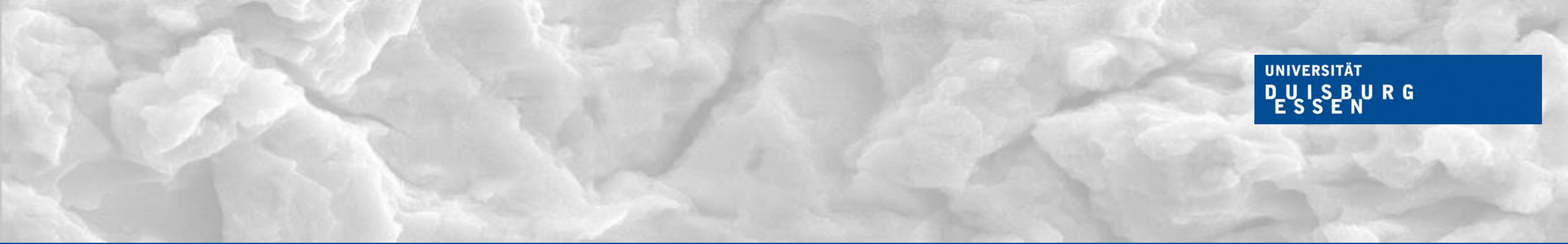

Investigation of surface damage caused by multiple laser-induced single bubble cavitation

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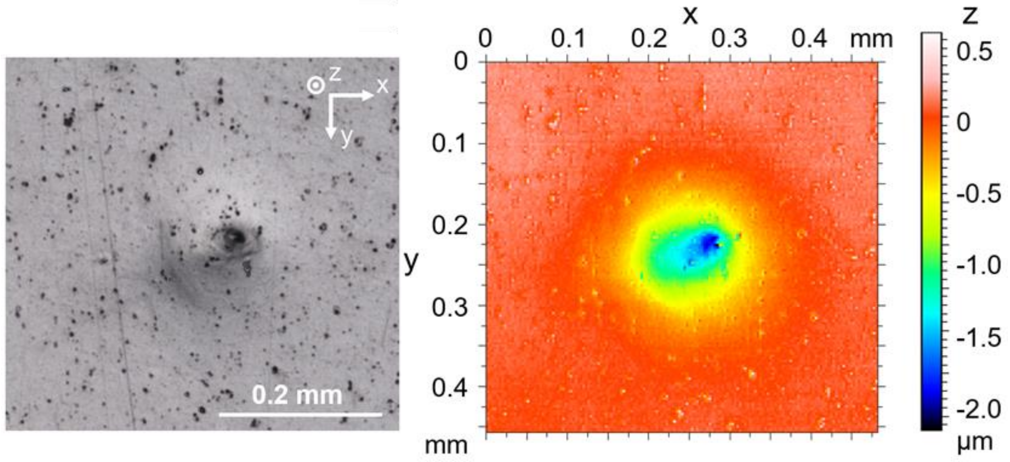
Motivation

- Most fundamental studies of cavitation damage formation are carried out on *soft materials* such as aluminum
- Cavitation erosion on *technical alloys* is typically investigated with acoustic cavitation
- Almost no work with single bubbles on technical alloys
- It is not clear whether the same damage mechanisms apply to technical as to softer materials



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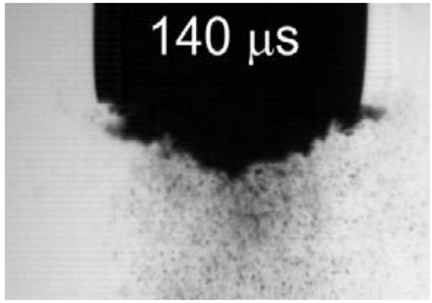

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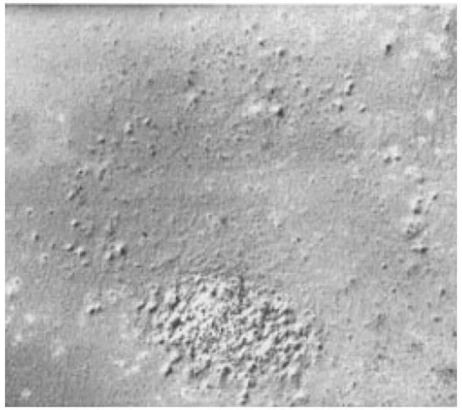

[3]

[1] Sagar et al., Materials Performance and Characterization 7/5 (2018)
[2] Znidarcic et al., Ultrasonics Sonochemistry 22 (2015) 482–492
[3] Philipp and Lauterborn, J. Fluid Mech. 361 (1998) 75–116

