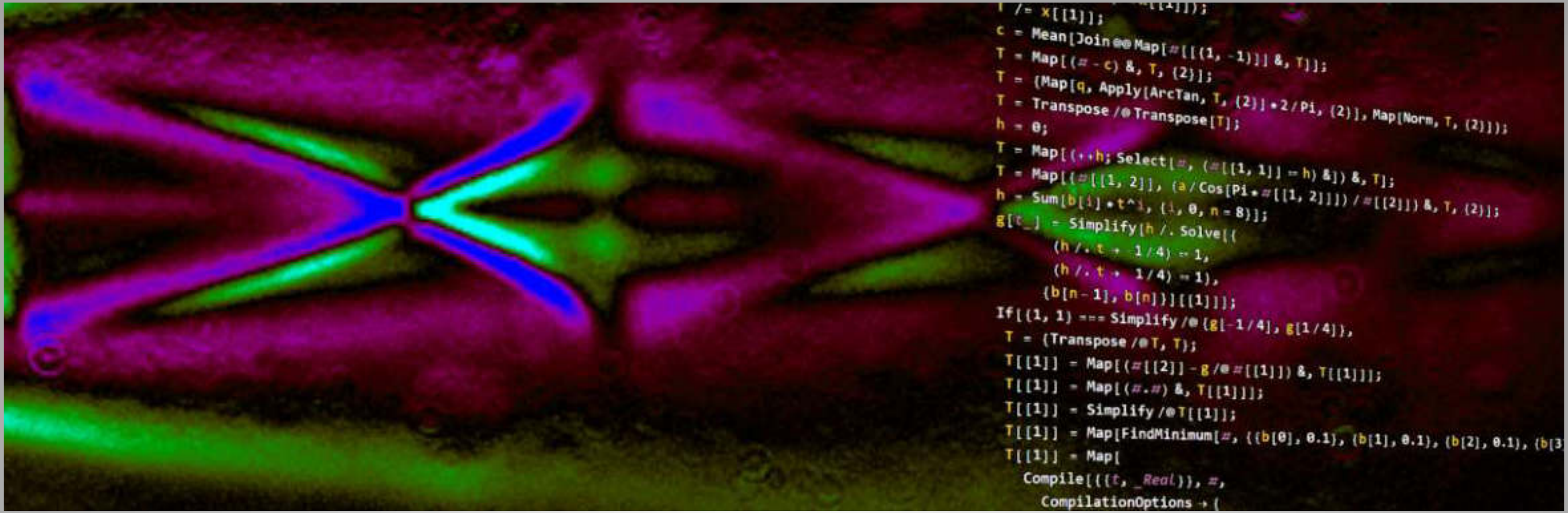


Spray condition monitoring for quality assurance

To watch the videos originally shown in this presentation please visit www.volinesystems.com

Oliver Stier & Aline Creuz

Outline

- Overview of process monitoring methods
- Schlieren monitoring of nozzle performance
- Particle impact monitoring by spray spot imaging
- Combination of schlieren and spot measurements
- Automatic nozzle clogging prediction
- New product for spray condition monitoring

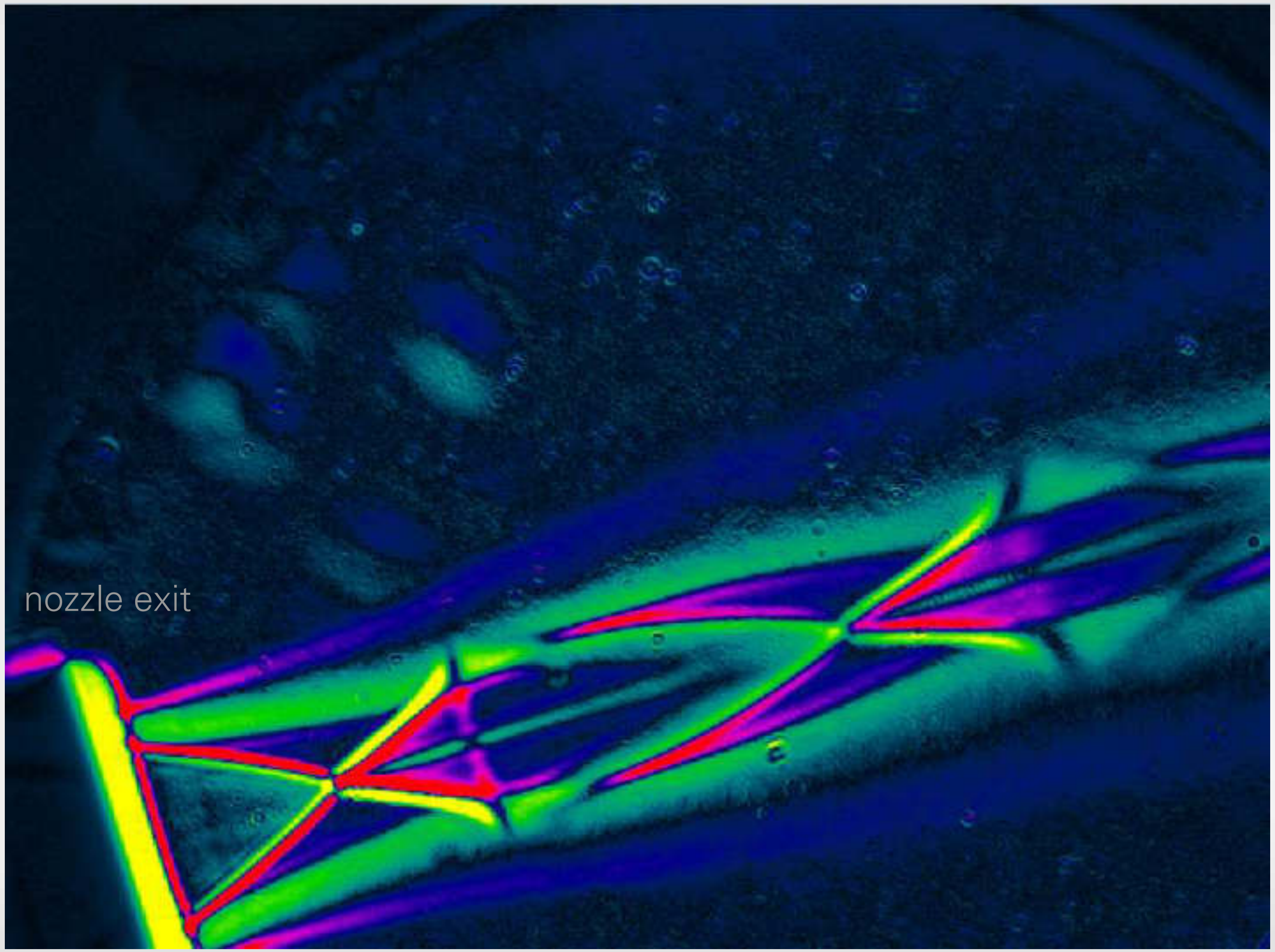
Process monitoring methods

High pressure CS systems		Nozzle integrity			Gas flow field			Particle phase			Deposition intensity
		wear	clogging present	clogging impending	total gas flow	conformance with reference	constancy	total mass flow (TMF)	TMF constancy	velocities	
CS system control		in throat	eventually	⊗	✓	⊗	⊗	✓	⊗	⊗	⊗
Acoustic monitoring		?	possibly (1)	?	⊗	⊗	⊗	⊗	possibly (2)	possibly (2)	possibly (1)
Schlieren imaging (3)		✓	✓	✓	⊗	✓	✓	⊗	⊗	⊗	⊗
PIV		unreliable	✓	unreliable	⊗	⊗	unreliable	⊗	✓	✓	⊗
Spot imaging (4)		⊗	✓	unreliable	⊗	⊗	⊗	⊗	✓	unreliable	✓
Deposition profile dimensional scan		⊗	✓	⊗	⊗	⊗	⊗	⊗	✓	unreliable	unreliable

Process monitoring methods (References)

1 D. Schimbäck, M. Steierl, M. Kettner, R. Sommerhuber, Online process monitoring for Cold Spray by using an acoustic measurement method
28th Cold Spray Club Meeting, Dublin, 28 April 2023
2 S. Koufis, N. Eskue, D. Zarouchas, J.A. Pascoe, Monitoring the Cold Spray Process: Real-time particle velocity monitoring through airborne acoustic emission analysis
30th Cold Spray Club Meeting, Barcelona, 26.04.2024
3 O. Stier, A. Creuz, J. Dahl Jensen, U. Krüger, Industrial Multi-Axis Cold Spray Manufacturing Using SIEMENS Software
CSAT Meeting, Leominster, MA, 23 June 2021
4 A. Creuz, O. Stier, Quick spray parameter assessment by in-situ measurement of material deposition
29th Cold Spray Club Meeting, Hamburg, 20 October 2023

