Inline Computational Imaging:
High-magnification Acquisitions with a Modified Microscope Systems

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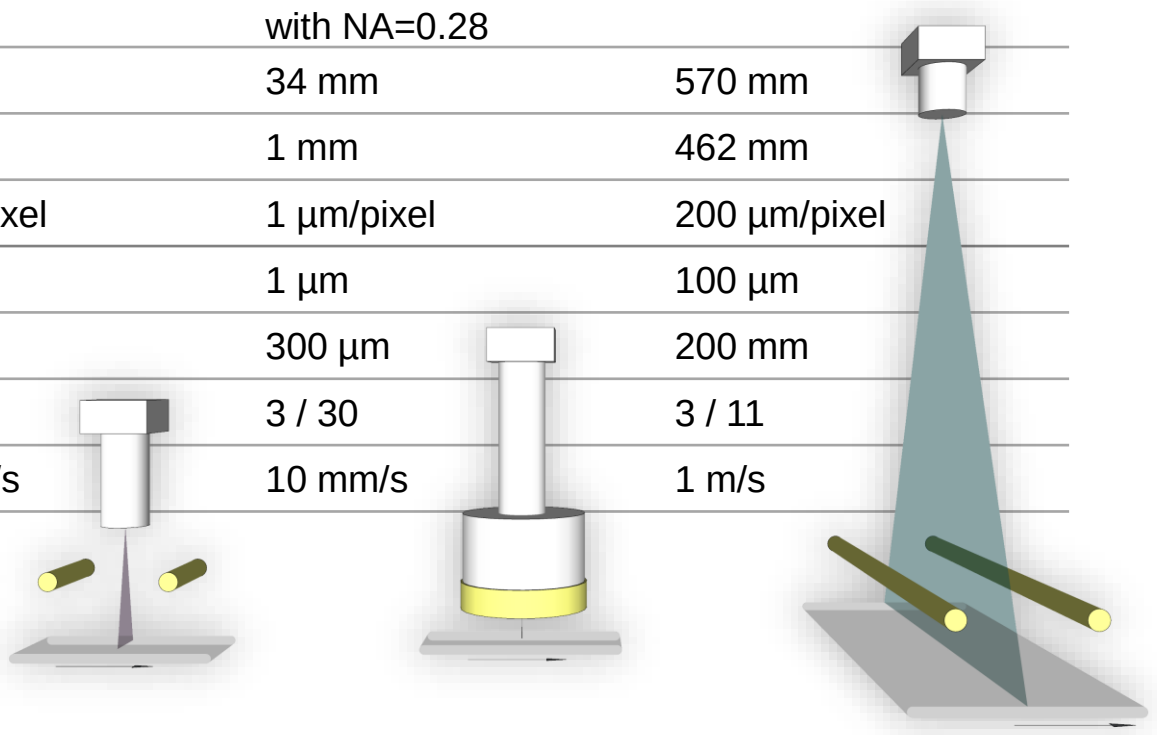
ICI SENSOR SYSTEM:
SCALABLE OPTICAL CONFIGURATIONS

Configuration Examples

	Standard Scale	Micro Scale	Large Scale
Optics	45mm f/4	Modified 10x industrial inspection microscope with NA=0.28	20mm f/2.8
Working distance	128 mm	34 mm	570 mm
Field of view	46 mm	1 mm	462 mm
Lateral resolution	20 µm/pixel	1 µm/pixel	200 µm/pixel
Depth resolution *)	20 µm	1 µm	100 µm
Depth range	10 mm	300 µm	200 mm
Min. / typ. viewing angles	3 / 11	3 / 30	3 / 11
Typical acquisition speed	100 mm/s	10 mm/s	1 m/s