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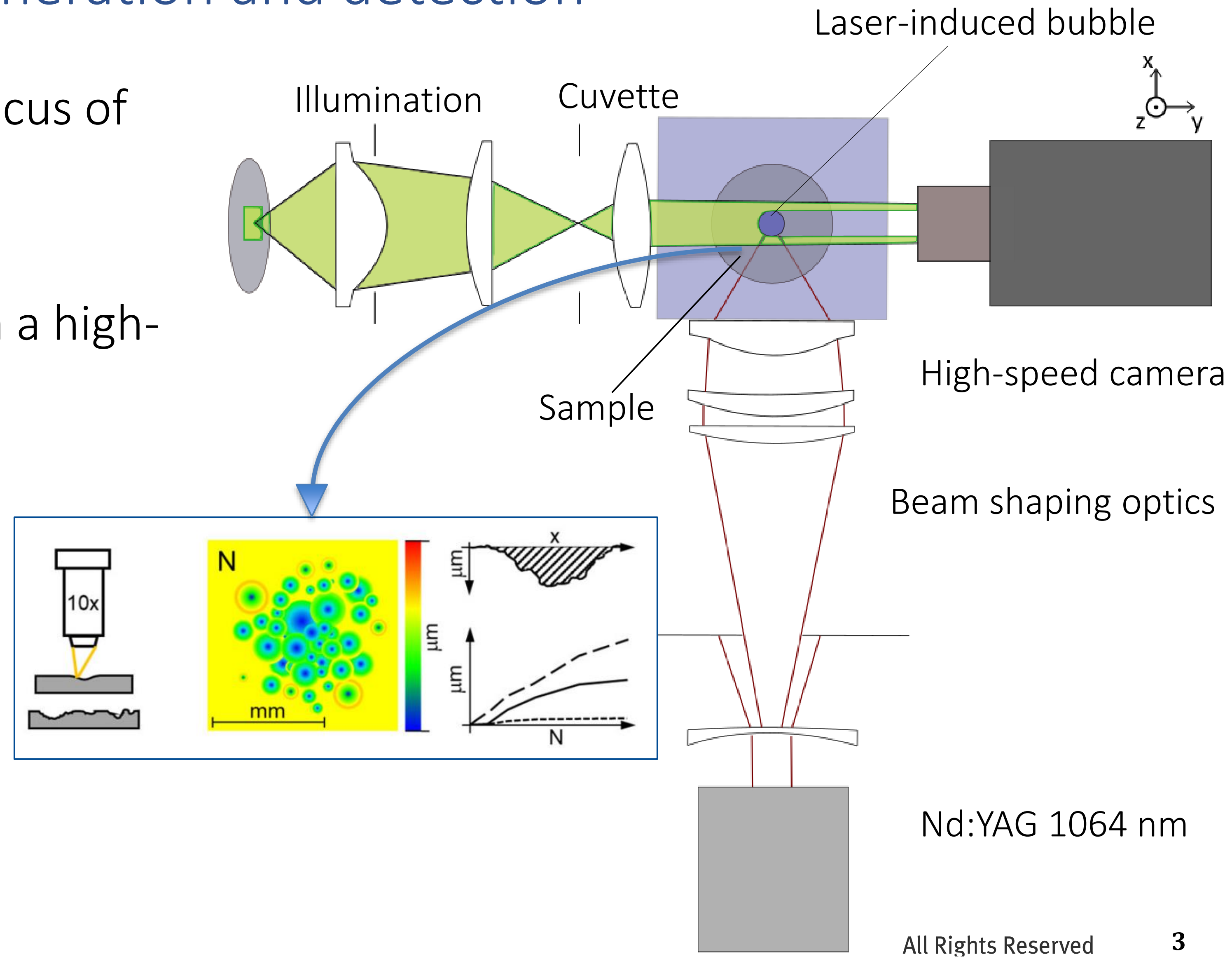
Experimental set-up: Bubble generation and detection

- Generation of bubbles with laser focus of 1064 nm Nd:YAG Laser
- Bubble dynamics are captured with a high-speed camera
- Ex-situ confocal and white light microscopy analysis



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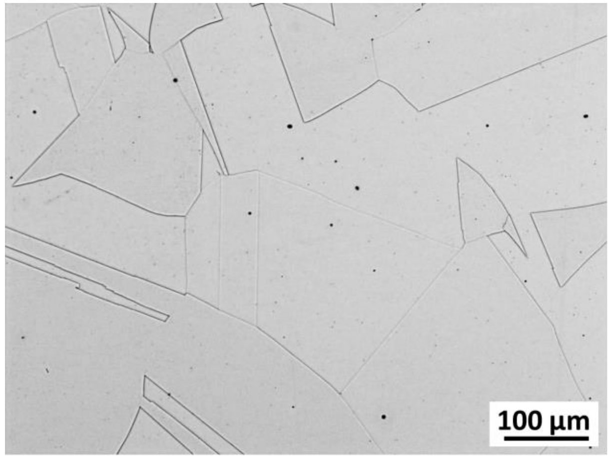
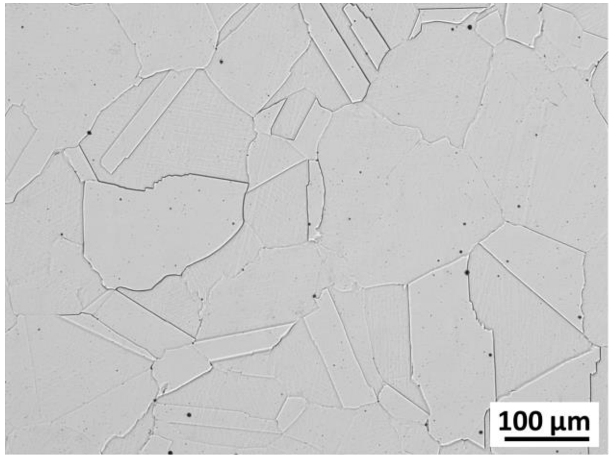
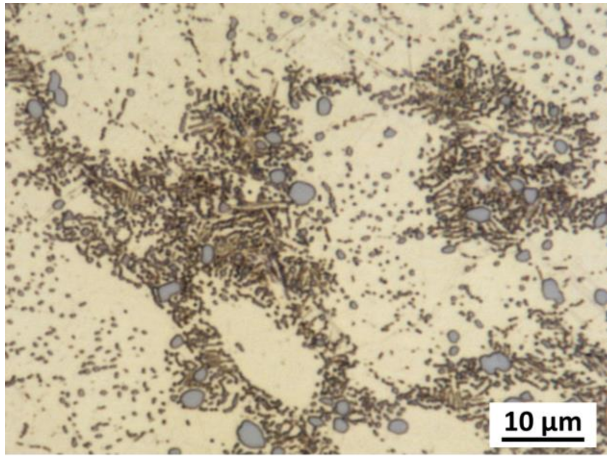
Materials







