# Multi Axis Machining of Ultraprecision Parts

MIC -2022 (Module Works Insider Conference)

LT Ultra-Precision Technology GmbH

www.lt-ultra.com

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LT ULTRA
OUR PROFESSION IS PRECISION

# Content

- Introduction
  - About LT-Ultra
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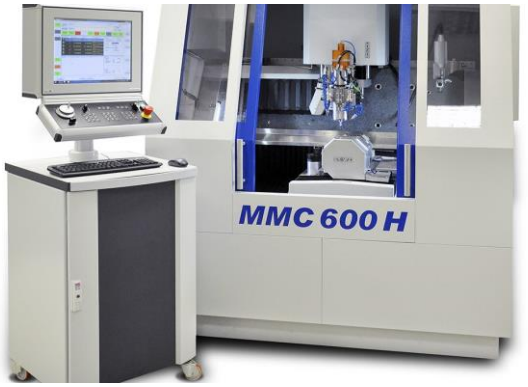
  - UP-Turning
  - CAM on Machine

# About LT-Ultra

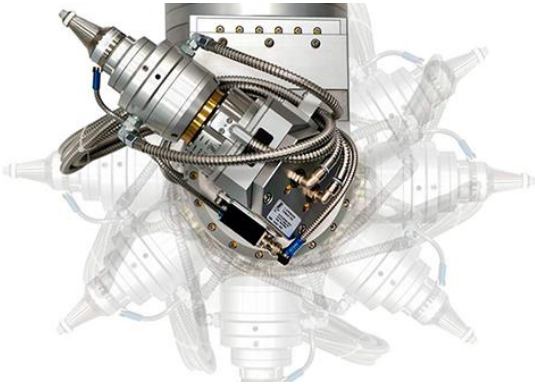
- Since 1995 in Aftholderberg
- Family-owned
- ~9000 m² production floor
- ~130 Employees


# About LT-Ultra

- UP-Machine
- UP-Components (Spindle, Axis, …
- Interferometer
- Shopfloor > 30 UP-Machines
- Beam Delivery Components







# What is Ultra Precision (UP)?

- Highest form and positioning accuracies << 1 µm (0,001 mm)
- High optical surface quality Sa <<10 nm (0,00001 mm)
- Micro/ Nano structuring if necessary

