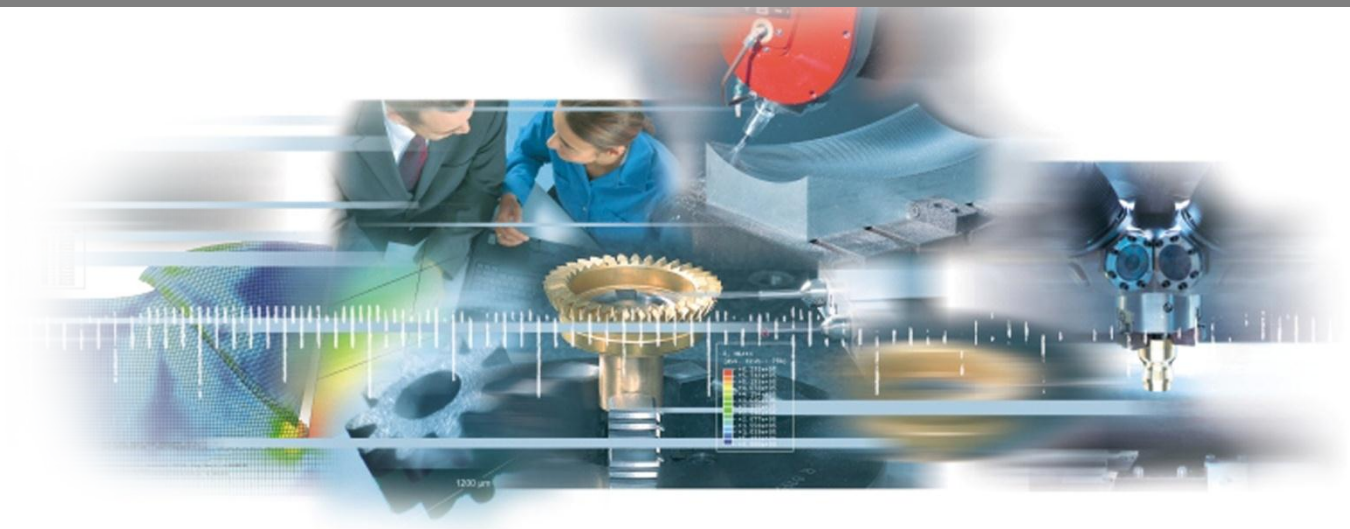
Micro Machining of Molds

Prof. Dr.-Ing. habil. Volker Schulze
Karlsruhe, 27.11.2013

wbk Institute of Production Science



Structure

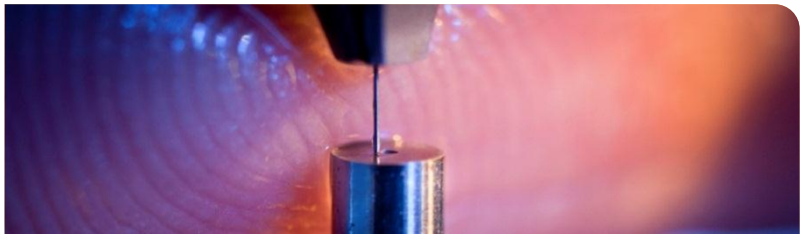
- History of micro machining at wbk
- Transfer of research results to industry
- New challenges
- Extensions in medical technology
- Further development

wbk Institute of Production Science
Micro Production MP

- Objectives: Process-reliable production, handling, assembly and quality assurance of and for micro mechanical components and targeted integration.

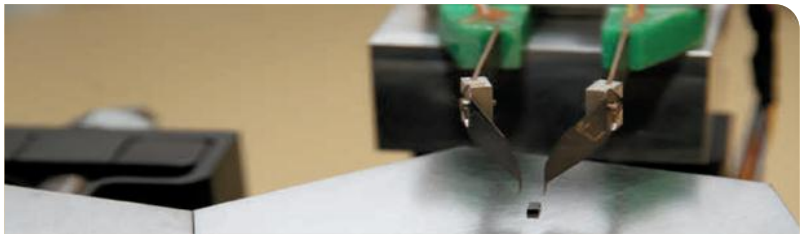
Process technology

- µ milling, µ EDM
- µ laser ablation
- µ molding



Machine technology

- µ assembly
- Handling
- Miniaturized machines



Process linkage

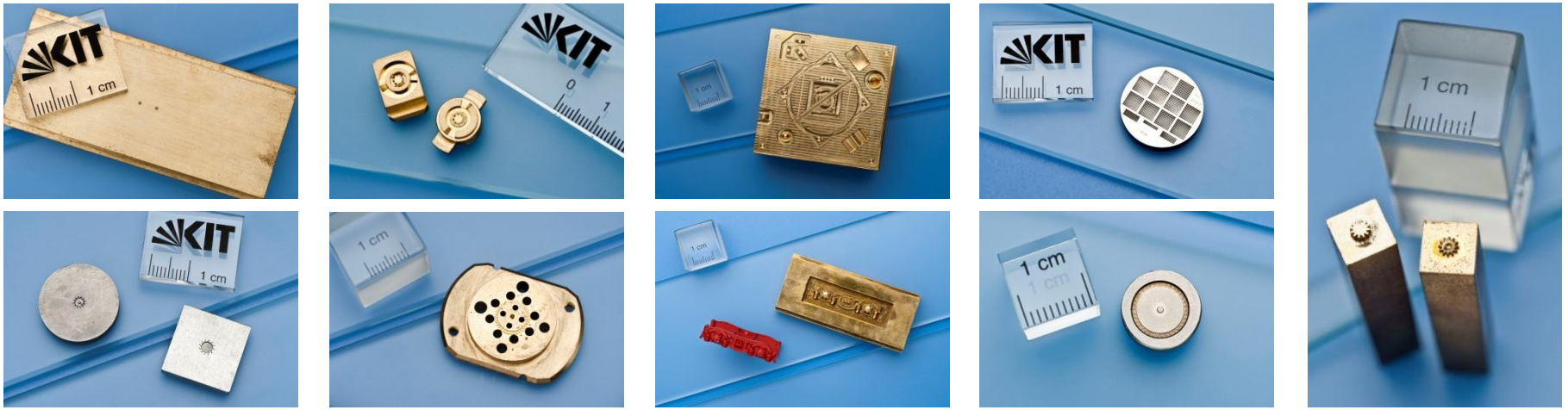
- Multi scale processes
- Method combination

Quality assurance

- Measuring methods and strategies
- Measuring data analysis
- Measurement uncertainty

History of micro machining at wbk
Collaborative research center 499

- Long history of micro machining at wbk by the CRC499
  Design, production and quality assurance of molded microcomponents made of metallic and ceramic materials
- The aim was to develop a process chain from prototype to mass production for micro-components made of metals and ceramics.
  - expand the range of materials for micro machining
  - reduce the geometrical dimensions
  - development of related manufacturing technologies, which can be used for prototype manufacturing as well as for mass production
  - indicate necessary requirements for a factory of micro machining



History of micro machining at wbk
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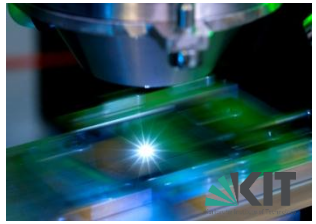
- *Manufacturing of micro molds - Primary structuring*

Milling

EDM

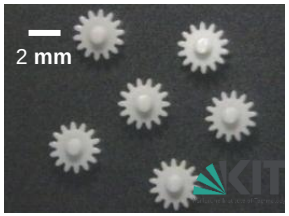
Laser ablation



Supply of large lot sizes by combining:
- primary structuring processes
- replicative processes

Replication: Micro powder injection molding (µPIM)