X2CrNiMo18-15-3 (316L©)

R_{yield} ≥ 190 MPa

$R_{tensile}$ = 490-690 MPa

hardness = 132 ± 4 HV10

X13CrMnMoN18-14-3 (P2000©)

R_{yield} ≥ 600 MPa

$R_{tensile}$ ≥ 900 MPa

hardness = 271 ± 7 HV10

contains ≈ 0.8 wt.% N

CuAl10Ni5Fe5 ("NAB")

R_{yield} ≥ 280 MPa

$R_{tensile}$ ≥ 650 MPa

hardness = 275 ± 11 HV10

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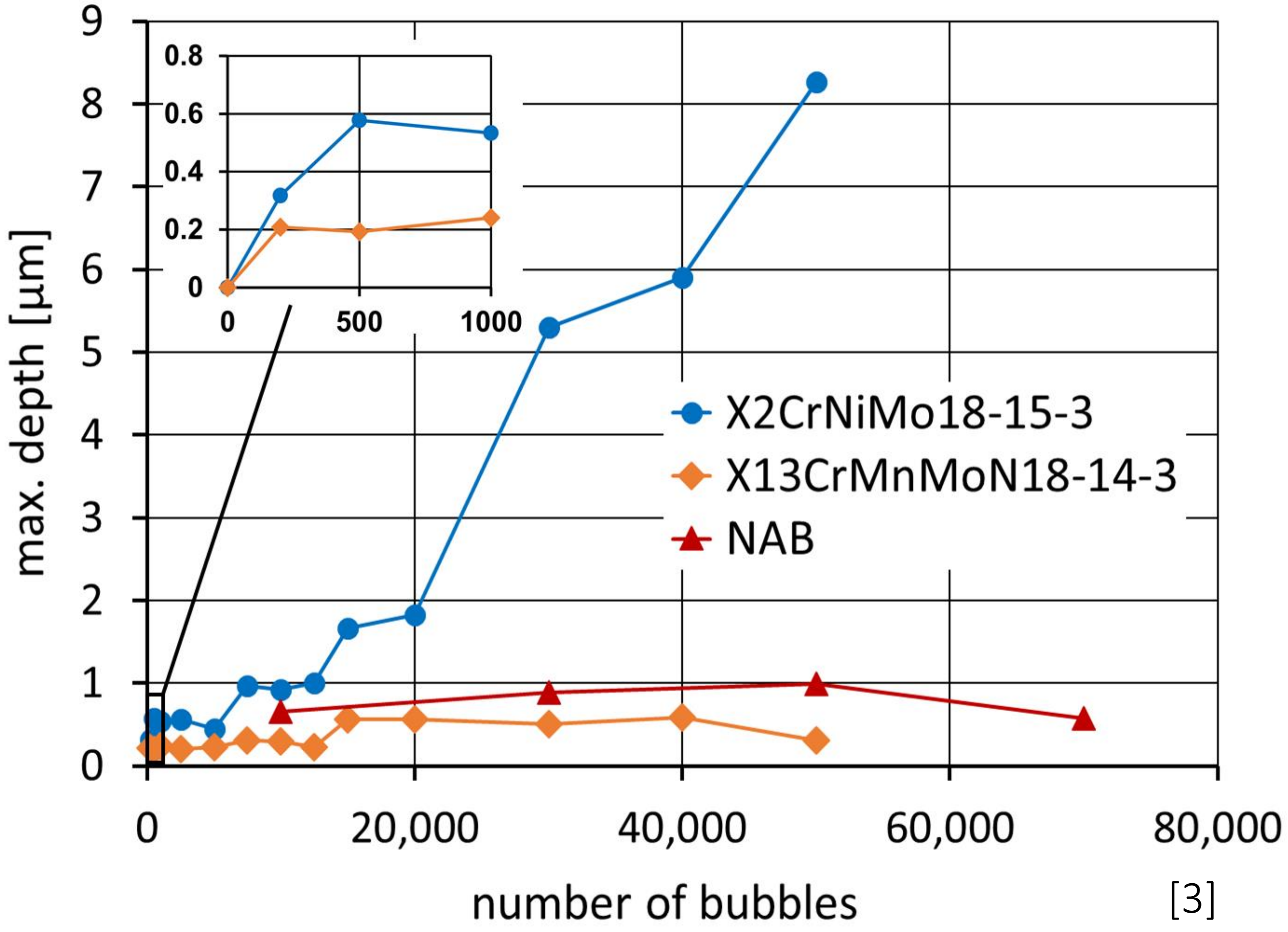
Ex-situ analysis of multi-bubble damage

- Maximum depth of the damage region is measured

- Ex-situ damage analysis
  → new sample for each data point

- Fluctuations are not physical

→ in-situ operando imaging of damage evolution



[3] S. Hanke and S. A. Kaiser, Wear 476 (2021)