→ Low cutting volume and forces

→ Typical UP-Turning / UP-Milling / UP-Planing

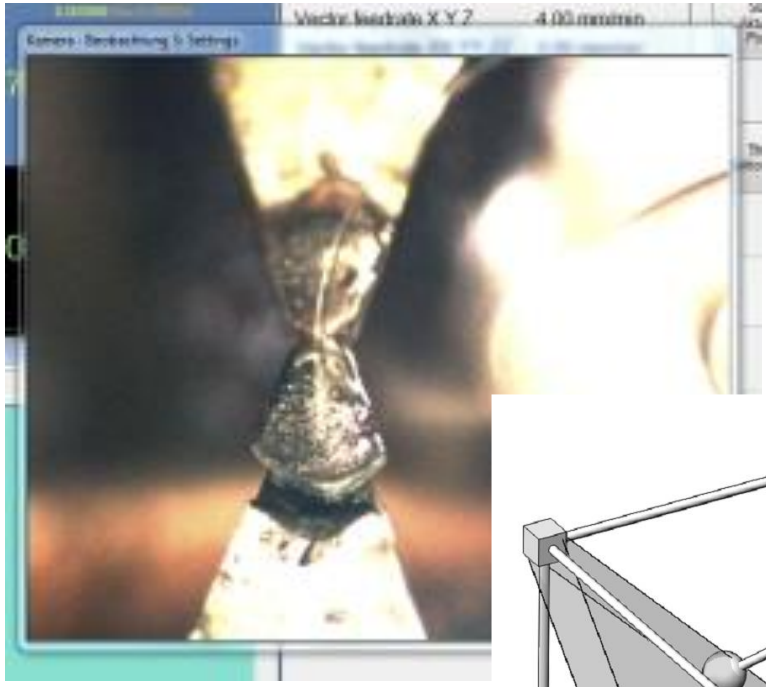


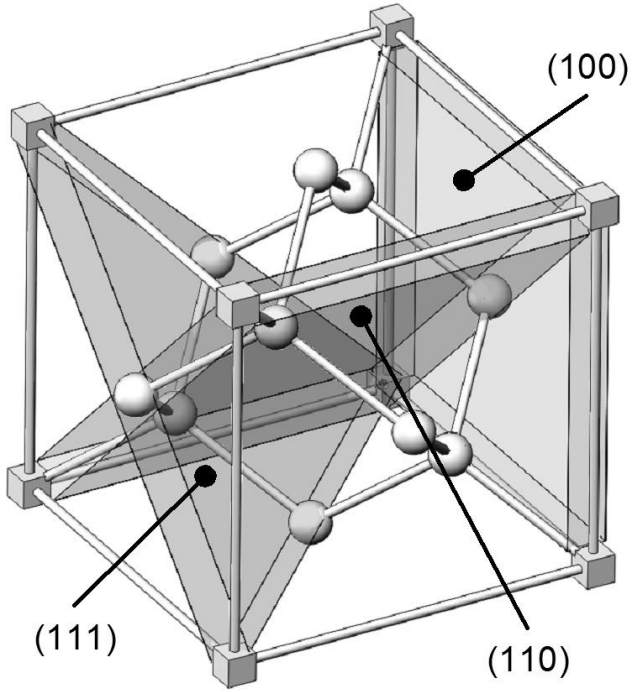
[1,2]

# How do we achieve UP Quality?

**Tools:**

- Monocrystalline diamond tools
- Beneficial anisotropy of diamond
- geometrically determined cutting edge
- Very low cutting radius (30 -80 nm)



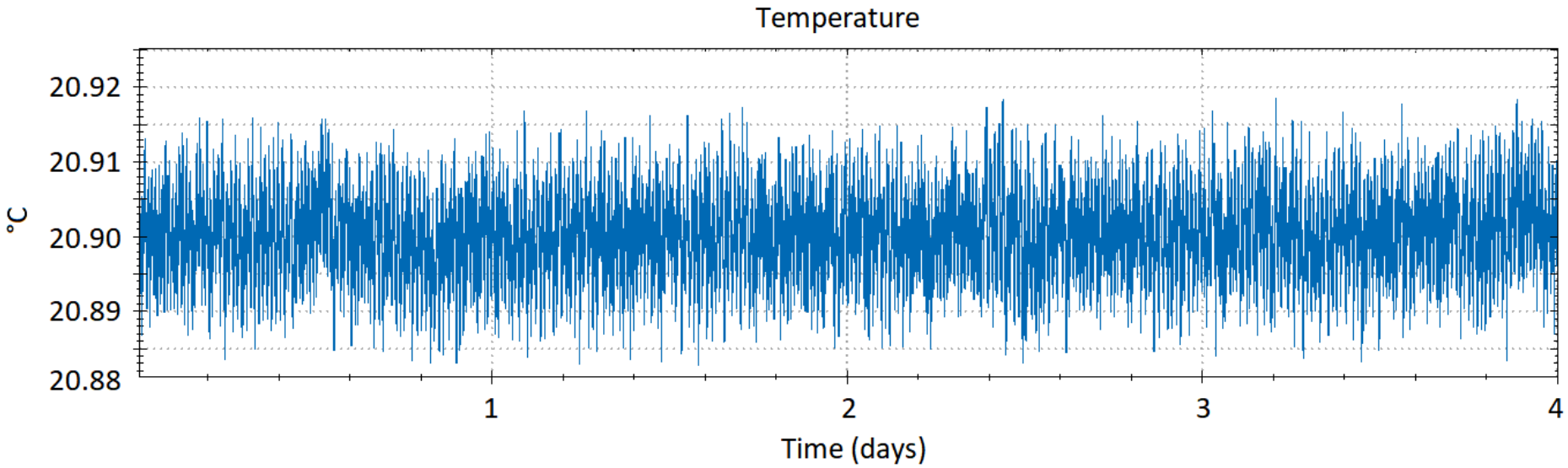





[1-4, 6-8]