*) using Light Field and Photometric Stereo



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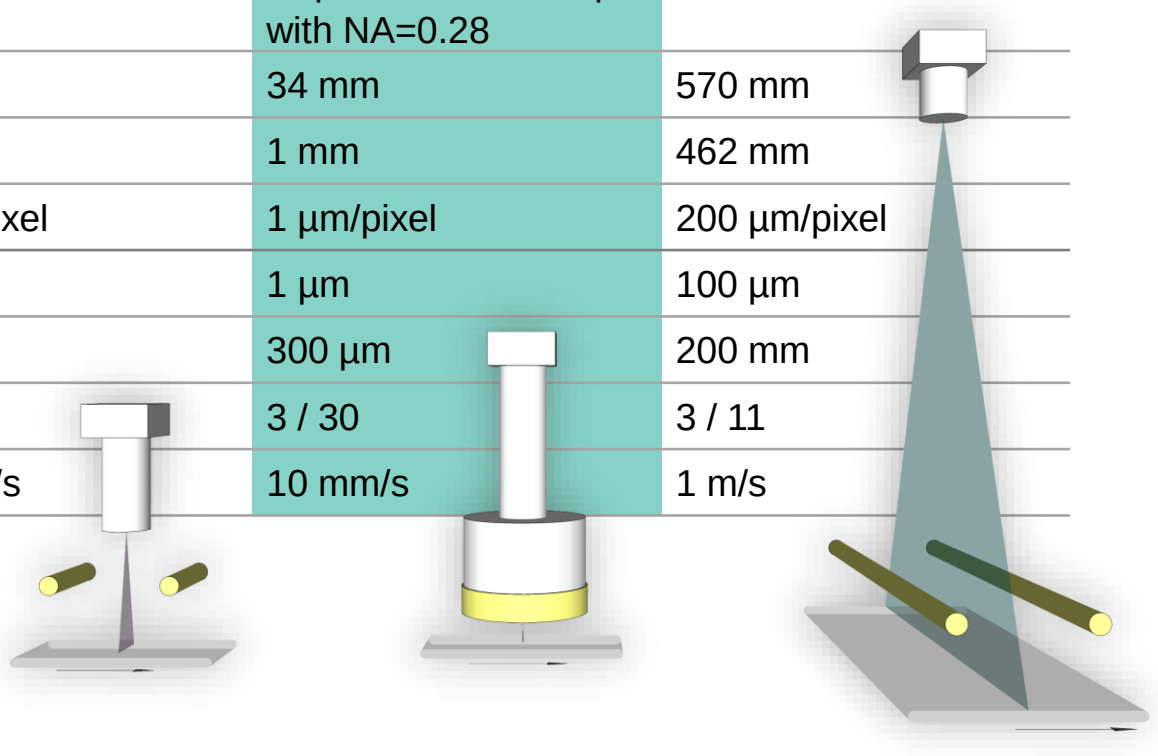
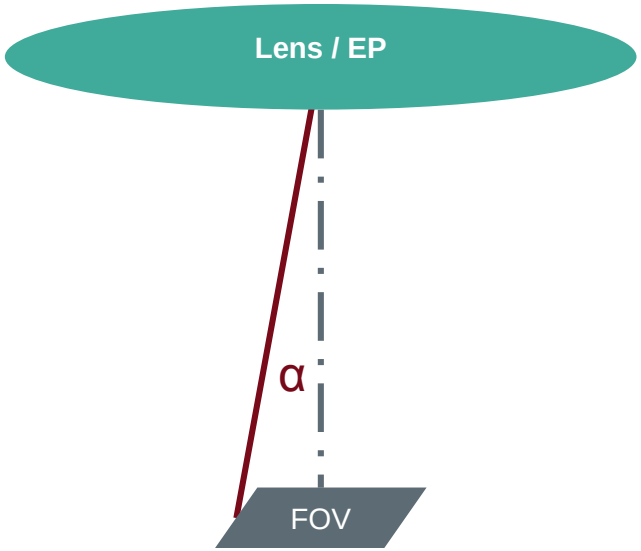


PROBLEMS IN MICROSCOPIC 3D IMAGING

- **Conventional microscopic 3D acquisition techniques require different kinds of scanning or structured illumination patterns**
  - Depth from Focus ▶ X-transport, focus stack in Z-direction
  - Confocal microscopy ▶ X,Y,Z Scanning
  - Structured light ▶ X transport (stop and go) structured pattern projection
- **Idea: scan large areas in an continuous non-stop motion**
  - Apply structure from motion (SfM) to microscopy
  - 3D information is retained from perspective changes due to a moving object during a **non-stop motion**
  - Conventional microscopes: hypercentric projection → no change in perspective