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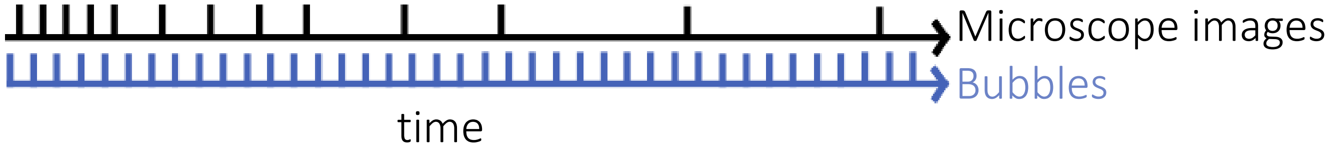
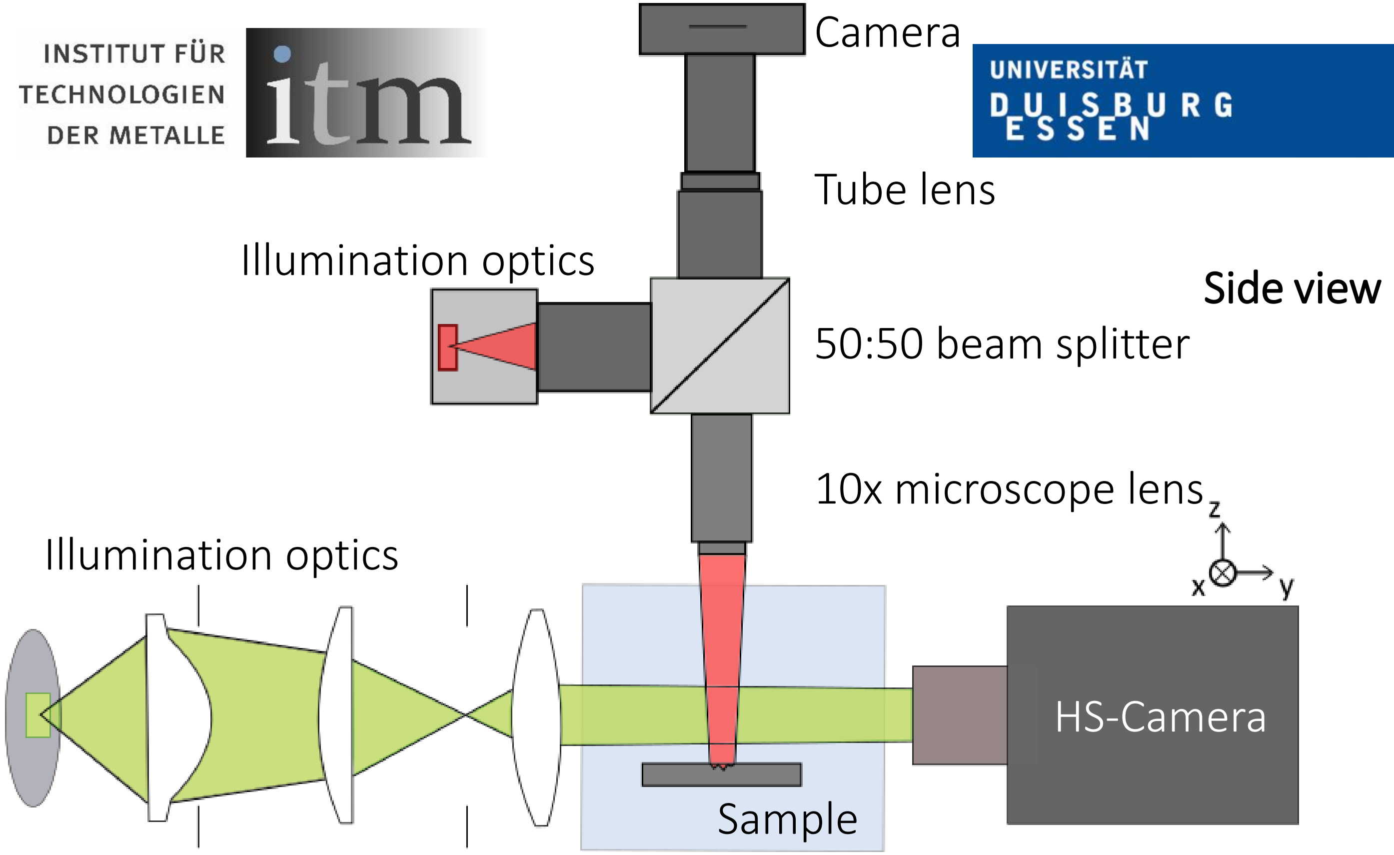
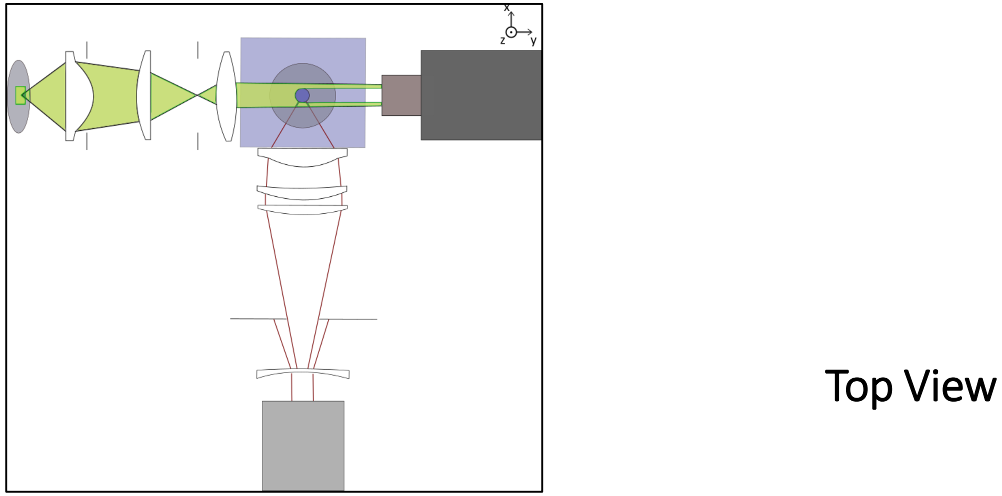
In-situ experiments

