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Ostschweizer
Fachhochschule

Polishing by Laser Remelting

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Polishing by Laser Remelting

- Optical fabrication technoloies OFT
- Laser polishing
  - process
  - fabrication chain
  - nextsteps
- Conclusions

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Optical Fabrication Technologies

- everything started with hand polishing

8000 BC
obsidian bracelet,
Anatolia

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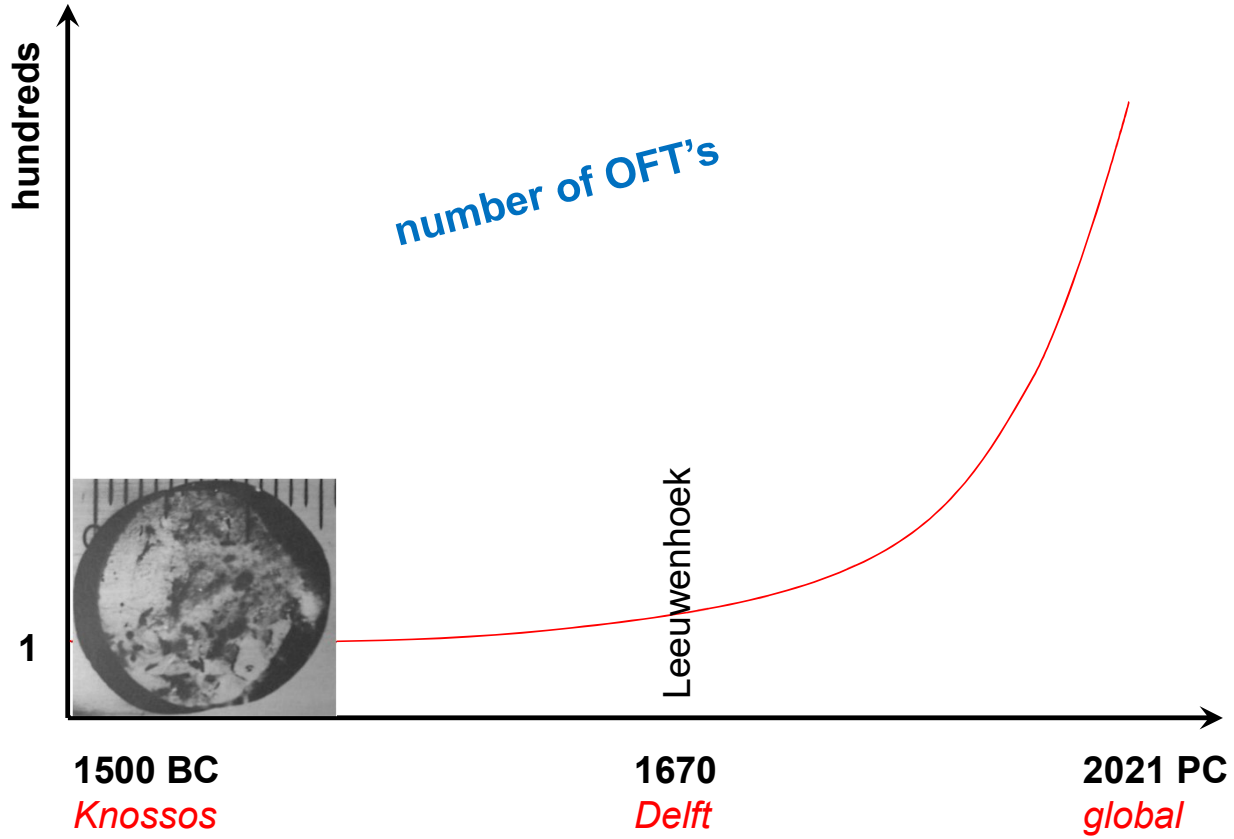
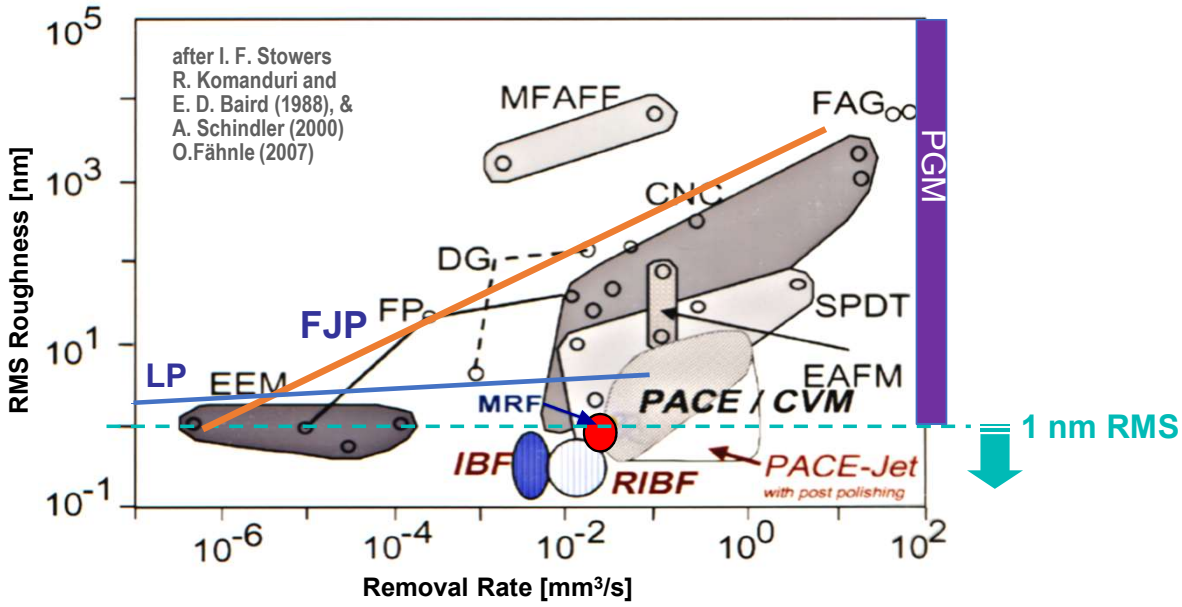
Optical Fabrication Technologies