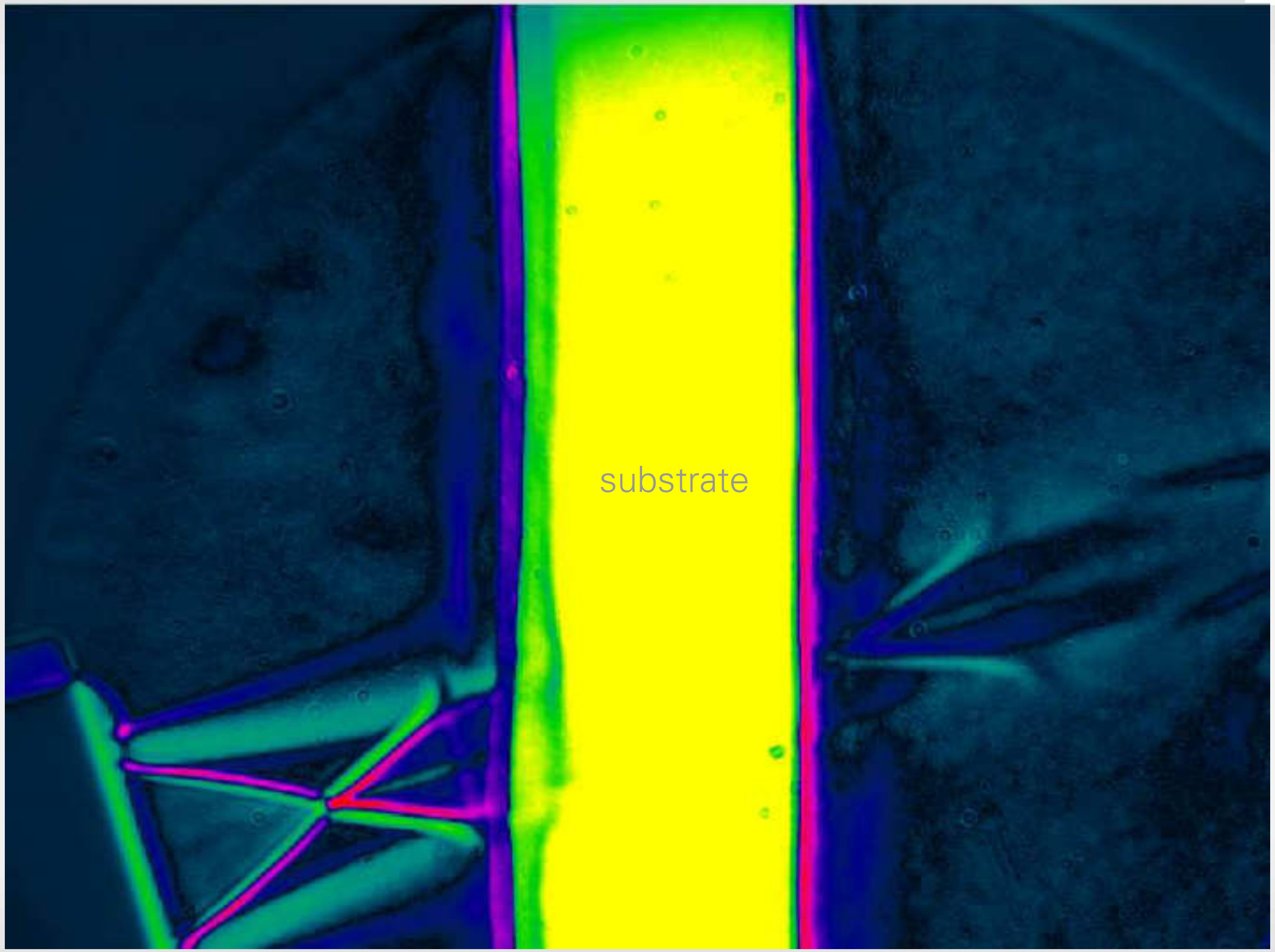
Schlieren monitoring



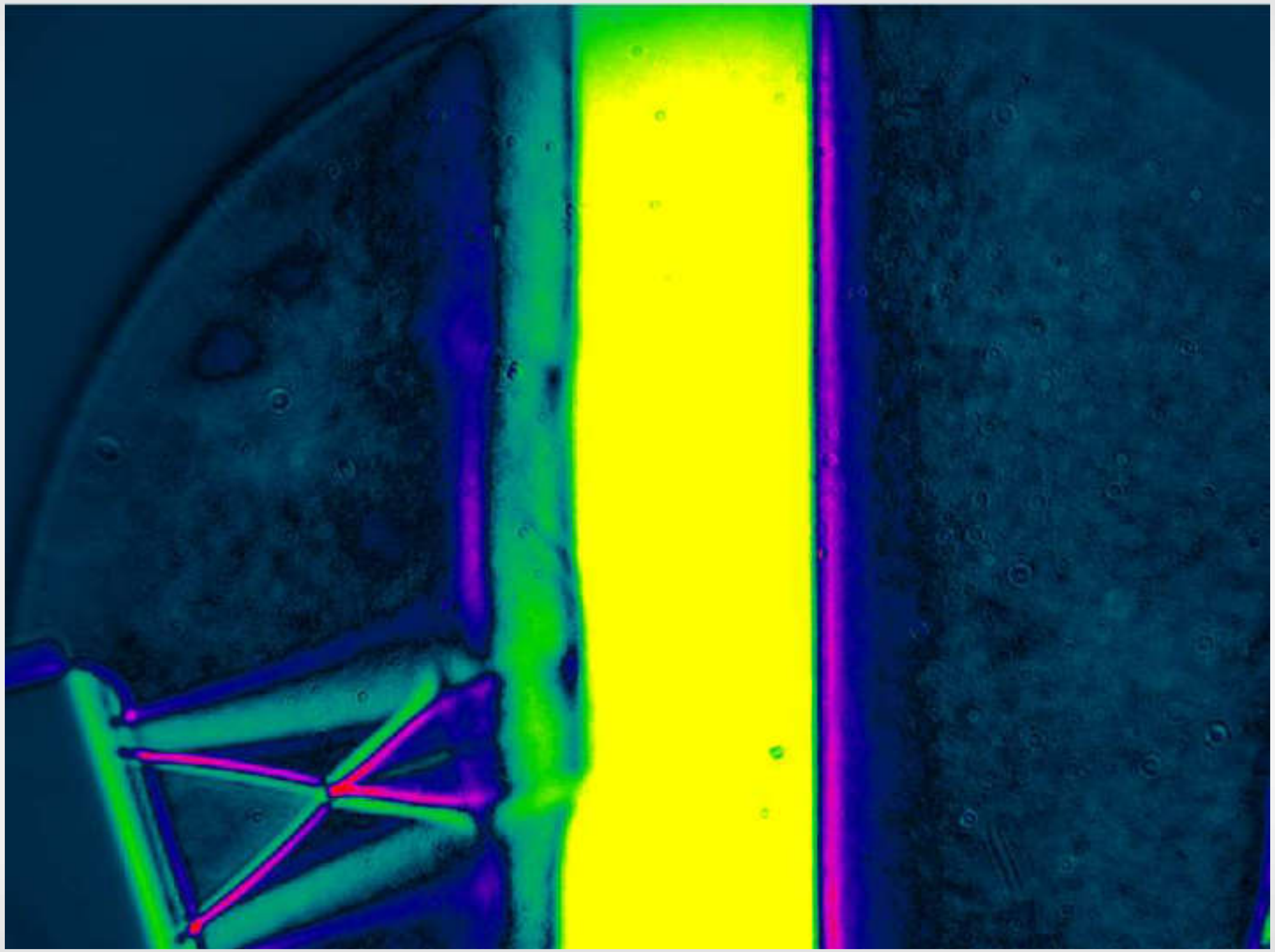
After-nozzle flow

CGT v27
P = 39 barg,
T = 600 °C

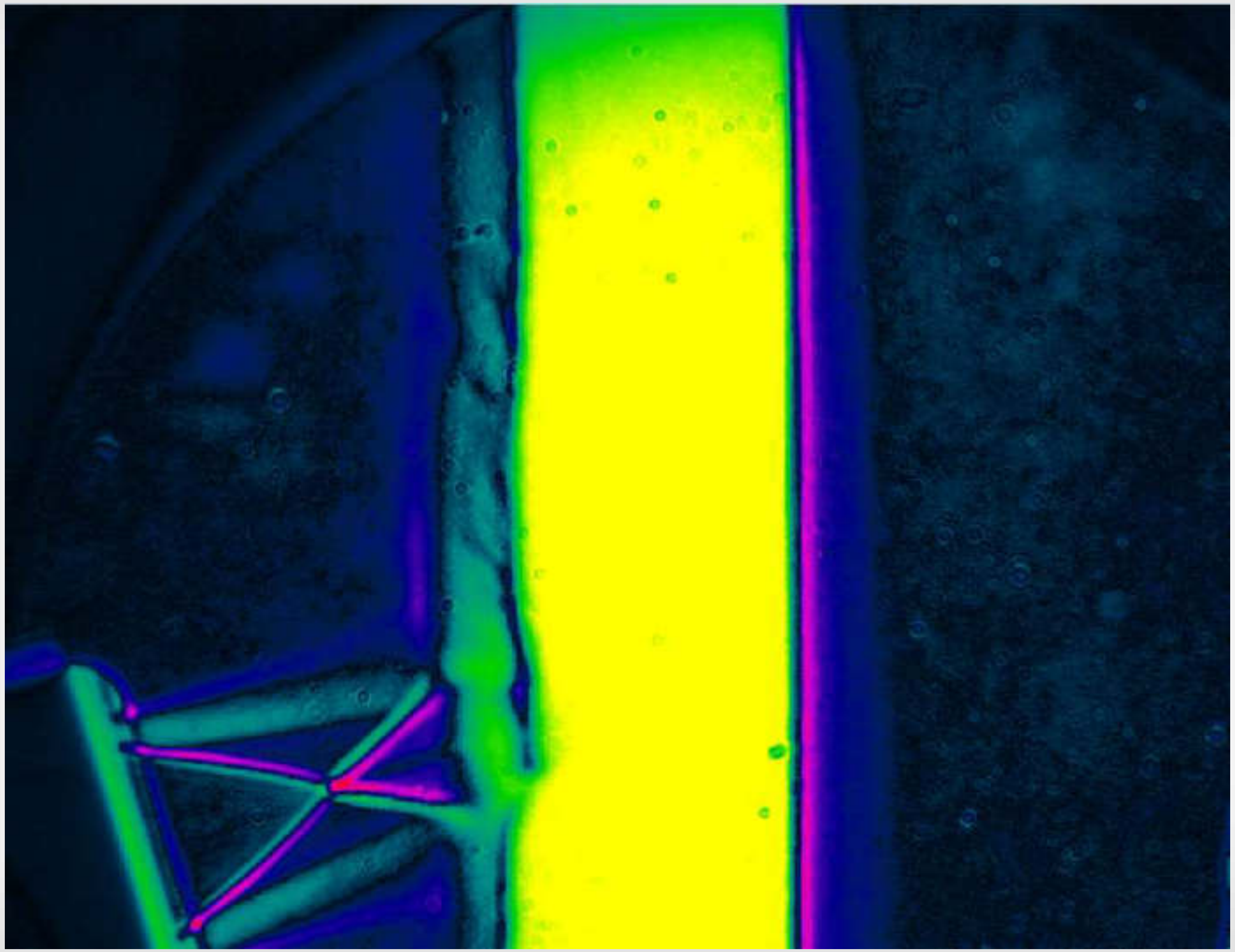
Schlieren monitoring



Schlieren monitoring

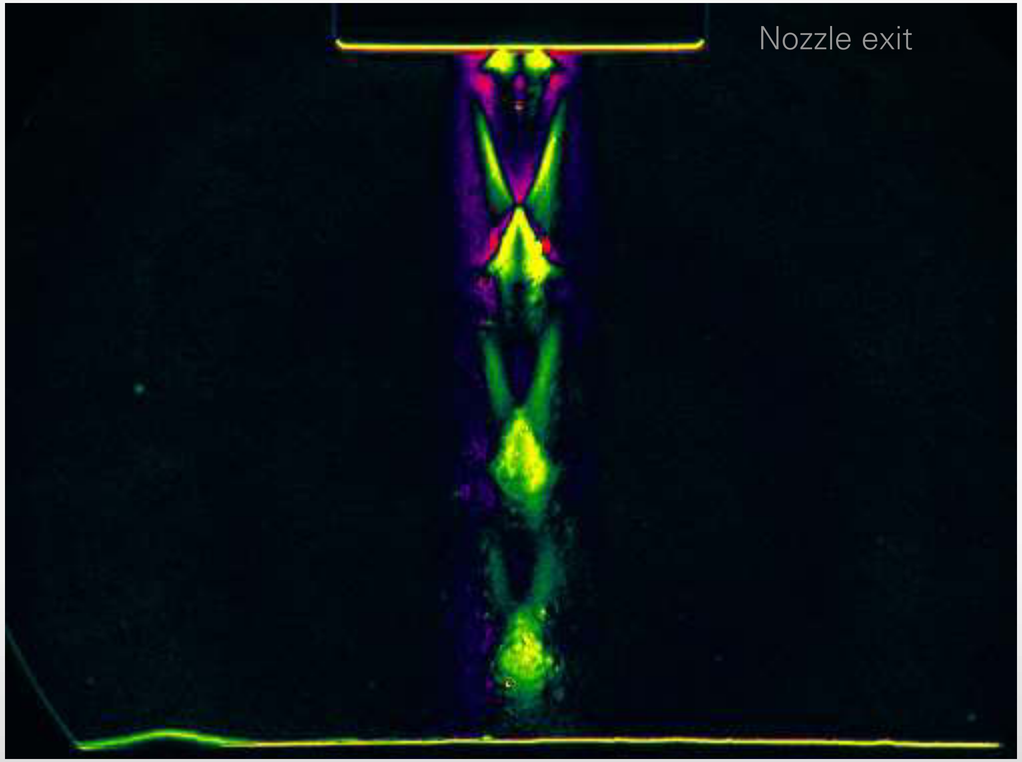


Schlieren monitoring



Schlieren monitoring
Pressure-dependent flow patterns (impact OUT 1)

P = 12 barg
T = 50 °C

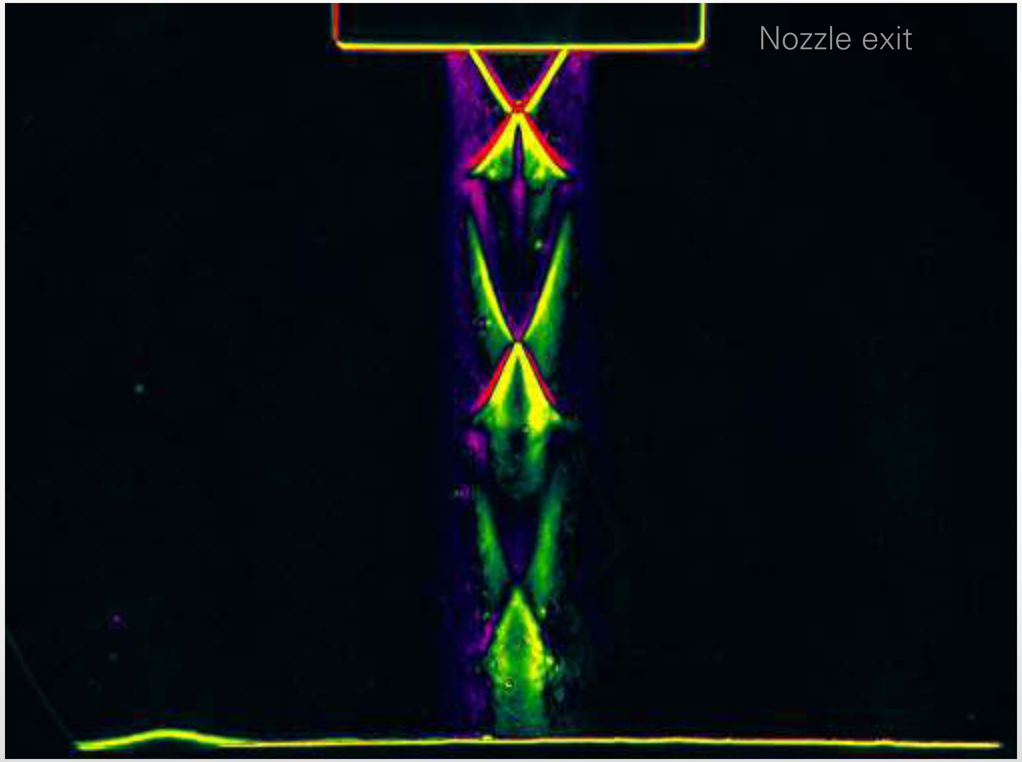


Overexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P = 16 barg
T = 50 °C

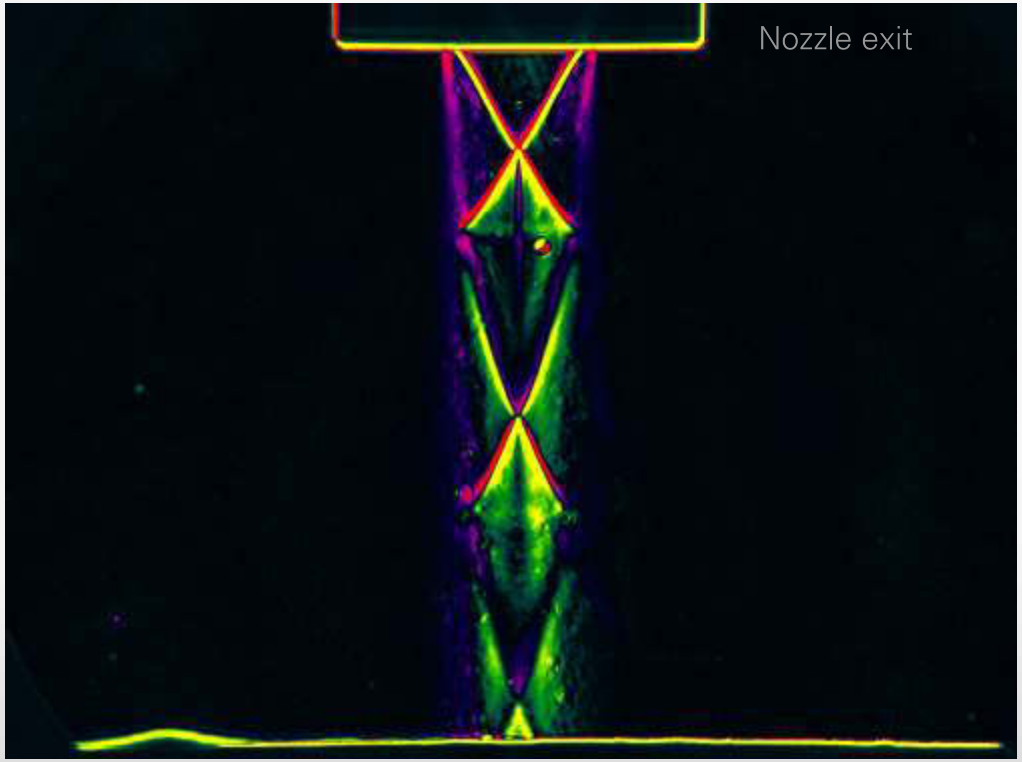


Overexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P = 20 barg
T = 50 °C

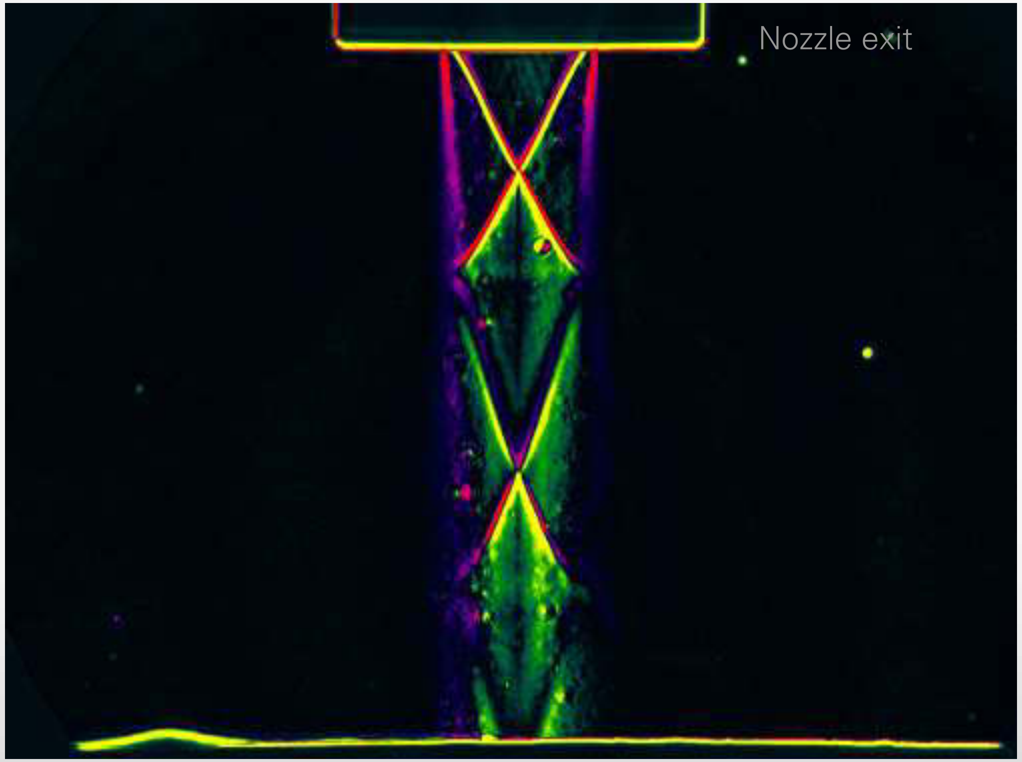


Overexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P = 24 barg
T = 50 °C

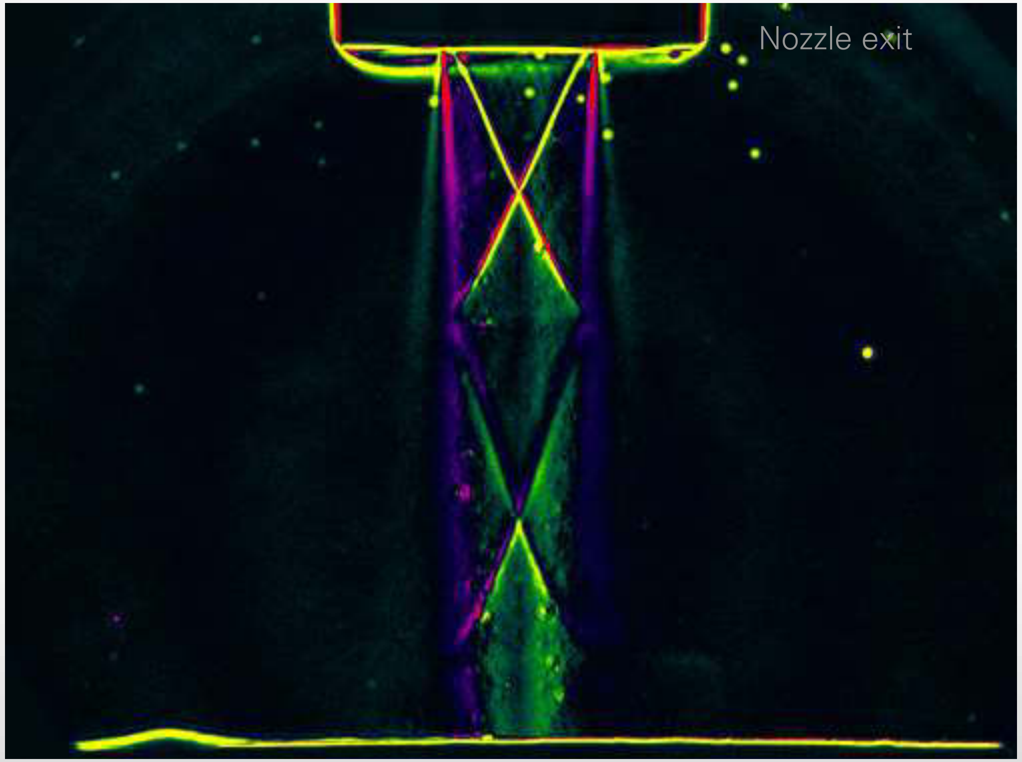


Overexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P = 28 barg
T = 200 °C

