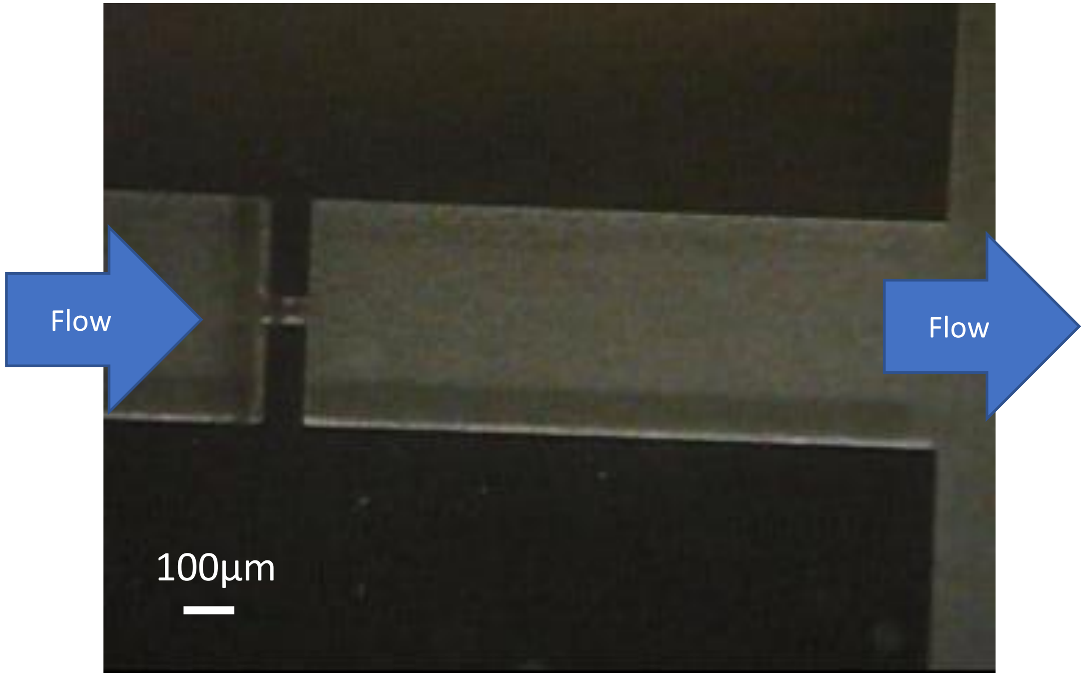




- Neg.: Erosion, noise, efficiency decrease.
- Pos.: Chemical reactions, wastewater treatement, medical procedures,...
- Impurities in liquid → lowering cavitation threshold
- Latent heat → Temperature gradients expected in flow

F. Ayela et al., *Physical Review E, 88, 043016 (2013)*
M. Petkovsek and M. Dular, *Int. J. Heat Fluid flow 44, 756-763 (2013)*
N. Rimbert *et al., Proc. 8th Int. Symp. Cavitation CAV2012, 1-6 (2012)*