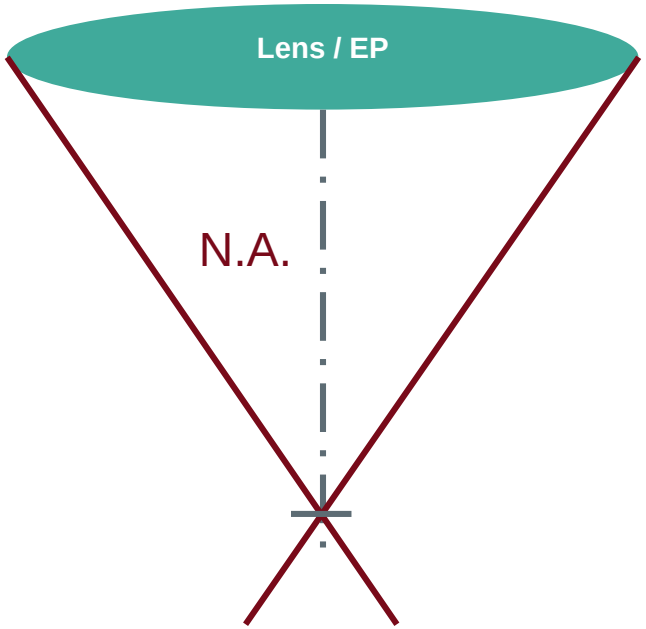
MAIN PROBLEMS IN HIGH MAGNIFICATION

Entocentric Projection



FOV << EP → small α

DOF

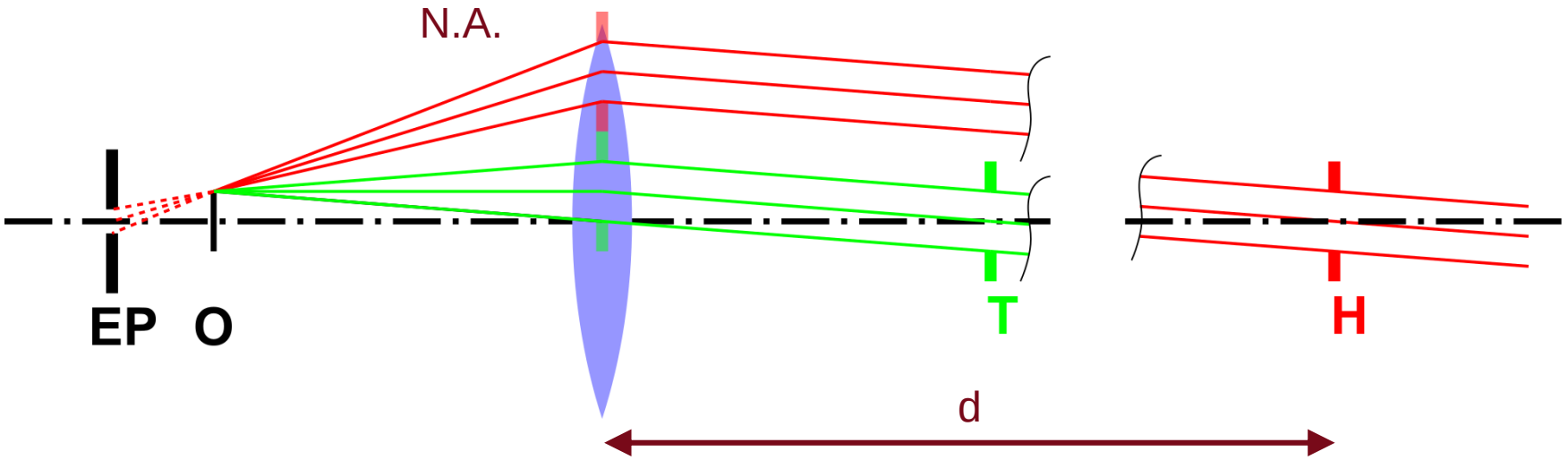


High N.A. → small DOF

Typical values (10x Magnification): α < 1.5°
N.A. = 0,28 → DOF 3.4 µm

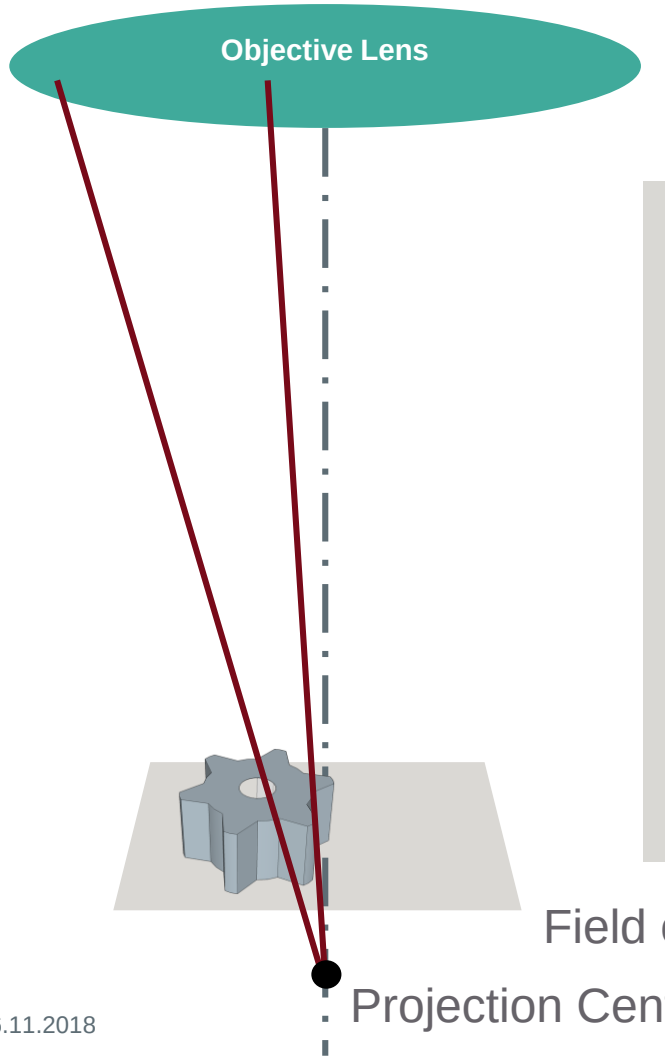
SOLUTION: ADDITIONAL APERTURE

- Include an additional aperture for increased DOF
- Aperture location defines the Perspective → hyprecentric projection is adventurous



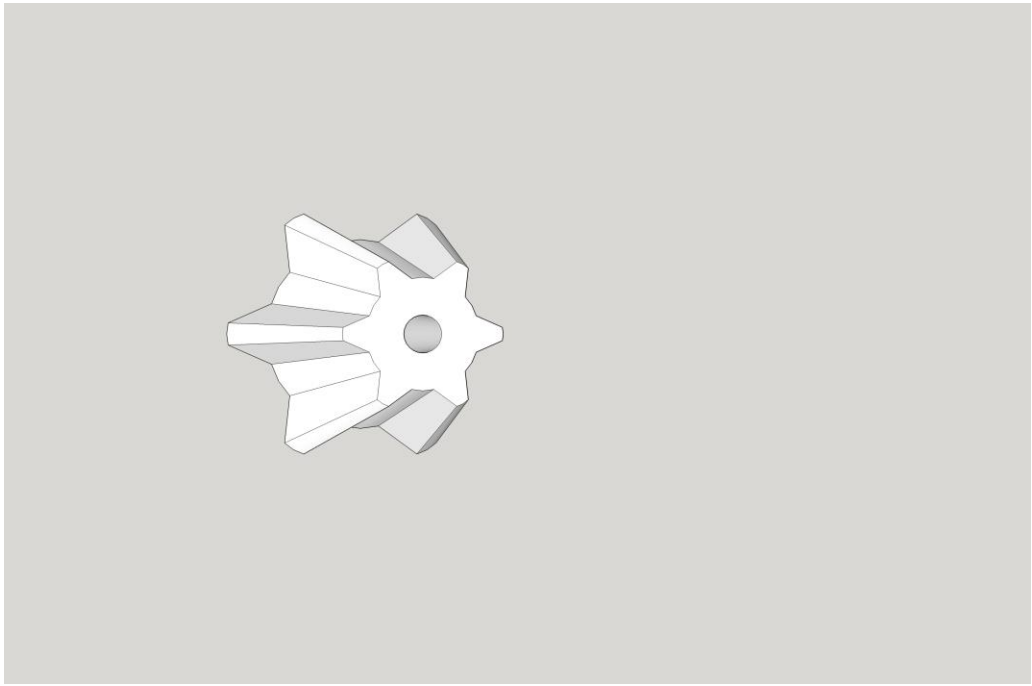
Question: Location (d)
Size (N.A.) of the aperture