- Incident-light microscope to investigate surface damage in situ
- Entire damage process can be observed in one single sample
- Increasing intervals between successive microscope images







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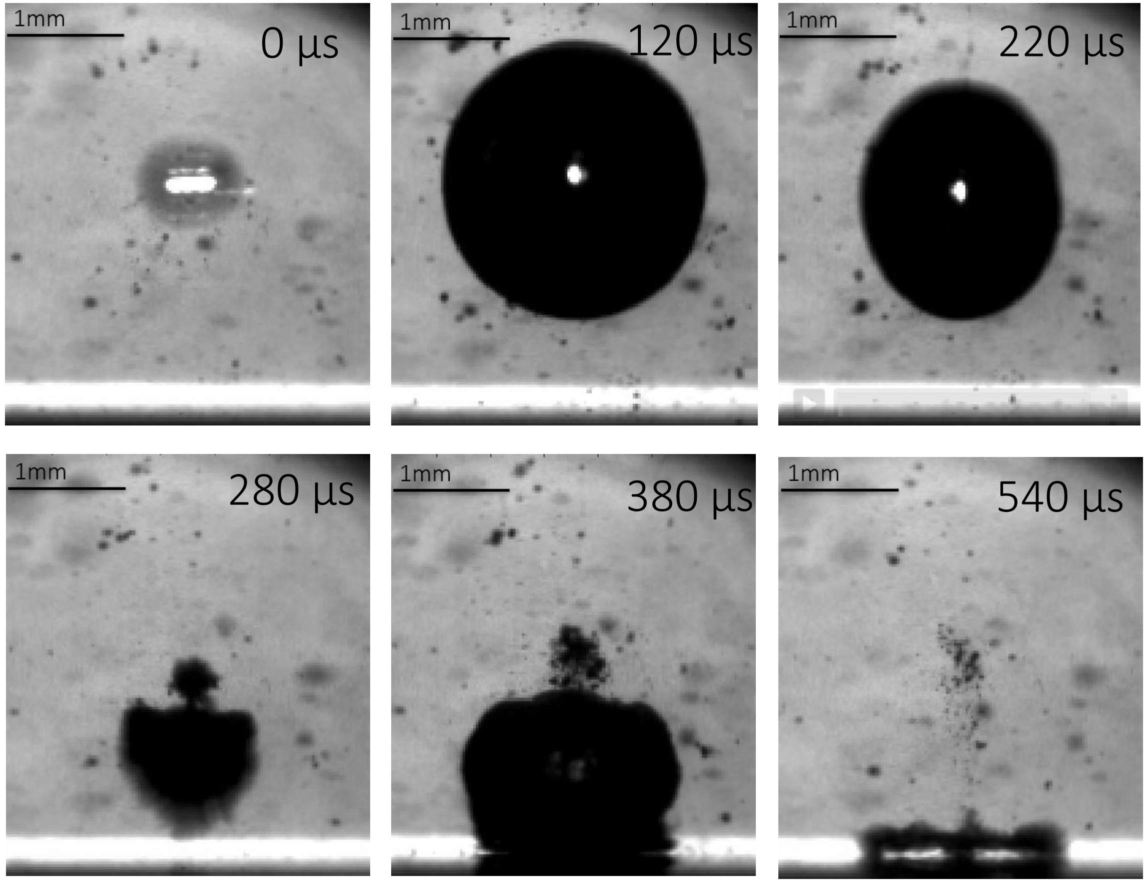
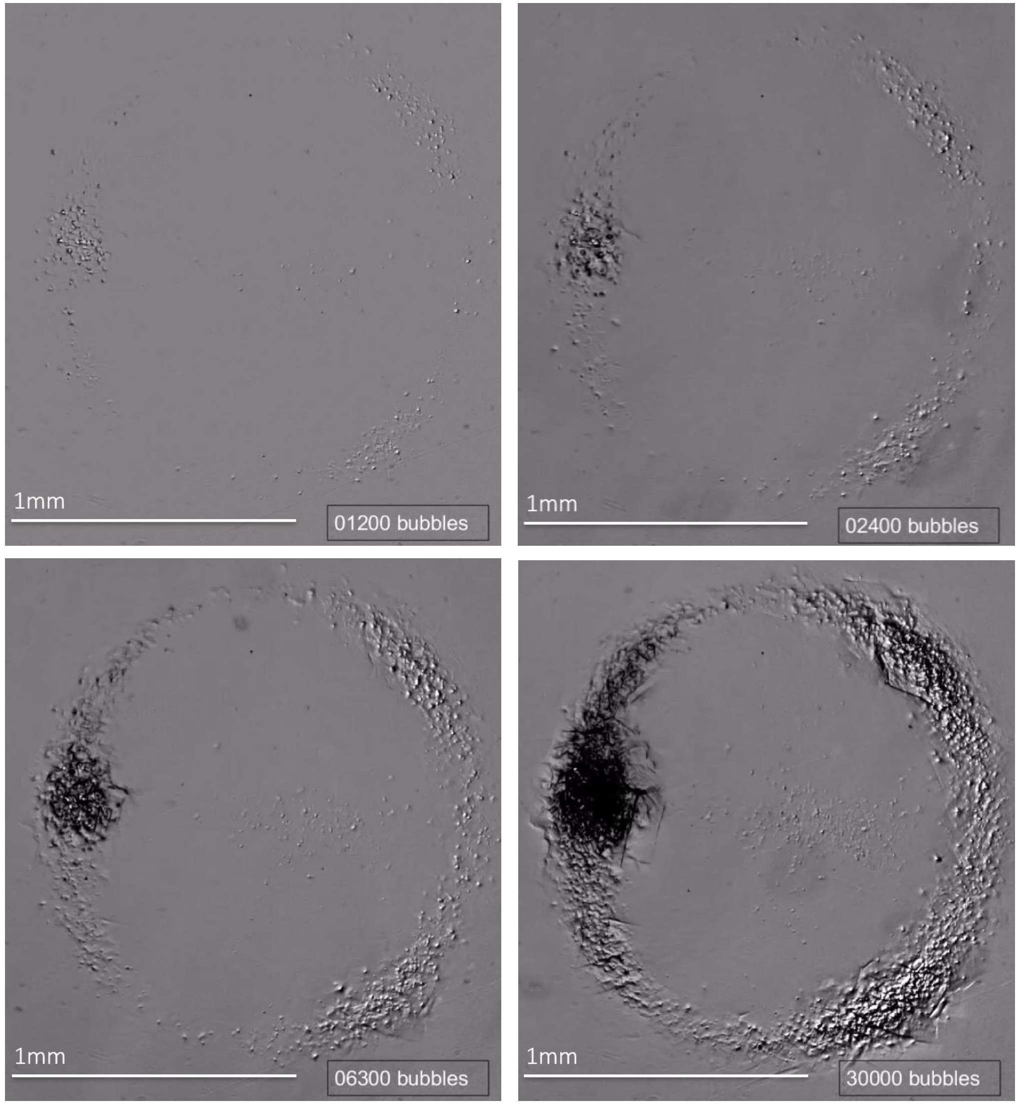
L316 Steel – γ = 1.4 r = 1.3 mm