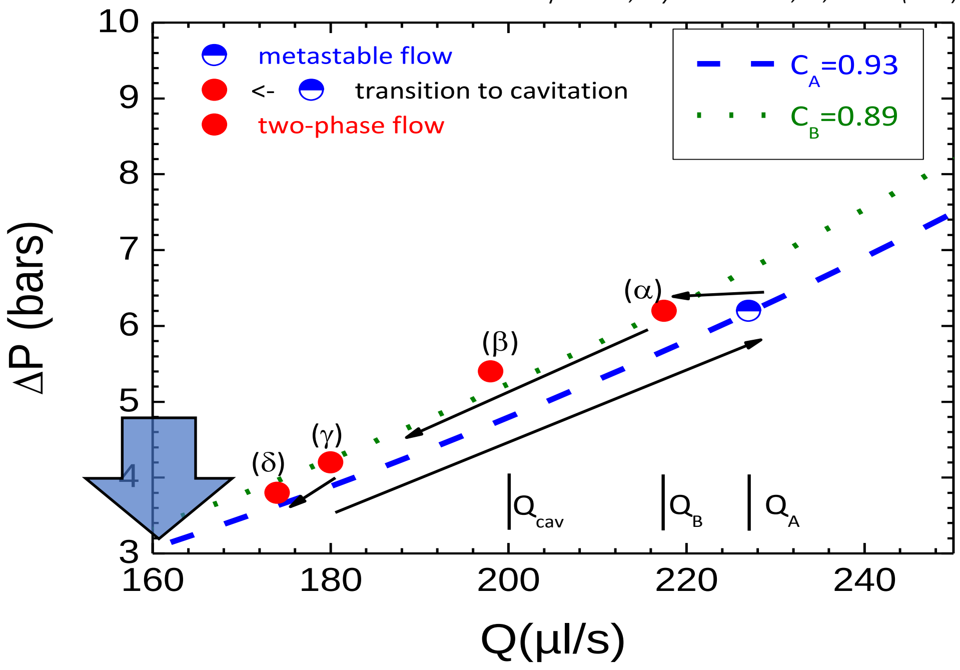
Microfluidic cavitating flow



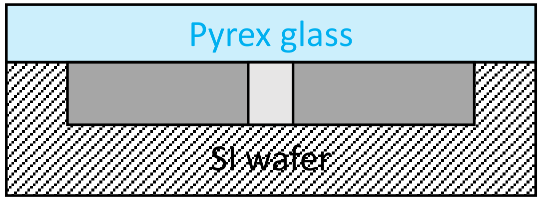
- Metastable flow single phase flow
- Steady state two-phase flow