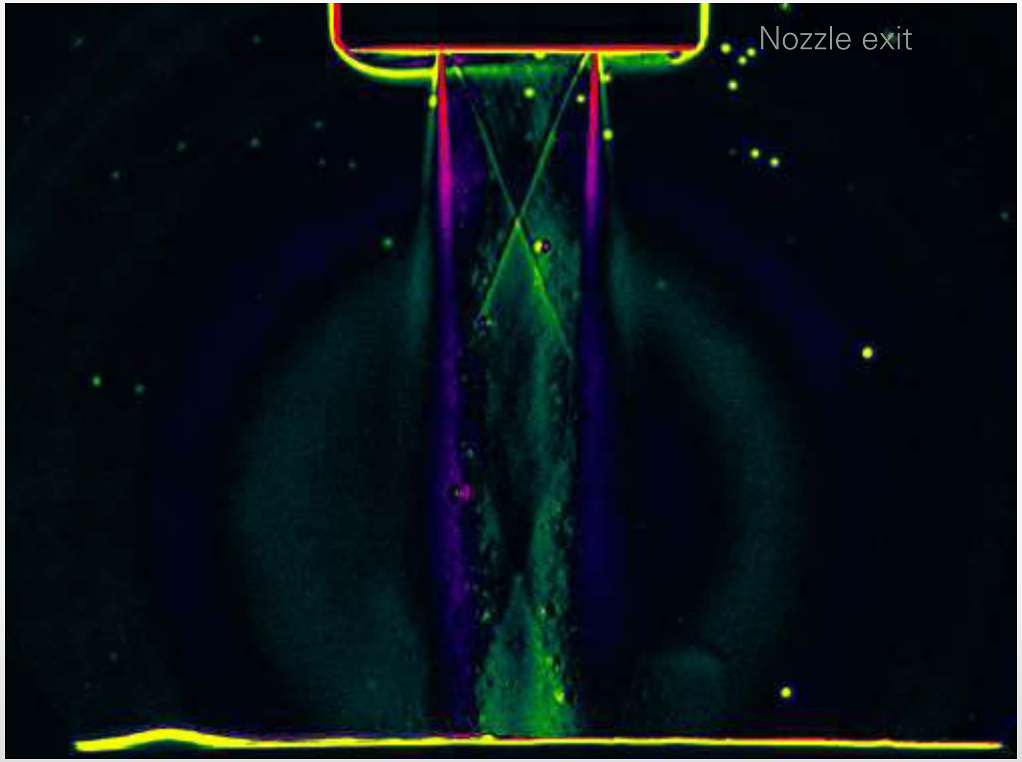


Overexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P =   32 barg
T = 200 °C

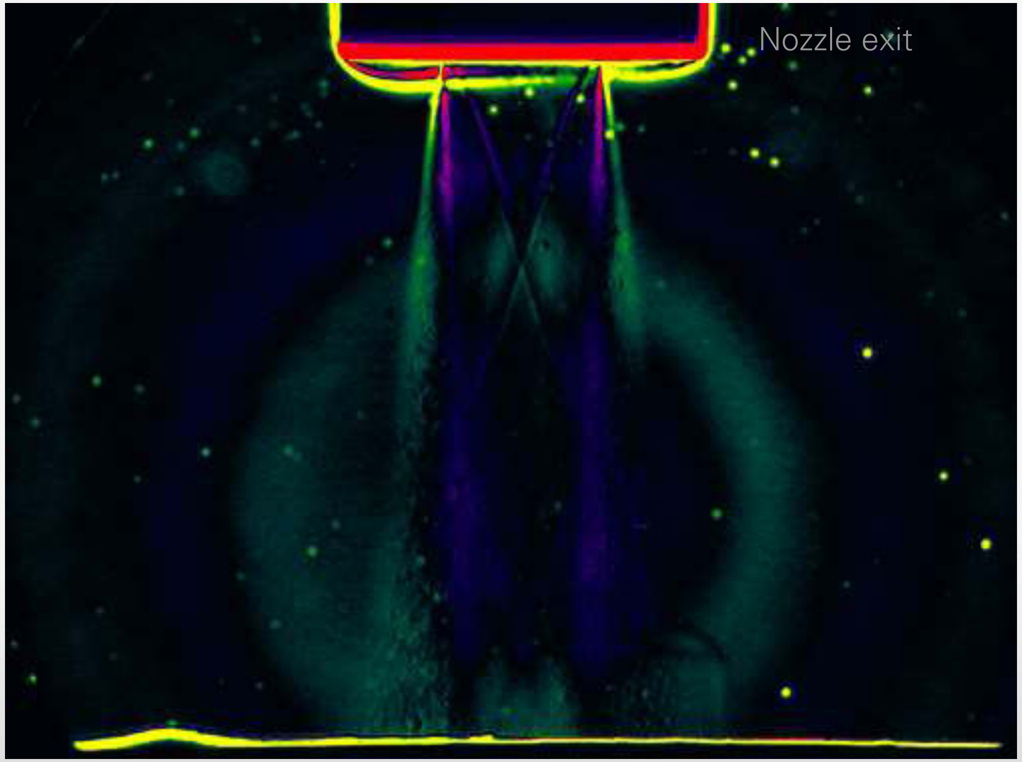


Overexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P =   35 barg
T = 600 °C

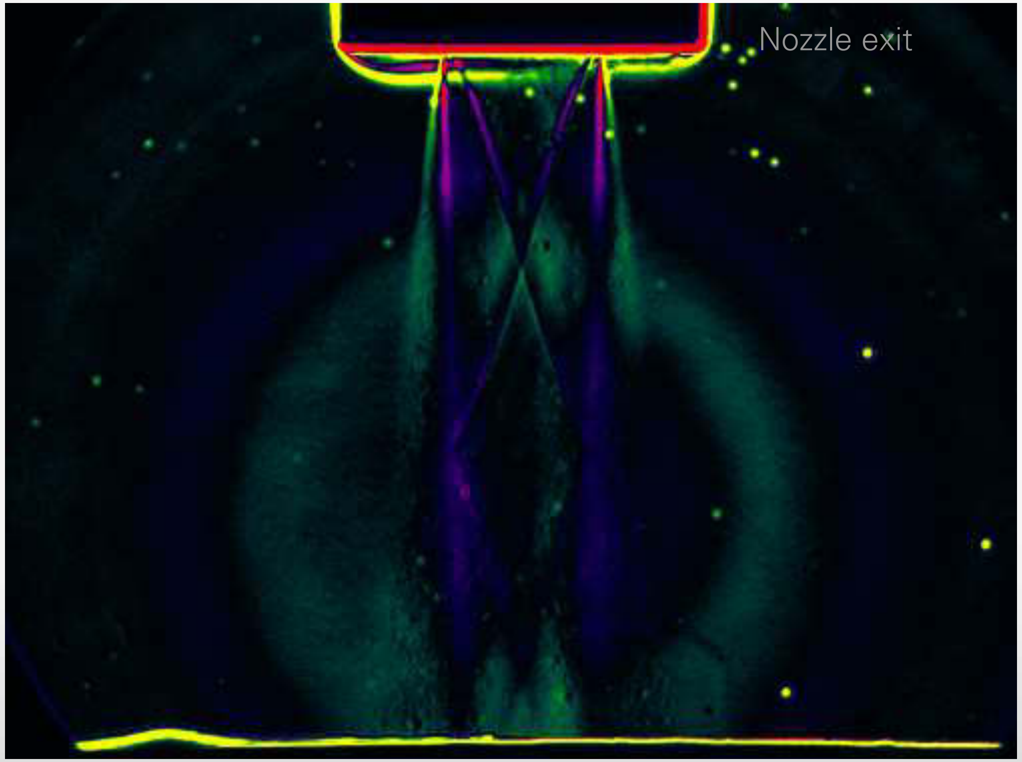


Pressure matching

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P = 36 barg
T = 400 °C

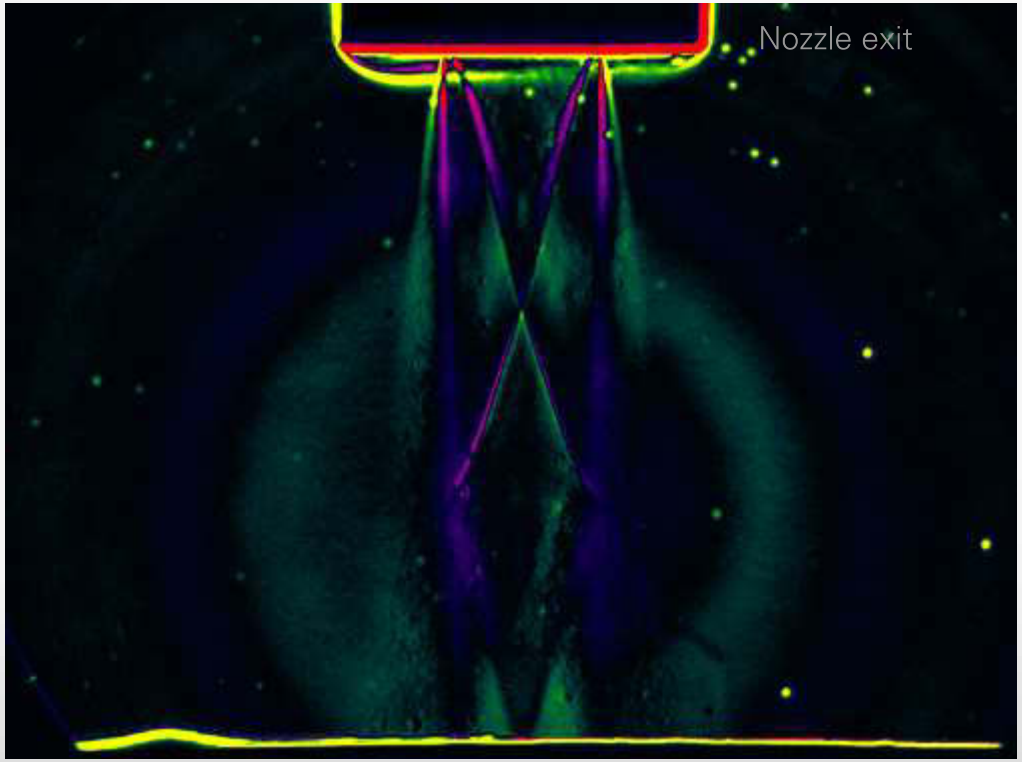


Underexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

P = 40 barg
T = 400 °C

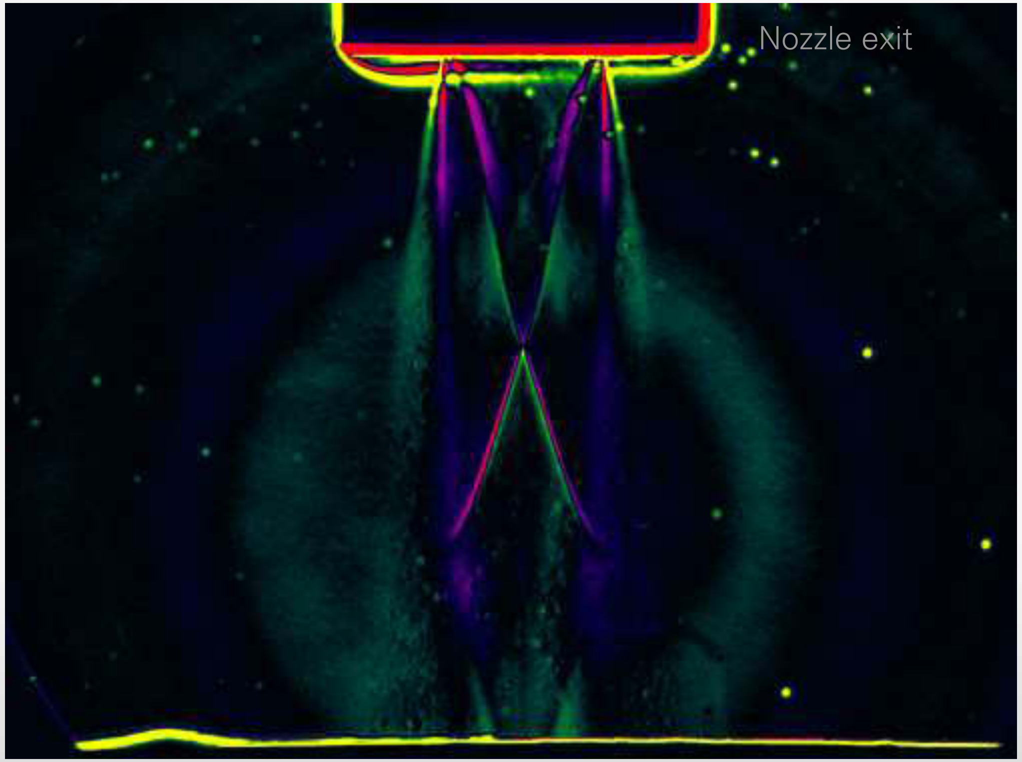


Underexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

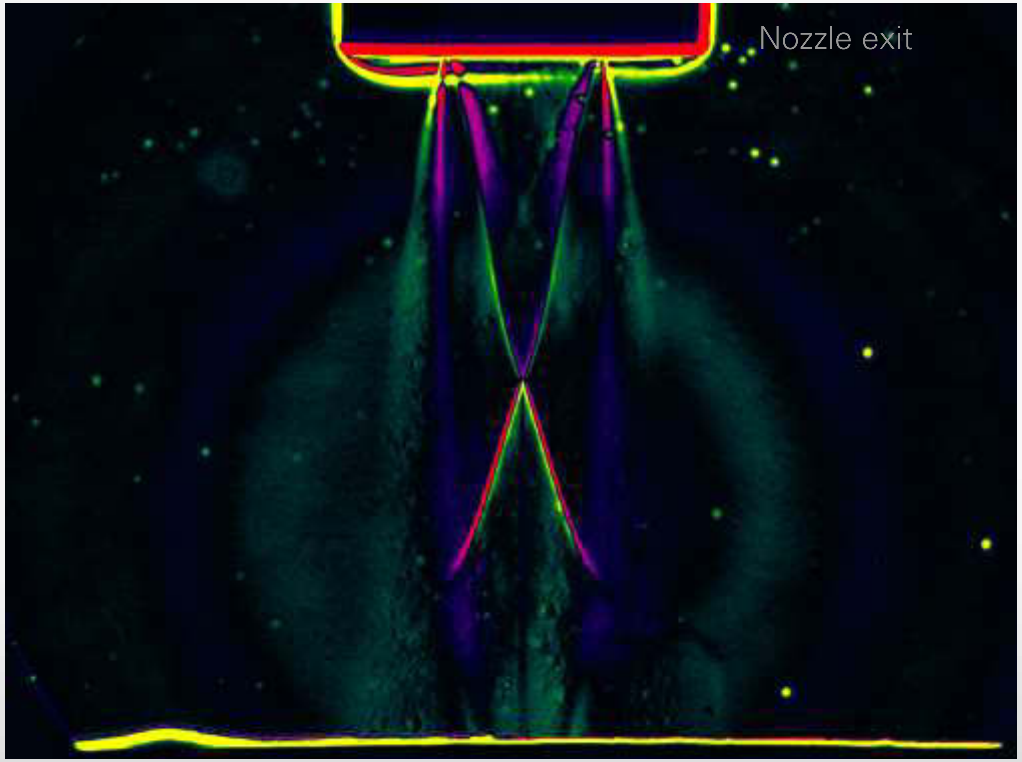
P =   44 barg
T = 500 °C



Underexpansion

Schlieren monitoring
Pressure-dependent flow patterns (impact OUT 1)

P = 48 barg
T = 500 °C

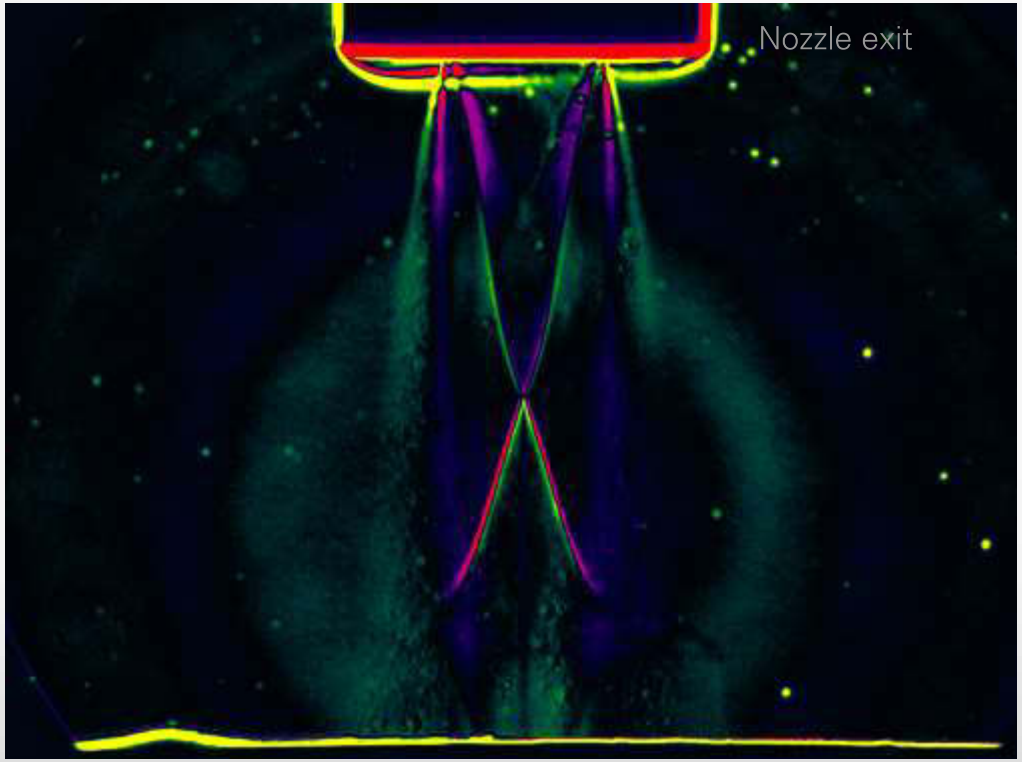


Underexpansion

Schlieren monitoring

Pressure-dependent flow patterns (impact OUT 1)