HYPERCENTRIC PROJECTION



Projection center behind the object → objects in the back appear bigger

Sensor Image



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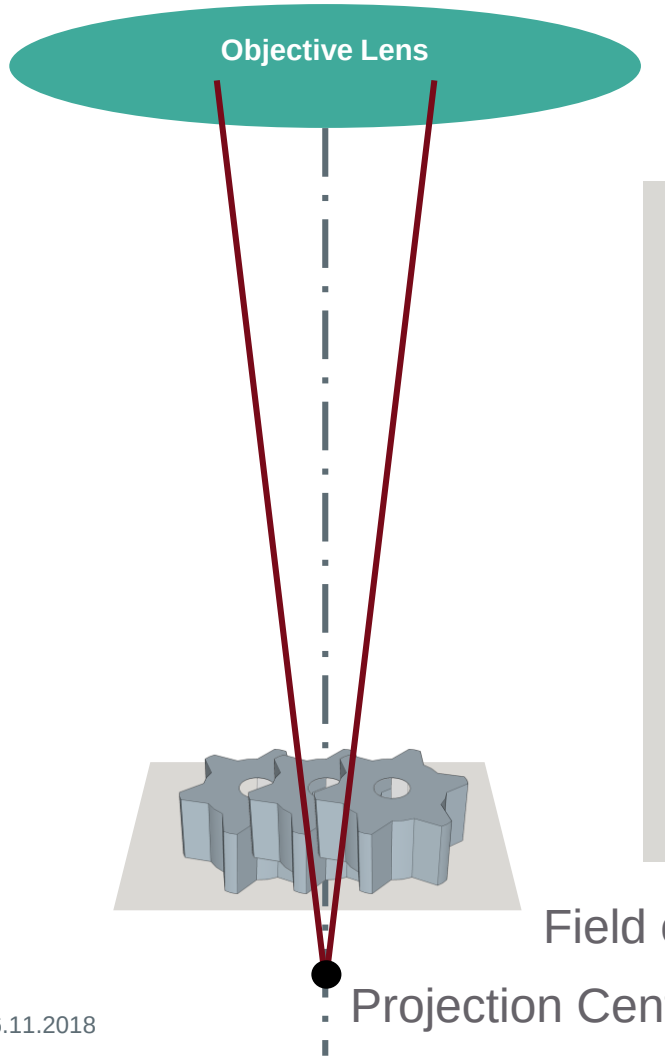

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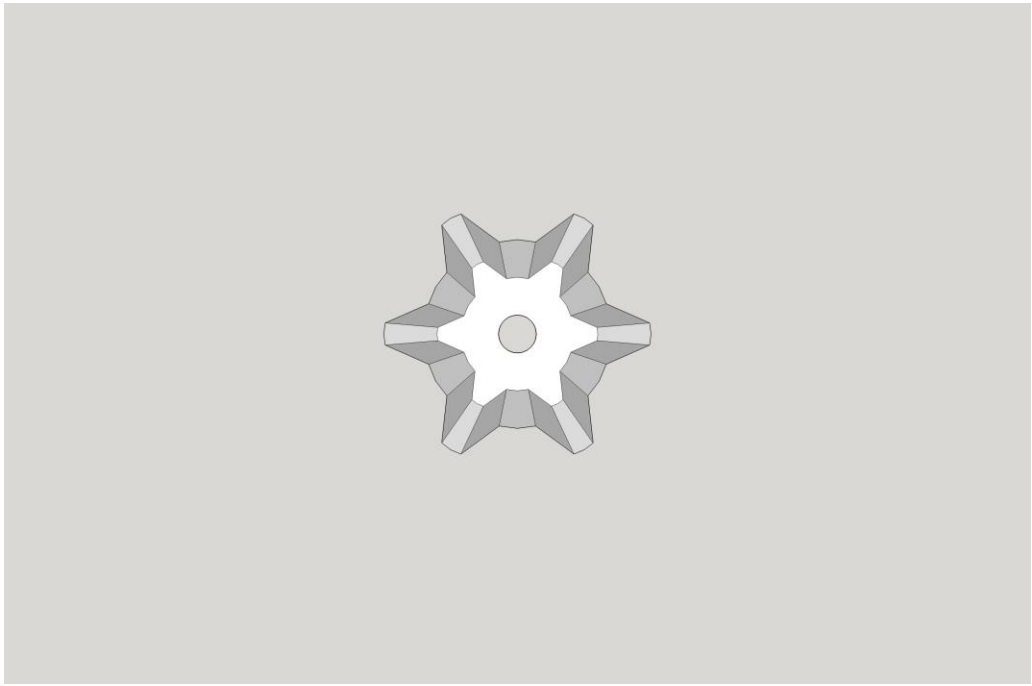