- Smooth surfaces and absence nucleation sites
- Flow hysteresis

F. Ayela et al., *Physical Review E, 88, 043016 (2013)*

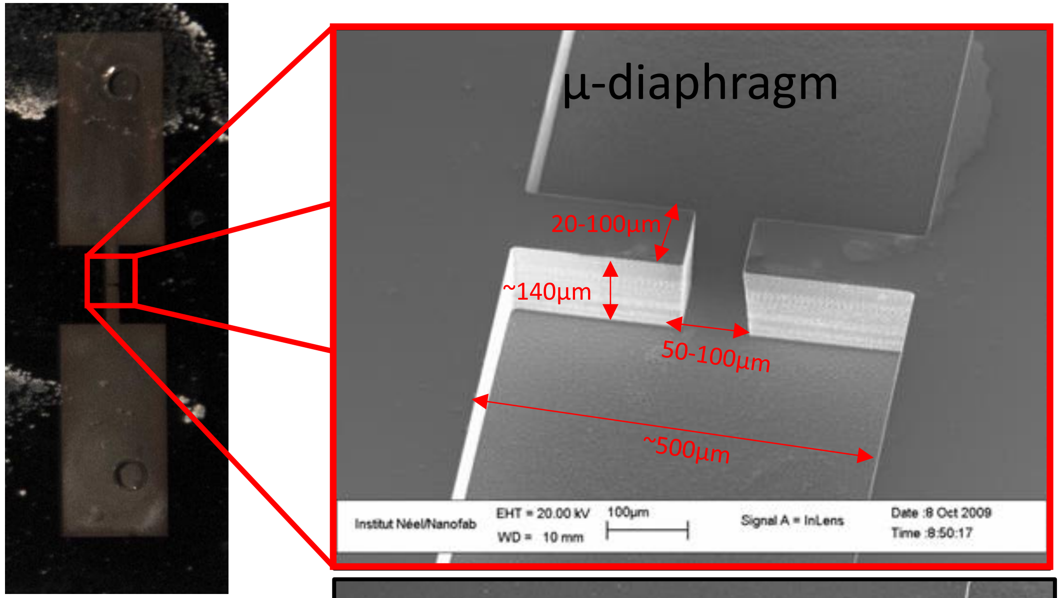


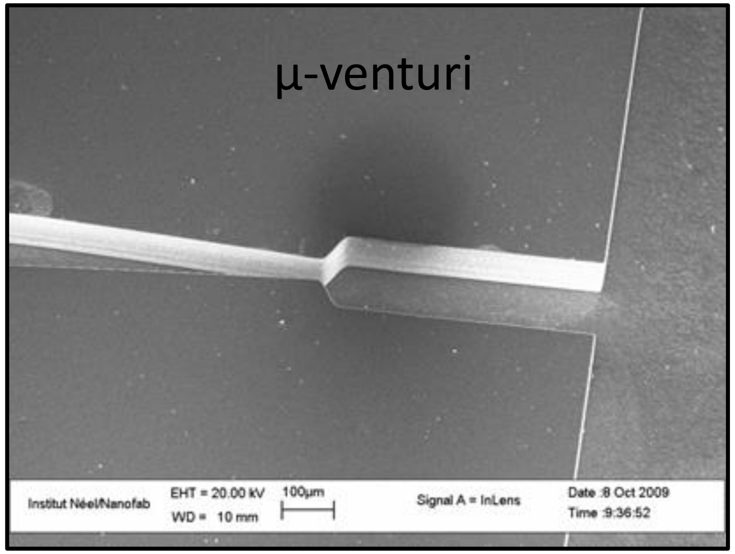
Microfluidic channels



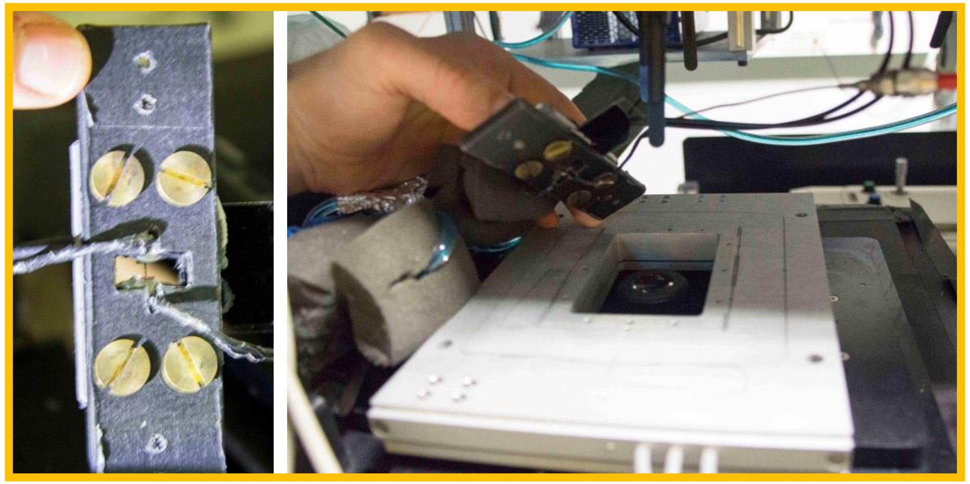
M. Medrano et al., *Phys. Fluids 23, 127103.*
F. Ayela et al., Oil Gas Sci. Technol 72, 19 (2017) (open access).

- Pyrex/Silicon/pyrex or Silicon/pyrex hybrid system
- Micromachining and DRIE process
- Anodic bonding of glass to silicon



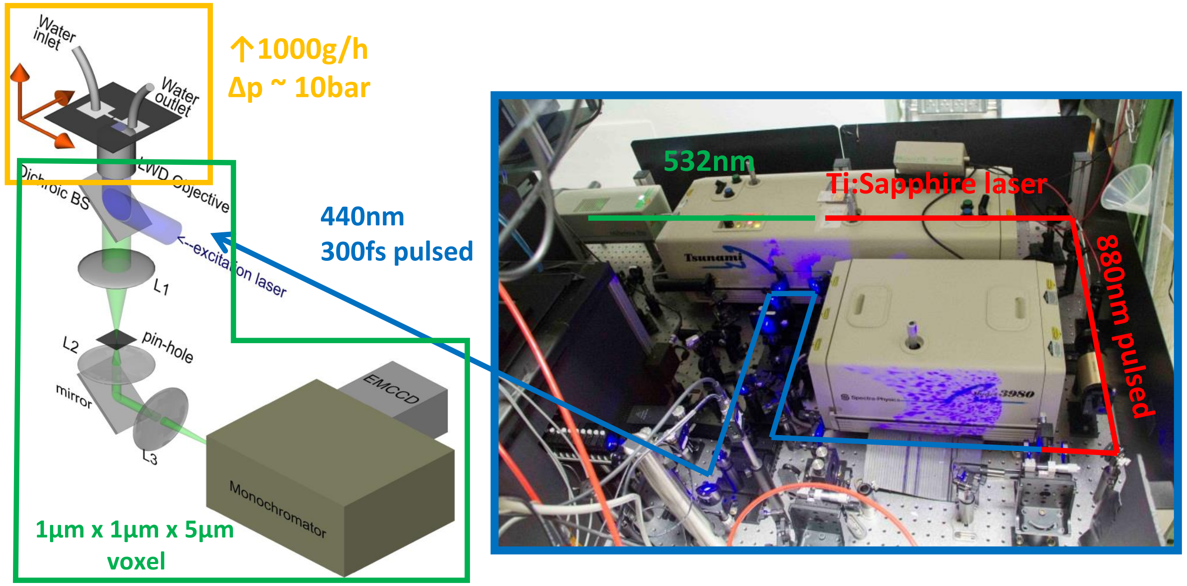


Achromatic confocal microscope → excitation and detection



- XYZ motion control of sample
- Ti:Sapphire laser + frequency doubling → tuneable range of pulsed excitation light

- Long working distance objective
- Confocal setup → confined acquisition volume
- Detection → monochromator and EMCCD



