LASER POLISHING OF 3D PRINTED PLASTIC COMPONENTS

ONLINE 3D PRINTING VALUE CHAIN EVENT

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ILT

The Fraunhofer Institute for Laser Technology ILT

Facts and Figures

- € 42.3 M operating budget (without investments) in 2019
- 75 % contract research revenue and 27 % base funding
- € 8.4 M in investments in 2019
- **566 employees** in 2019, of this 182 scientists and engineers, and 282 student assistants
- DQS certified according to DIN EN ISO 9001
- One patent per month on average
- One to two spin-offs per year on average
  (More than 30 Fraunhofer ILT spin-offs in the last 25 years)
- Approx. 10-15 participations in trade fairs and more than 20 organized events (conferences, seminars) per year
- Approx. 15 Ph.D. graduates at RWTH faculties per year
- Over 70 master, bachelor degrees per year

468 patents between 1985 and 2016 – corresponds to ∅ 1 patent / 3.5 weeks

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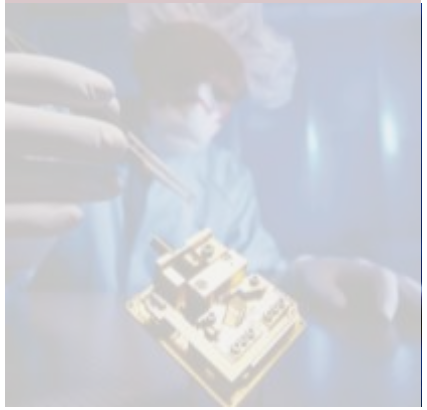
Technology Focus

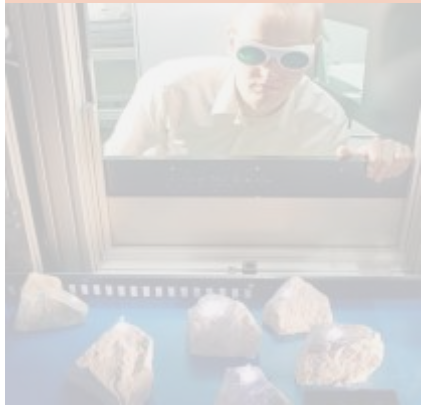
LASERS AND OPTICS



LASER MATERIAL PROCESSING

MEDICAL TECHNOLOGY AND BIOPHOTONICS

LASER MEASUREMENT TECHNOLOGY



- Laser Cutting
- Laser Welding
- Soldering
- Heat Treatment
- Cladding
- Laser Metal Deposition
- Rapid Manufacturing
- Process and Beam Control
- Machine and Control Technology
- Plastics Cutting and Welding
- Cleaning
- Marking
- Drilling
- Micro Joining
- In-Volume Structuring
- Polishing
- Thin Film Processing
- Ultrashort Pulse Processing
- Micro Structuring
- Nano Structuring
- Simulation

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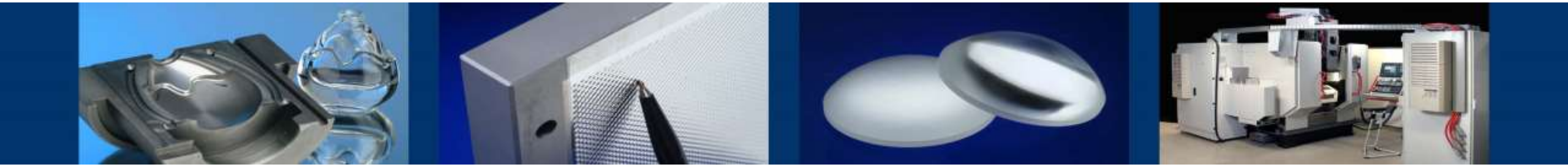
Products and Services: Polishing



Applications Metals
- Tools, dies and mould making
- Implants
- Design surfaces with multi gloss level
- Polished and structured surfaces
- Further applications

Applications Optics
- Aspheric and freeform optics made form glass and fused silica
- Spectacle lenses made form plastics

Laser Polishing Machines
- Machine tools for laser polishing of metals, glasses and plastics
- Concepts for machines with work piece weights from 0.1 to 200 kg
- 5 and 3 axes processing (axes system and laser scanner)
- CAM-NC data chain for 5 and 3 axes processing
- Fully automated polishing