- … numbers have been rising



Optical Fabrication Technologies

- … today hundreds of techniques



FAG: Fixed Abrasive Grinding
CNC: Computer Numerical Controlled Polishing
FP: Float Polishing
LP: Laser Polishing
EEM: Elastic Emission Machining
SPDT: Single Point Diamond Turning
EAFM: Electrolytic Abrasive Mirror Finishing

DG: Ductile Grinding
(R)IBF: (Reactive) Ion Beam Figuring
PACE: Plasma Assisted Chemical Etching
CVM: Chemical Vapor Machining
MFAFF: Magnetic Field Assisted Fine Finishing
MRF: Magnetorheological Finishing
FJP: Fluid Jet Polishing

S. Jacobs.

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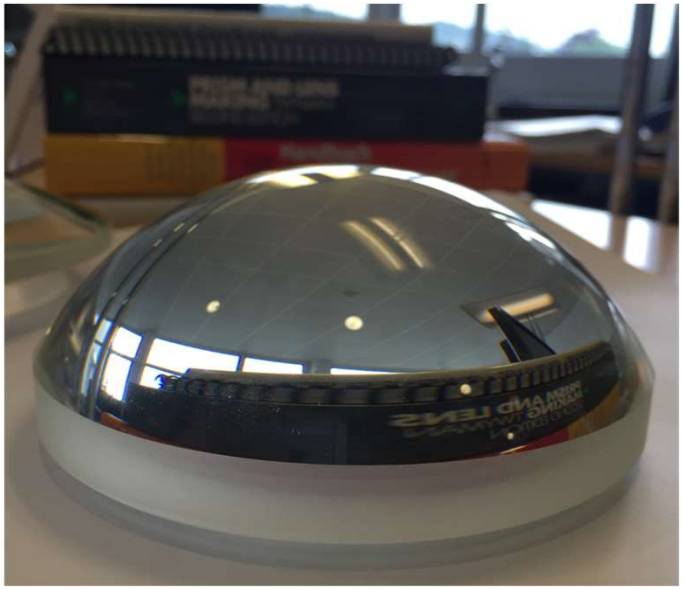
Optical Fabrication Technologies

- … selection criteria

- fabrication cost
- through-put
- geometry
- dimension
- surface quality
- material

- surface roughness
- 3/ shape accuracy
- 5/ defects
- MSF
- material stress
- SSD
- residuals