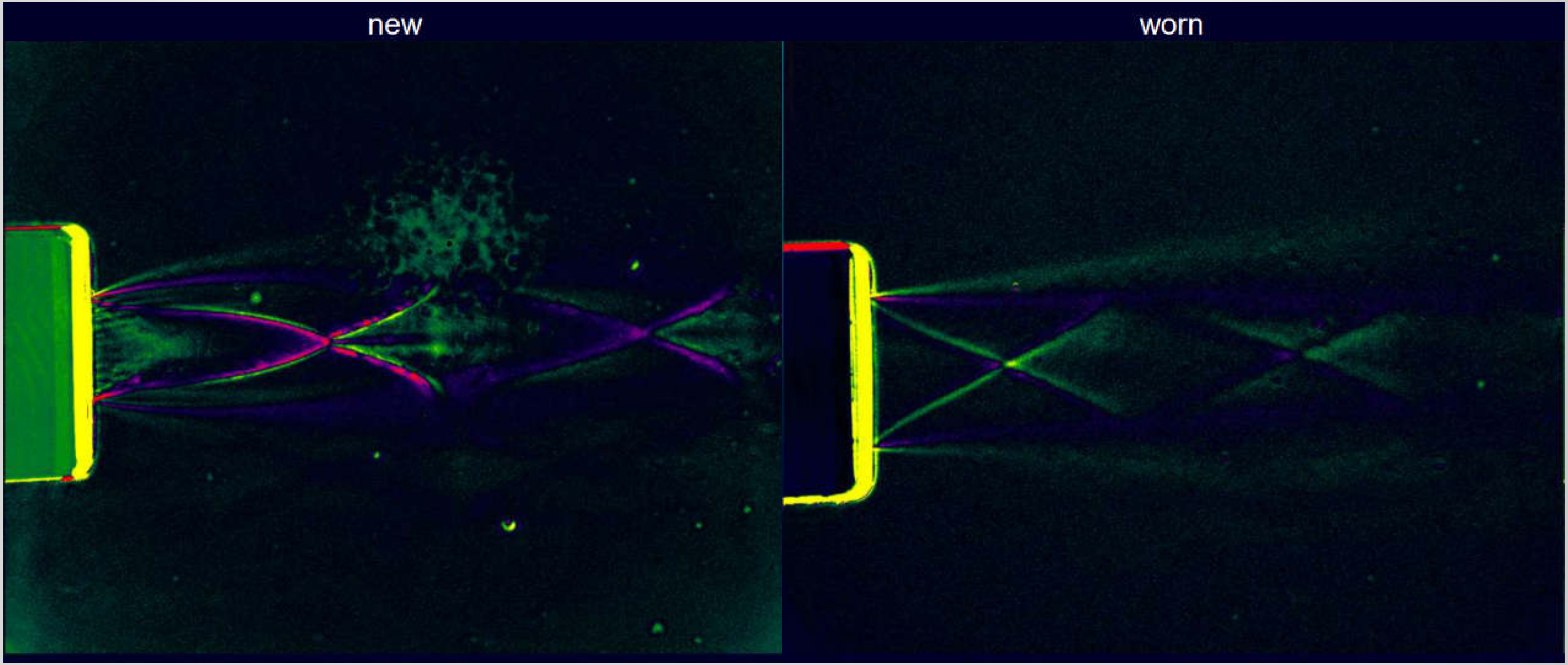
P =   50 barg
T = 600 °C



Underexpansion

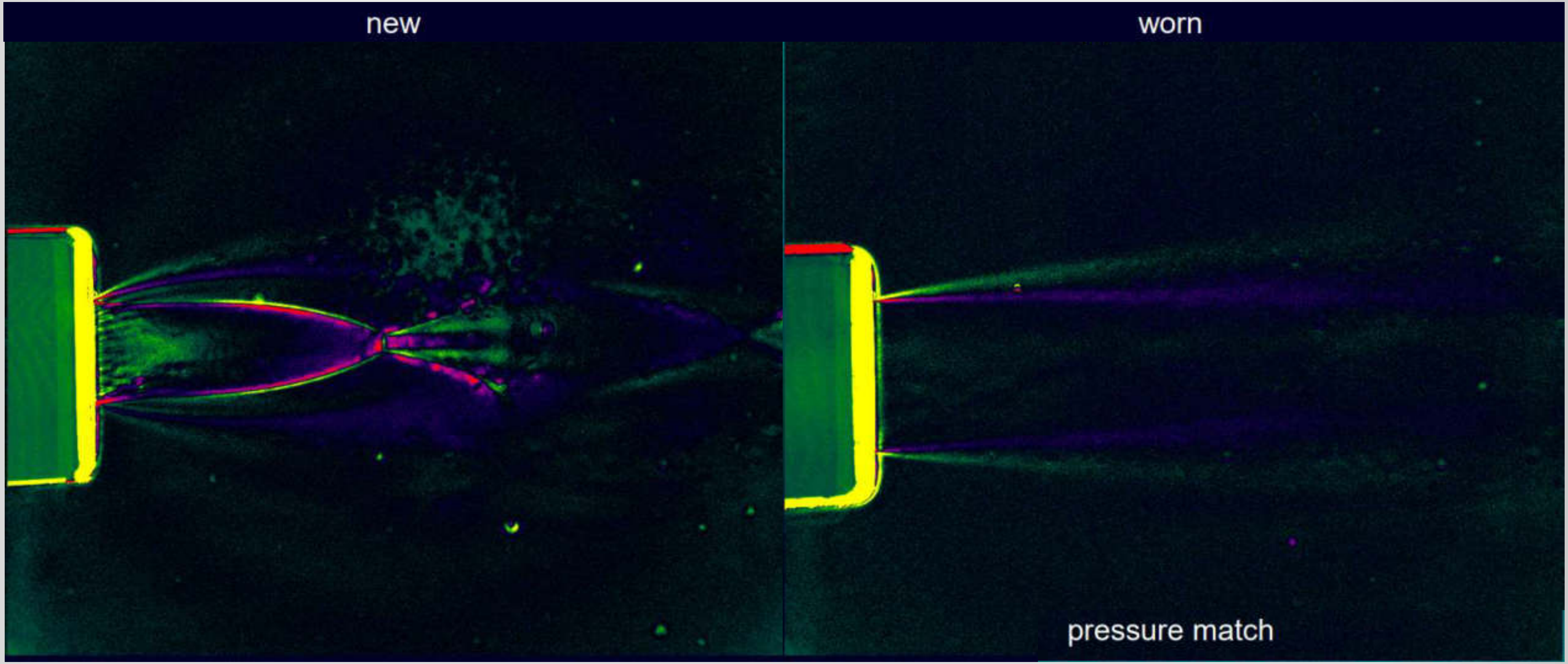
Schlieren monitoring: Nozzle wear

High pressure cold spray nozzle 50 bar, 500 °C



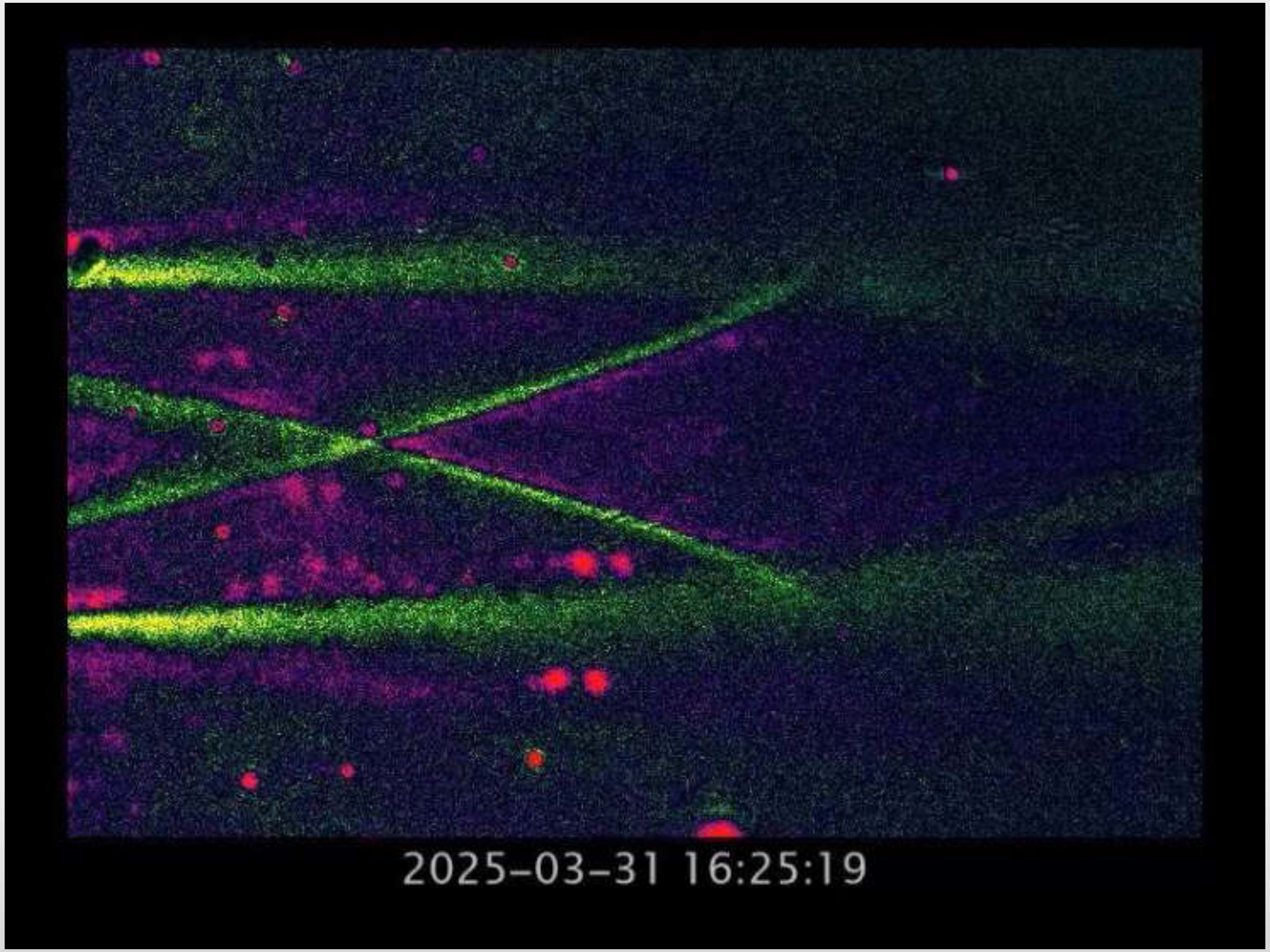
Schlieren monitoring: Nozzle wear

High pressure cold spray nozzle 66 bar, 600 / 700 °C



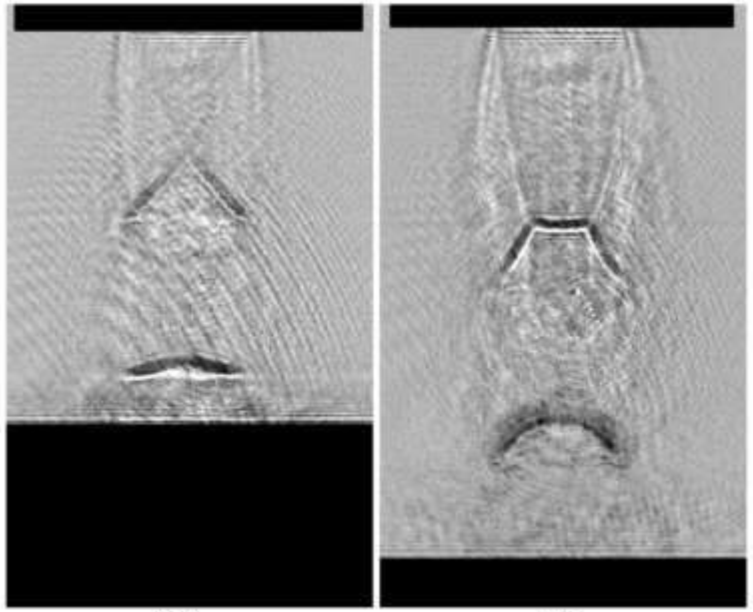
Schlieren monitoring: Nozzle clogging

Aluminum, OUT1, 500 °C: Nozzle dusting after 4 min spraying



We gratefully acknowledge Alex List, Frank Gärtner, Max Mosig, and Julio Gutiérrez de Frutos, HSU Hamburg, for experiments at their cold spray lab.

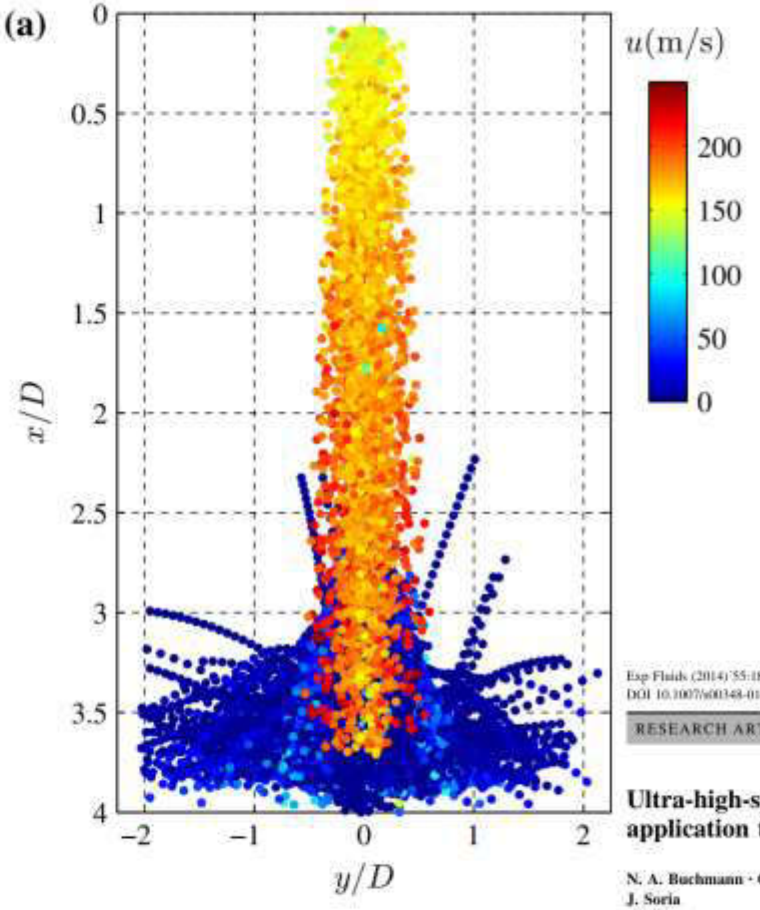
Spray spot observation

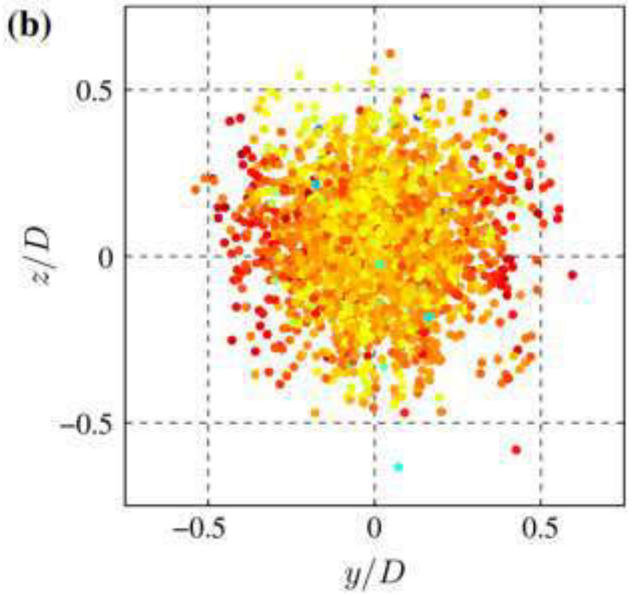


(a) (b)