Your Application
- Feasibility studies
- Test and adaption of laser polishing for your application
- Processing of test parts
- Processing of small series

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Introduction and Motivation

Surface finishing for 3D-printed polymer parts

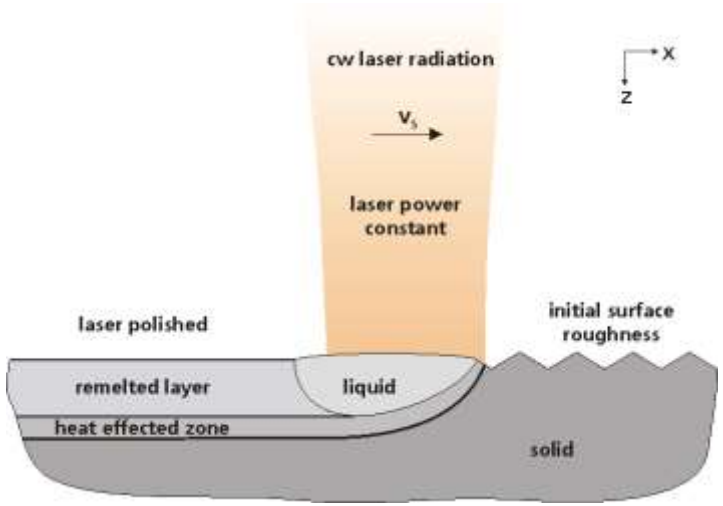
- Current processes for surface finish:
  - Vibratory grinding (1)
  - Manual grinding and polishing (2)
  - Chemical etching
  - Sand blasting
  - Painting (3)
- Typical deficits:
  - Foreign particles in the surface
  - Low reduction of roughness
  - High costs
  - Changes in geometry / edge rounding
  - Low selectivity

New approach: Laser polishing

1) https://de.beta-layout.com/3d-druck/info_materials.html 2) https://www.makerbot.com/de/professionals/post-processing/sanding/
3) https://3druck.com/3d-druckmaterialien/xtc-3d-verleiht-3d-gedruckten-objekten-eine-ebenmaessigere-oberflaeche-3028167/

Surface Finish with Laser Polishing

Procedural principle



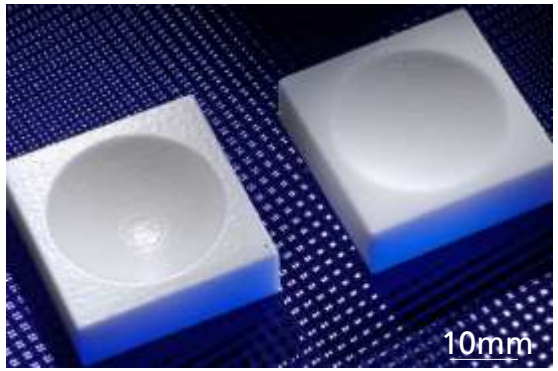
- Surface near absorption of laser radiation
- Heating and melting of the surface material
- Smoothing of roughness in melted state through surface tension

Examples

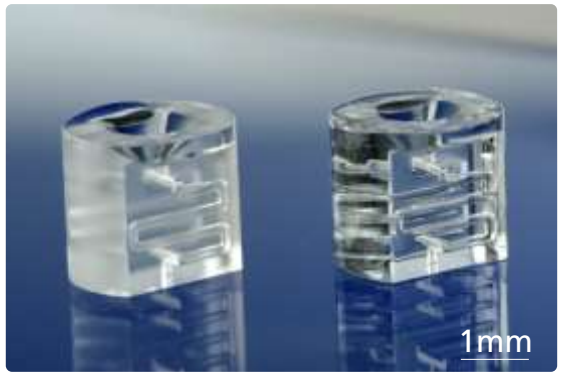
Glass Optics (BK-7)

Guide Vane (Titanium)

3D printed parts (PA12)



Microfluidic (fused silica)