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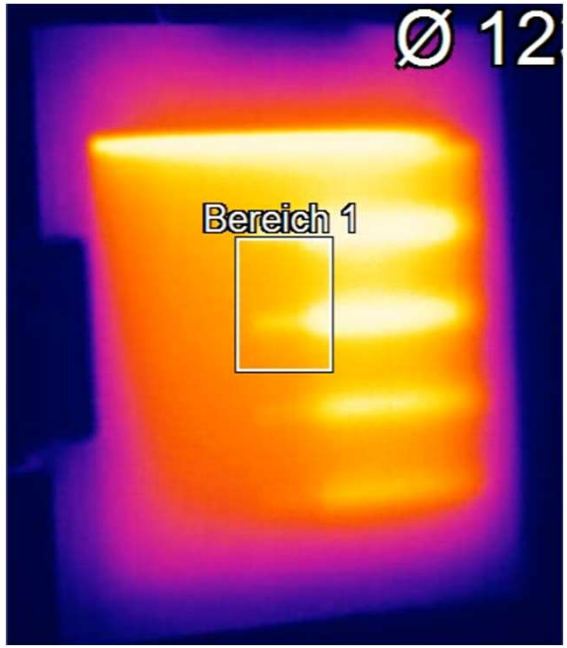

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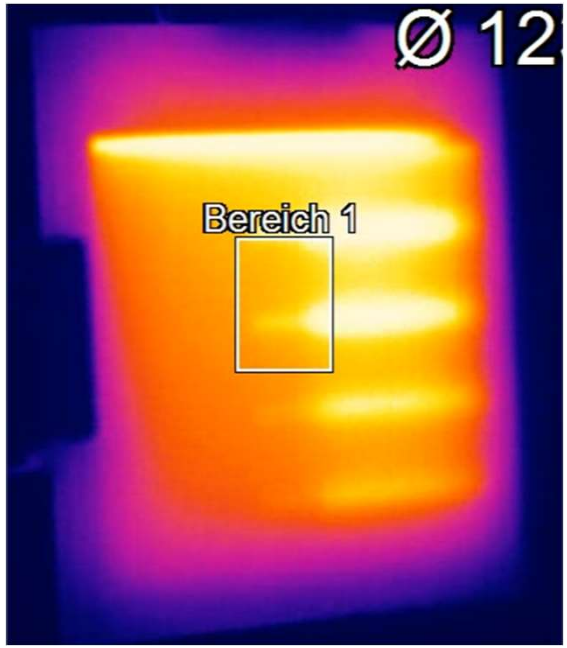

- ➢ **no residuals**
- ➢ **arrays**
- ➢ **10um FP**
- ➢ **fast**
- ➢ **all shapes**
- ➢ **no mech.contact**

- ➢ **fused silica, BK7…**
- ➢ **Sq 2 nm rms**
- ➢ **MSW**

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Laser polishing

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- surface quality
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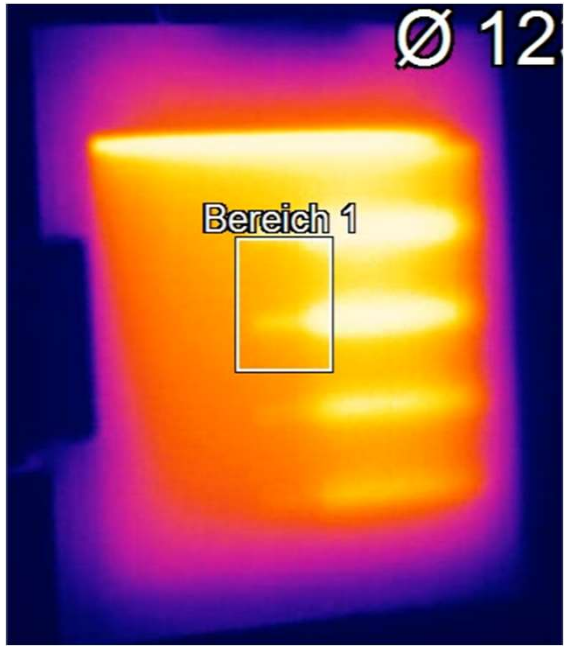
- **surface roughness**
- 3/ shape accuracy
- 5/ defects
- **MSF**
- **material stress**
- SSD
- **residuals**



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Laser polishing: process

- … remelting material
- two regimes: trade off

Laser polishing: process

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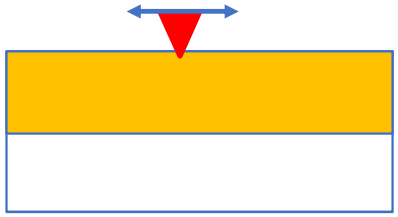
- two regimes: trade off



- continuous wave
  - deeper melting zone
  - shape
  - roughness
  - mechanical stress
  - refractive index
  - MSW