Fig. 6 Coherent image visualisation of the gas phase of the underexpanded jet; **a** NPR = 3.75, $Z/D = 3$; **b** NPR = 6, $Z/D = 4$. Flow is from *top* to *bottom*

a thin plane within the jet and standard 2D tracking methods would result in a depth-averaged particle velocity





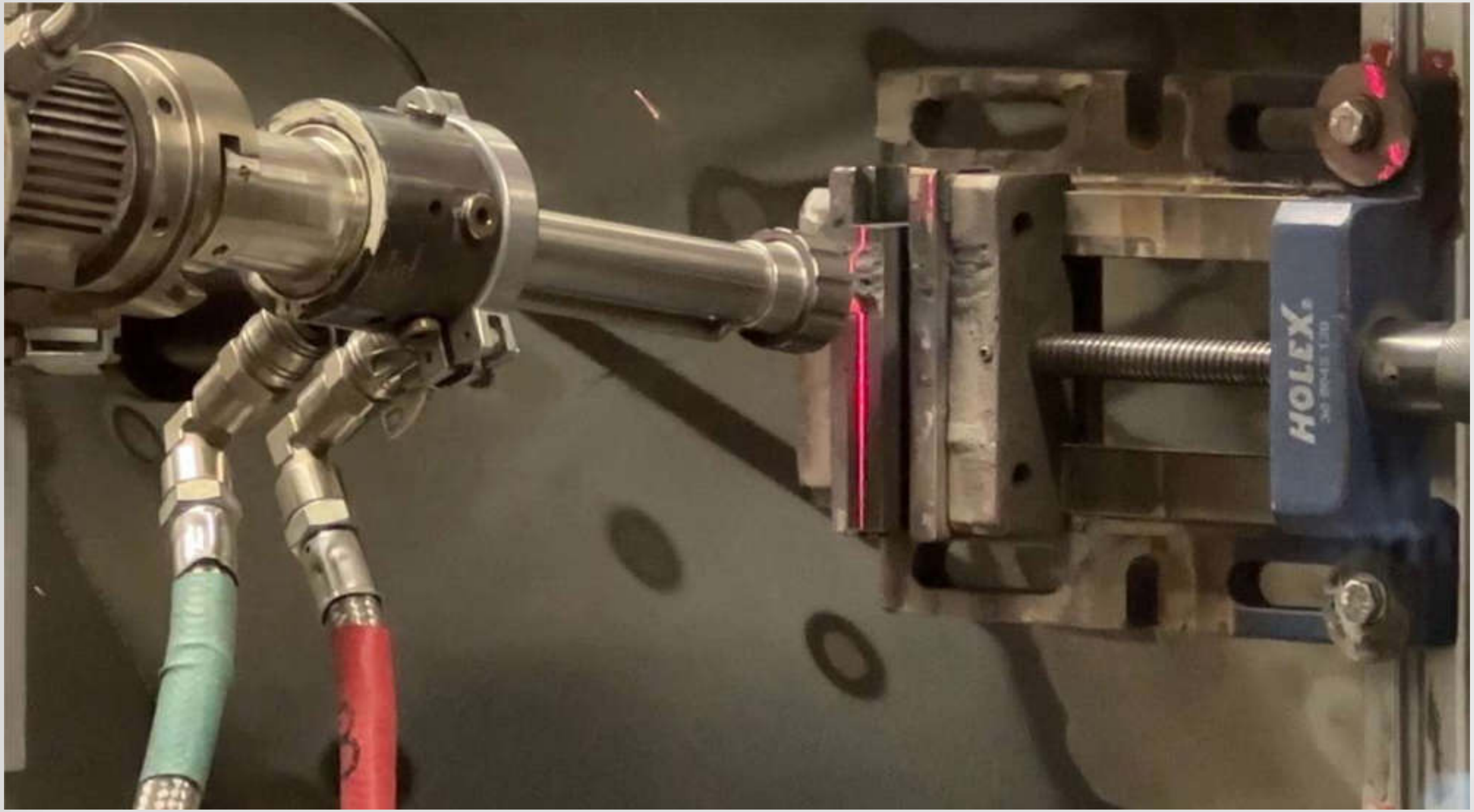
Exp Fluids (2014) 55:1842
DOI 10.1007/s00348-014-1842-1

RESEARCH ARTICLE

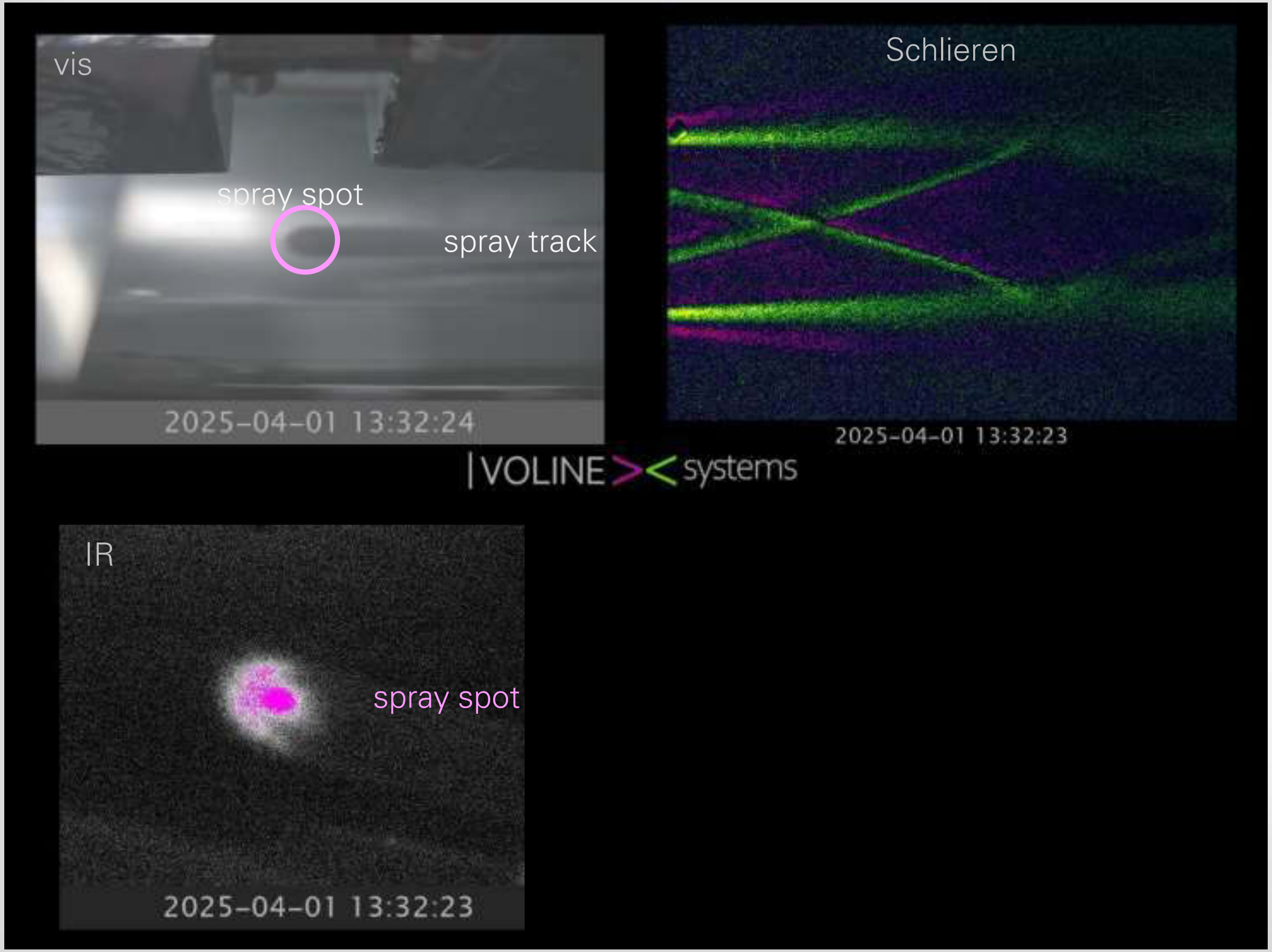
Ultra-high-speed 3D astigmatic particle tracking velocimetry: application to particle-laden supersonic impinging jets

N. A. Buchmann · C. Cierpka · C. J. Kähler · J. Soria

Spray spot observation



Spray spot observation



Spraying of Aluminum 99.7

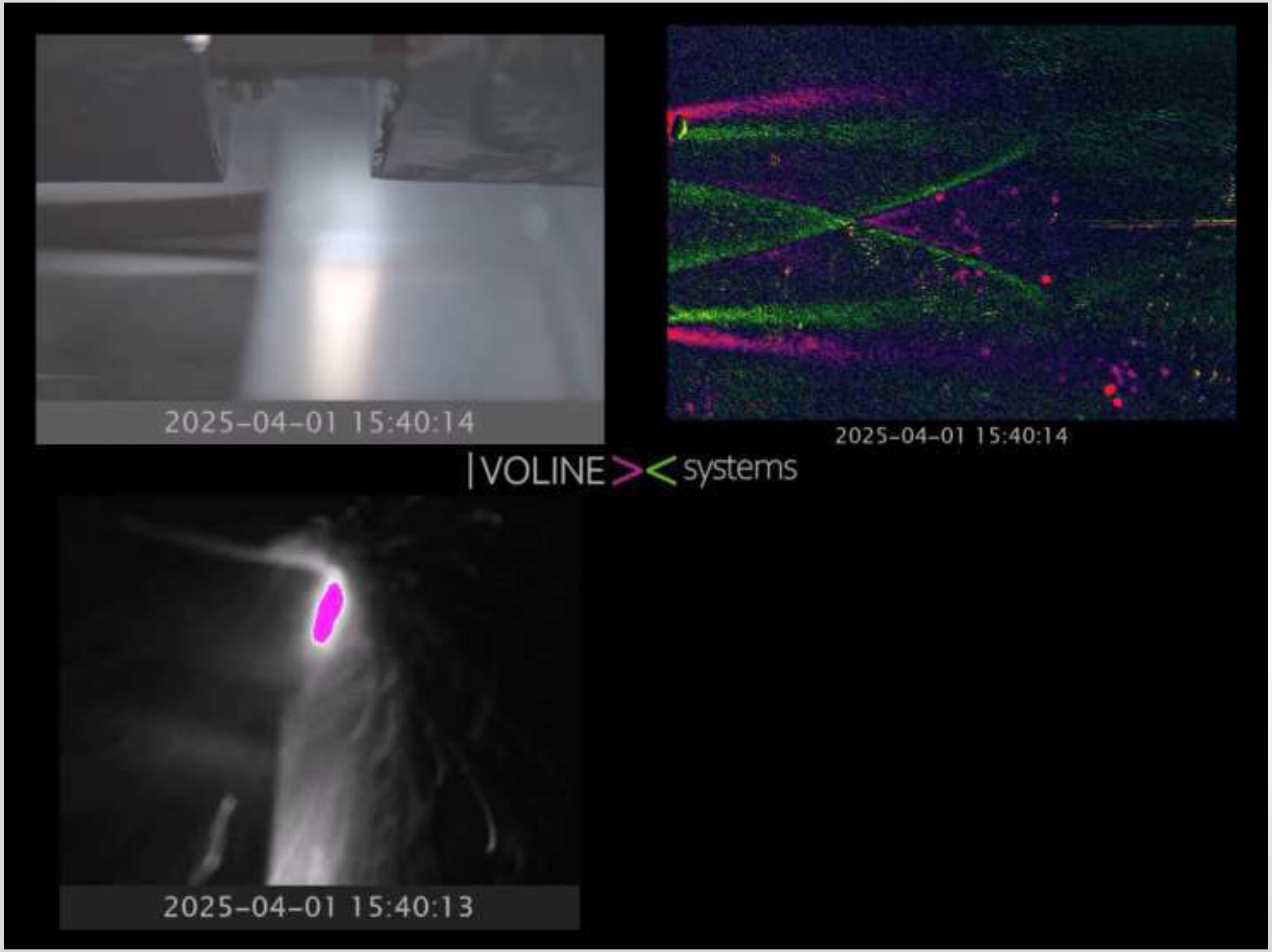
We gratefully acknowledge Alex List, Frank Gärtner, Max Mosig, and Julio Gutiérrez de Frutos, HSU Hamburg, for experiments at their cold spray lab.

Spray spot monitoring
Aluminum

Detail

We gratefully acknowledge Alex List, Frank Gärtner, Max Mosig, and Julio Gutiérrez de Frutos, HSU Hamburg, for experiments at their cold spray lab.

Spray spot observation

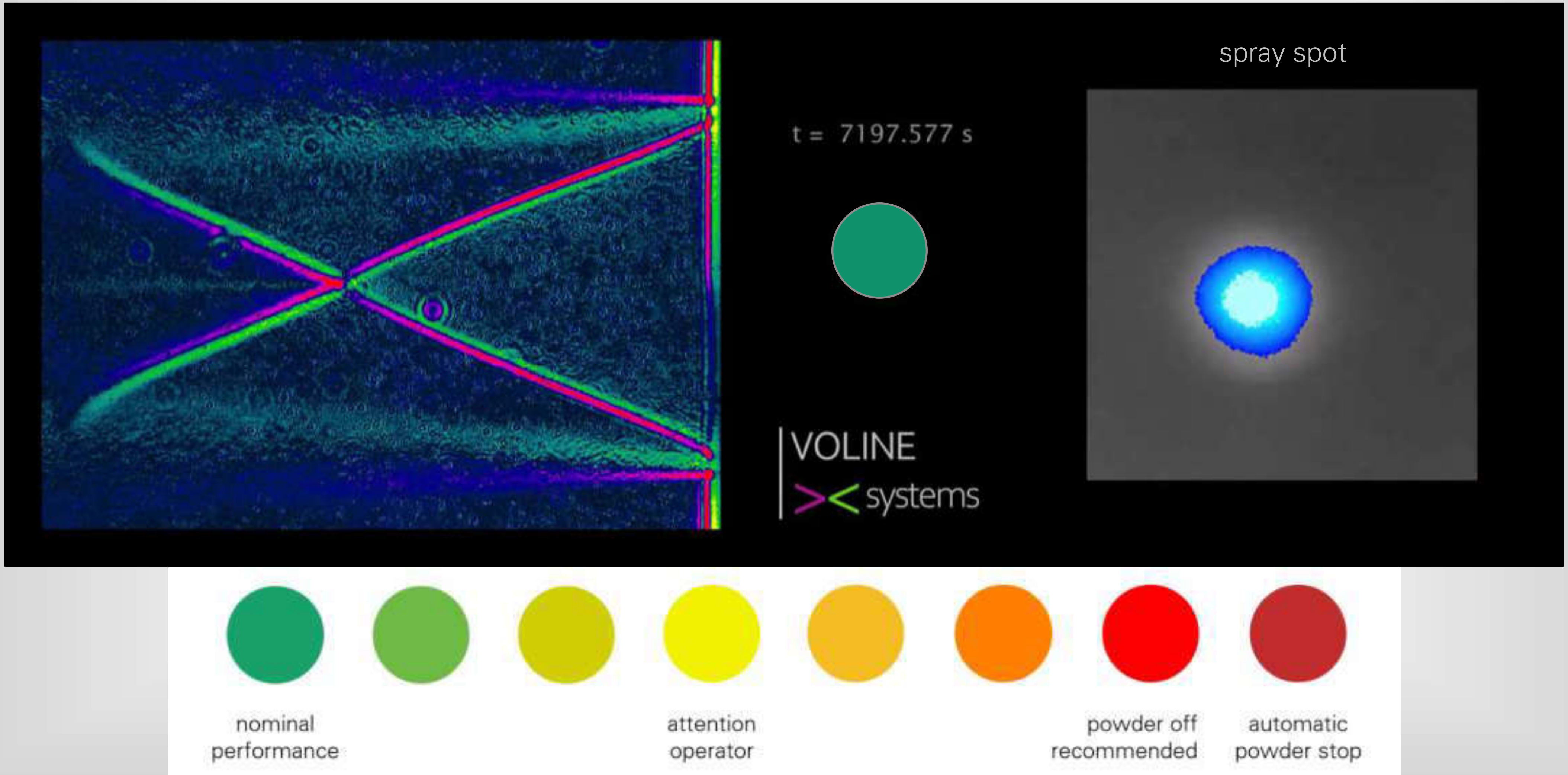


Spraying of cp-Ti

We gratefully acknowledge Alex List, Frank Gärtner, Max Mosig, and Julio Gutiérrez de Frutos, HSU Hamburg, for experiments at their cold spray lab.