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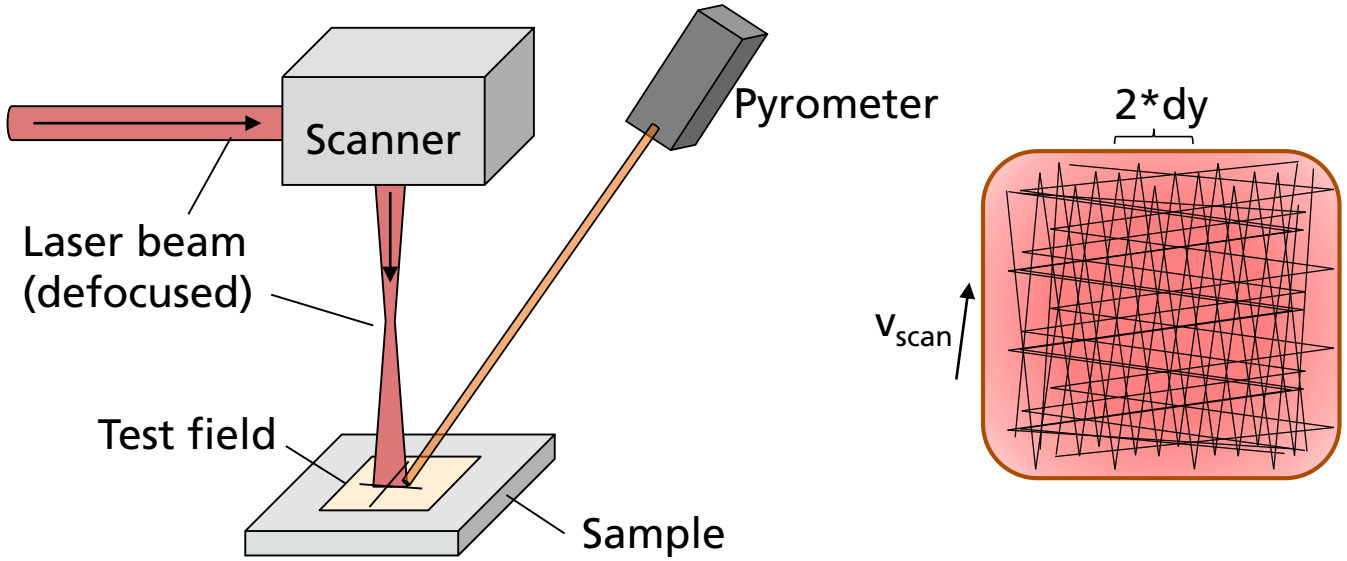
Laser polishing of SLS parts

Quasi-Top-Hat strategy with temperature control

- CO_2-Laser
- Bidirectional scanning strategy
- High scanning speed v_{scan} (5-10 m/s)
- High track distance dy (100-200 µm)

  → Multiple repetitions per second
- Defocused laser beam (d_S = 2-4 mm)
- Using a temperature control
- Main process parameters:
  - Process temperature
  - Interaction time