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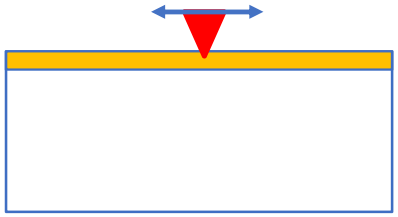
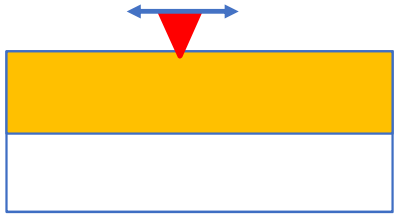
Laser polishing: process

- … remelting material
- two regimes: trade off



- short pulses
  - shallow melting zone
  - shape
  - roughness
  - mechanical stress
  - refractive index
  - MSW



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Laser polishing: process

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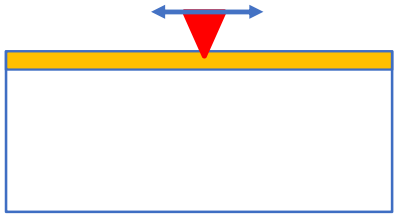
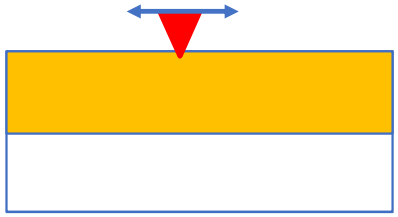


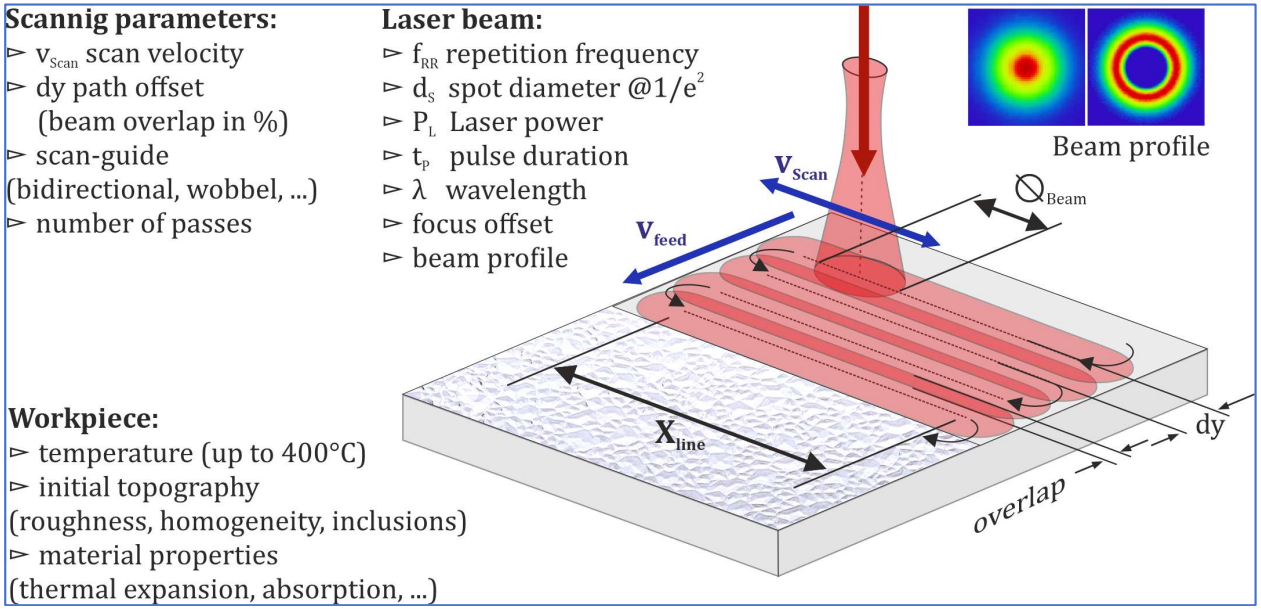
- short pulses
  - shallow melting zone
  - shape
  - roughness
  - **mechanical stress**
  - refractive index
  - MSW



- continuous wave
  - deeper melting zone
  - **shape**
  - roughness
  - mechanical stress
  - **refractive index**
  - **MSW**