µPIM: ZrO_2 gears



Demonstrator: Micro planetary gear

History of micro machining at wbk
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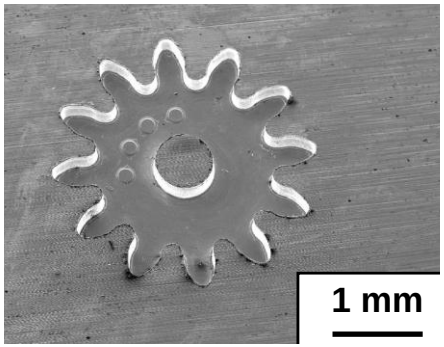
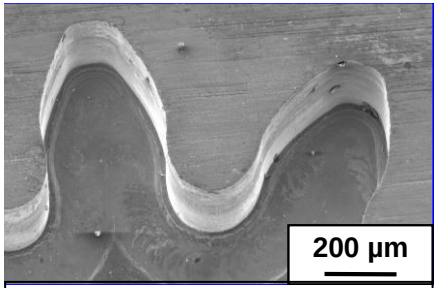
- Different advantages and disadvantages:

micro milling

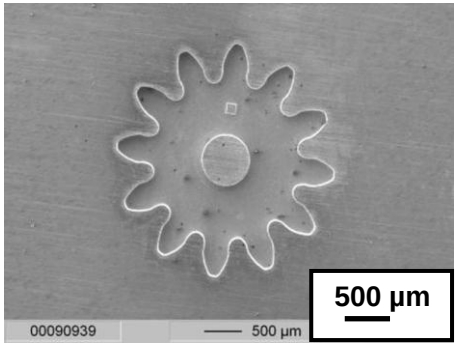


30CrMo6



+ removal rates
+ geom. flexibility
- hardness limited to 64 HRC

micro EDM



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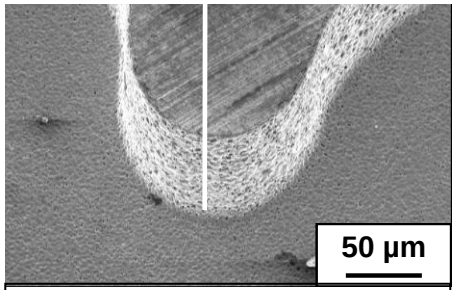
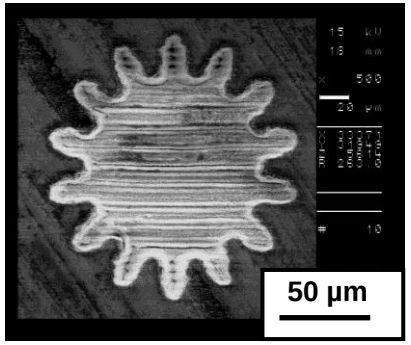
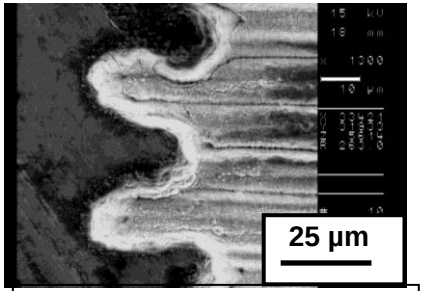


+ not limited in hardness
+ geom. flexibility
- removal rates

micro laser ablation



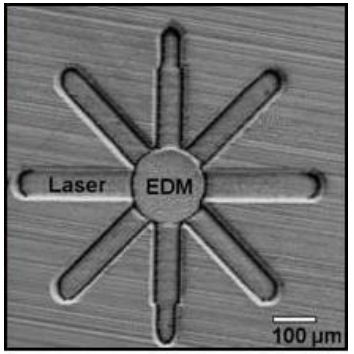
WC-12Co



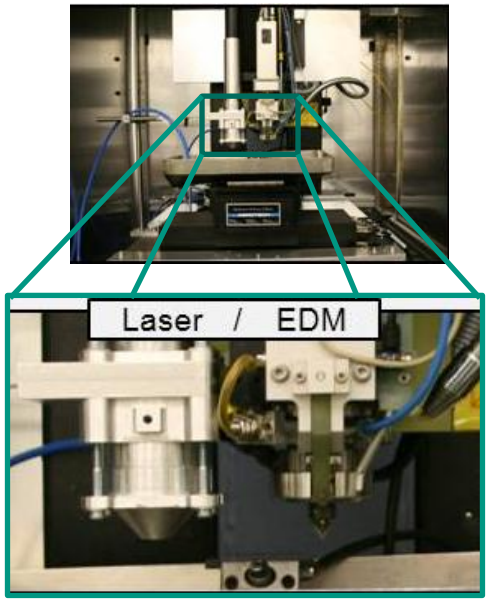
+ wide range of materials
+ miniaturization
- removal rates

History of micro machining at wbk
Collaborative research Centre 499

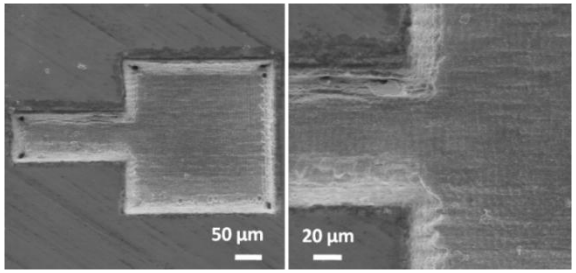
- In addition to a process optimization, different processes such as laser and electrical discharge machining were combined.
  - Advantages of the combination
    - Higher precision
    - More speed
    - Lower costs
- Optimization of the mold inserts



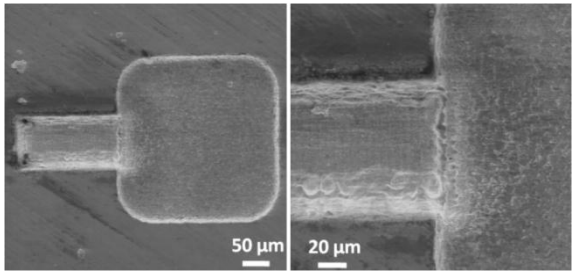
	only laser	only EDM	combination
total time	22.4 min	impossible	9.63 min
total cost	19.49 €		9.75 €
time saving			57 %
cost saving			50 %



pure laser ablation

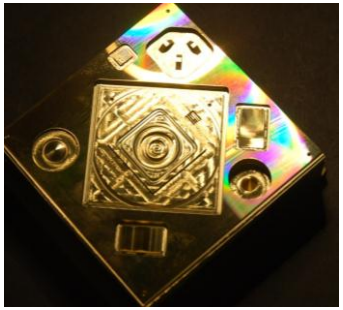


combination of laser with EDM

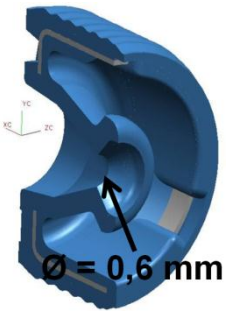


Transfer of research results to industry
CRC 499 transfer project T6

- Development of a method for effort optimized process chains
- Transferring micro manufacturing knowledge from the CRC 499 into companies
- Comparing several CAM-programs with a test work piece

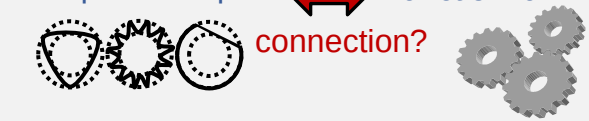


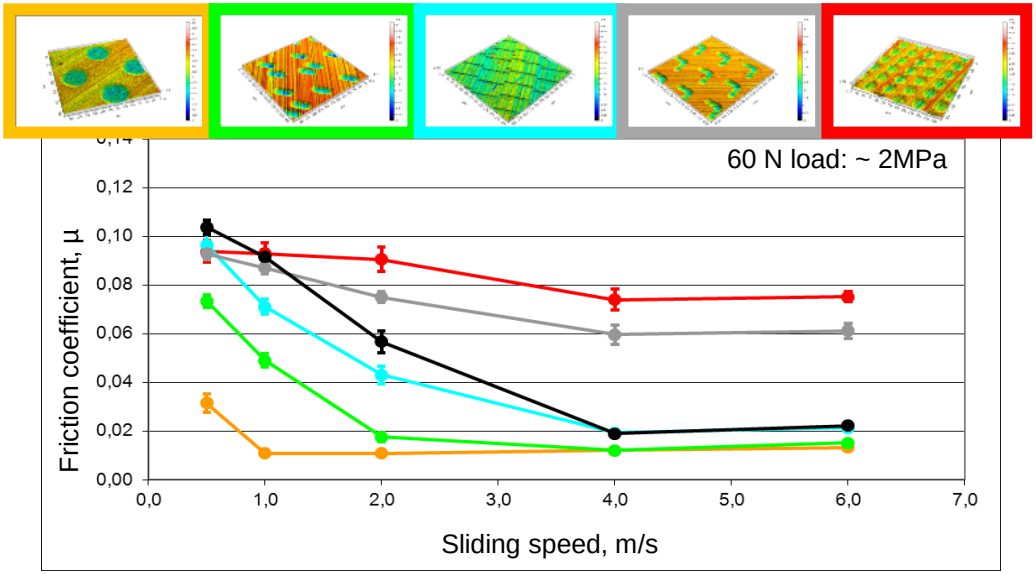
- Challenge: manufacturing one part often with small tolerances
  - Developing a process chain for molded die inserts
- Challenge: manufacturing many parts infrequently
  - Developing a process chain for several molded parts
  - Developing a process chain for plastic, metal and ceramics
  - Detecting the break-even point between casting and machining