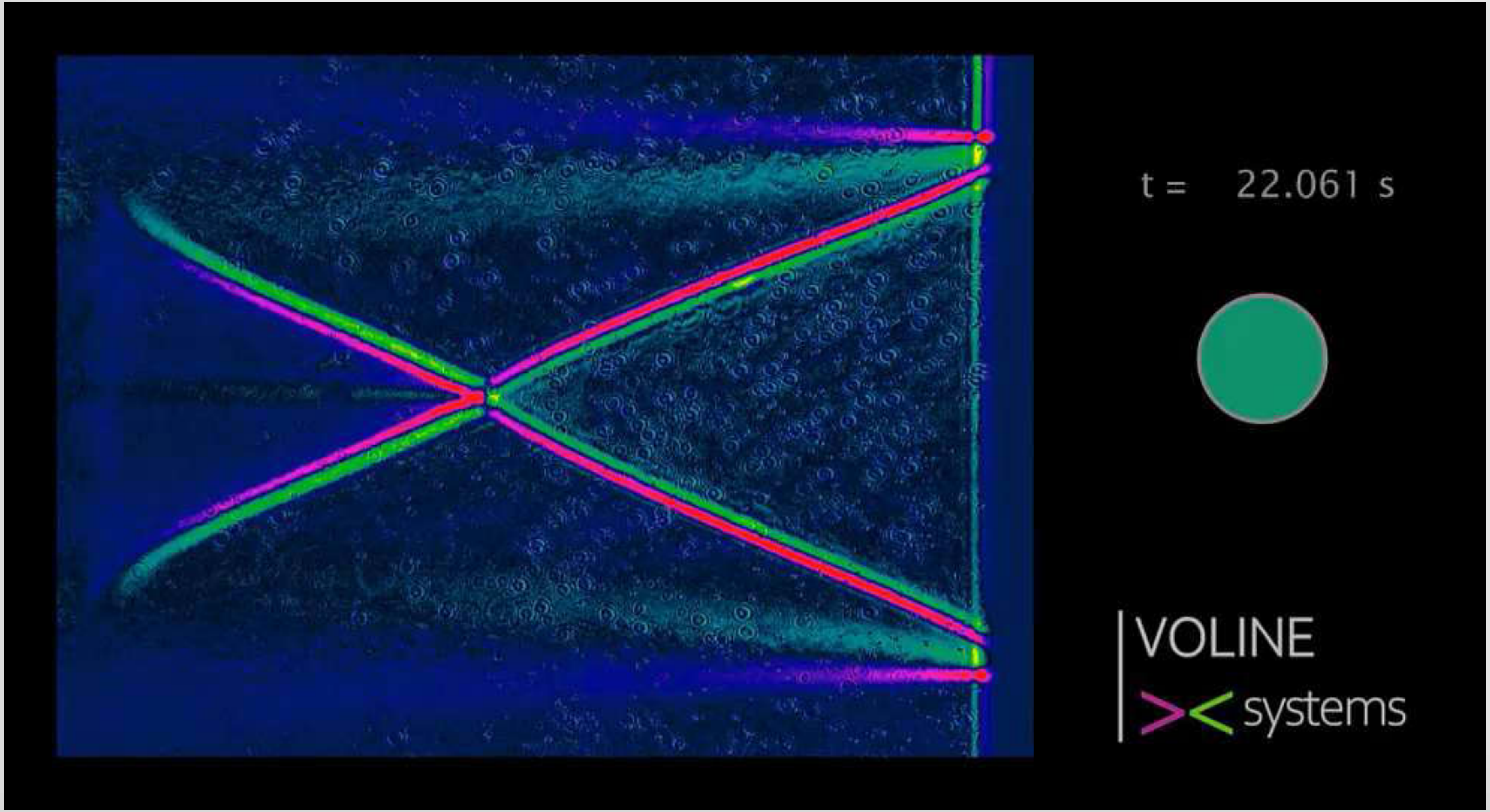
Schlieren monitoring: Clogging prediction

Ideal nozzle operation (2 hours)



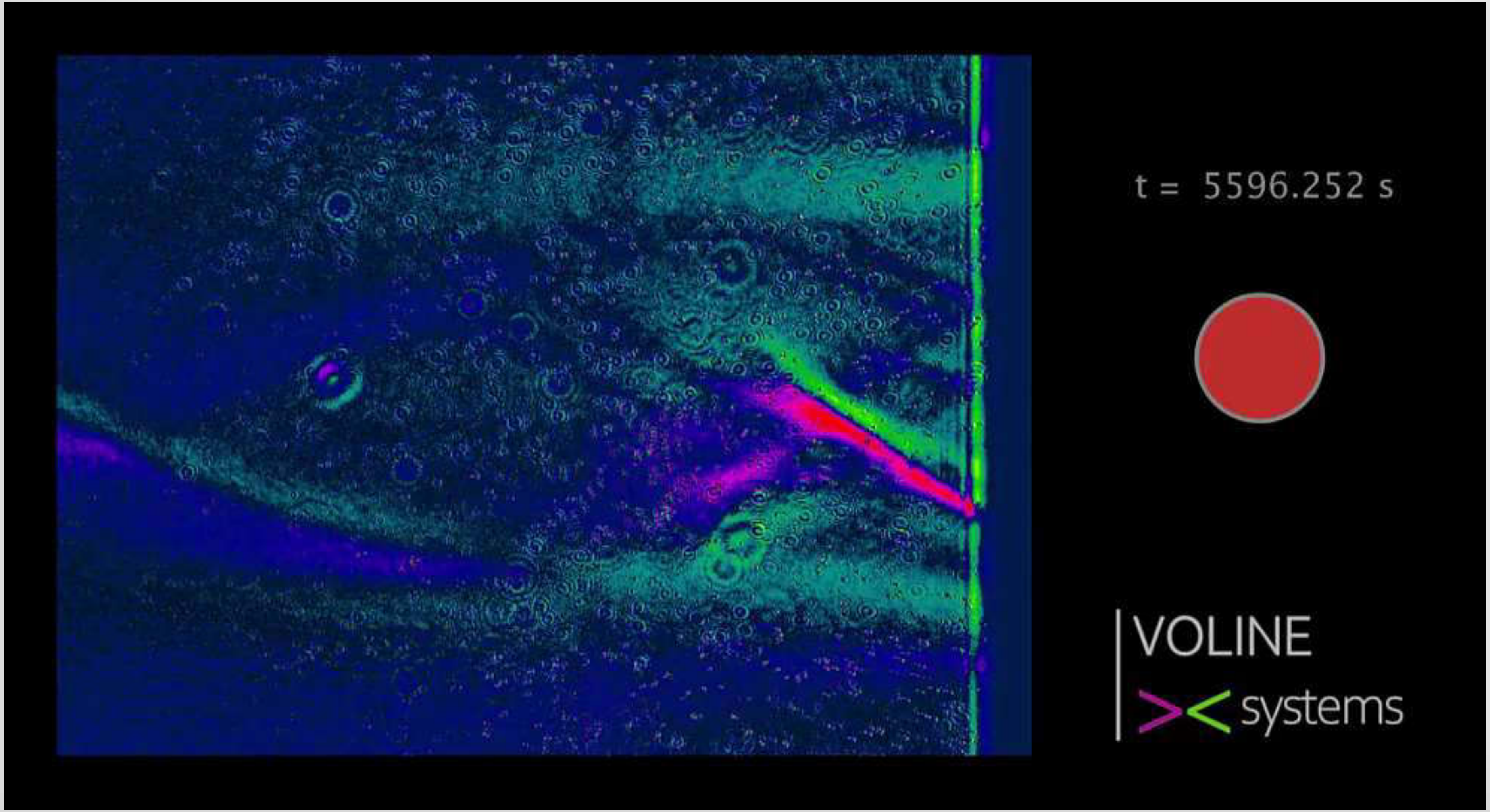
Schlieren monitoring: Clogging prediction

Automatic warning for impending clogging



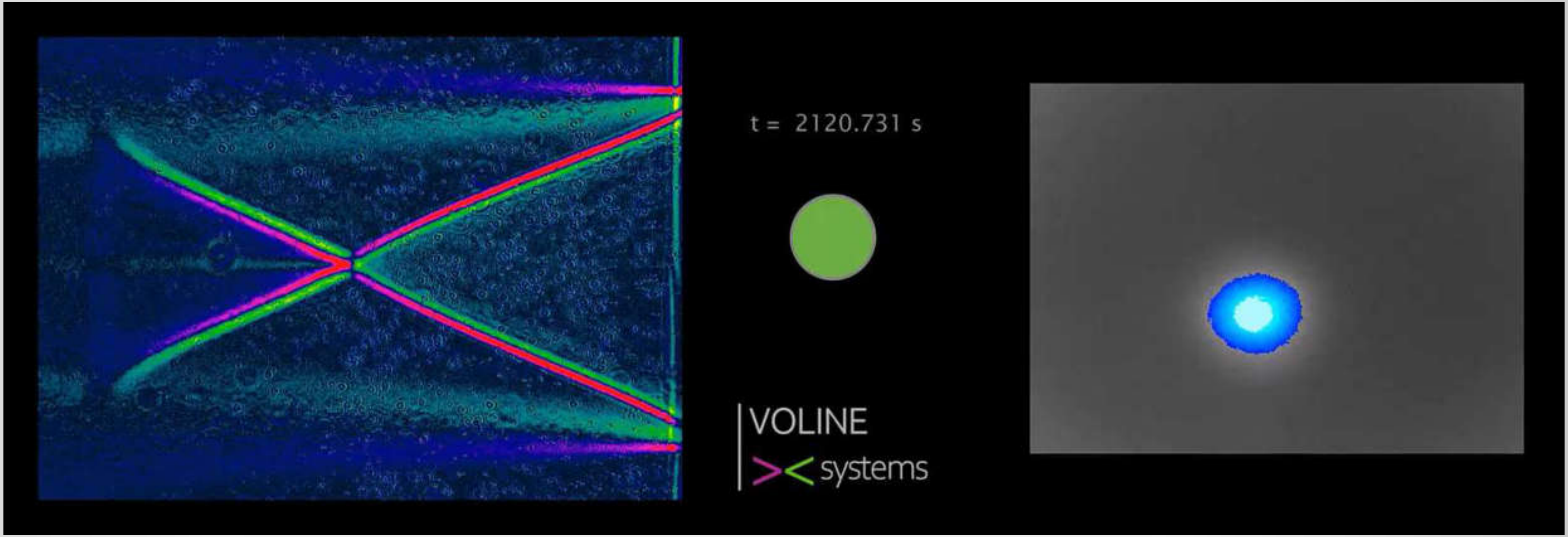
Schlieren monitoring: Clogging prediction

Automatic warning for impending clogging



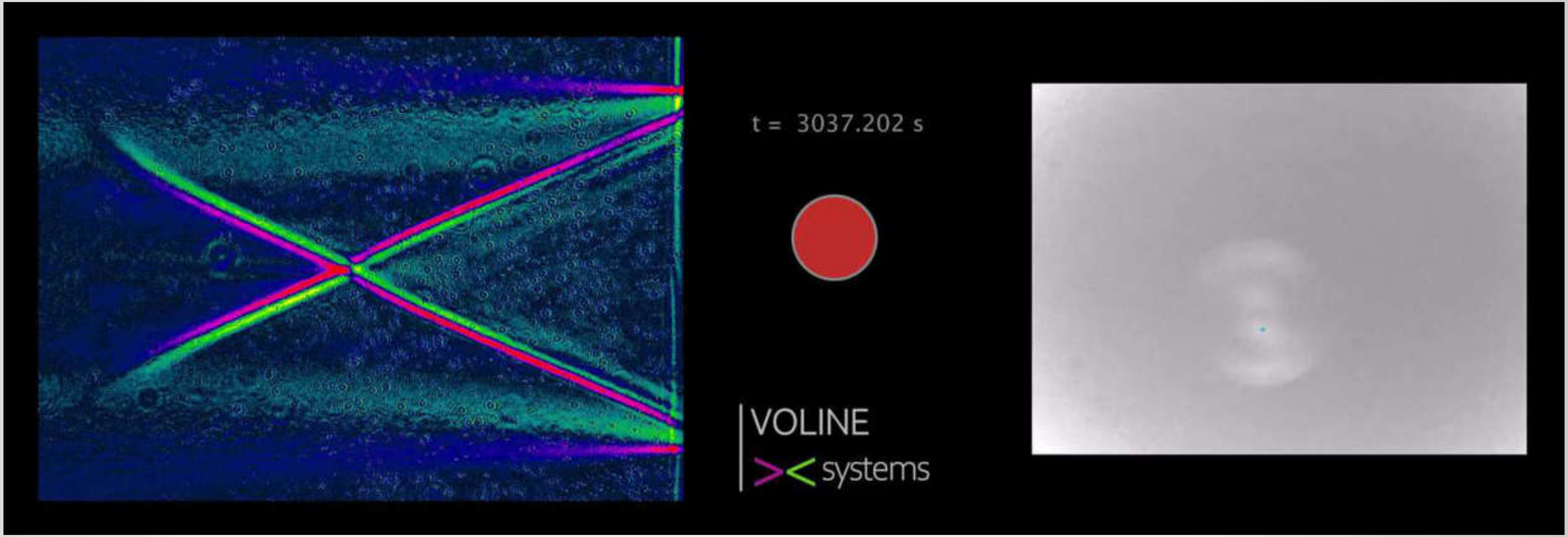
Schlieren monitoring: Clogging prediction

Early warning for impending clogging. Clogged after 40 min



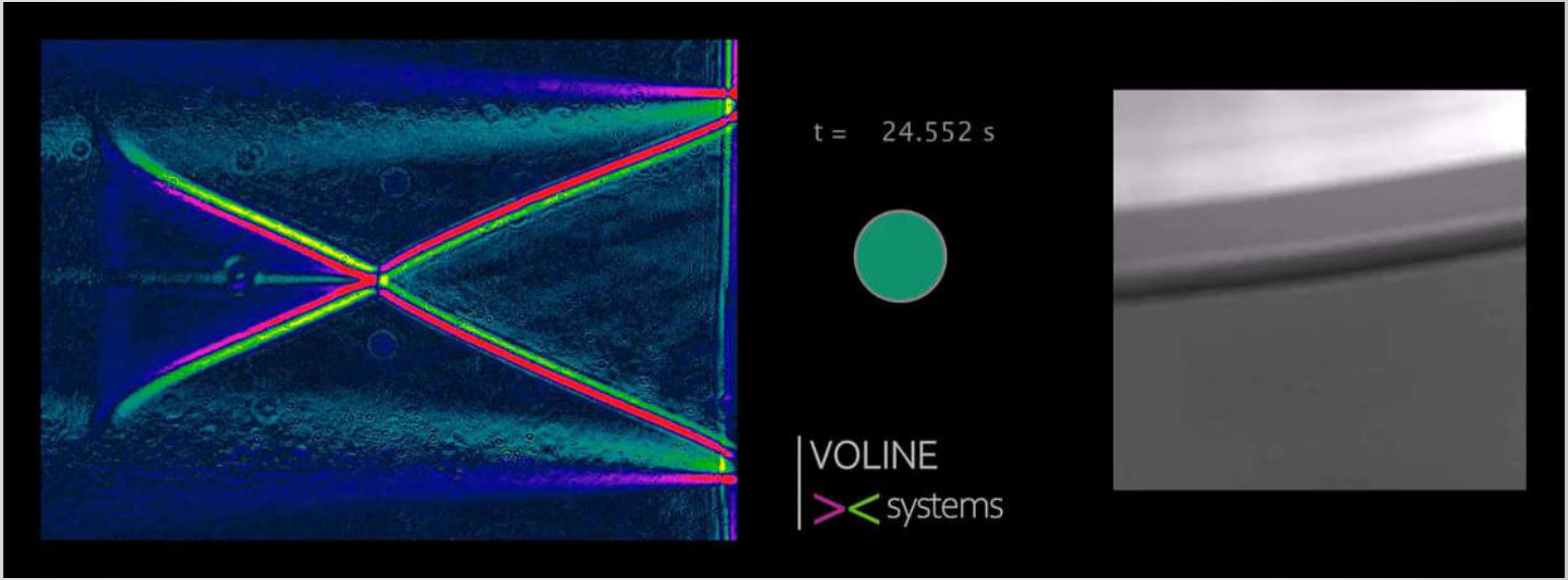
Schlieren monitoring: Clogging prediction