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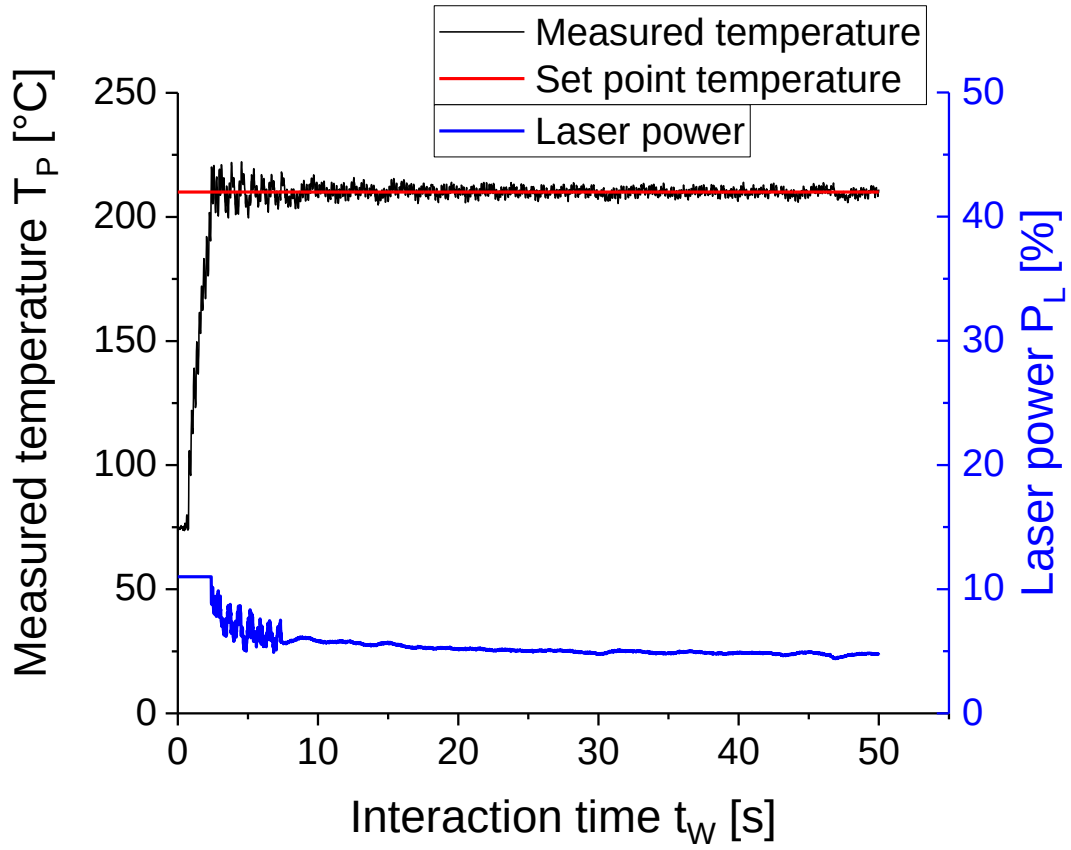
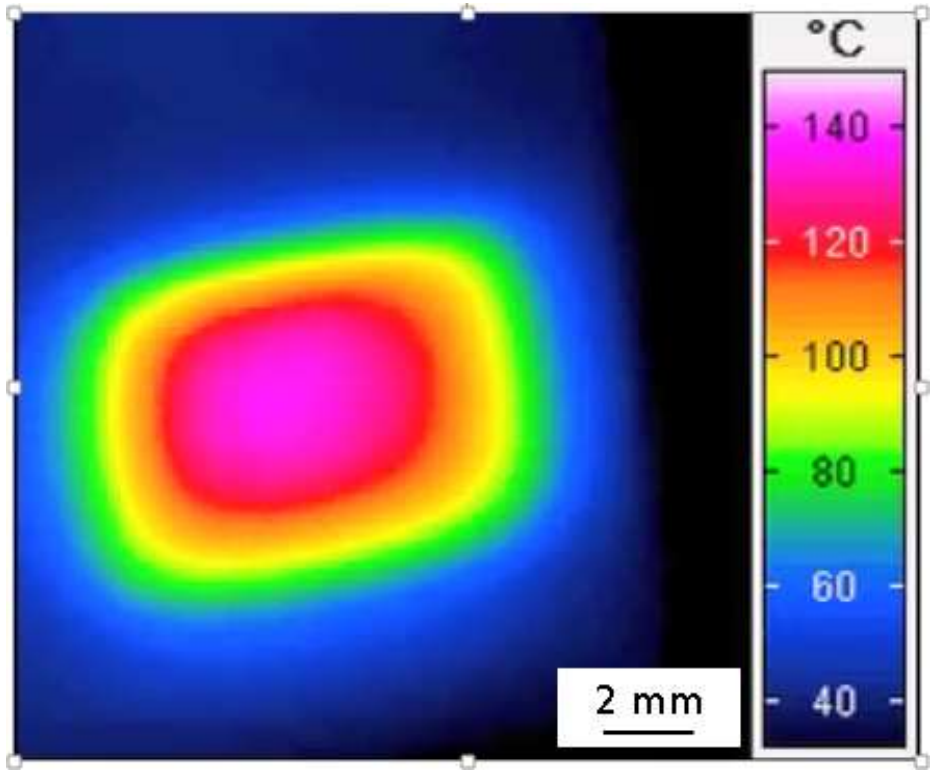
Laser polishing of SLS parts

Quasi-Top-Hat strategy with temperature control





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Laser polishing of SLS parts