# How do we achieve UP Quality?

- UP-machines:
  - Low cutting force [<< 1 N]
  - Low Vibration [granite base, isolation systems,…]
  - Very low temperature fluctuation [+/- 20 mK (+/-0,020 K) or better]



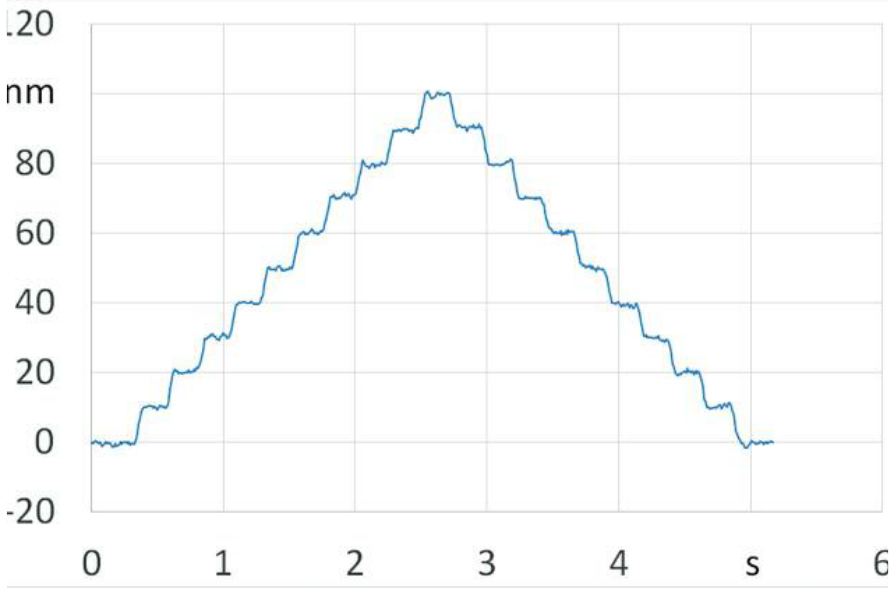



[1-4, 6-8, 13]

# How do we achieve UP Quality?

- UP-machines:
  - Contact free bearings [e.g. hydrostatic bearings, high stiffness]
  - Direct drive + glass scale [No stick-slip]
  - Path deviation [ ~ 8 pm (0.000000008 mm) resolution]
  - High Position accuracy [<< 10 nm (<< 0.00001 mm) ]
    → minimal chip size

  - Experience:
    Since our founding in 1995
    we only focused on UP-Technology



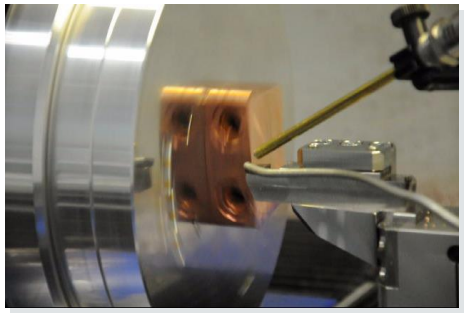


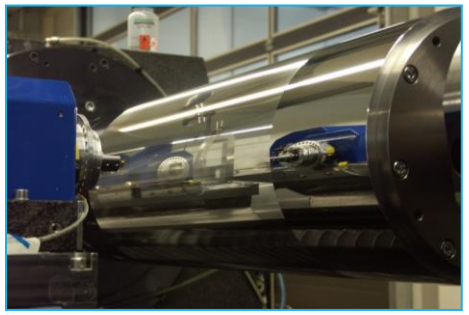

[1-4, 6-8]

# UP-Machines

- „ALL“-Kind of UP machines
  - UP-milling
  - UP-turning / UP-drum-Turning
  - UP-grinding
  - UP-polishing
  - Engraving
  - Measure machines
  - CUSTOMized