beam direction



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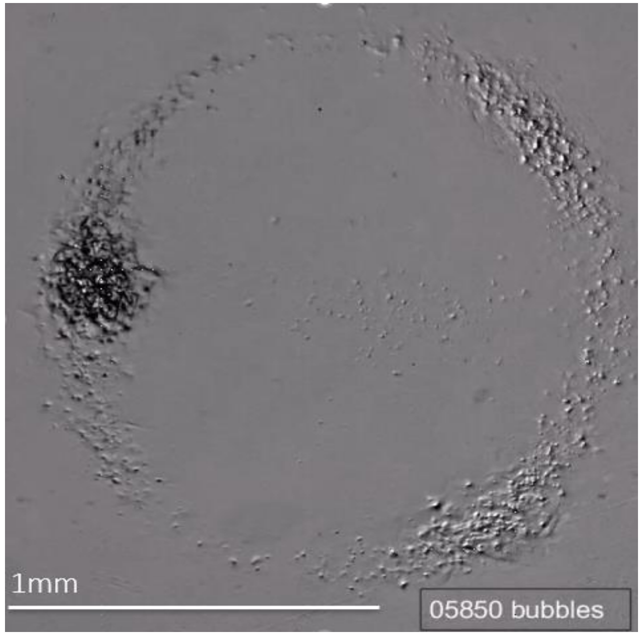
Side view