Transfer of research results to industry
FunkProMikro

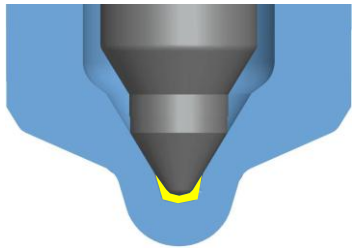
- Function-oriented micro-controlled manufacturing processes
- Development of methods and strategies for describing the function-oriented allowable shape variations
- Find causal relationships between the work piece shape and function fulfillment
- Through modular solutions, the results are transferable to similar processes and products



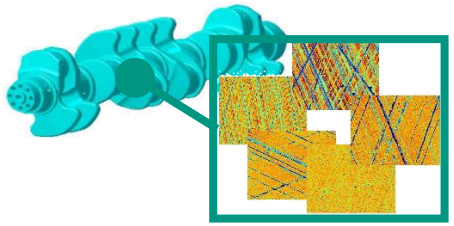


Demonstrator:

Holes in injection nozzles

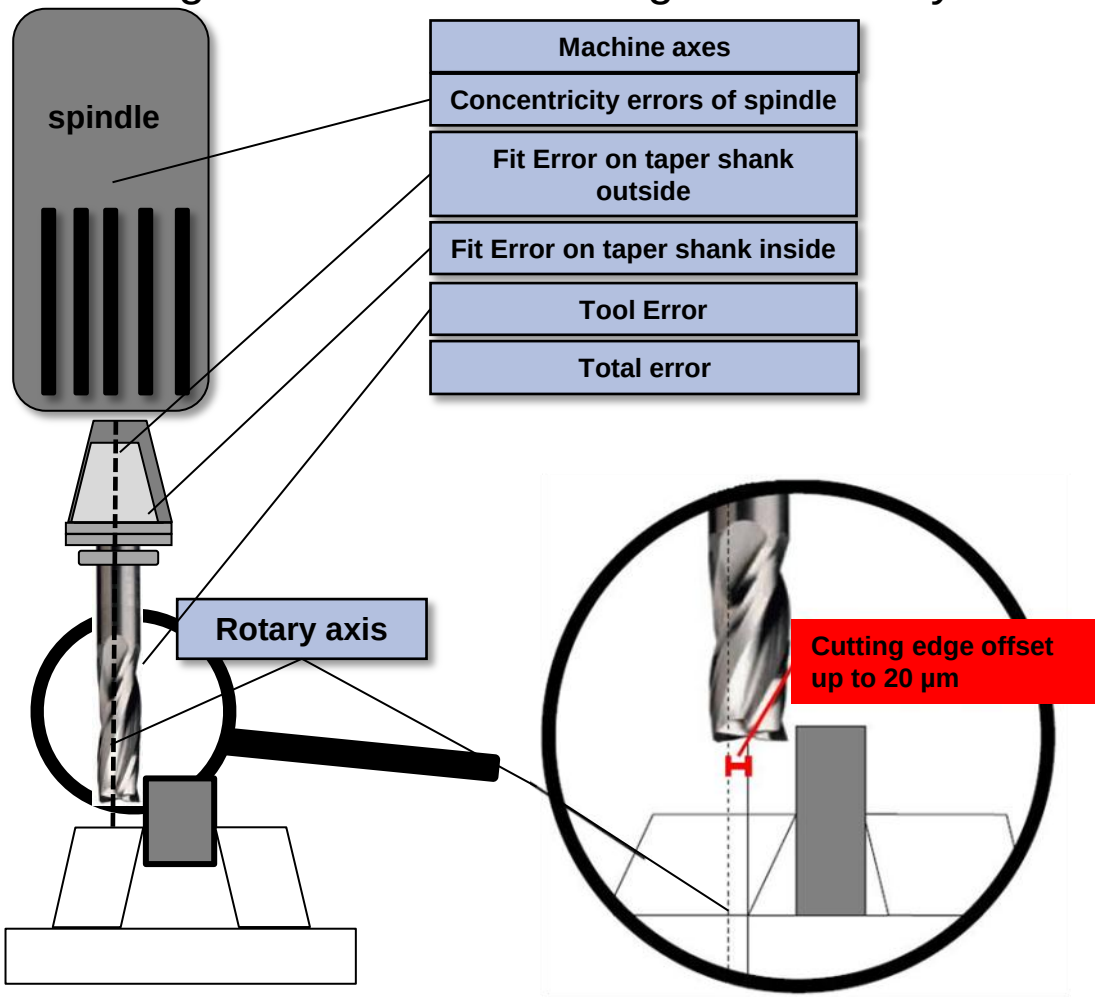


Crankshaft bearing seats



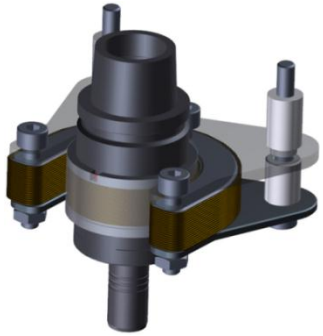
Transfer of research results to industry
Hydrospan

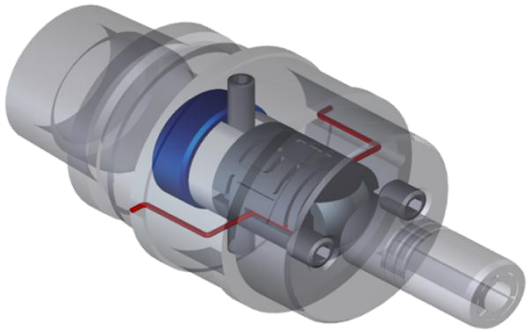
- Big share of manufacturing errors in micro milling is caused by radial run-out