- WP from mm to m size
- equipment for automation and in line measurement

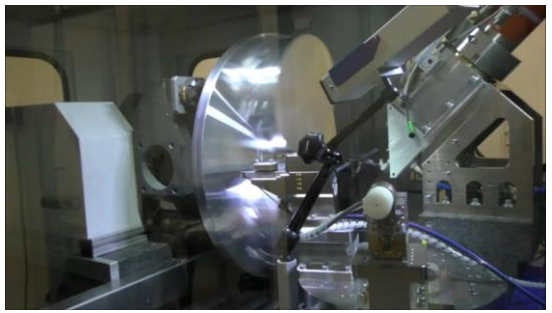



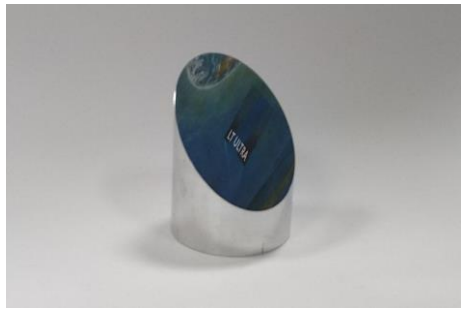

# UP-Turning – Aspheric mirrors

- UP-Turning (no grinding or polishing)
- Shape according the aspheric equation
- Also Off-Axis / Freeform

- Shape < 80 nm / 100 mm (typical)

- Roughness ~1-2 nm (Sa)
- Reflective coatings (if necessary)