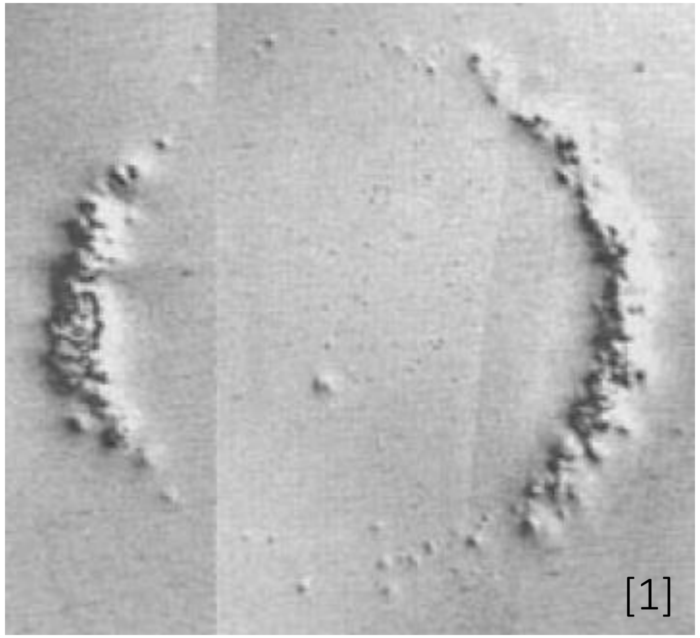
Top View

Damage formation at $\gamma = 1.4$

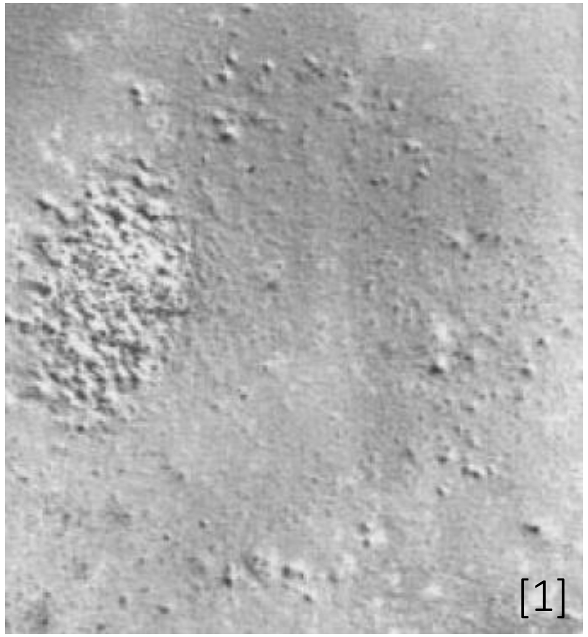
Steel – 5850 bubbles



Aluminum – 100 bubbles



Steel – 5000 bubbles



[1] Philipp and Lauterborn, J. Fluid Mech. 361 (1998) 75–116

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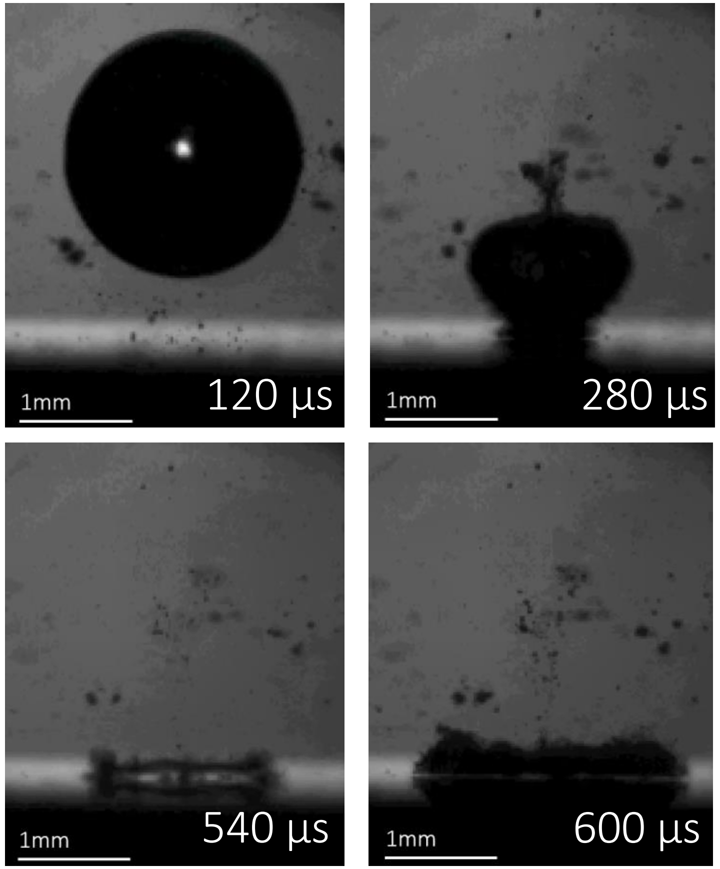
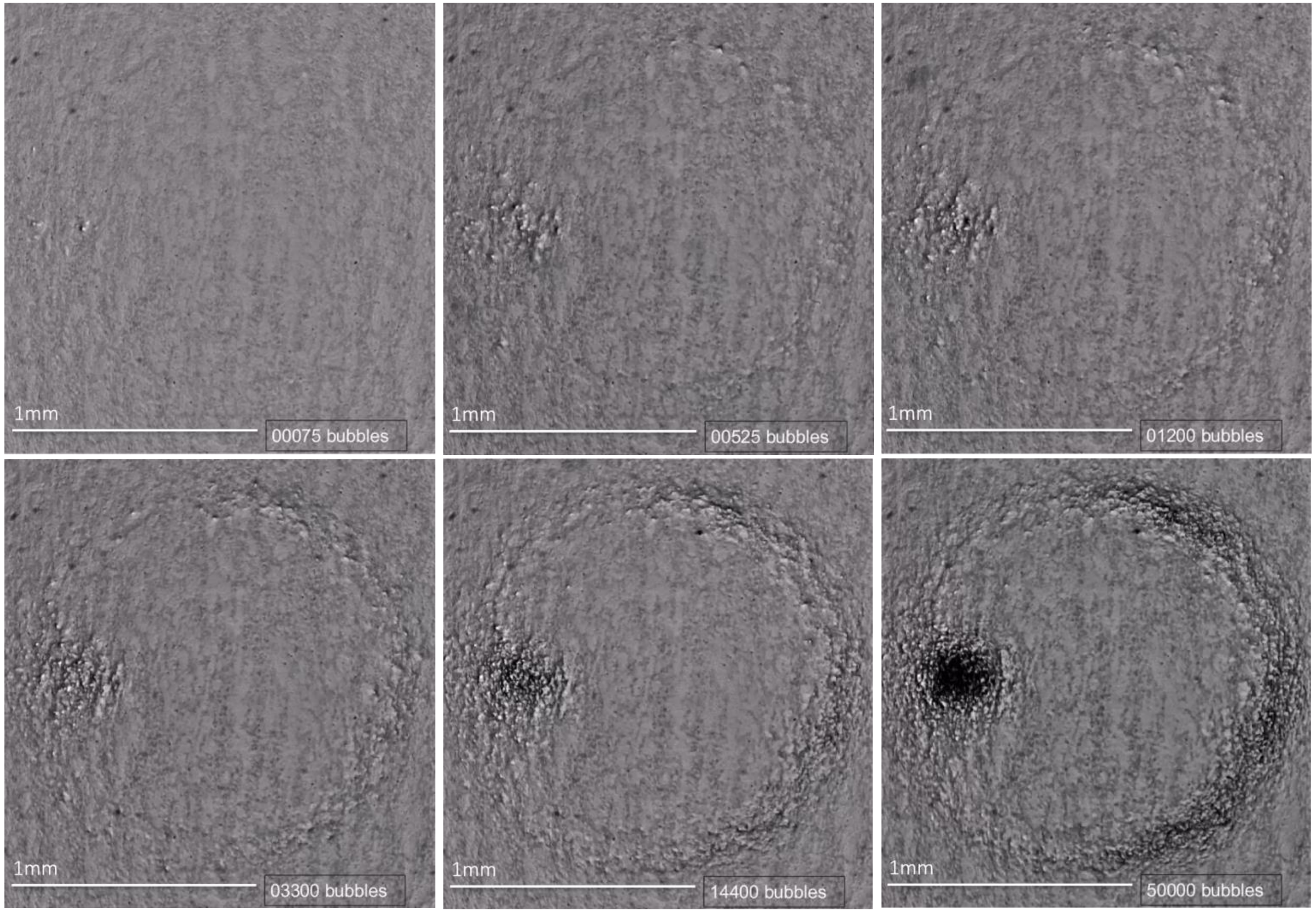
NiAl-Bronze - $\gamma=1.36$ $r=1.25$ mm