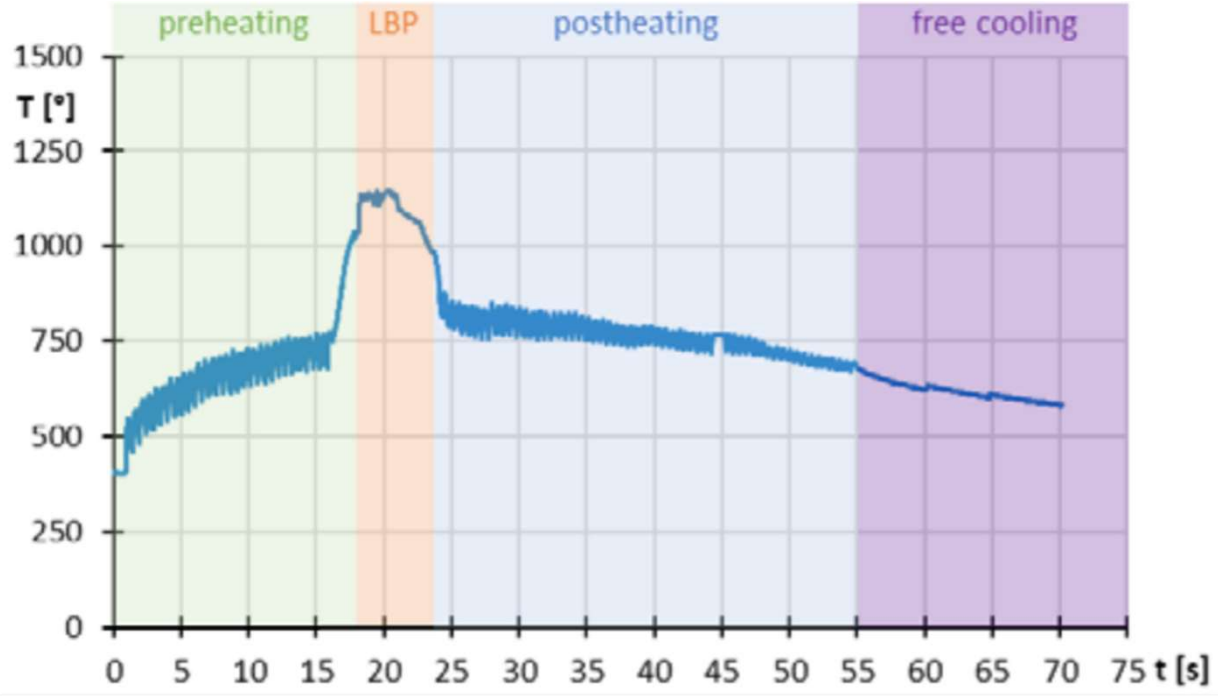
Laser polishing: process

- … remelting material
- process parameters
  - starting roughness
  - starting temperature
  - process kinematics
  - overlap
  - energy & intensity
  - scan velocity
  - dwell time map software



Laser polishing: process

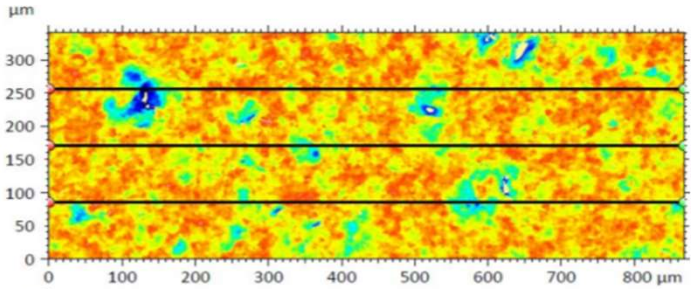
- … remelting material
- process parameters
    - (1) pre-heating
    - (2) LP processing
    - (3) post-heating



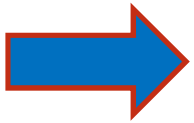
Laser polishing: process

- … remelting material
- performance (fused silica)

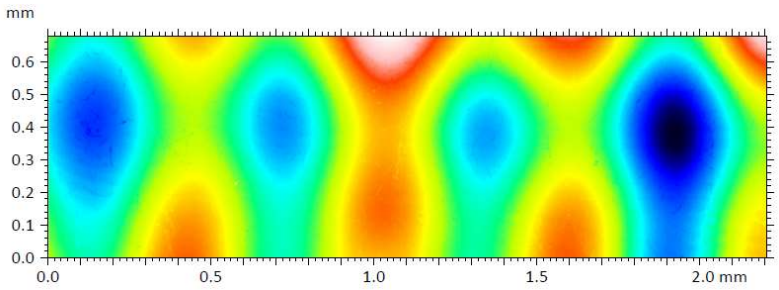
fine ground surface Sq 1200 nm rms



ISO 25178 - Rauheit (S-L)		
F: [Analyseablauf] Ausgerichtet (LS-Ebene)		
S-Filter (λs): Gauß, 2.5 µm		
L-Filter (λc): Gauß, 0.08 mm		
Höhen-Parameter		
Sq	1.118	µm
Sp	4.811	µm
Sz	11.47	µm
Sa	0.8523	µm



laser polished surface Sq 2 nm rms



ISO 25178 - Rauheit (S-L)		
F: [Analyseablauf] Ausgerichtet (LS-Ebene)		
S-Filter (λs): Gauß, 2.50 µm		
L-Filter (λc): Gauß, 0.08 mm		
Höhen-Parameter		
Sq	2.27	nm
Sp	36.08	nm
Sv	55.65	nm
Sz	91.72	nm
Sa	1.55	nm