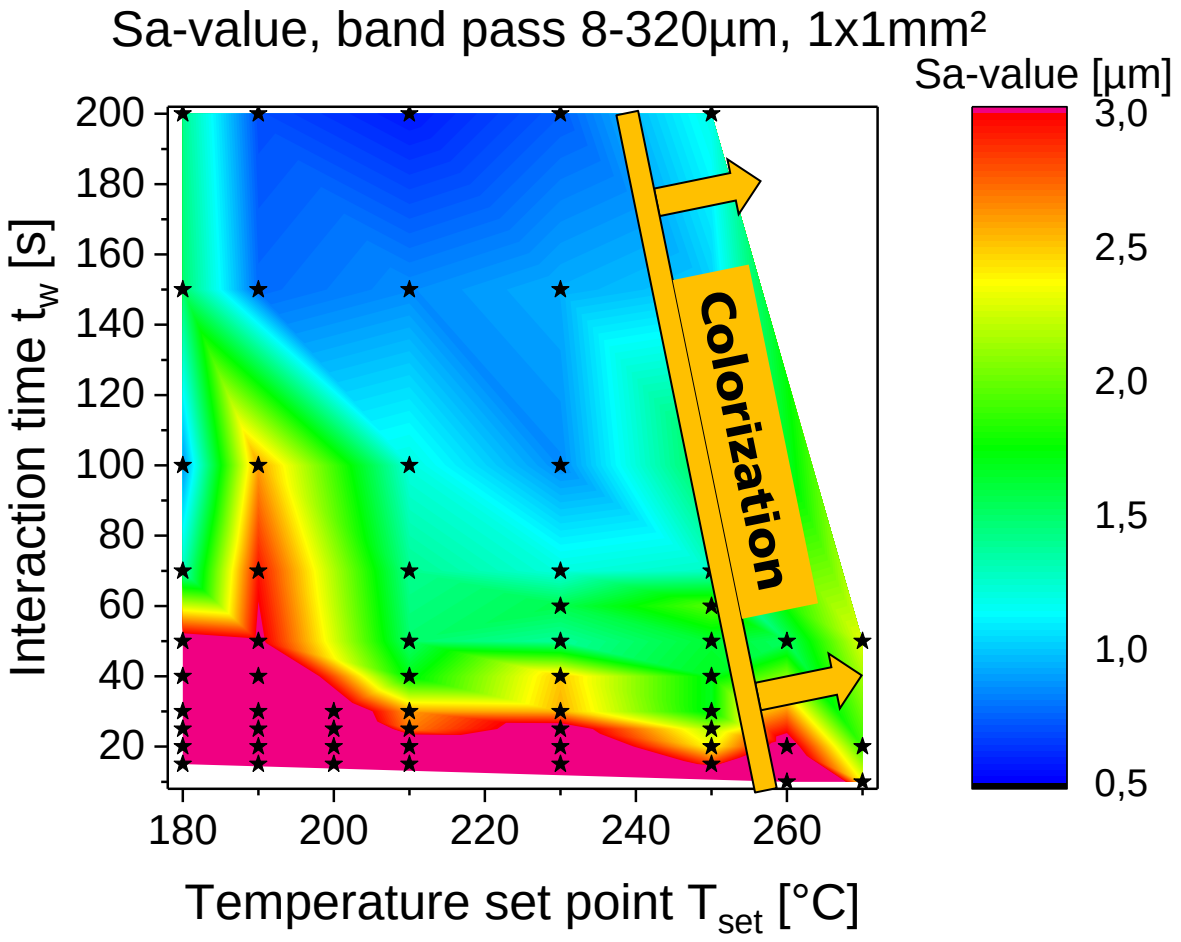
Influence of temperature and time on roughness – material PA12

- Main process parameters:
  - Process temperature
  - Interaction time
- 2-dimensional experimental design

→ Influence of temperature and time on roughness

- Material PA12:
  Lowest roughness at T_{set} = 210°C, t_w = 200s

  Higher interaction times possible



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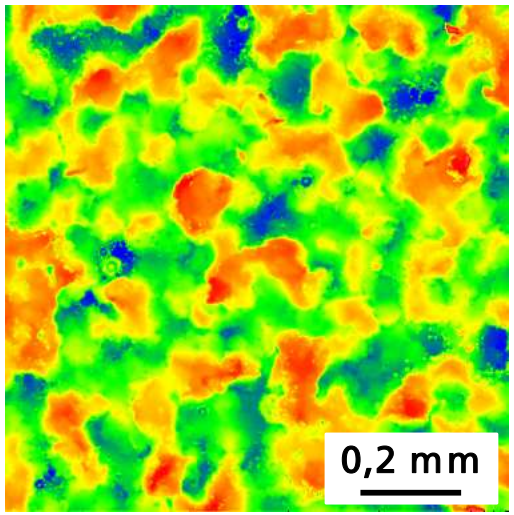
Laser polishing of SLS parts
Roughness after Laser Polishing