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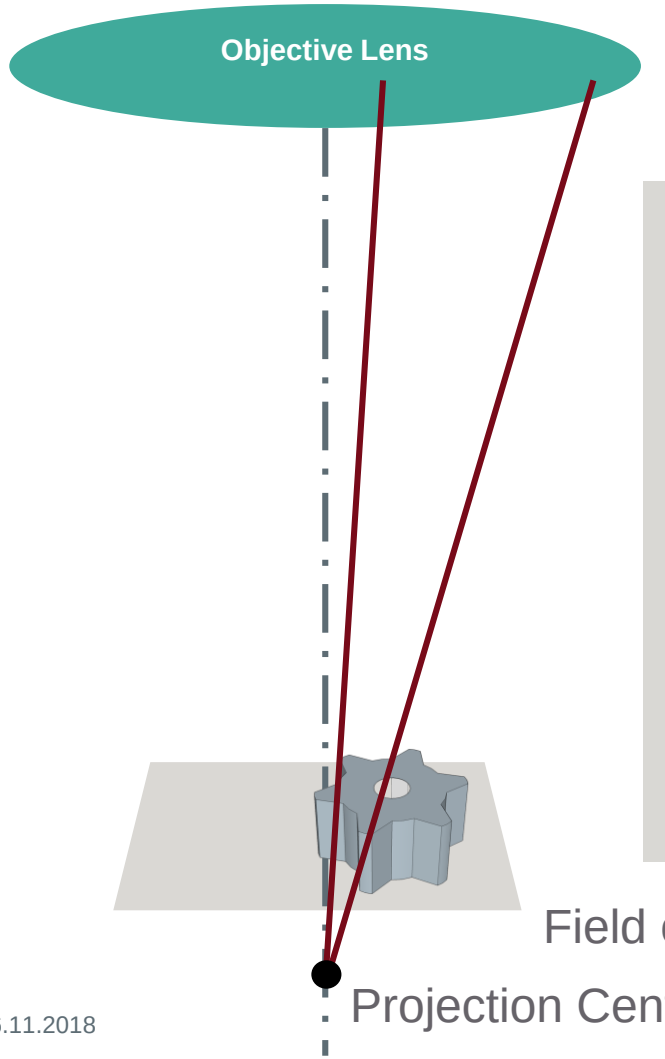