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Laser polishing: fabrication chain

- … remelting material

CNC fine ground

SQ = 500 – 1000 nm rms
ssd = 20 um

selective laser etching

SQ = 500 – 1000 nm rms
ssd < 5 um

laser polishing

Sq = 2 – 4 nm rms

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Laser polishing: next steps

- … stay as long as needed: only
- in situ, in process quality monitoring

*Oliver Faehnle, Rolf Rascher, Christian Vogt, and Daewook Kim, "Closed-loop laser polishing using in-process surface finish metrology," **Appl. Opt.** **57**, 834-838 (2018)*

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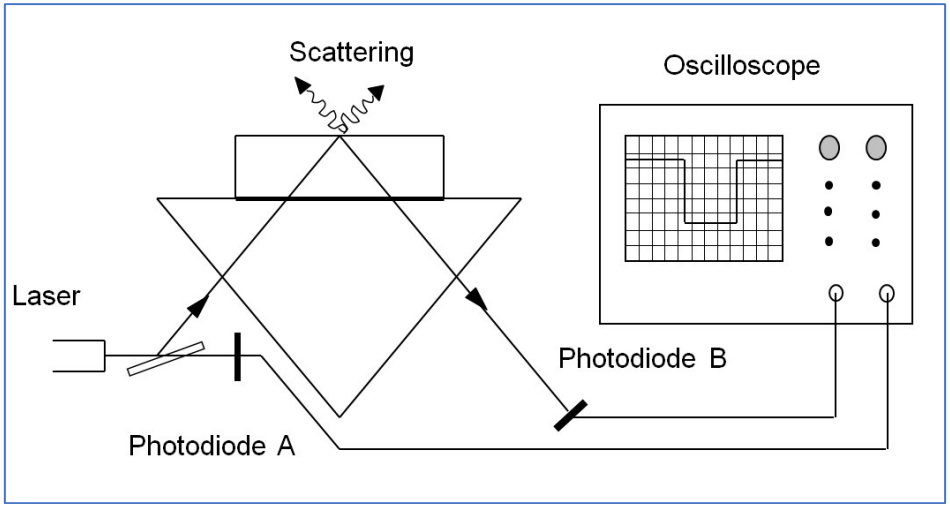
Laser polishing: next steps

- … stay as long as needed: only
- in situ, in process quality monitoring: IRM
  - quality detection from «within»



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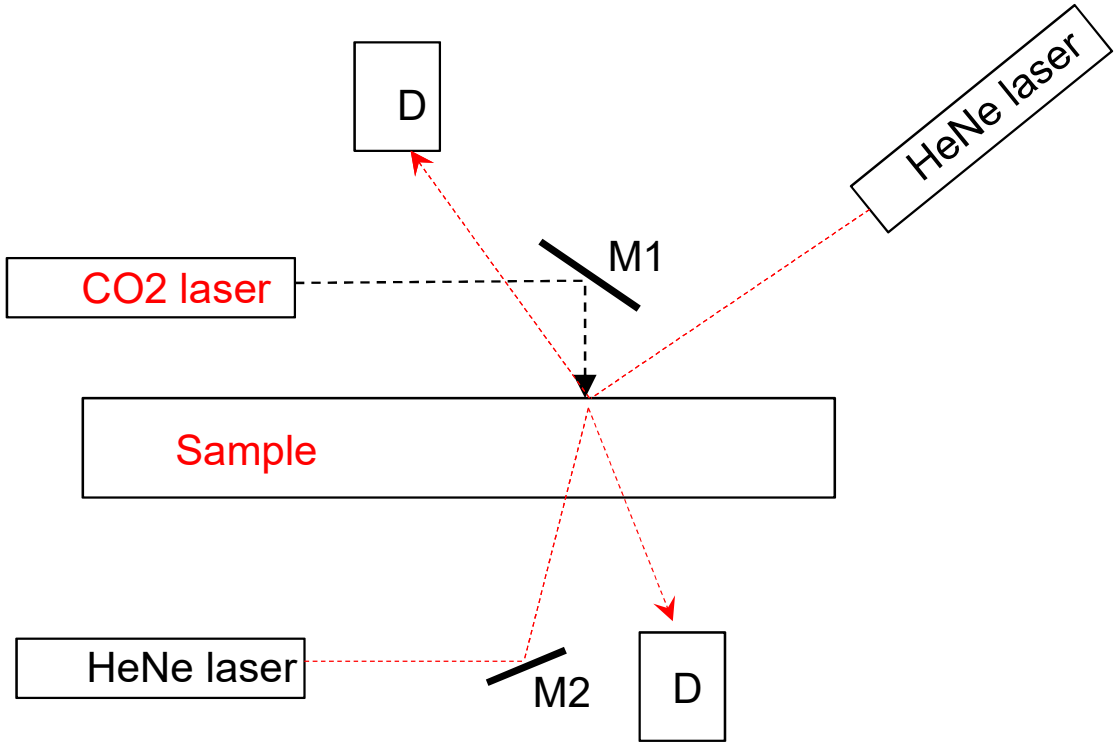
Laser polishing: next steps