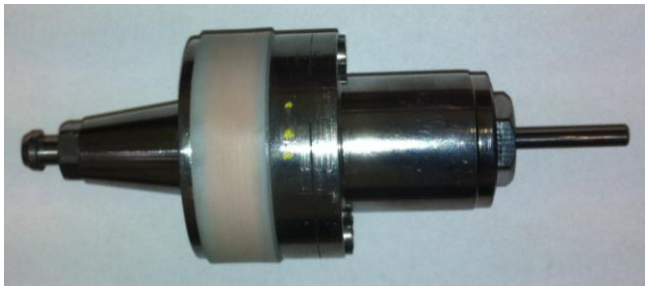


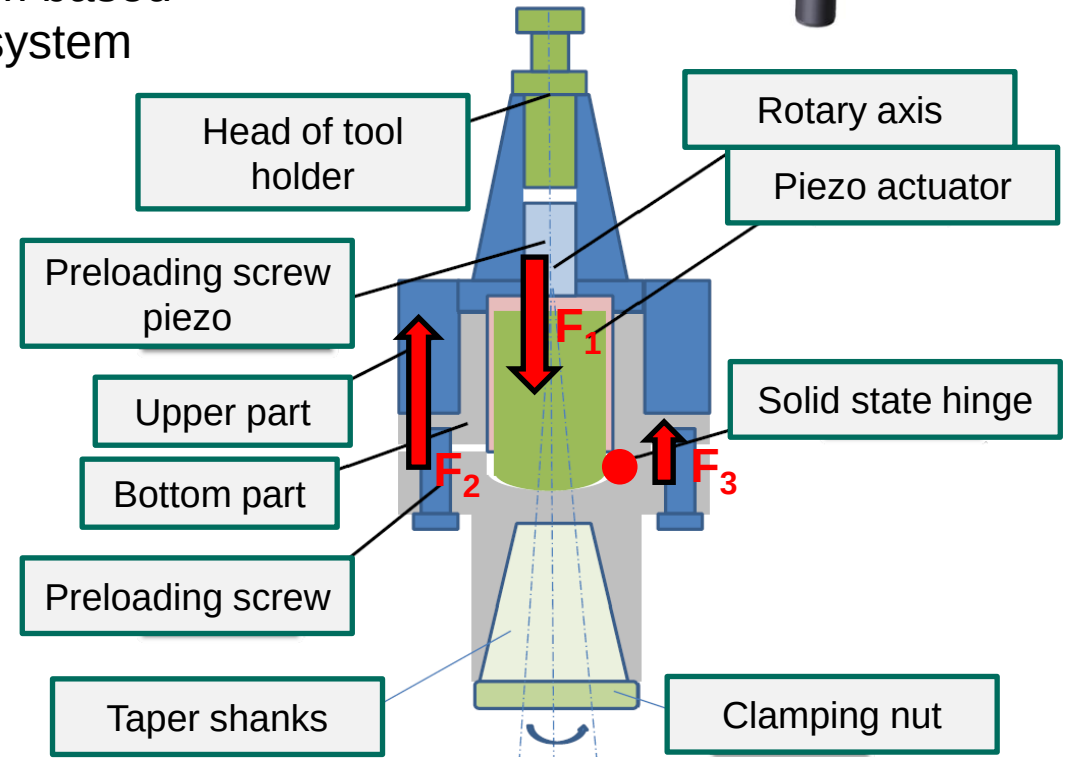
Transfer of research results to industry
Hydrospan

- Implementation of an efficient and precise, low-vibration mechatronic system consisting of a hydrostatic spindle, and a mechatronic automated adjustable clamping system.
- The adjustable clamping system based on a HSK 25 Tribos clamping system



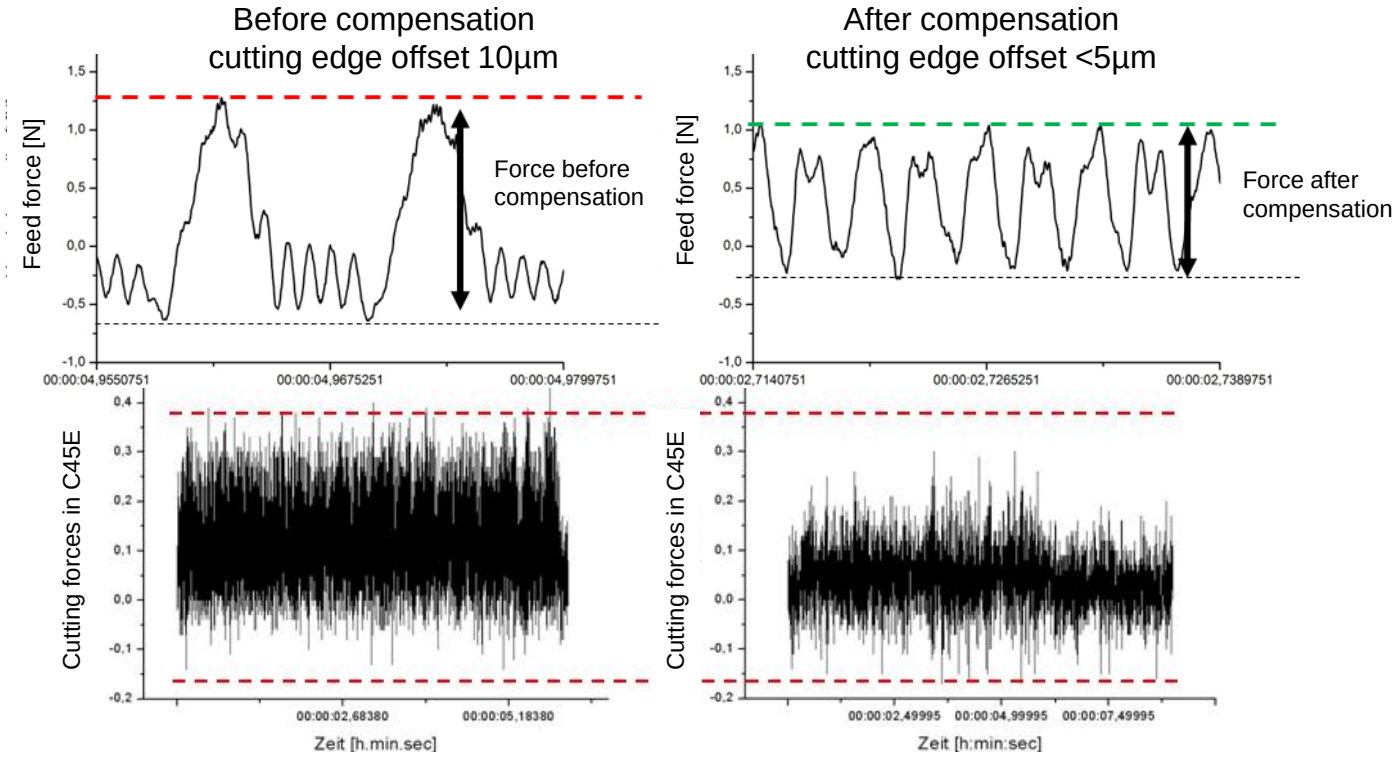




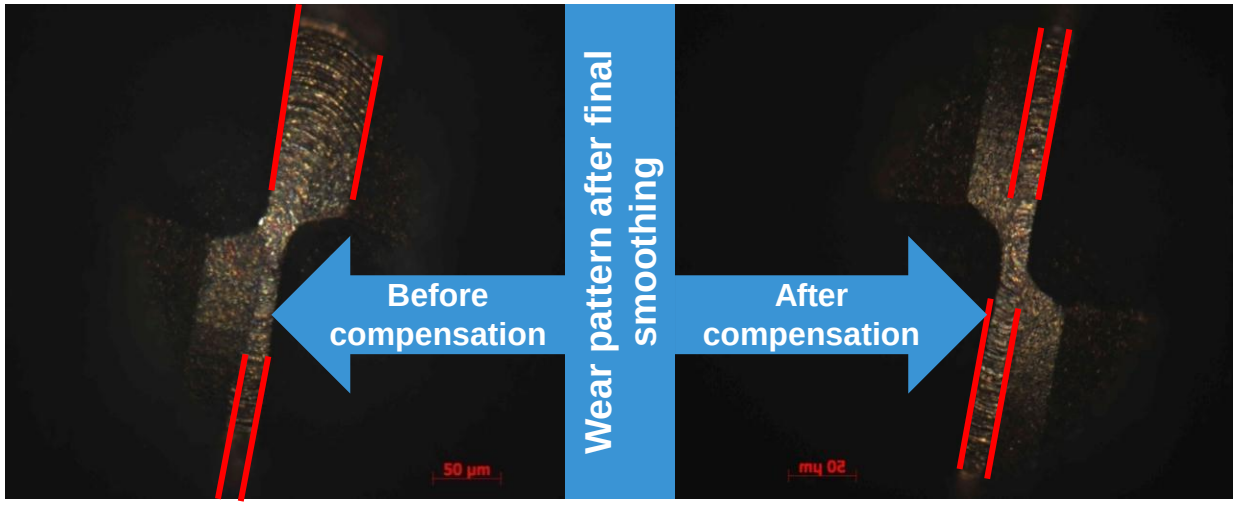


Transfer of research results to industry
Hydrospan

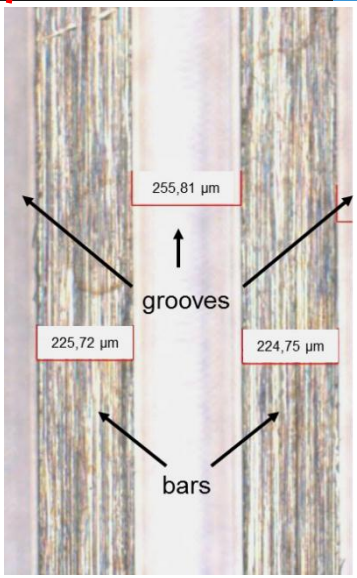
- A significant reduction of cutting forces are possible (for example up to 40%).
- Reduction of cutting edge displacement increases accuracy, process stability and life of micro milling cutter.
- Time to implement the mechatronic compensation <10 sec.