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Side view

beam direction

Top View

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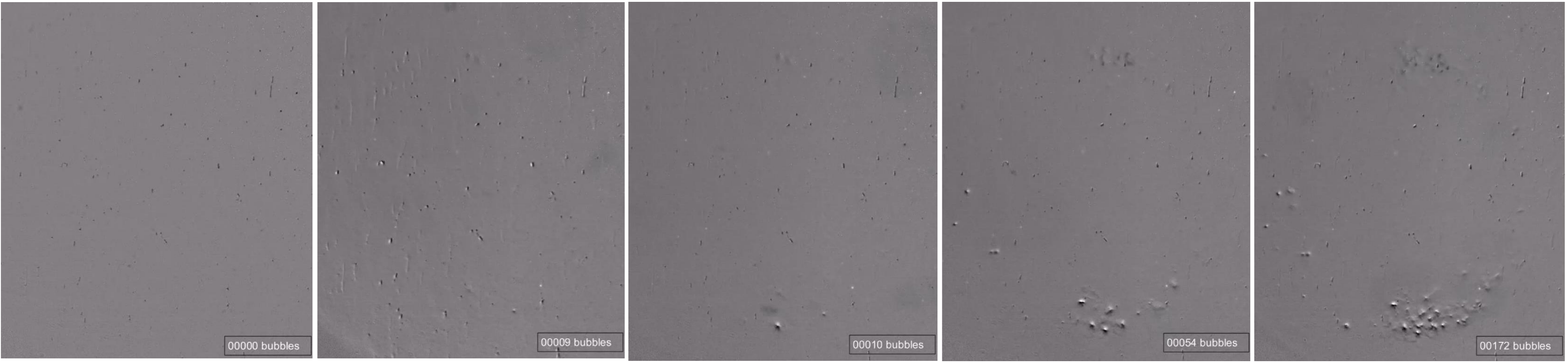
L316 Steel $\gamma = 1.3$ $r = 1.25$ mm



beam direction

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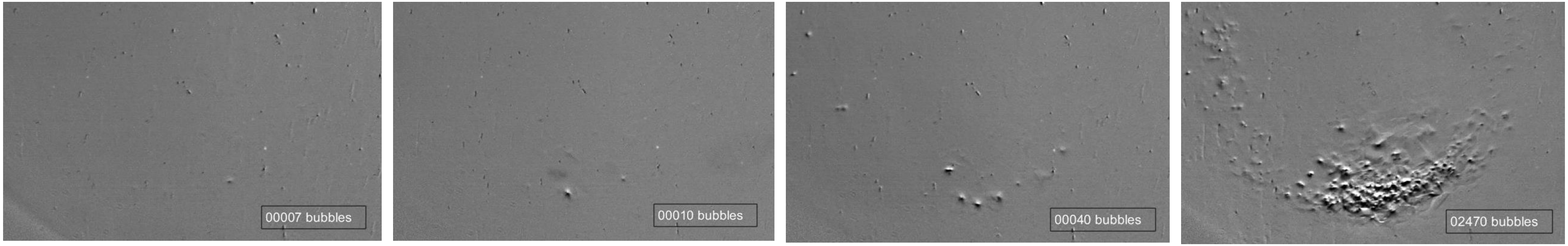
Conclusions

- In-situ microscopy allows following the damage process step by step
- Even technical alloys show first damage after just a few cavitation bubbles
- For gamma γ ≈ 1.3 –1.4 this damage occurs in small individual pits, each in the area of the second collapse



- Next: Correlation with more detailed ex-situ analysis, parameter variations

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