- … stay as long as needed: only
- in situ, in process quality monitoring: IRM
  - quality detection from «within»
  - during laser polishing



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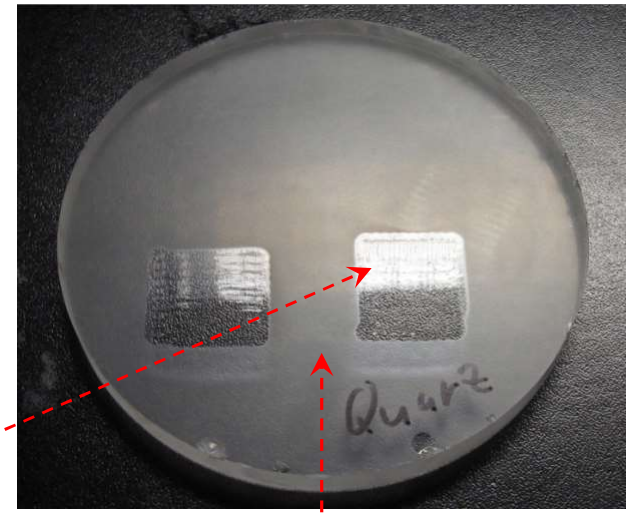
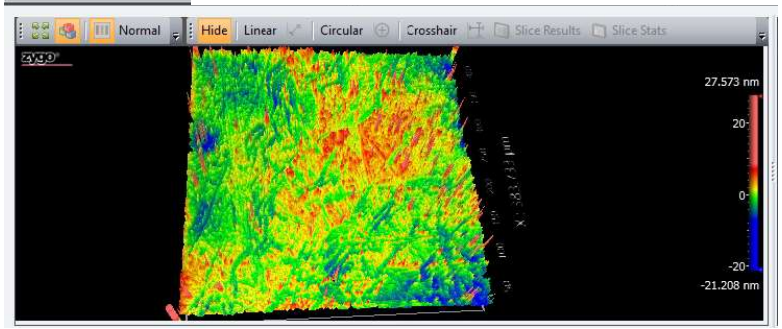


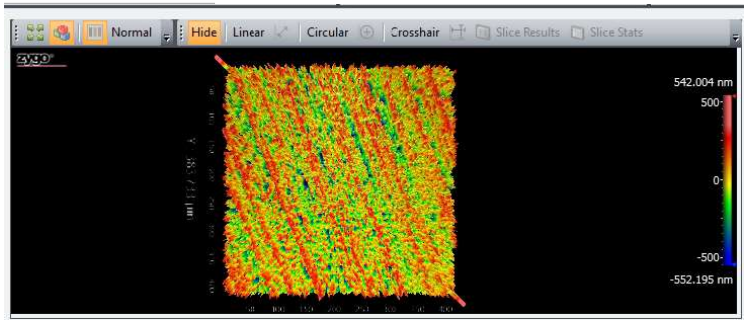
2.7 nm rms

Results		
Sa	2.110	nm
Sq	2.774	nm
Sz	48.781	nm
Size X	383.733	µm
Size Y	383.733	µm
FOV	0.42 x 0.42 mm	



170 nm rms

Results		
Sa	131.811	nm
Sq	166.209	nm
Sz	1094.199	nm
Size X	383.733	µm
Size Y	383.733	µm
FOV	0.42 x 0.42 mm	