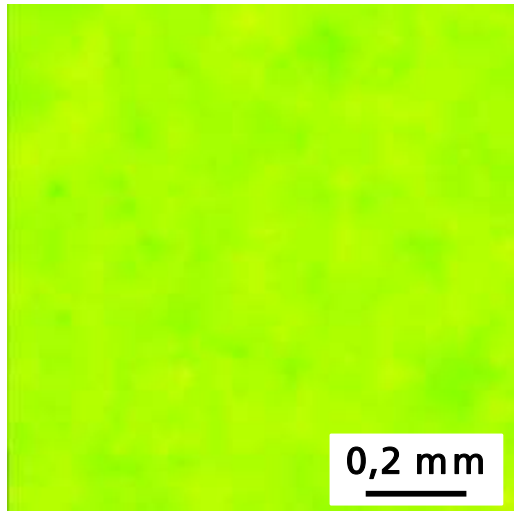
Test field on SLS-printed PA12 20x20 mm²

Roughness **before** laser polishing



Sa ≈ 16 µm
PV ≈ 80 µm

Roughness **after** laser polishing



Sa = 0.3 µm
PV = 5.2 µm

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Laser polishing of AM polymer parts
Material spectrum

Which materials can be laser polished?

- General Requirement: **thermoplastic** material
- For some materials a preheating or drying is required
- Quasi-Top-Hat strategy to determine suitable polishing parameters

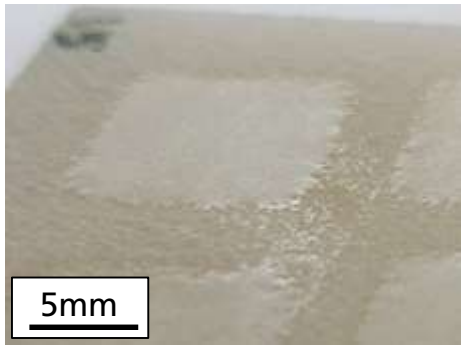
Example materials

PEEK TPU PA12 PA6 PLA PMMA ABS PP PC

SLS-printed TPU

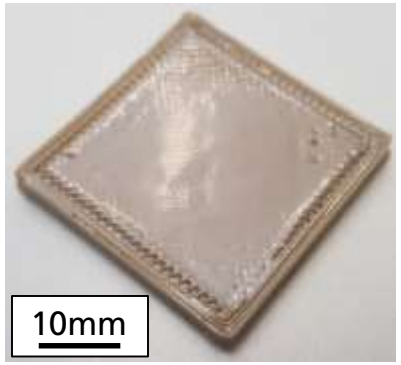
Sa = 0.12µm*

SLS-printed PP



Sa = 0.59µm*

FDM-printed PEEK



Sa = 0.13µm*

*Measurement area = 1x1mm²

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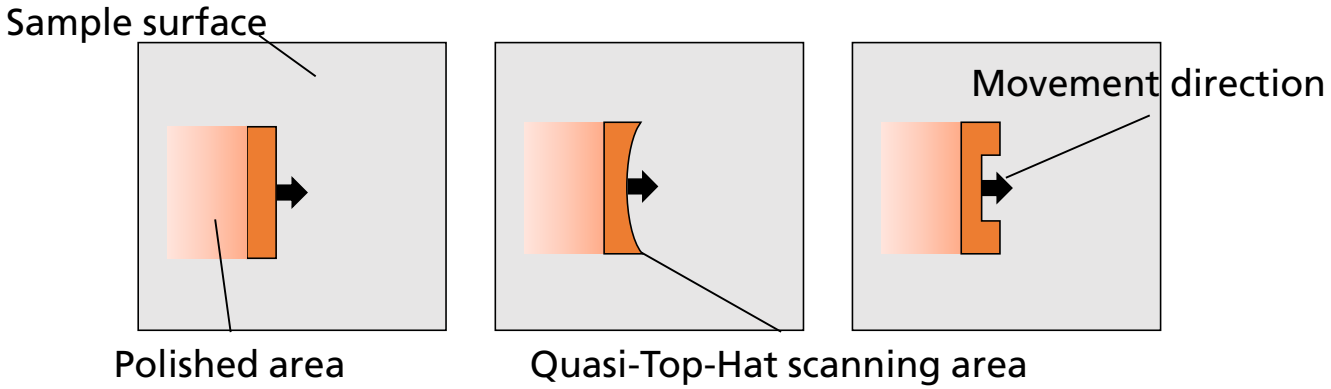
Laser polishing of AM polymer parts
Different geometries

Which geometries can be laser polished?