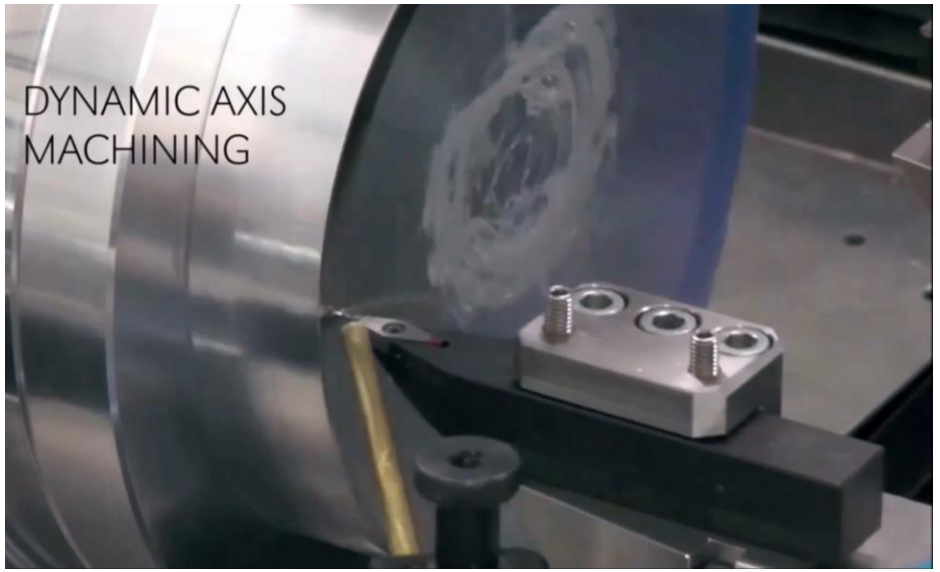


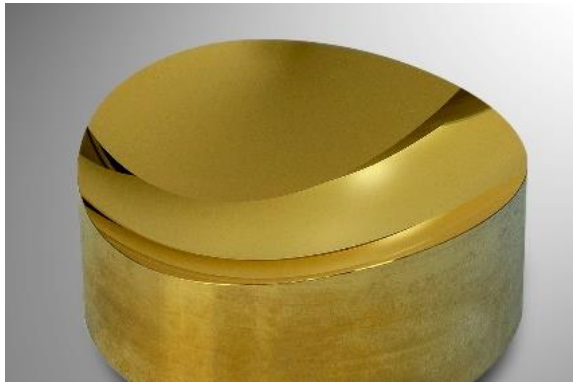


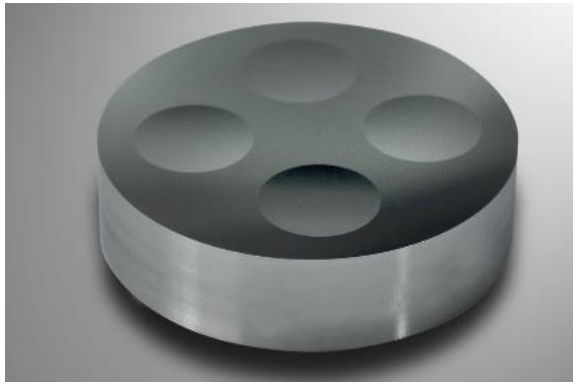

# UP-Turning – Freeform

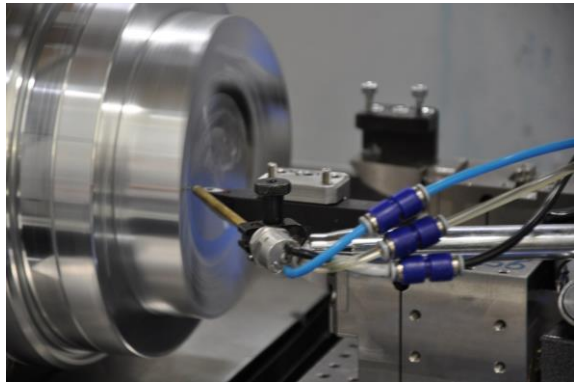
- DynamicAxisMode (SlowTool machining)

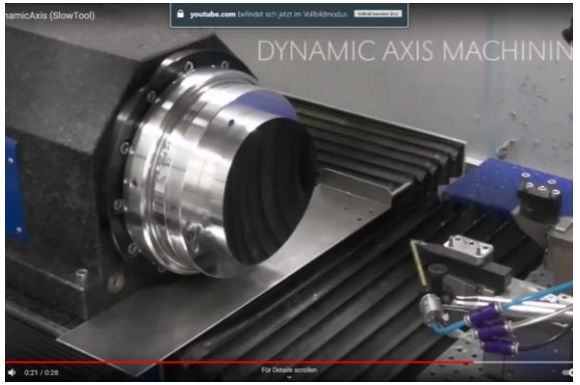
- UP-Machine with additional C-Axis
  - C-Axis speed typical < 100 rpm





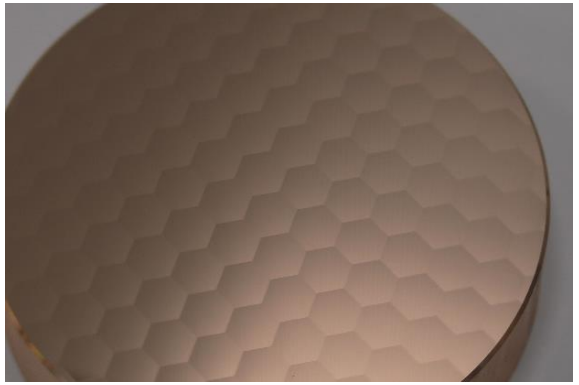


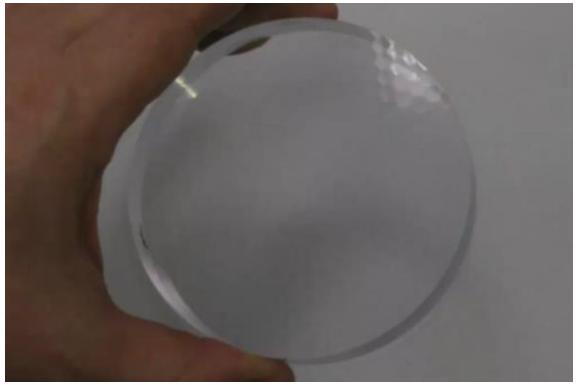


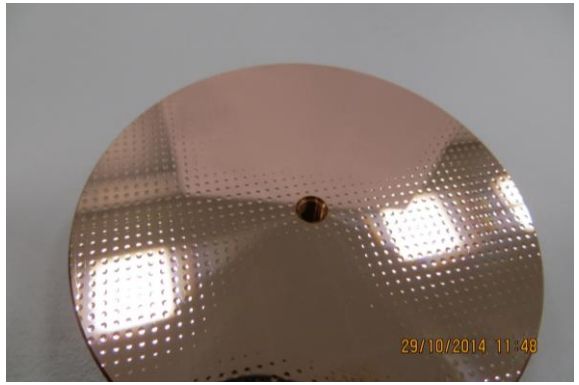
# UP-Turning – Freeform

- Freeform machining with FastToolAxis (W)
- Additional C-Axis

- Higher spatial frequency
  - Depending on setup (Piezo / Voice-Coil/…)