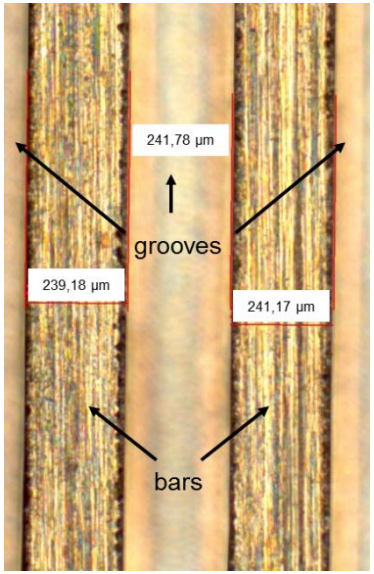


Transfer of research results to industry
Hydrospan



255,81 µm wide groove is almost 16 µm larger than desired.



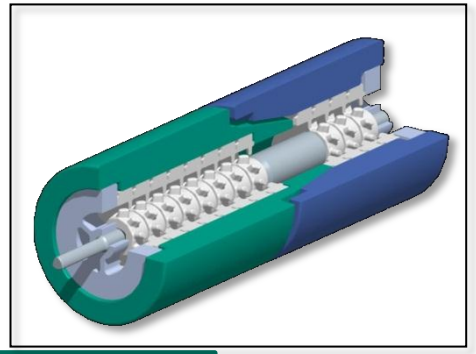


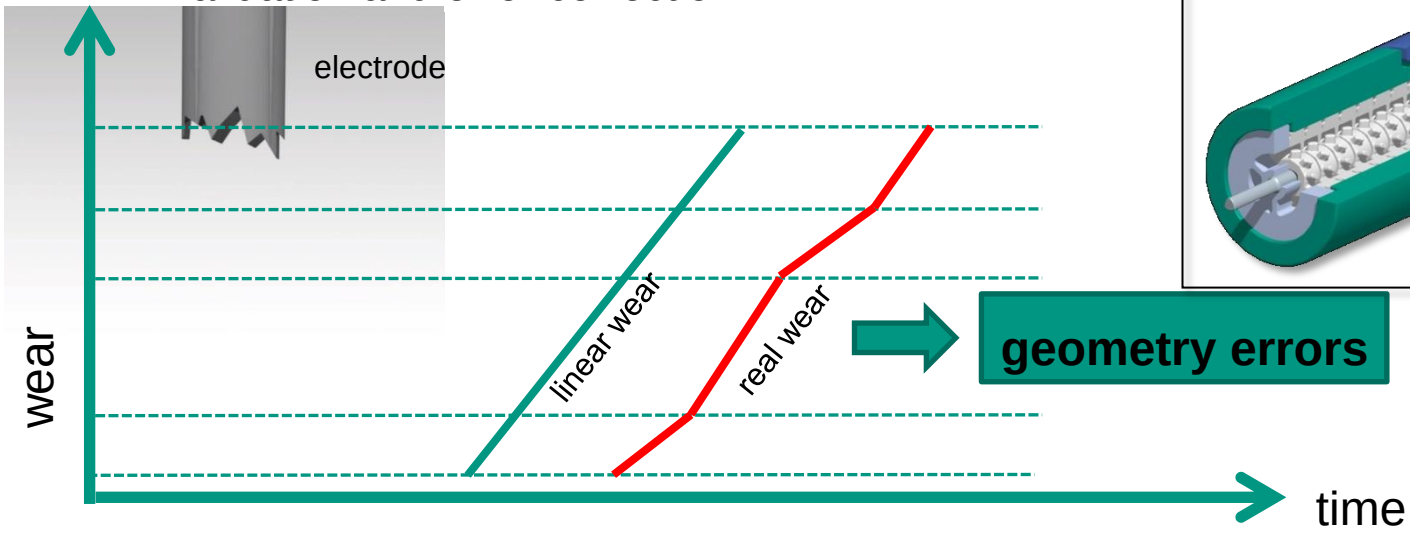
Compensation of the cutting edge displacement leads to tolerances of about 1-2 µm.

New challenges I
Control unit for EDM-milling

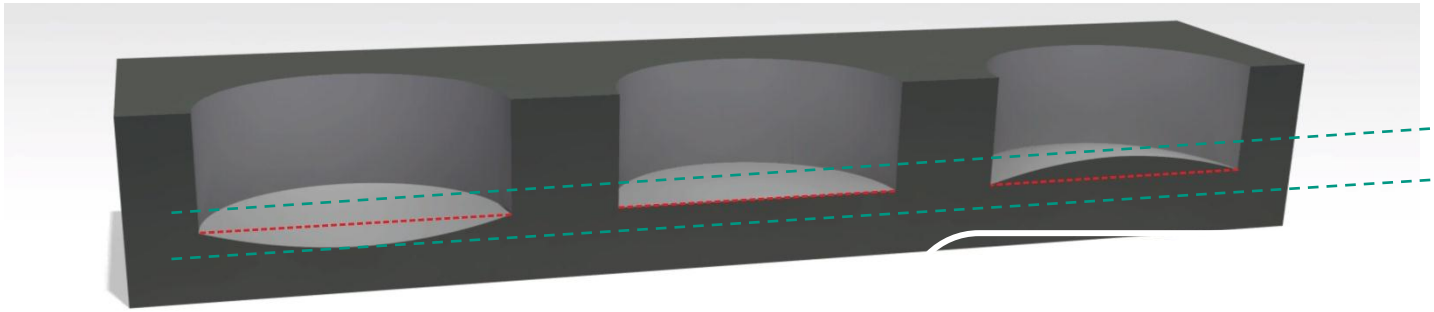
- Electrode material wears during processing
- Inconsistent wear due to material inhomogeneity changing flushing conditions in the working gap and depth of erosion
- Electrode wear must be compensated automatically to produce dimensionally accurate target geometry can
  - EDM machine equip with scanning sensor
  - Confocal white light sensor for acquisition of geometry errors
  - Software implementation for automatic geometry validation and error correction

Micro turbine demonstrator





New challenges I
Control unit for EDM-milling

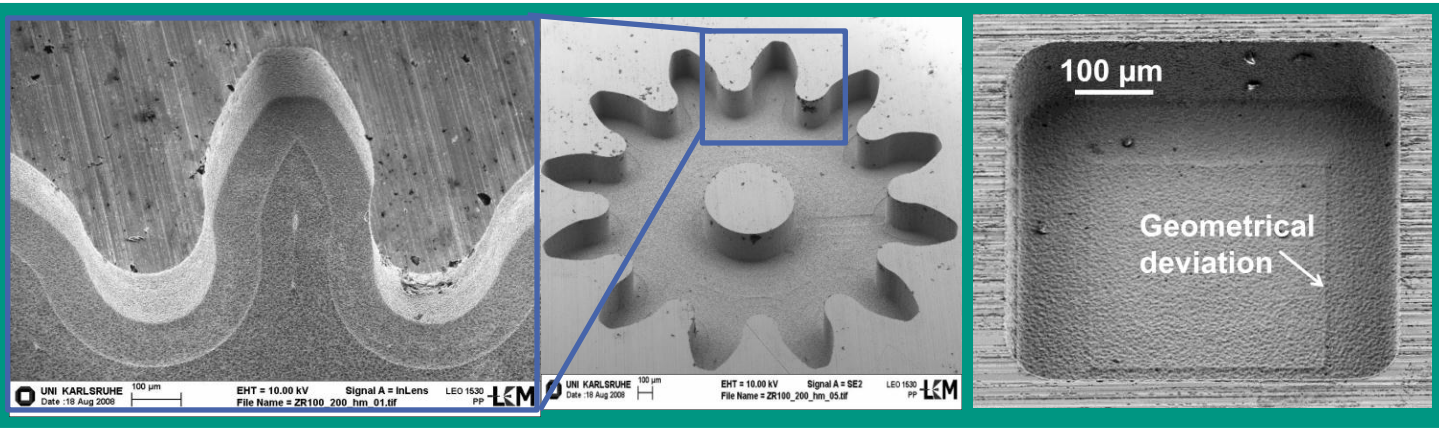


Wear compensation too high
- ➢Cavity too deep
- ➢Surface concave
- ➢Irreparable damage