- Small 2D areas (arbitrary shape)
  → Quasi-Top-Hat scanning strategy
- Large 2D areas (> 30x30 mm²)
  → Movement of QTH-Field
- Simple 2,5D structures
  → No adjustment of laser process for deviations from a flat surface of ~20-30°
- Real 3D parts
  → Rotation of part necessary
  → Hidden areas cannot be polished

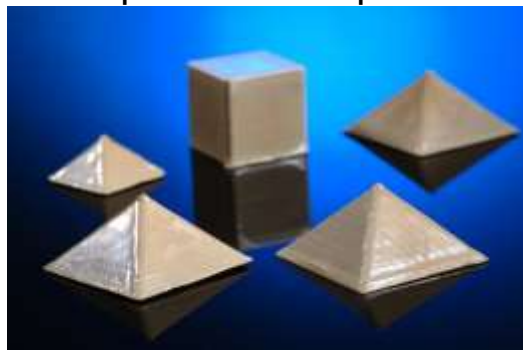
Processing strategy for large areas



Processing of different geometries

SLS-printed PA12 parts

FDM-printed PEEK parts



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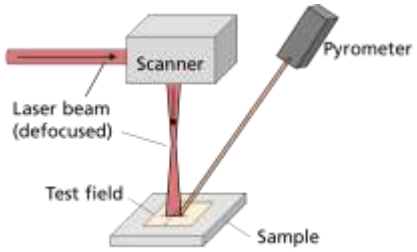
Summary and Outlook

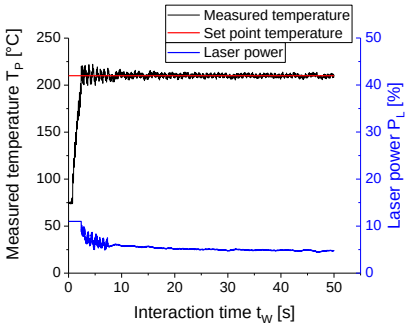
Summary

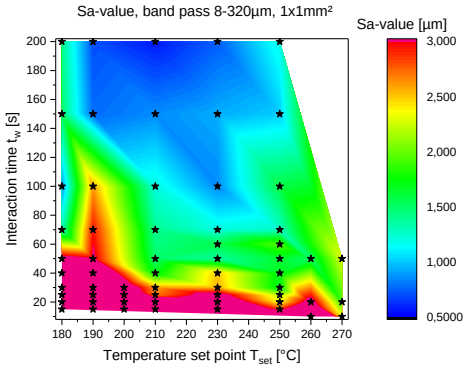
- New approach for polishing 3D-printed polymer parts
- Contactless, non-abrasive surface finish with laser polishing
- Fully digital and automatable process
- Polishing of thermoplastic materials, e.g. SLS and FDM parts
- Achieved roughness between Sa = 0.1 µm and Sa = 0.6 µm depending on the material
- Process is still in research state but shows great potential for industrial application

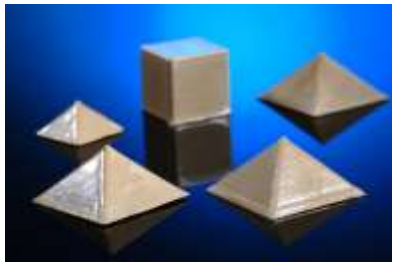
Outlook

- Polishing of real 3D parts
- Application of process on a real business case
- Combining the laser polishing with other finish methods for even smoother surfaces and smaller process times









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Save the date

4th Conference on Laser Polishing LaP 2020 - ONLINE
September 16 to 17, 2020, Aachen, Germany

Thank you very much for your attantion.

Questions?

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