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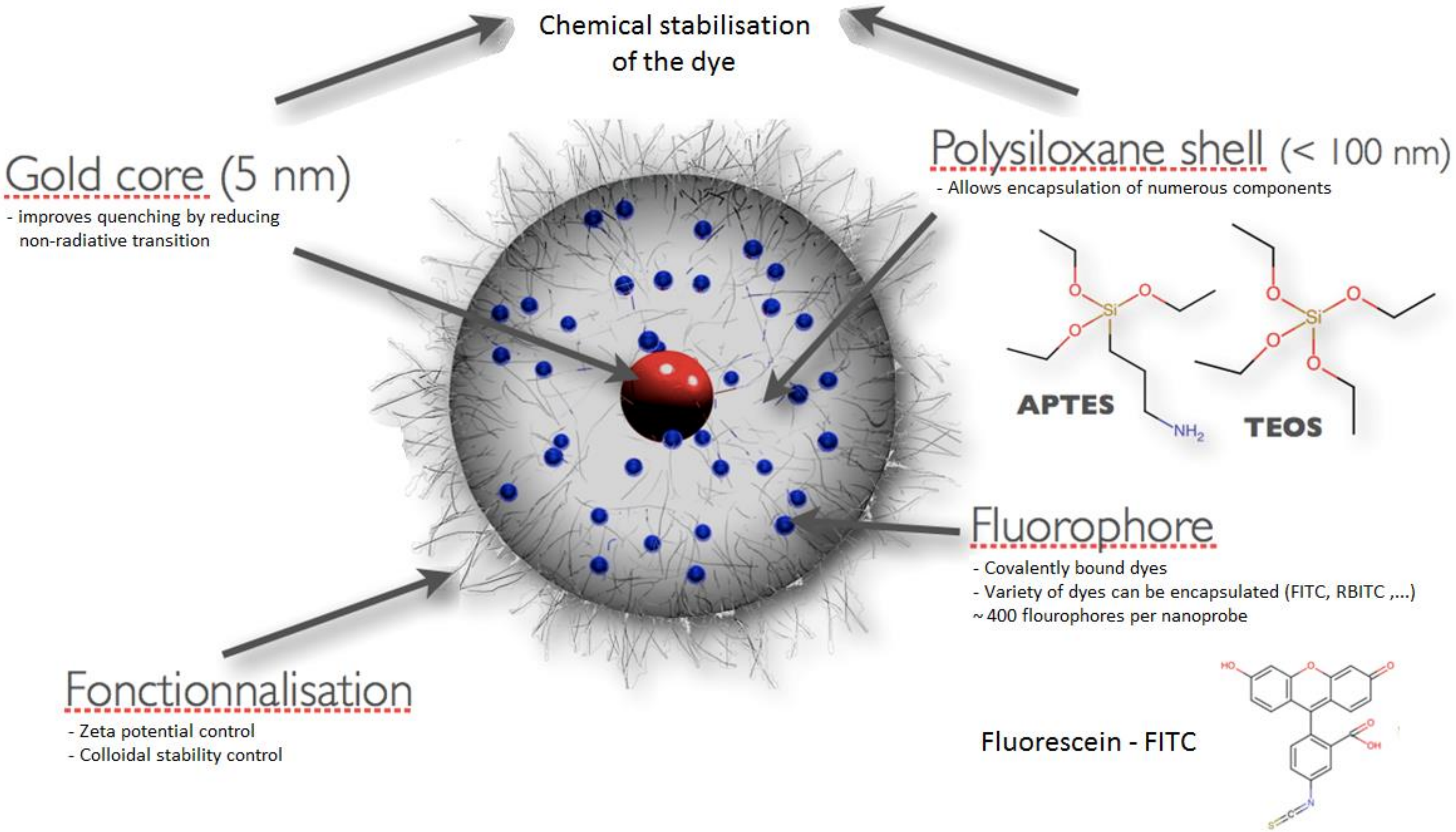
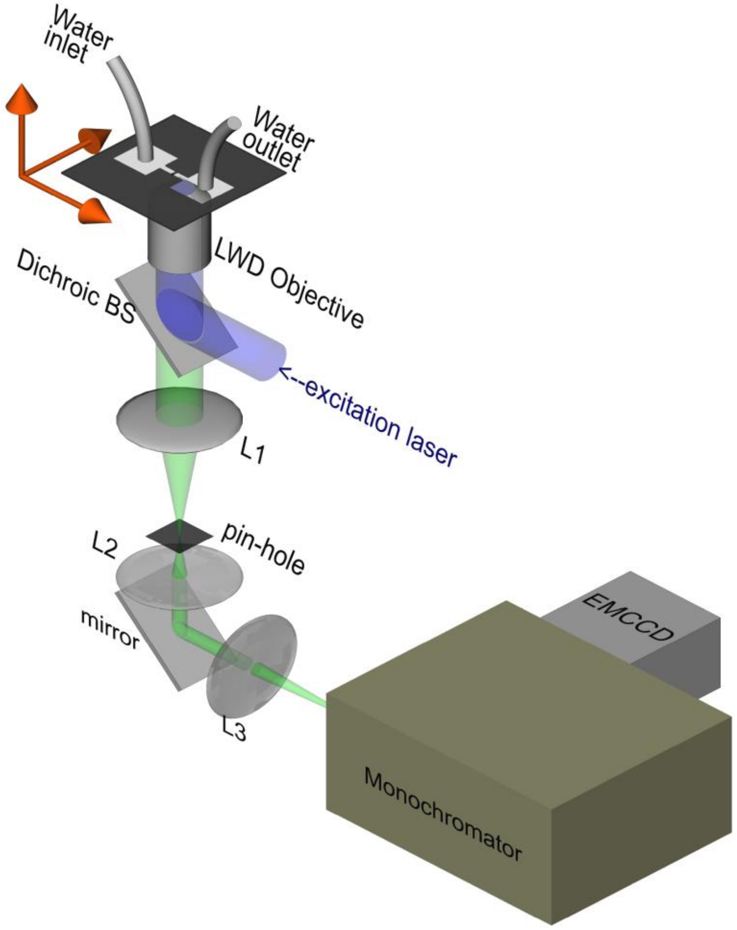
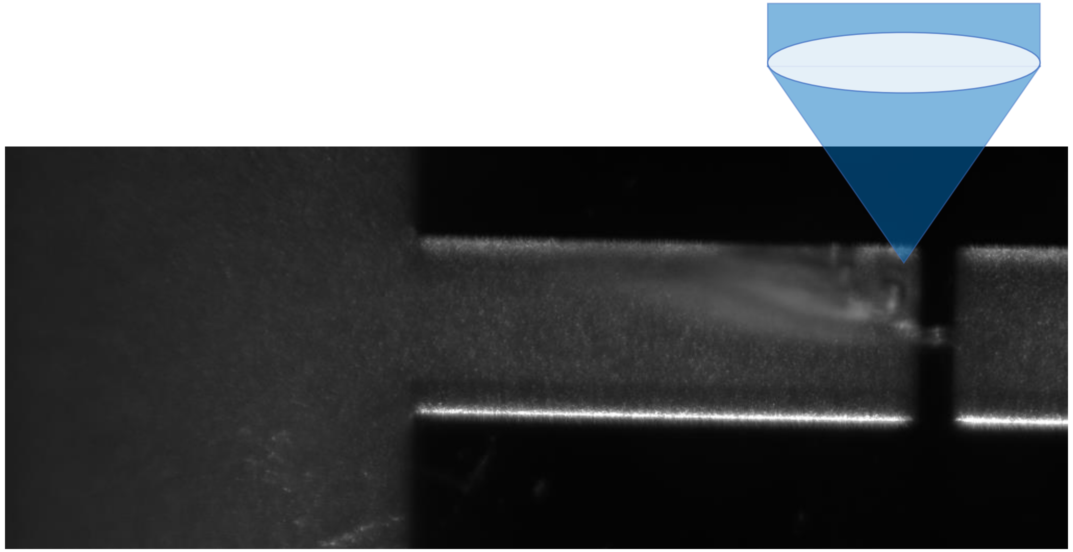
Temperature sensitive nanoprobes