Correct wear compensation
- ➢Target depth
- ➢Flat surface

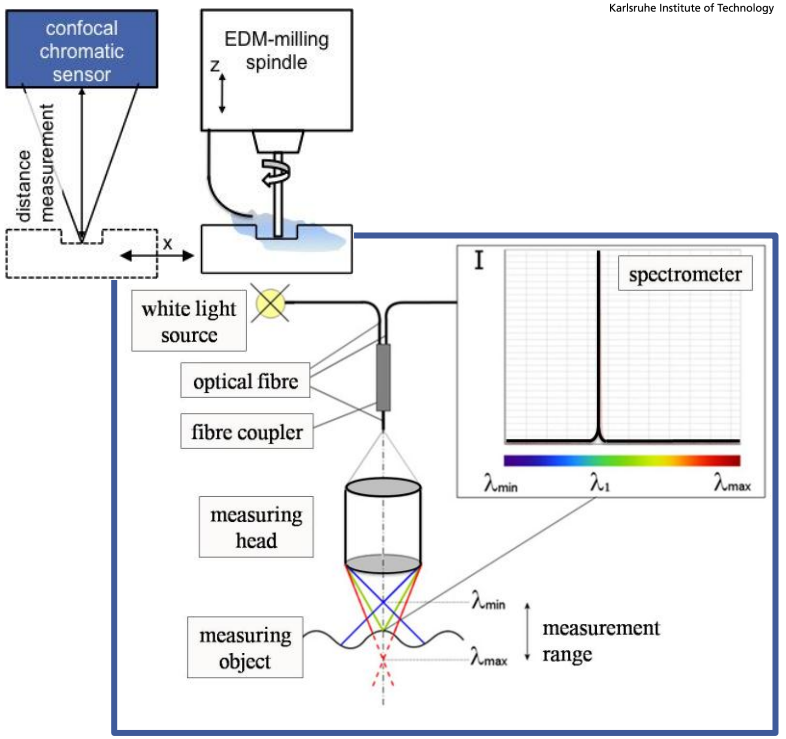
Wear compensation too low
- ➢Cavity not deep enough
- ➢Surface convex
- ➢Reworking process possible

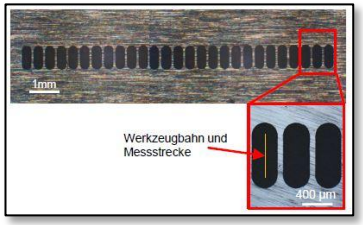
geometry deviation



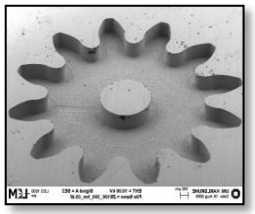
New challenges I
Control unit for EDM-milling

- Quality control circuit
  - Creation of CAM data
  - Automatic parameter determination
  - Production of the cavity
  - Measurement of the cavity
  - Compensating the difference geometry
  - Final measurement



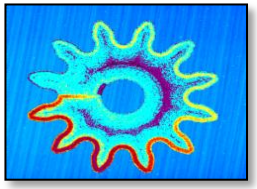


parameter determination

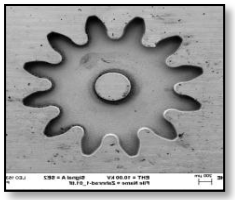


production

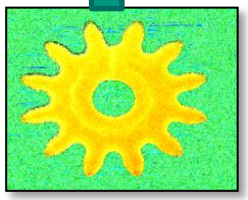
QR-loop



measurement



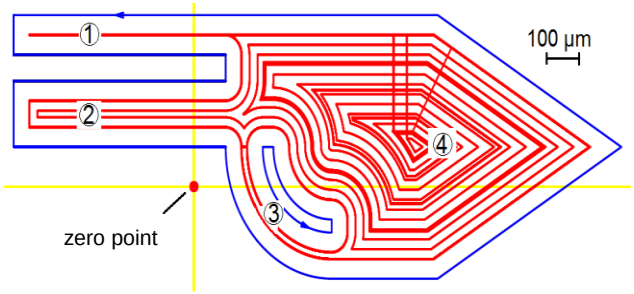
reprocessing

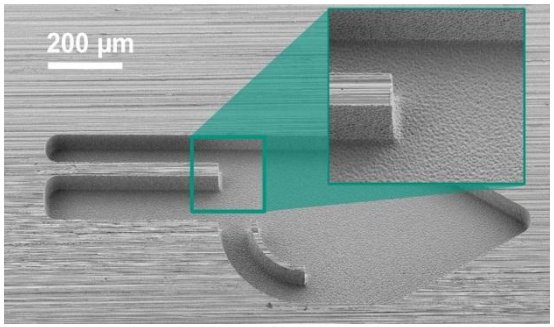


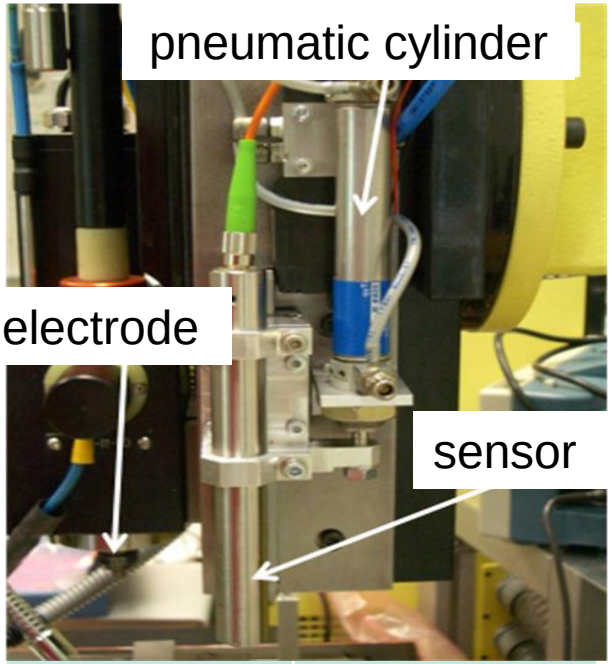
measurement

New challenges I
Control unit for EDM-milling

- Abort criteria were reached after 5th process loop
- Maximum deviation of manufactured depth: 2 µm
- Maximum deviation of waviness of the surface:1 µm (range of the achievable surface roughness)