Early warning for impending clogging. Clogged after 40 min



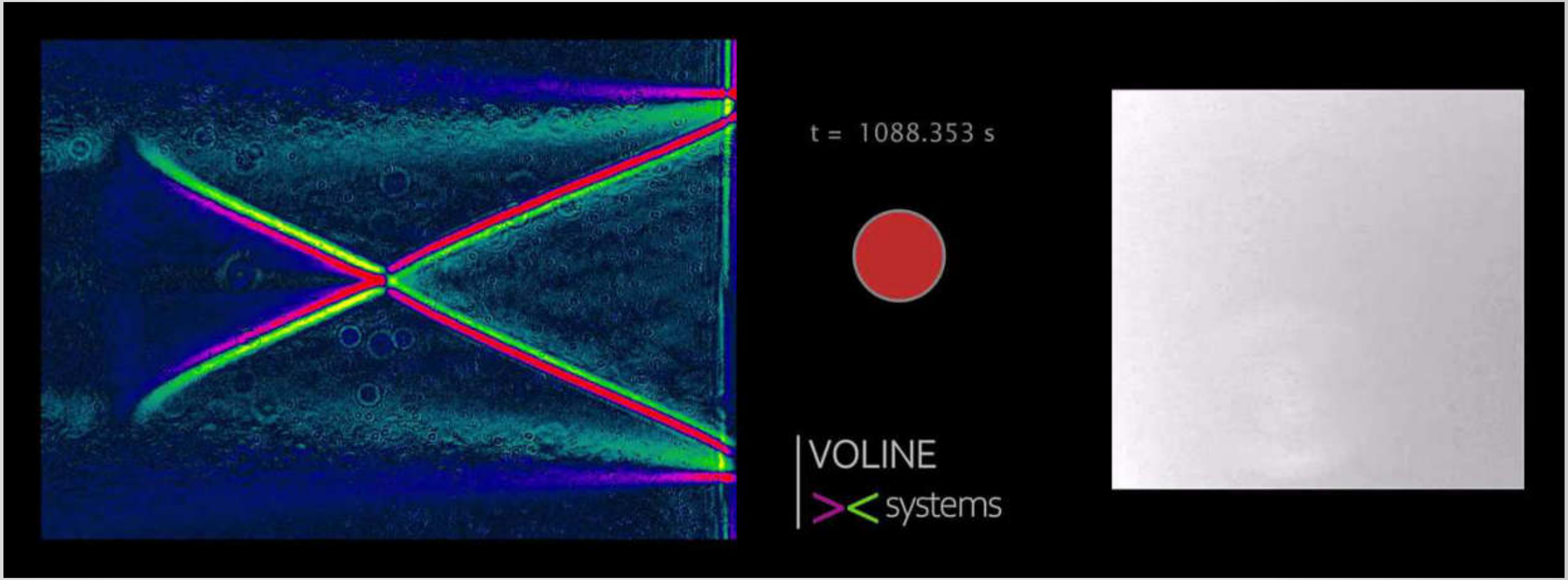
Schlieren monitoring: Clogging prediction