M. Martini et al., *J. Phys. Chem. C,113 (41), 17669.*

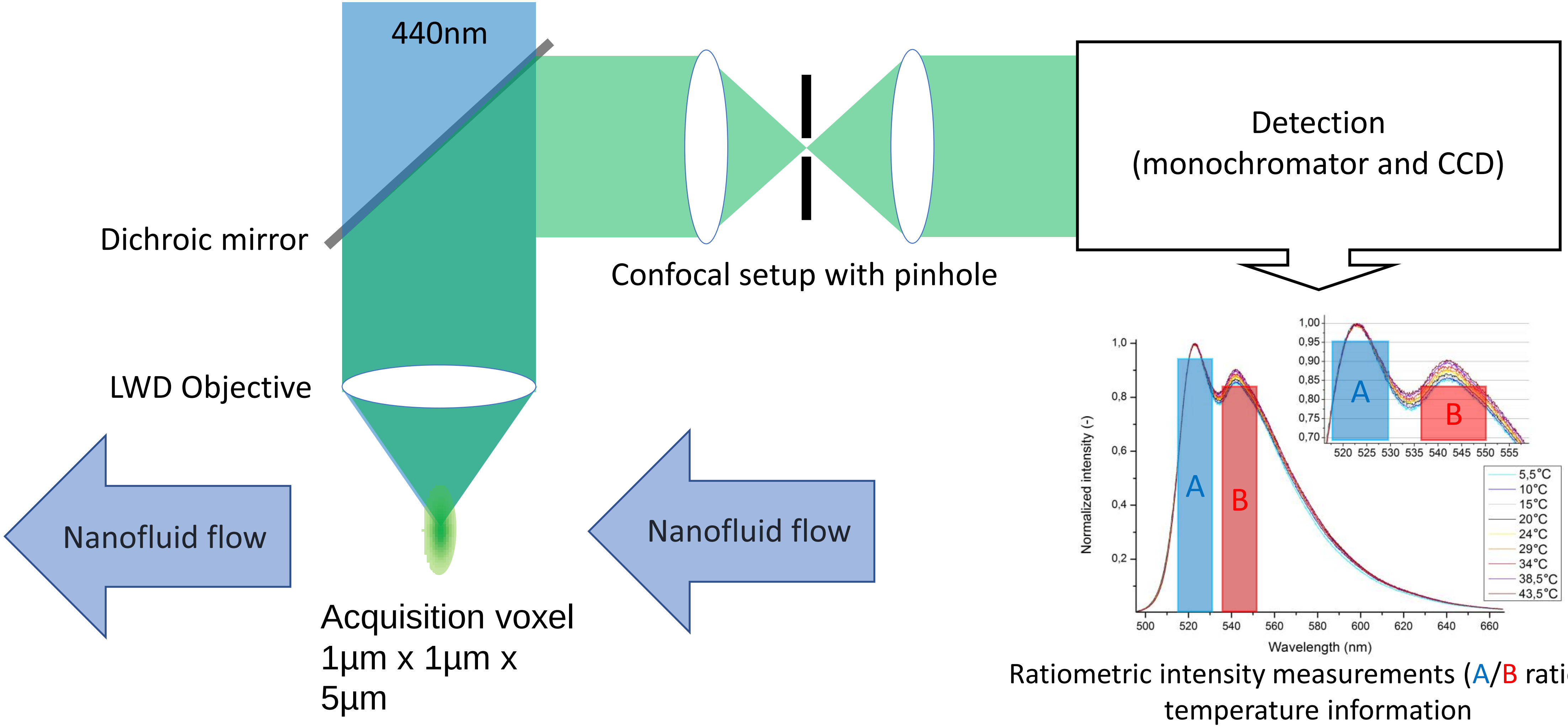
Temperature mapping in microchannels with fluorescein nanoprobes