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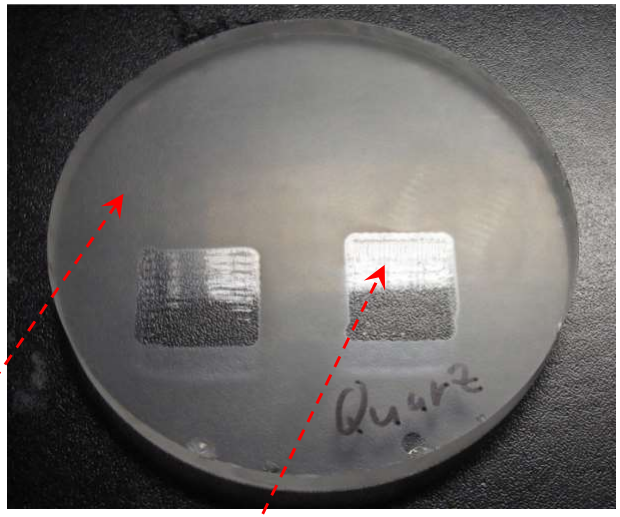
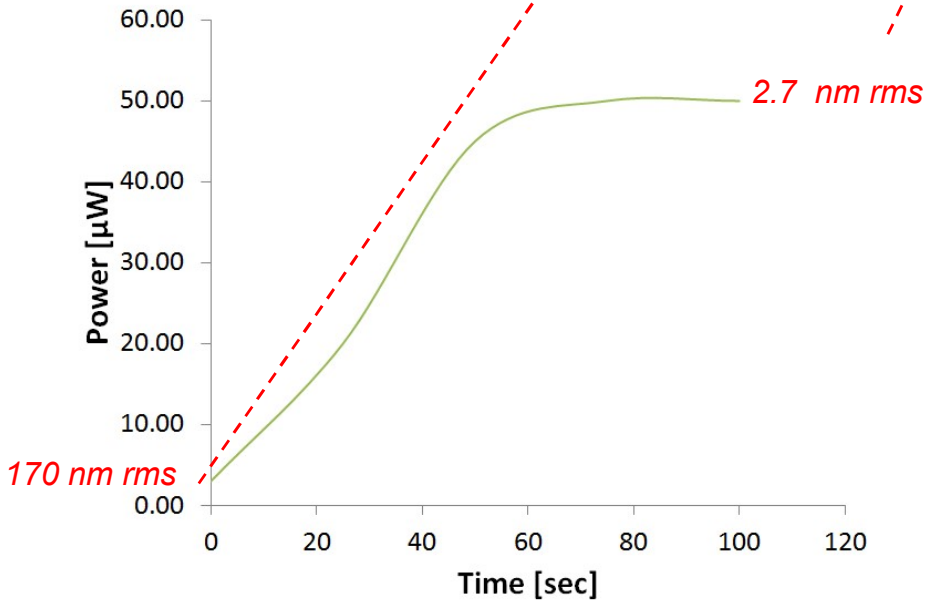
- in situ, in process quality monitoring: IRM





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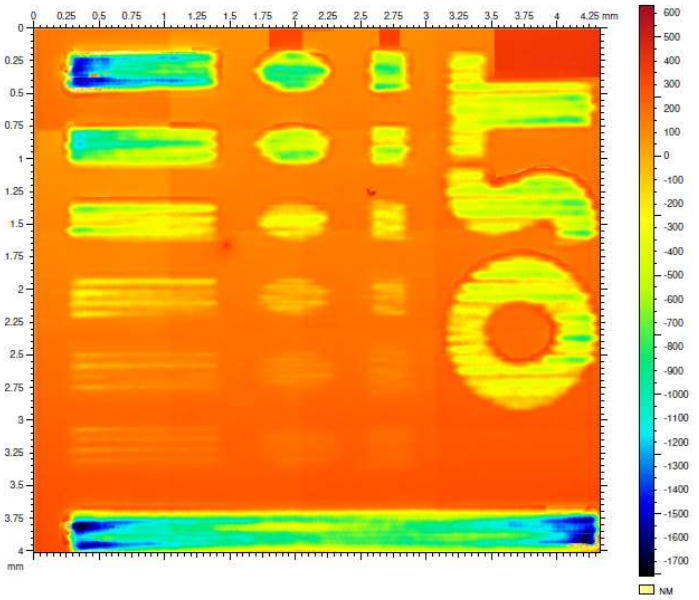
Conclusions

- **… laser polishing**
  - is fast, non contact, no residuals, ccp with small FP
  - works for some materials nicely
  - 2 process windows:
    - roughness reduction only
    - ablation
  - works excellently together with SLE
  - nextsteps: in situ , in process control



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