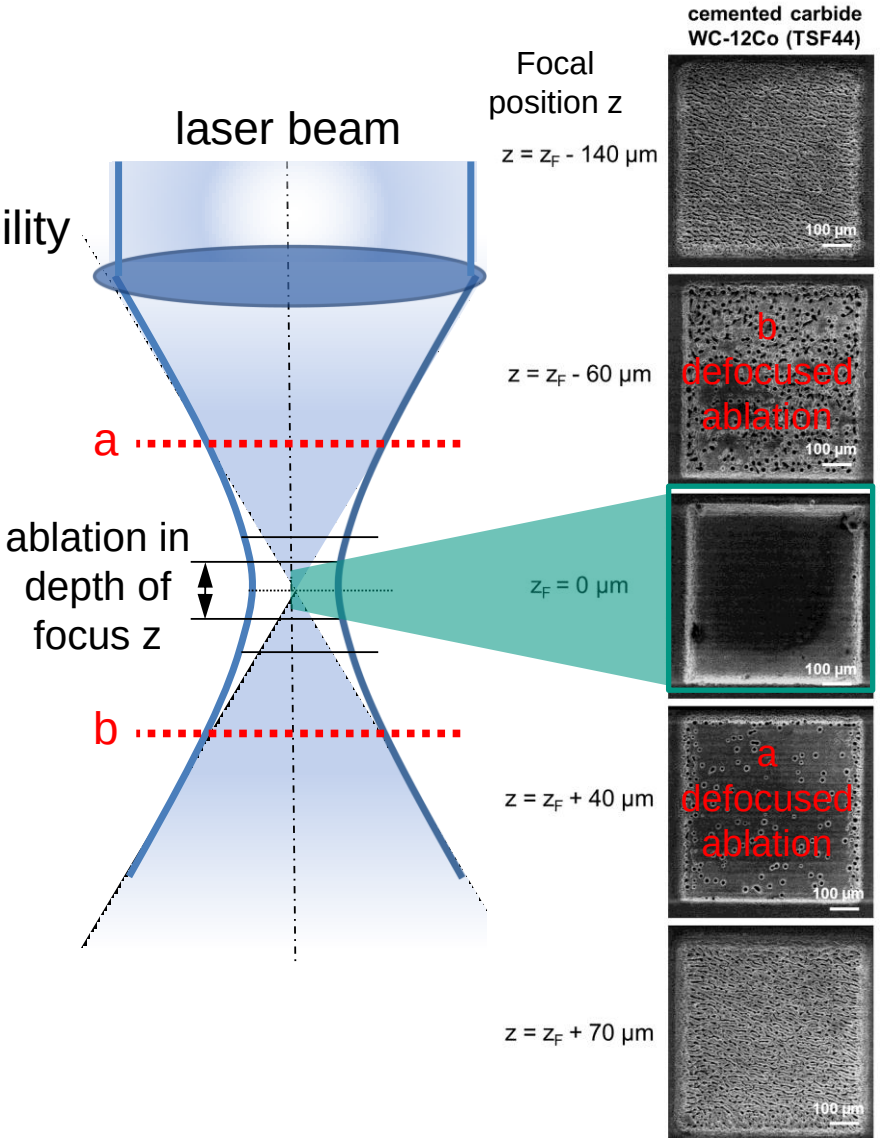


resolution	50 nm
focus spot	Ø 5 µm

New challenges II
Acoustic control for laser ablation

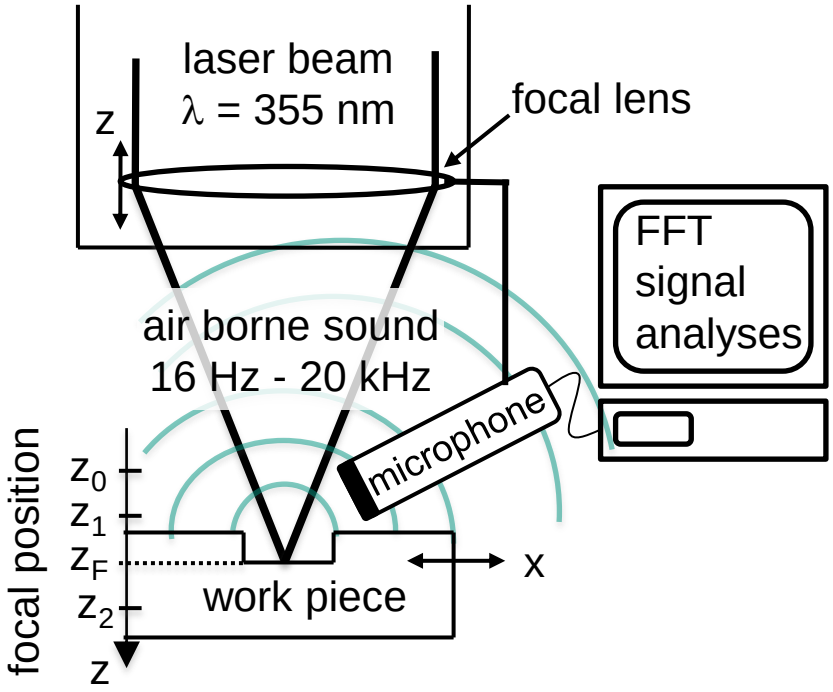
Specific challenges in 3D laser ablation with UV-lasers

- Process stability, reliability and repeatability
- Knowledge of focal position is of particular importance
  - Sublimation occurs in depth of focus z
  - Defocused ablation can lead to melt, cracks, pits and bad surface quality
- Objective and repeatable determination of focal position for various materials and surface conditions



New challenges II
Acoustic control for laser ablation

- Focus position must be placed into working area zA (sublimation)
- Focal search is problematic for varying optical properties optical (ceramic: white, glass: transparent, polymer: black)
- Positioning of laser focus into working area zA = zF □ 20 µm by detection of acoustical air-borne sound emission
- Approach:
  - Signal acquisition
  - Signal processing (FFT)
  - Signal analysis
  - Control of laser position

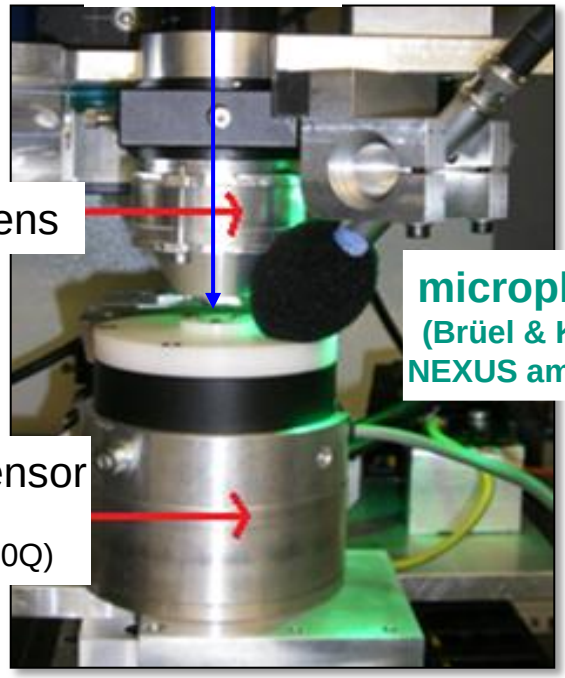


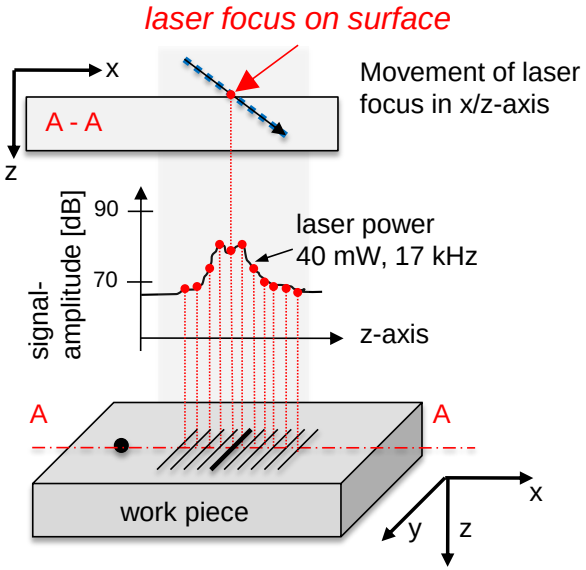
Prof. Dr.-Ing. J. Fleischer, Prof. Dr.-Ing. G. Lanza, Prof. Dr.-Ing. habil. V. Schulze

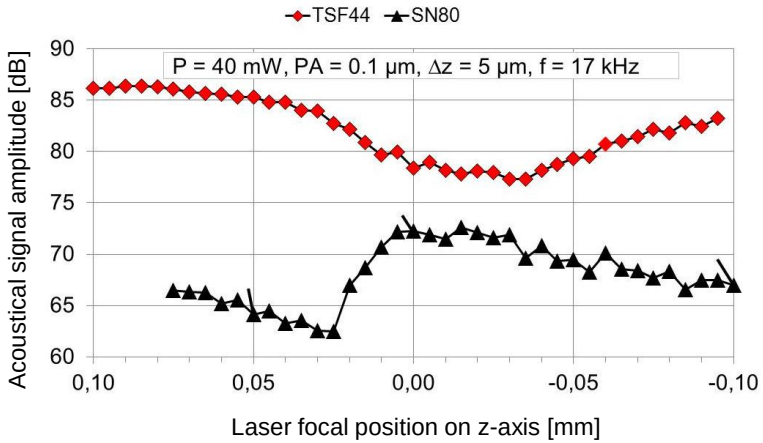
New challenges II
Acoustic control for laser ablation

Result: Validation by 15 tests on WC-12Co

- Max. deviation zOF to zAF
  = 6.9 µm < tolerance of +/- 20 µm
- Acoustic criterion for focal positioning
  (zAF ≈ zOF): search of local minimum