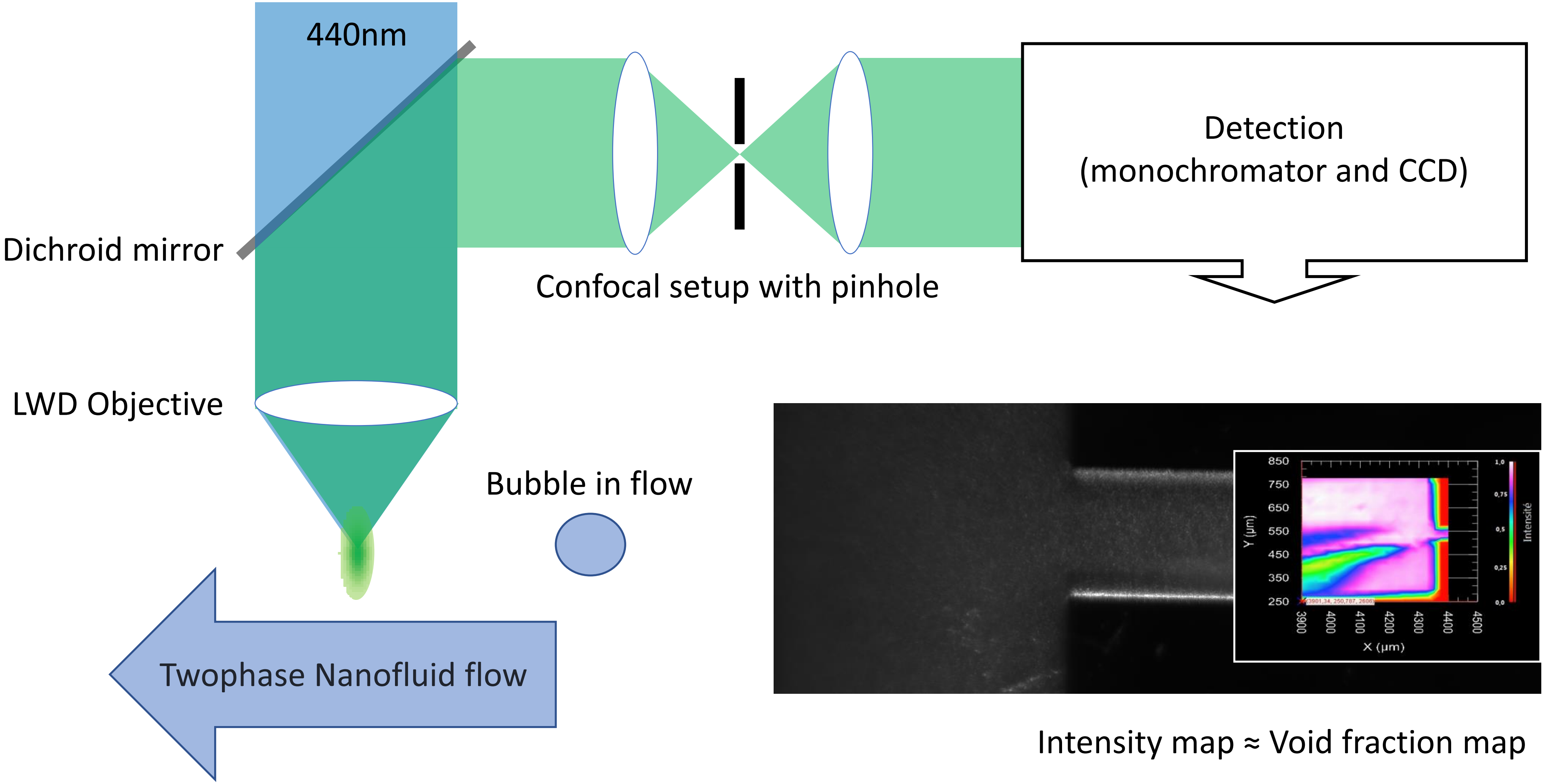
- Raster scanning and recording spectrum.
- Steady state two phase flow
- 3D confinement of acquisition volume.