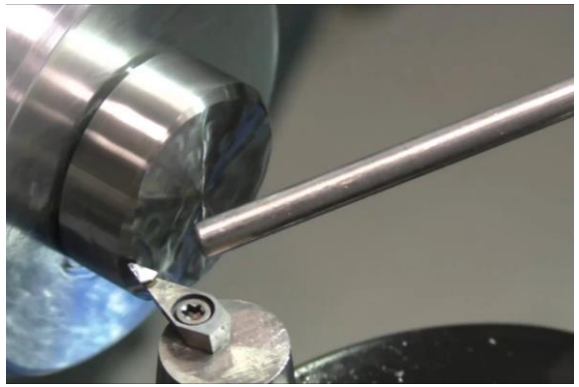


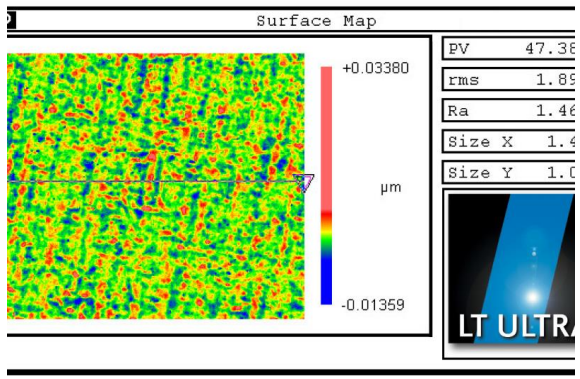


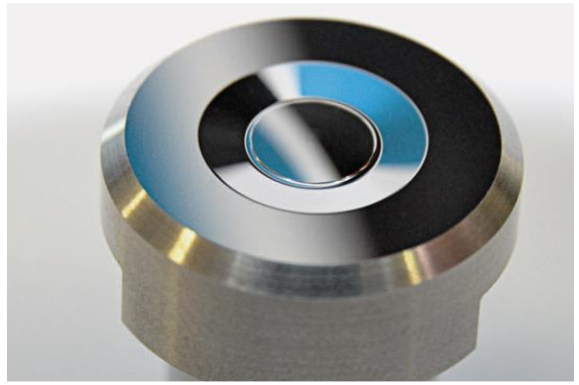
[6,7,12]

# UP-Turning – Steel

- Diamond turning in steel
  - Ultrasonic assisted, special setup
  - Carbon affinity reduced
  - Roughness ~1-2 nm (Sa)
  - Freeform
  - Also in glass (e.g. BK7) or Si