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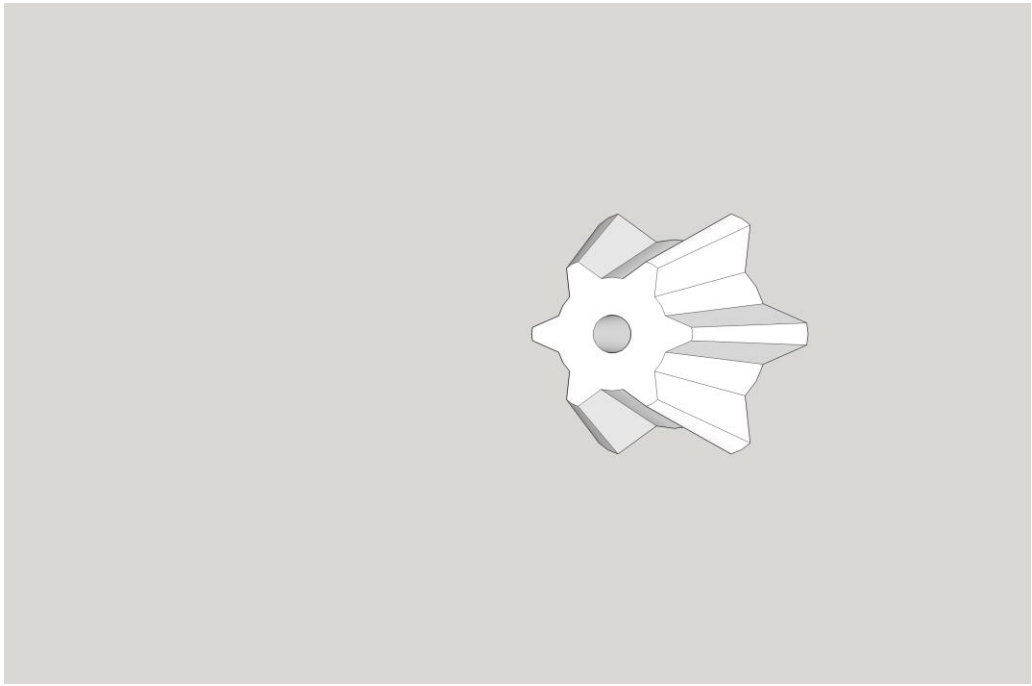
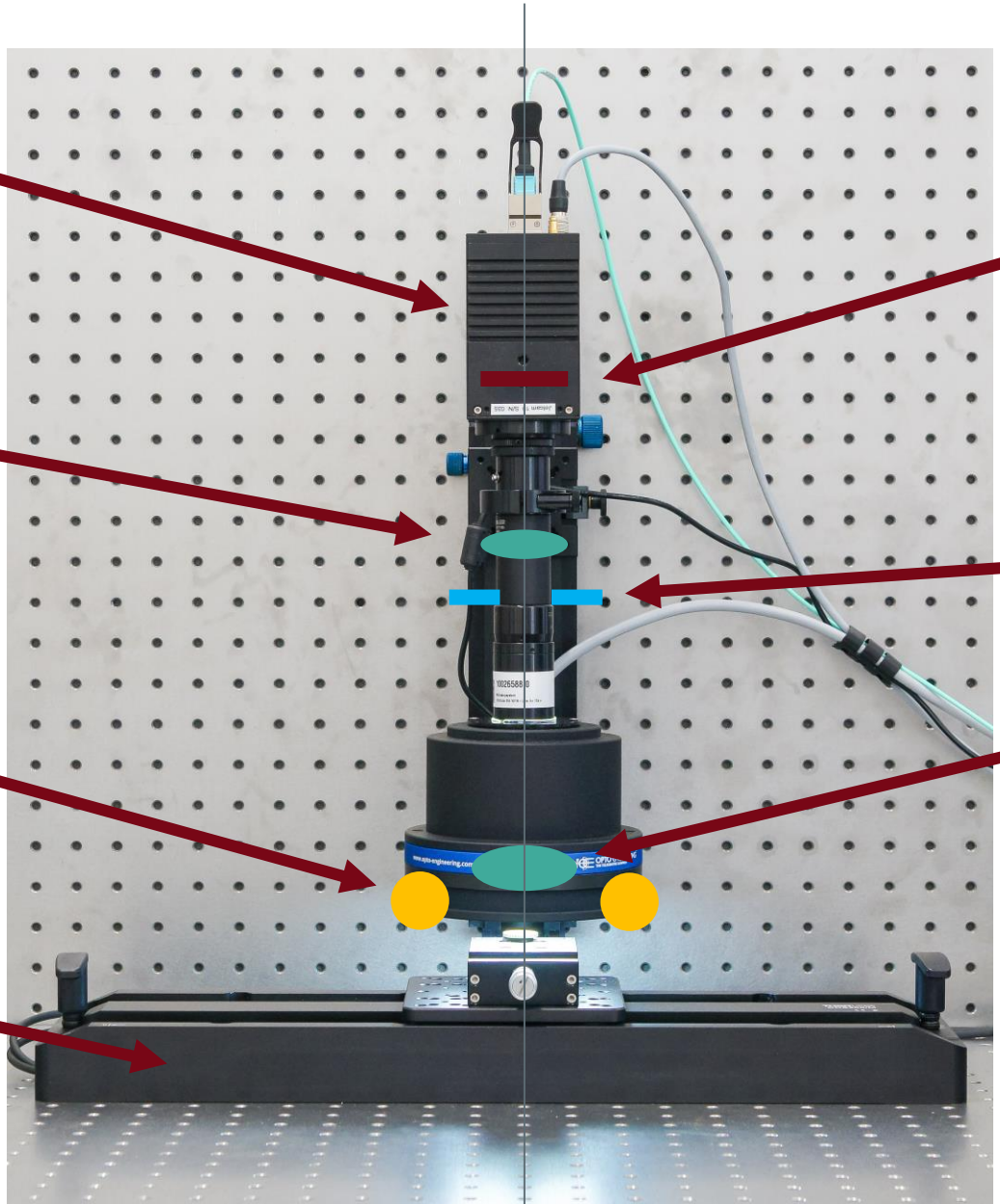
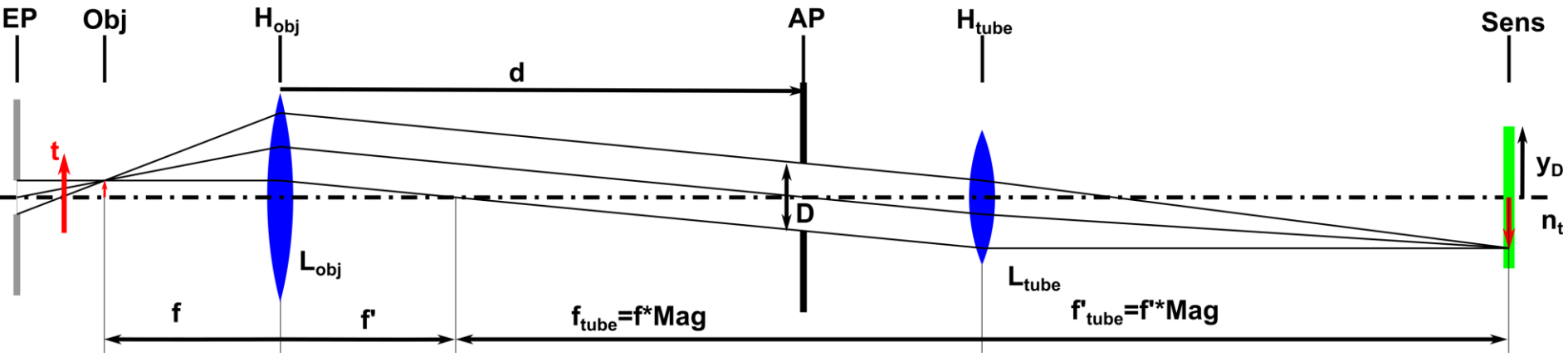