Luminescence intensity mapping → temperature measurements



Ratiometric intensity measurements (A/B ratio) → temperature information

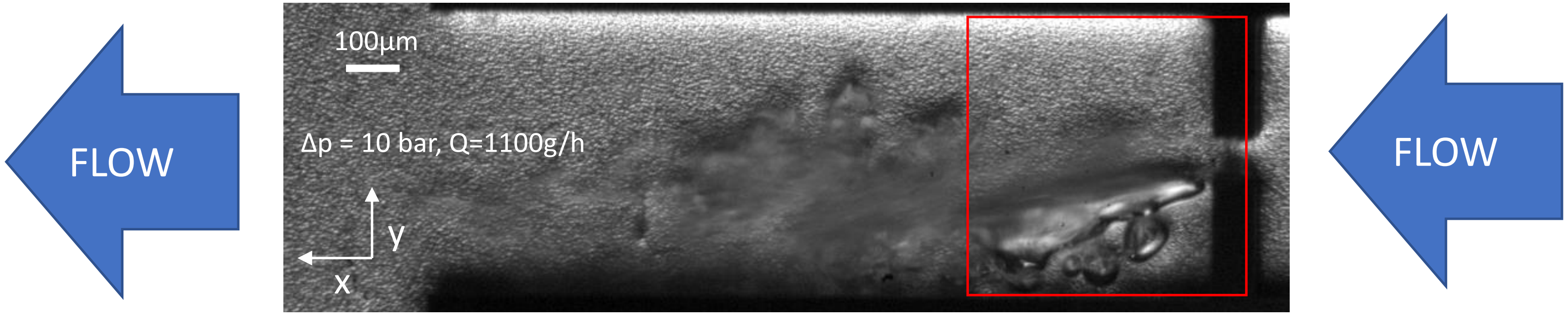
Luminescence intensity mapping → Void fraction



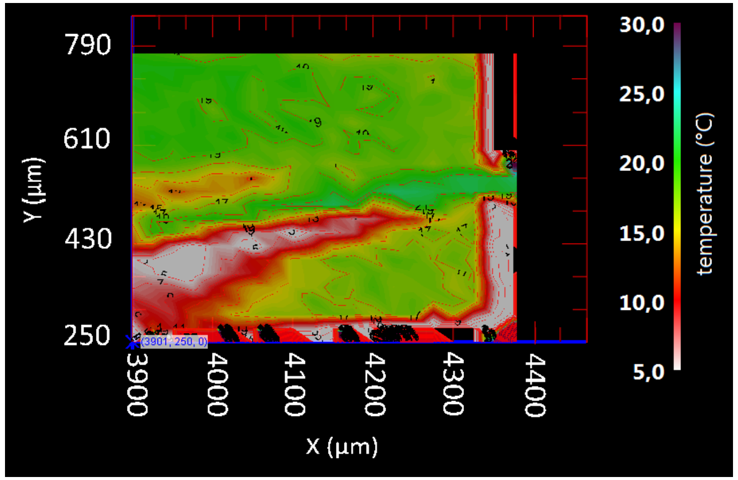
Intensity map ≈ Void fraction map

Temperature mapping in microchannels with fluorescein nanoprobes

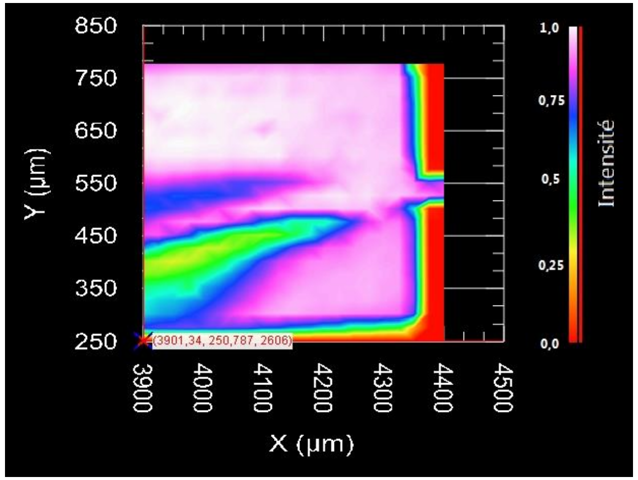
- Z = half way in channel; 1100g/h; 10bar.