Early warning for impending clogging. Clogged after 15 min

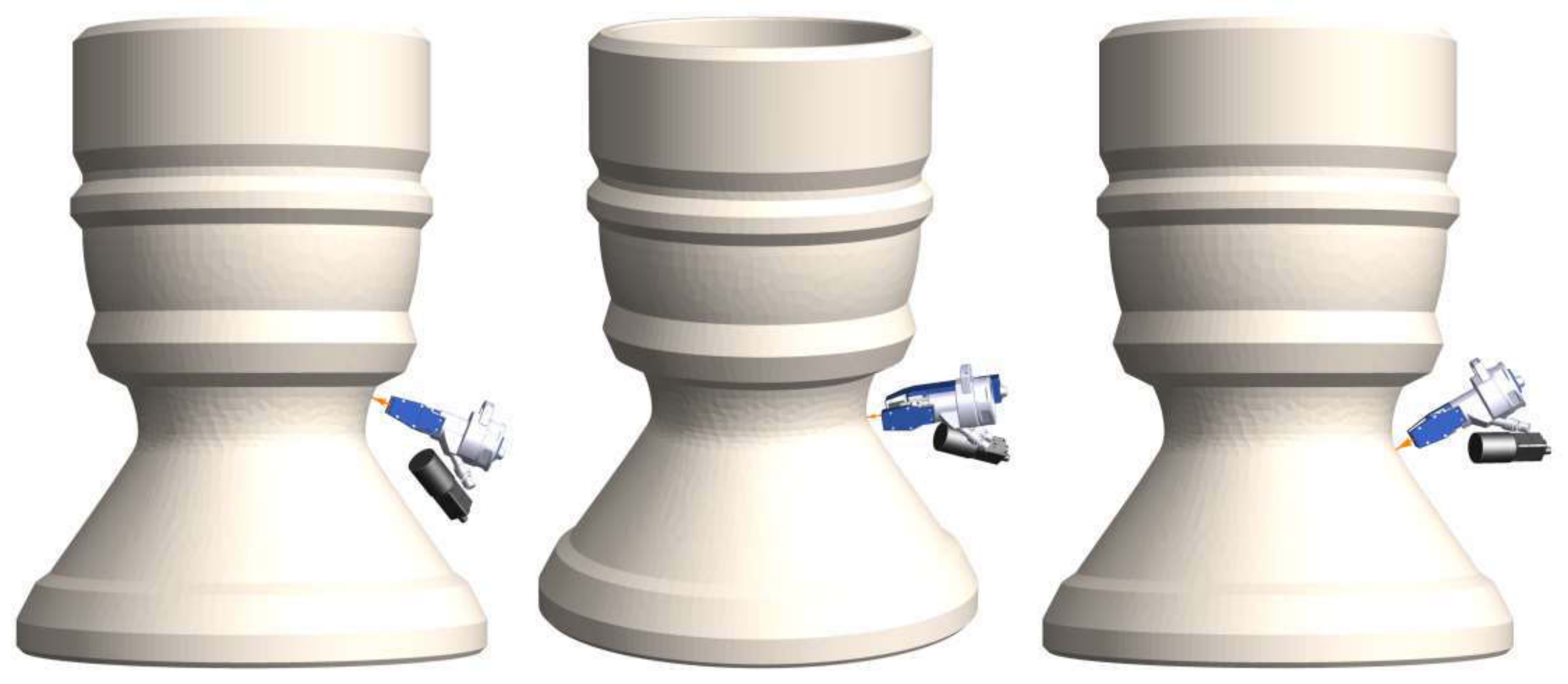


Schlieren monitoring: Clogging prediction

Early warning for impending clogging. Clogged after 15 min



Gun-mounted Schlieren system + spot cam

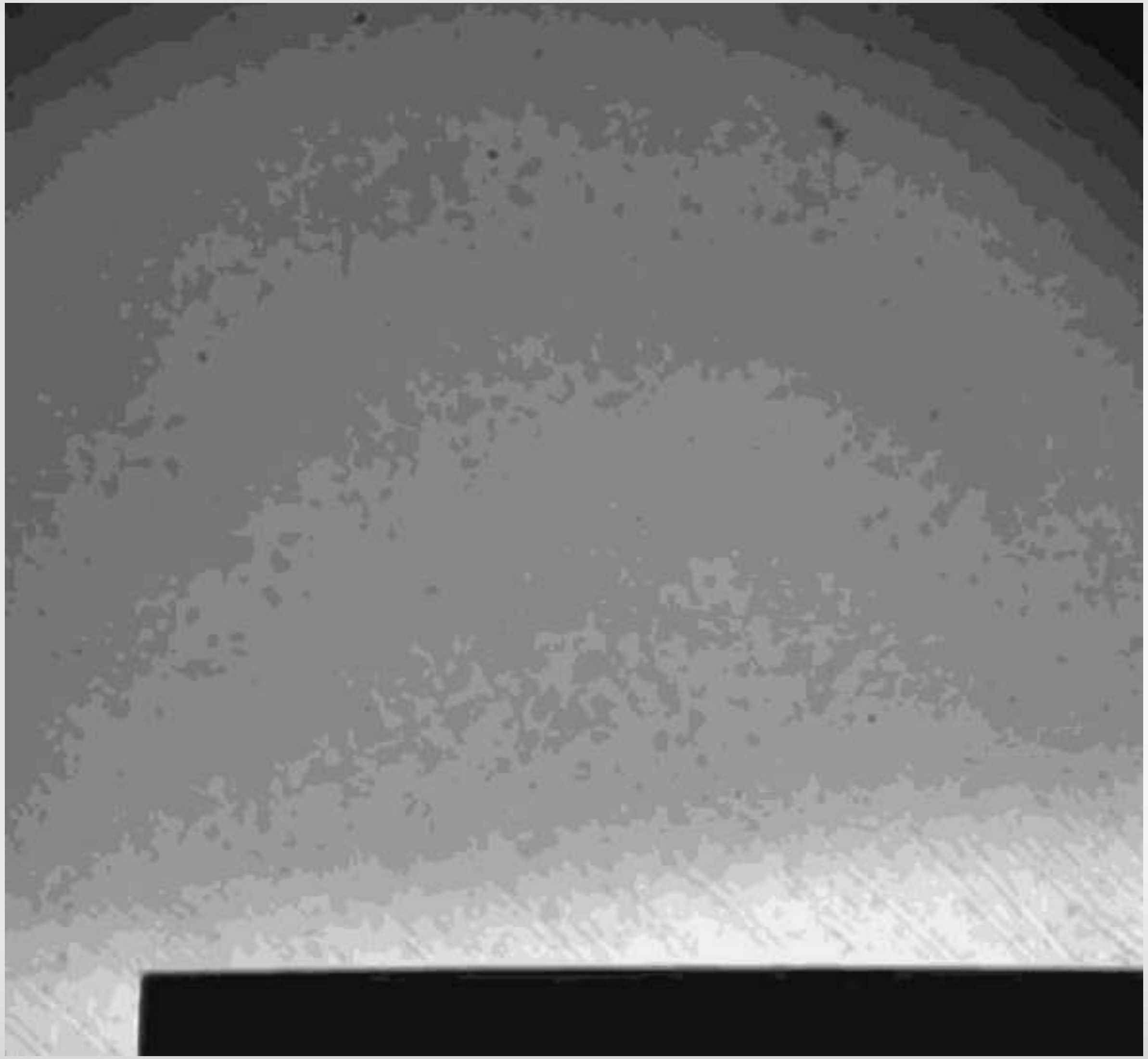


Gun-mounted Schlieren system + spot cam

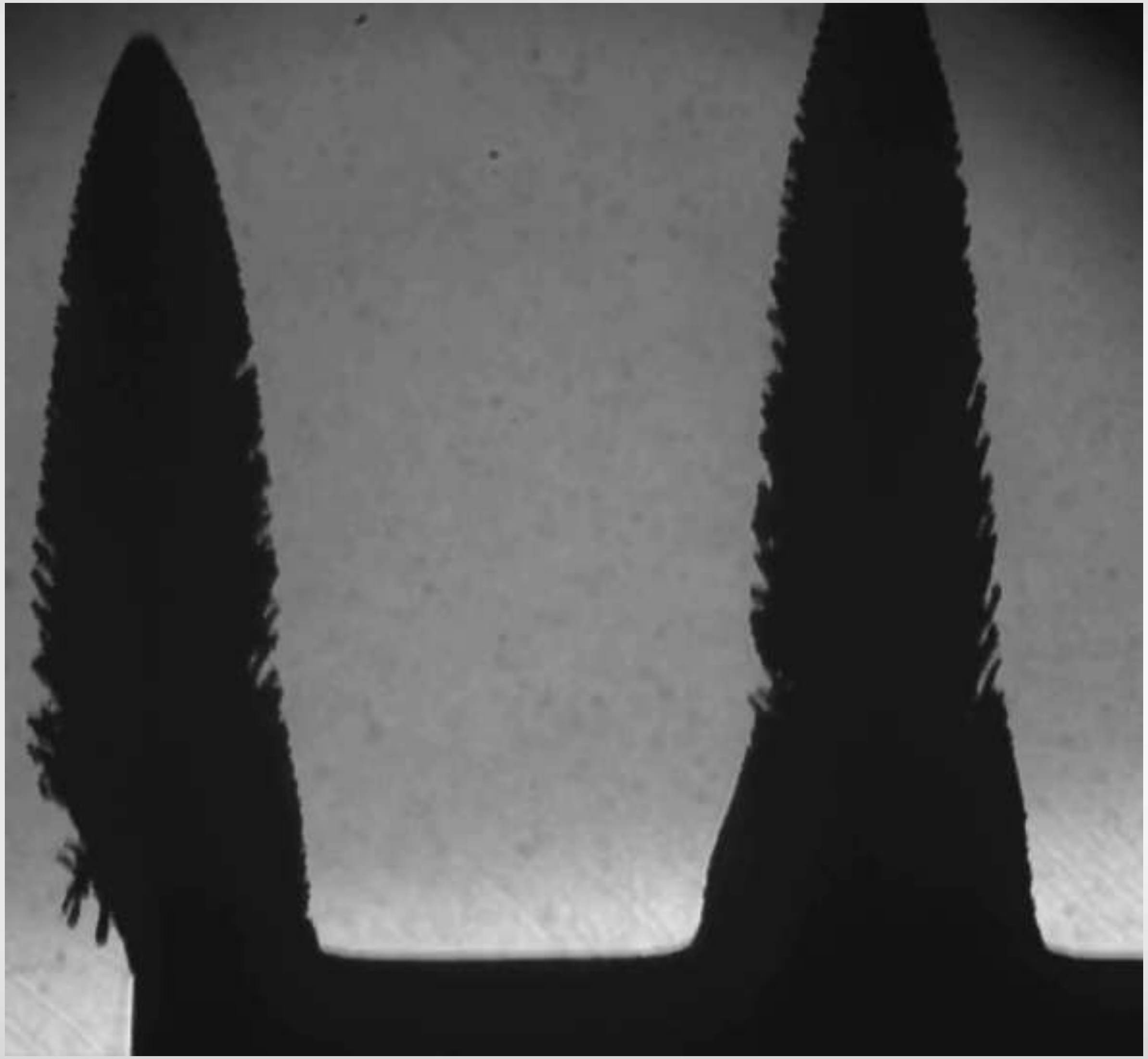
Vision CR

Shadowgraph: Vision CR

Particle impact

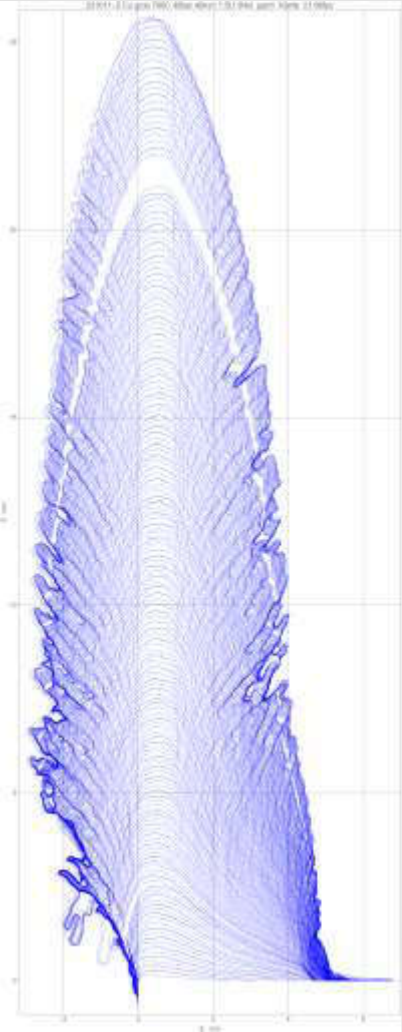


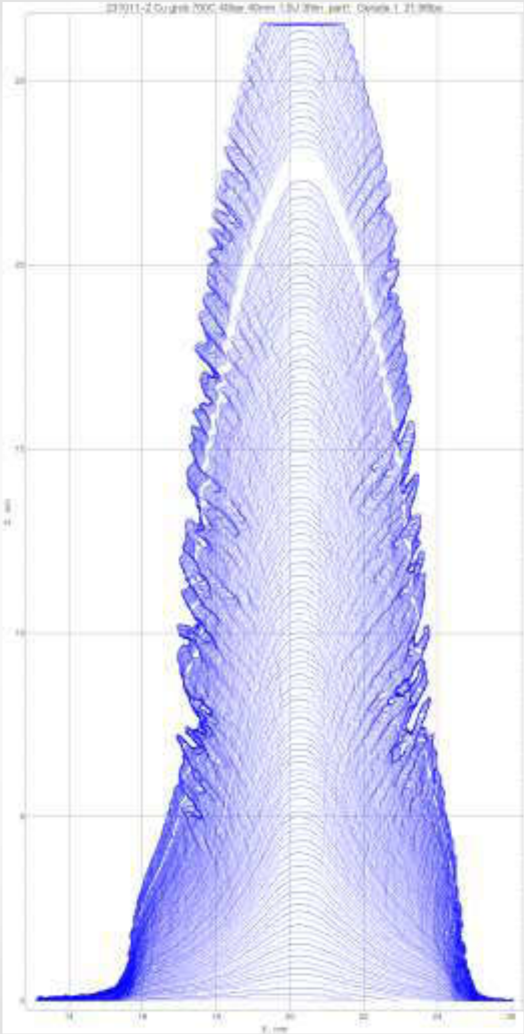
Shadowgraph: Vision CR



Automatic contour extraction: Vision CR

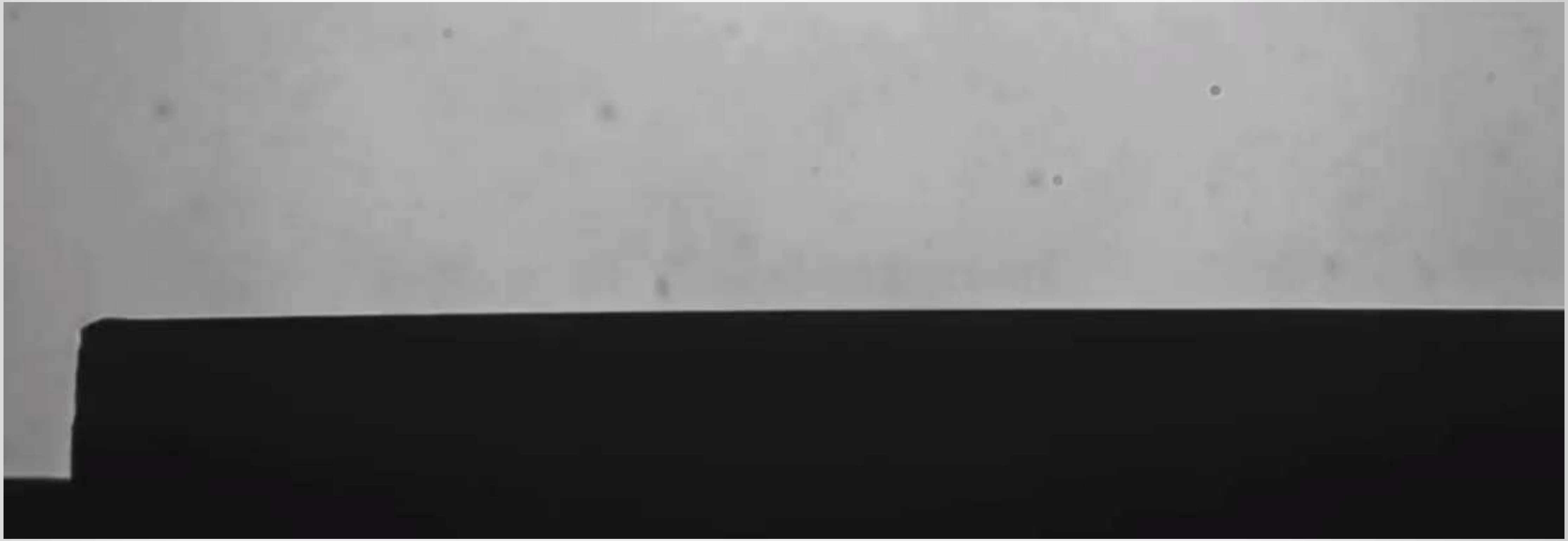
Particle impact



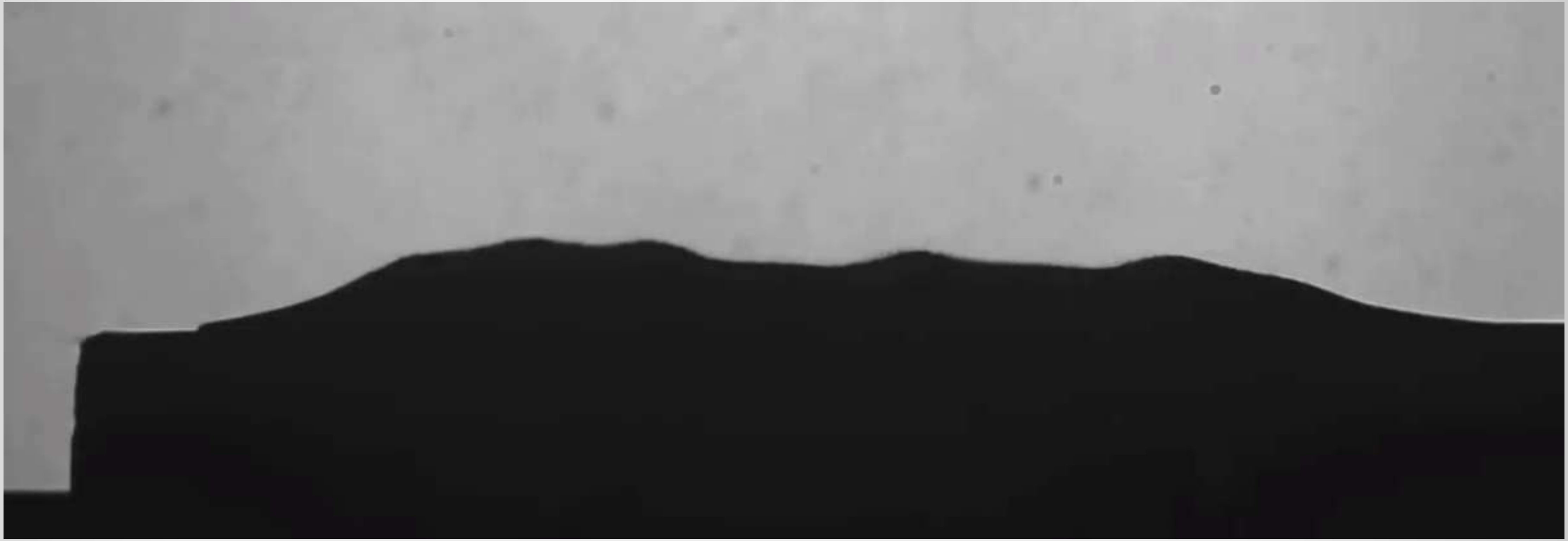


Shadowgraph: Vision CR

Particle impact



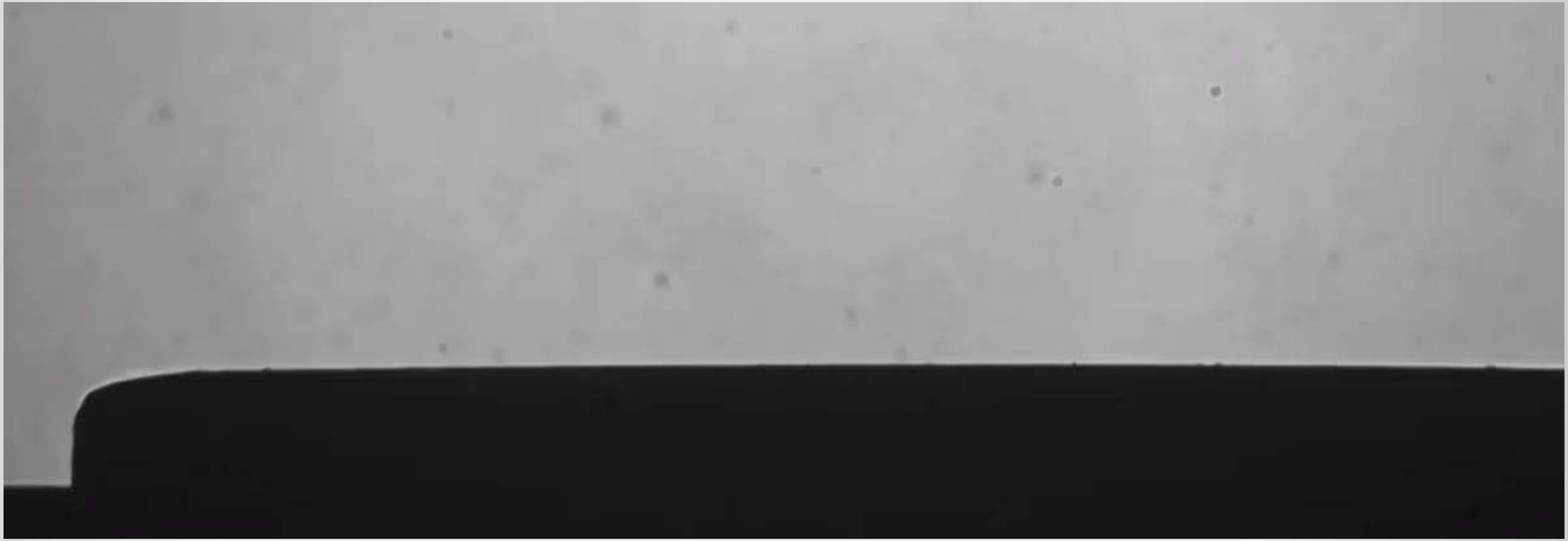
Shadowgraph: Vision CR



Particle impact

Shadowgraph: Vision CR

Particle impact

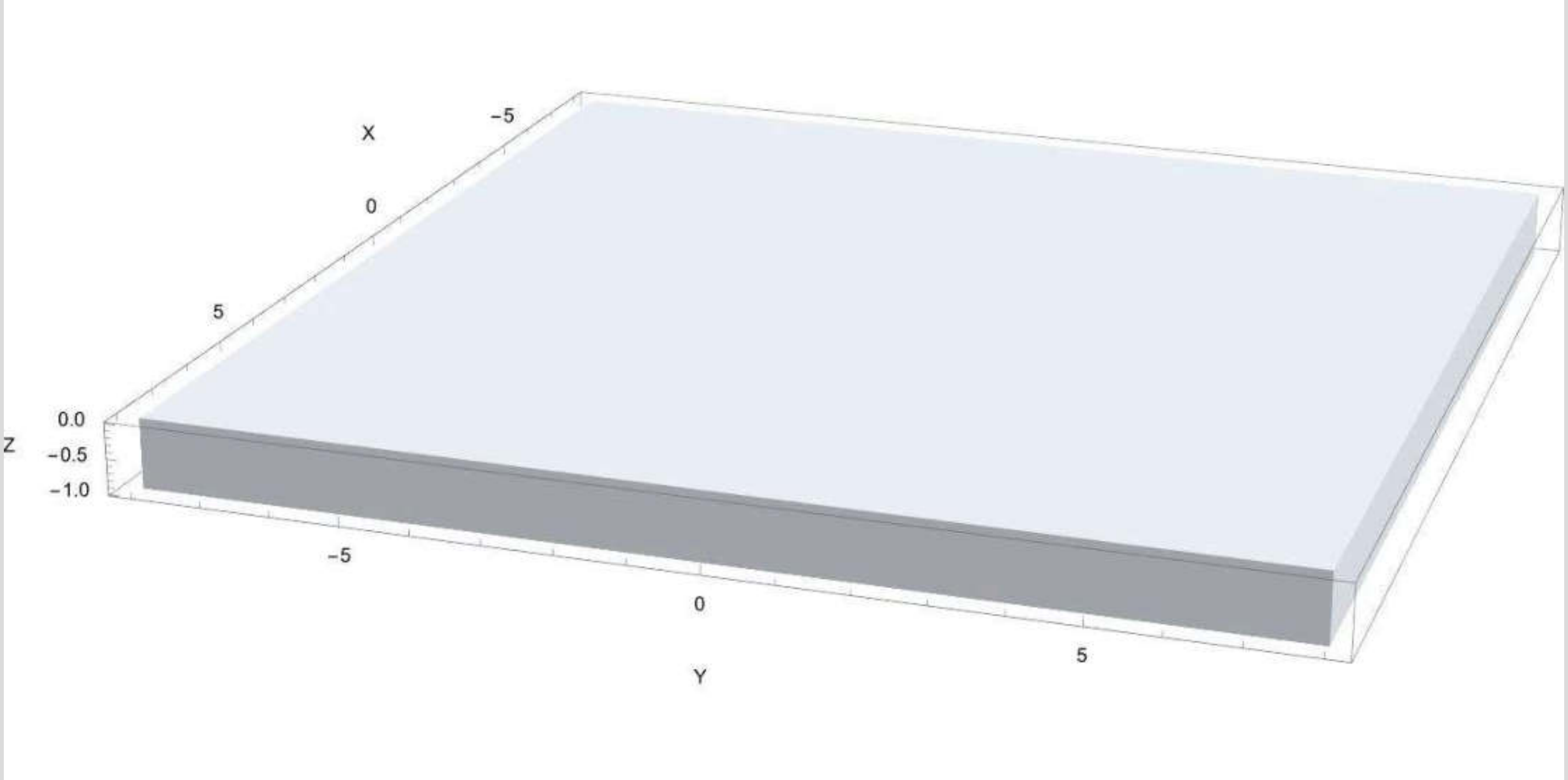


Shadowgraph: Vision CR

Particle impact

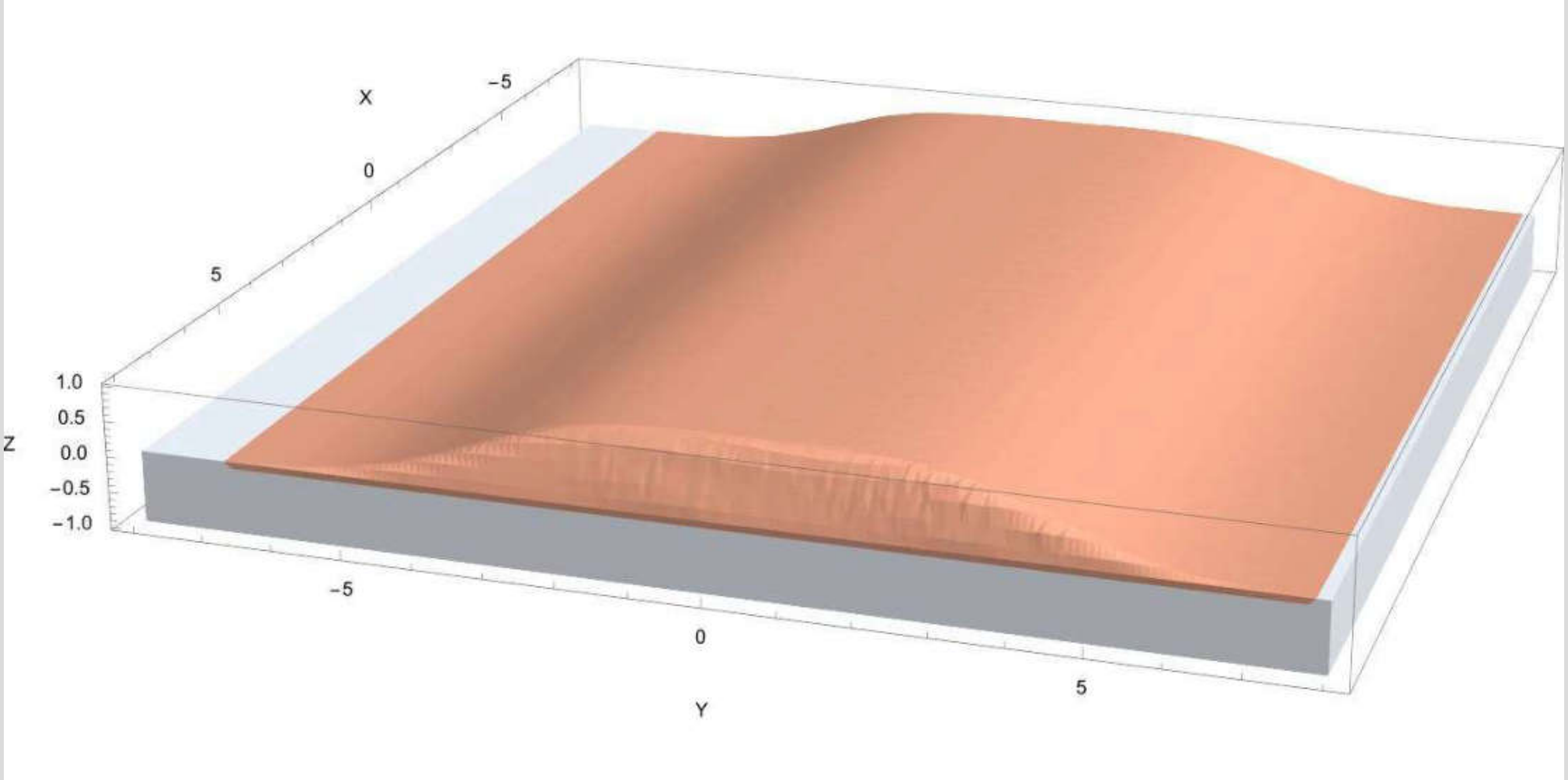
Shadowgraph data parametrized simulation

Particle impact



Shadowgraph data parametrized simulation

Particle impact



Spray condition monitoring solution

VOLINE >< systems

To watch the videos originally shown in this presentation please visit www.volinesystems.com

Vision GM	Gun-mounted schlieren monitor
Vision SH/SL	Spot cams
Vision CR	Classical rugged schlieren monitor

VolineSystems.com

Made in Berlin.