SETUP


High Speed Camera
Tube Lens
Light Source
Transport
Sensor
Aperture
Objective Lens

OPTIMAL OPTICAL CONFIGURATION



- **Aperture Position d**
  - $d\uparrow$ → perspective angle ↑ → depth resolution ↑
  - d too big → light cone gets vignette by lens
    max. d depends on $FOV\ N.A.$: of the objective lens

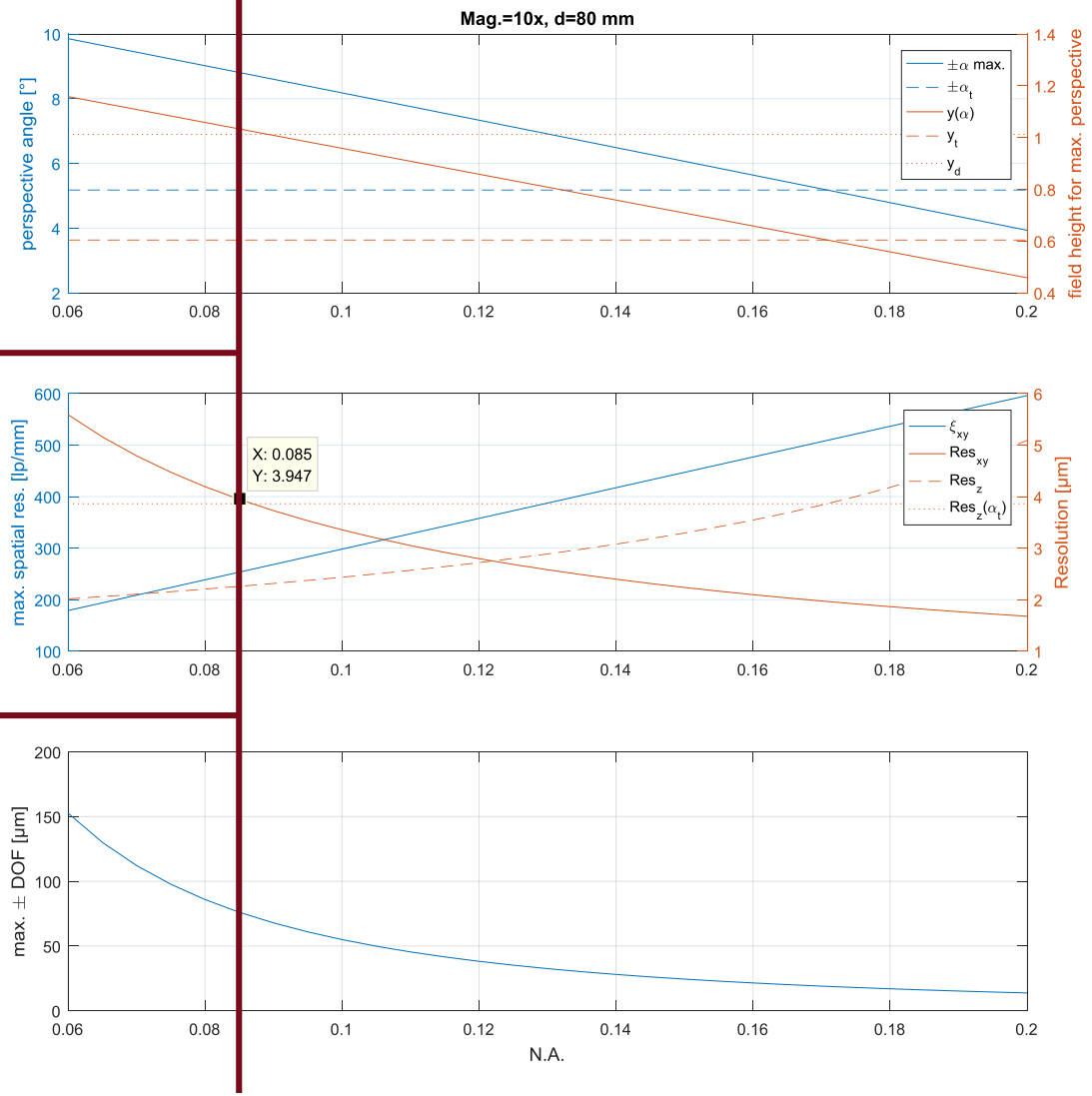
- **Aperture Diameter D**
  - $D\downarrow$ → $DOF\uparrow$ → optical Lateral resolution ↓

APPLICATION SPECIFIC SWEET SPOT

vignetting, non-linear perspective & Res.