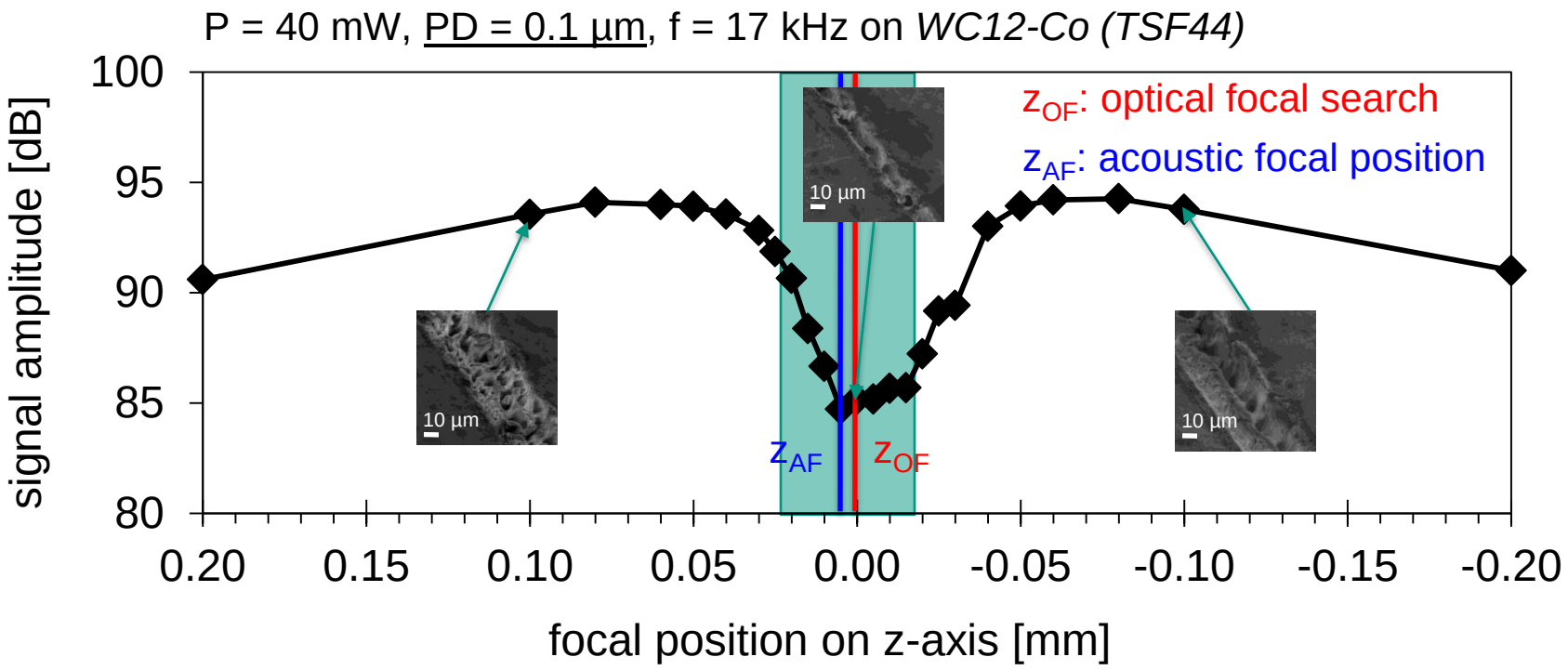






Acoustical signal amplitudes for WC12-Co (TSF44) and Al_2O_3-ZrO_2 (SN80)

New challenges II
Acoustic control for laser ablation

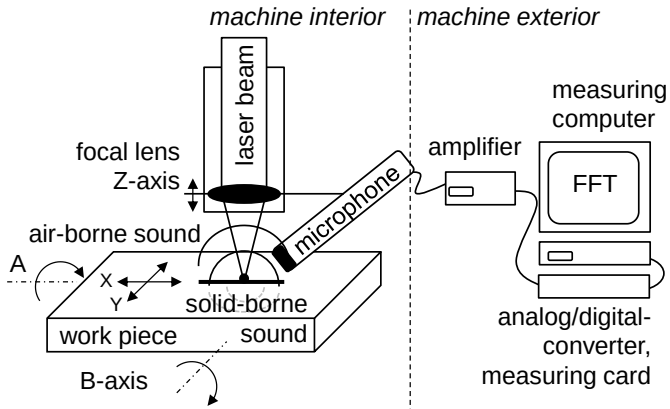


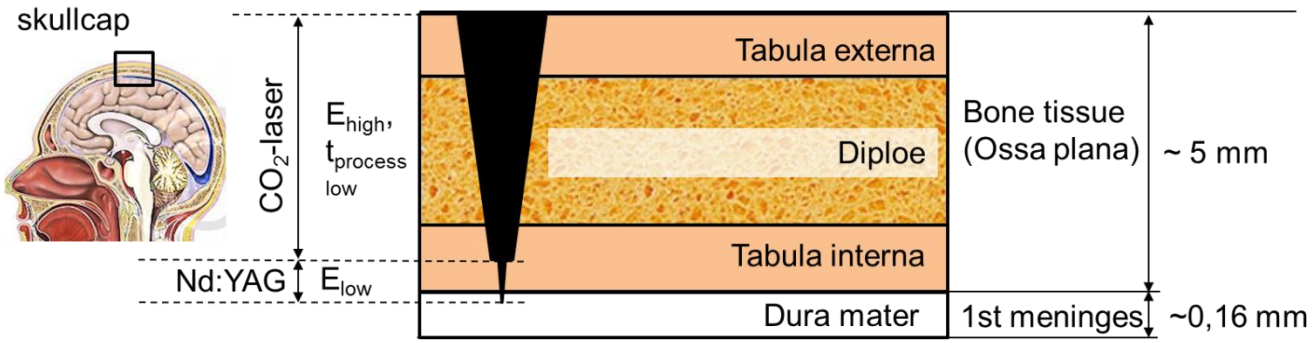
Extensions in medical technology
Bone cutting by laser

Advantage of laser application in scull base surgery

- reduction of trauma for patients
- no mechanical forces act on patients
- no sterilization of tools needed (contact free ablation)
- high flexibility

- Challenge is the depth/transition control: bone to soft tissue
- Abort criterion for transition area is needed



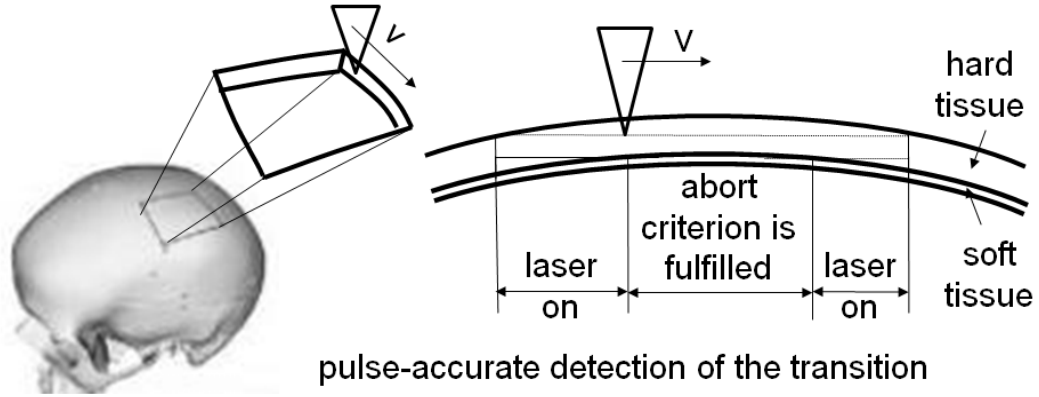


Extensions in medical technology
Bone cutting by laser

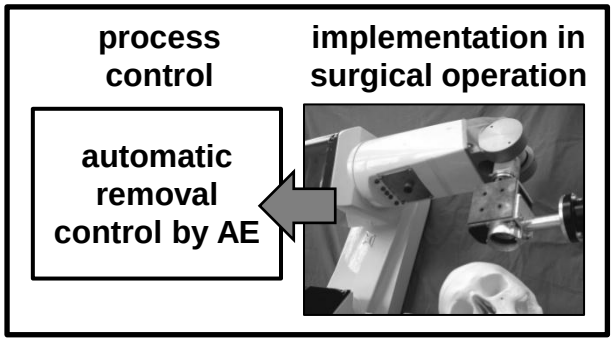
Acoustic approach

- Different AE for bone and soft tissue (after FFT)
- Cooperation with
  Institute for Process Control and Robotics (KIT)
  Department of Oral and Maxillofacial Surgery
  (Heidelberg)

- Using this control system, the meninges should be as spared as possible. This happens thanks to a selective turning on and off of the laser ablation.



pulse-accurate detection of the transition



Thank you for your attention!

Prof. Dr.-Ing. habil. Volker Schulze
Manager of Manufacturing and Materials Technology

Kaiserstr. 12, 76131 Karlsruhe
Tel.: +49 721 608 **42440**
Volker.Schulze@kit.edu
www.wbk.kit.edu