- Latent heat → thermal effect.



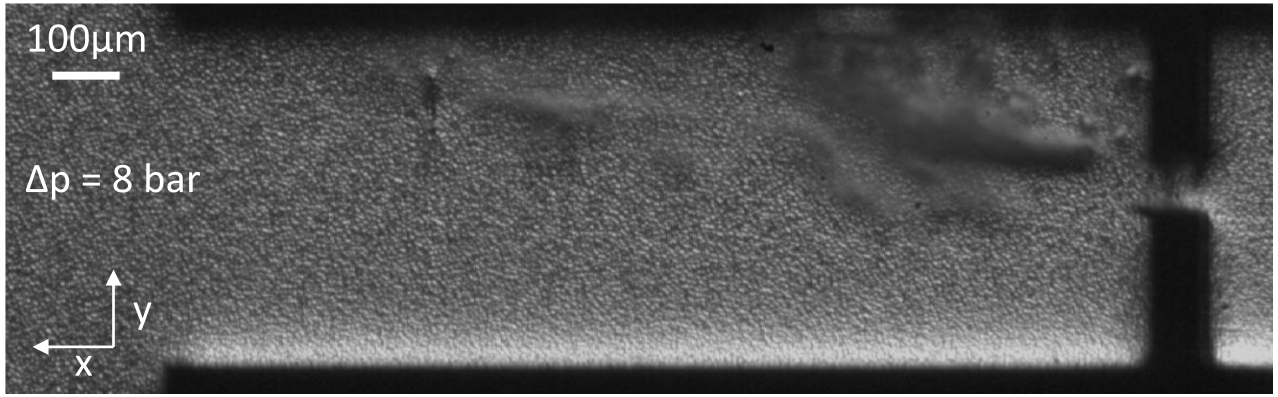
Temperature map

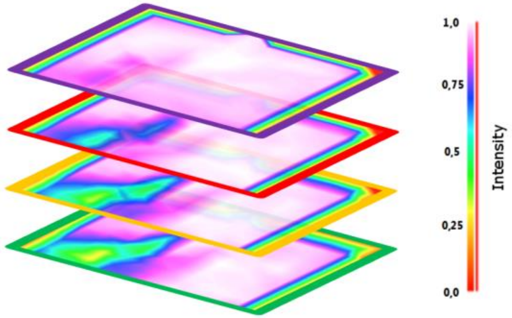


Intensity / Void fraction map

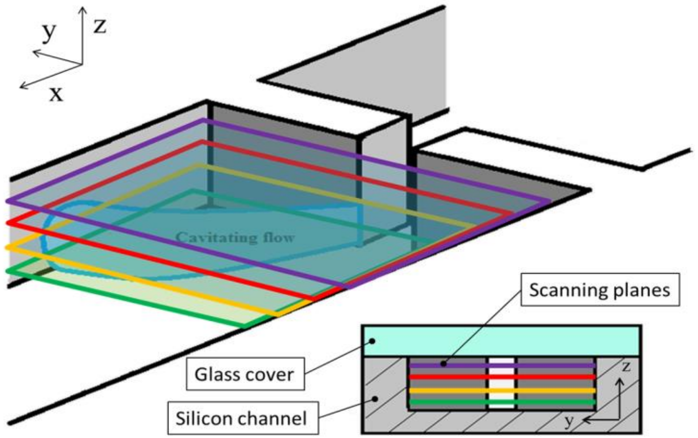
Temperature mapping in microchannels with fluorescein nanoprobes

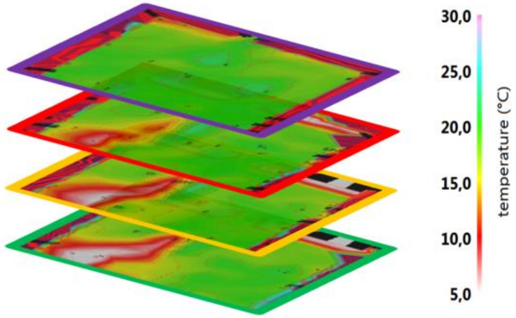
- Multiple 2D mappings performed at different heights in channel.
- 3D flow characterisation





3D void fraction mapping





3D temperature mapping

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Conclusions

- Ratiometric intensity measurements → temperaure and void fraction mapping of cavitation flow.
- Confocal setup → Confined acquisition volume → 2D and 3D flow characterisation.
- Indications of strong thermal effects in cavitating flow.

Perspectives

- Hydrodynamic cavitation radical yield by chemiluminescence intensity measurements.

D. Podbevsek et al., j.ultsonch., 43, 175-183 (2018).

Acknowledgments

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