worse Res_{xy}

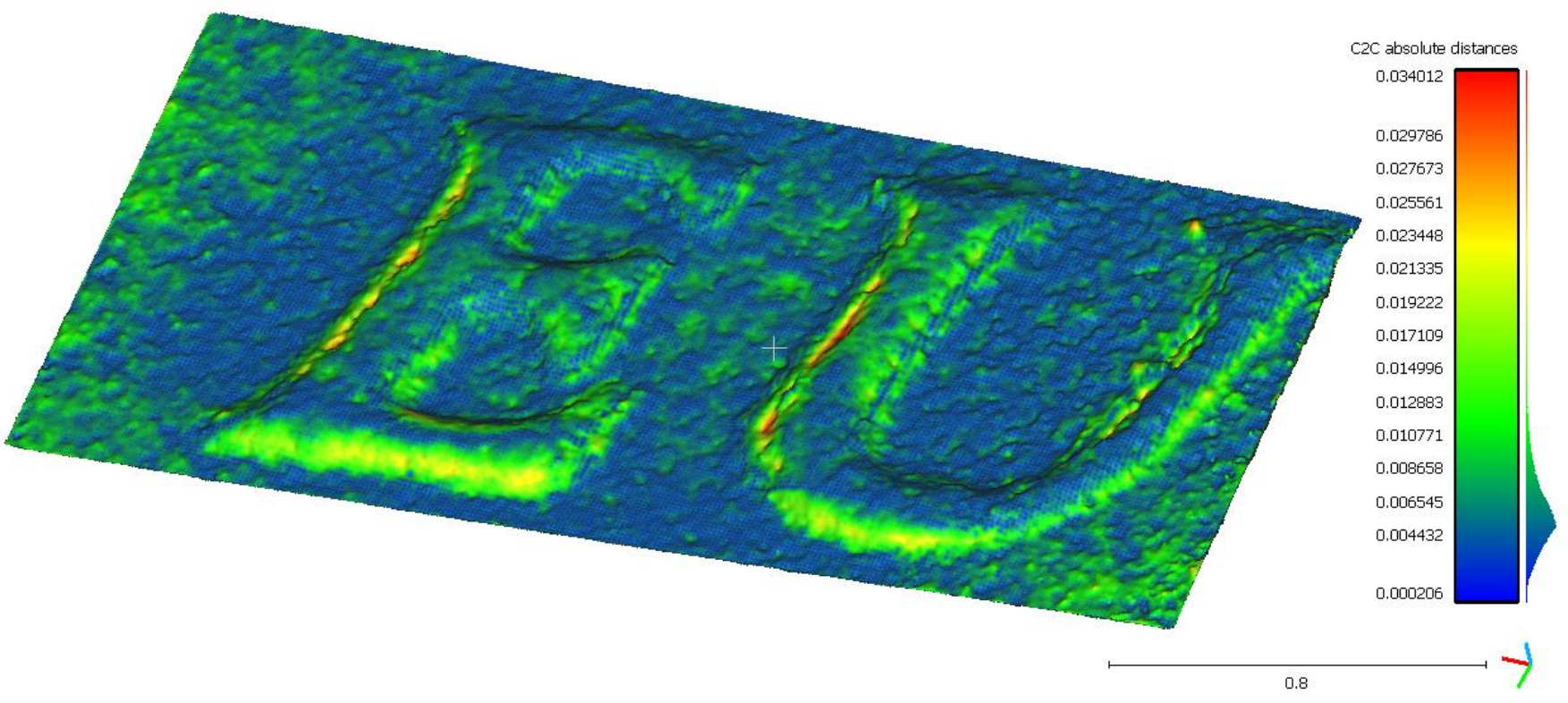
larger DOF



$N.A.$ = 0.085 → Res_{xyz} = 3,9 µm, DOF = +/- 80 µm

EXPERIMENTAL RESULTS

- Letter height 1mm
- Embossing depth ~70µm
- Metallic → hight gloss
- Transport up to 10 mm/s



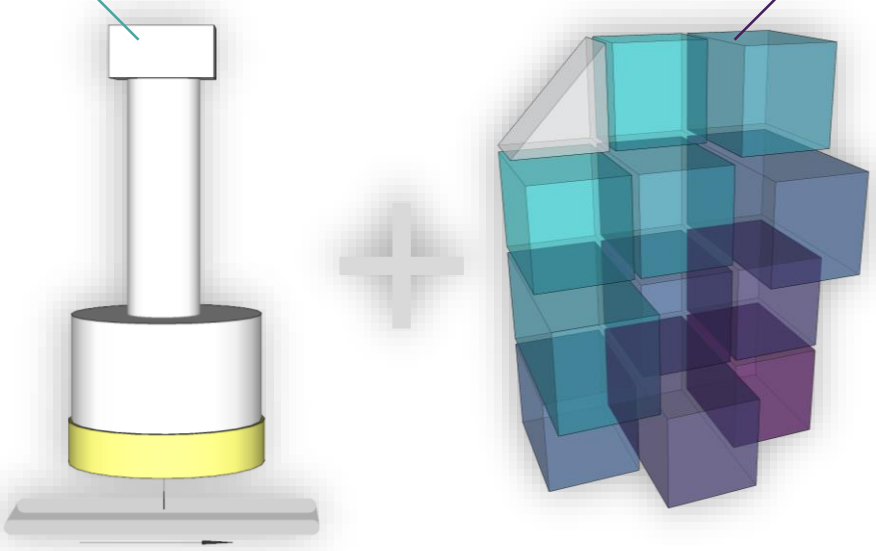
EXPERIMENTAL RESULTS

ICI Sensor System

Single Sensor Technology for Simultaneous Light Field and Photometric Stereo Capture

ICI Software Modules

Generic Computational Imaging Library for 2D/3D Tasks



- **Robust feature matching** does not brake down for out-of-focus areas → usable DOF two times the calculated values → **300µm usable DOF**
- Using **light field** + **photometric stereo** depth resolution increases by factor 4 compared to conventional stereo depth resolution → **1 µm depth resolution**
- **Lateral sampling 1µm/pix**

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

THANK YOU!

Lukas Traxler, 07.11.2018