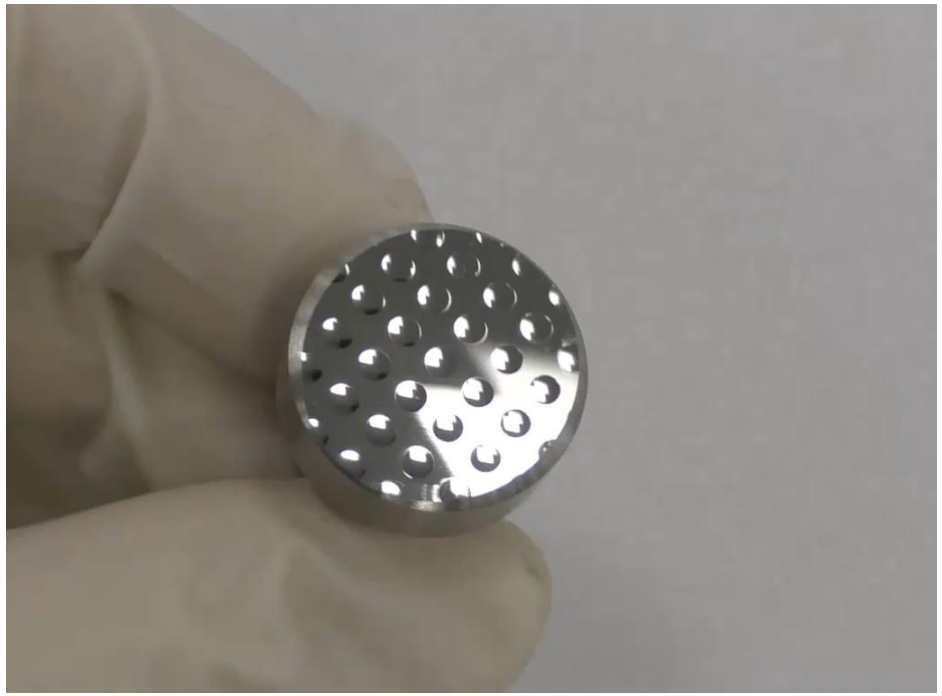


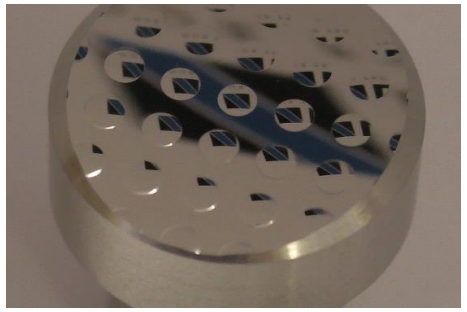


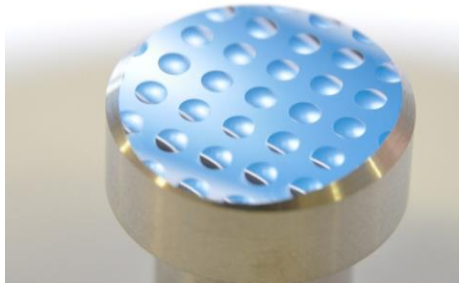



# UP-Turning – Seel, Example

- Primary profile (Toroid)
  - WP Ø 19 mm
  - Toroid Sag 0.9 mm
- Lens array (convex)
  - Ø 2 mm
  - Rad. 10 mm
- Sa ~ 1.5 nm (in steel)

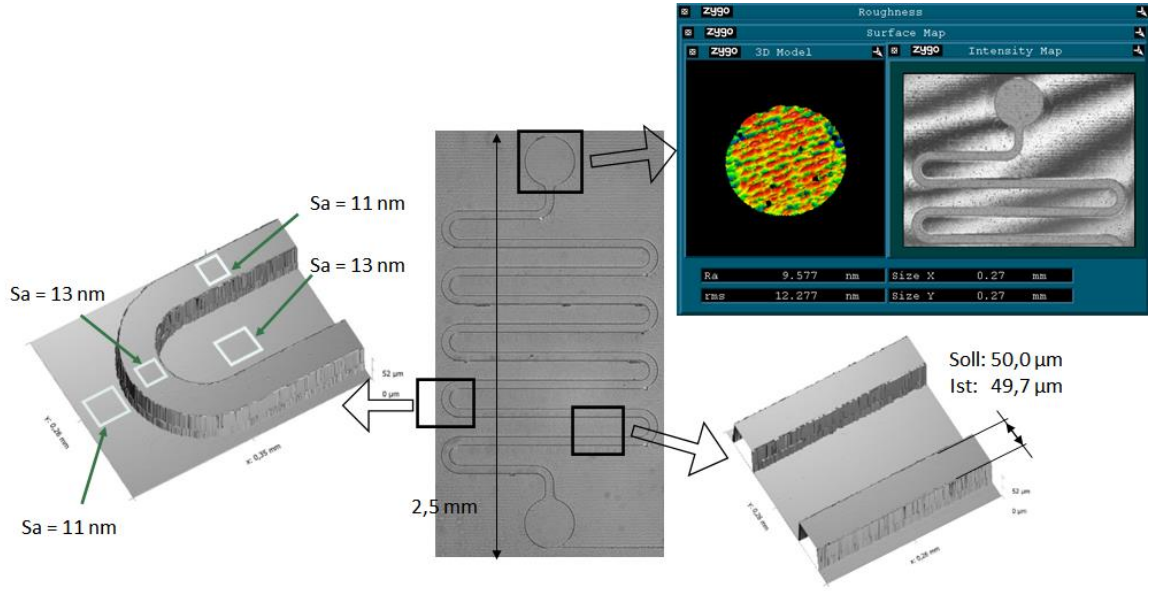


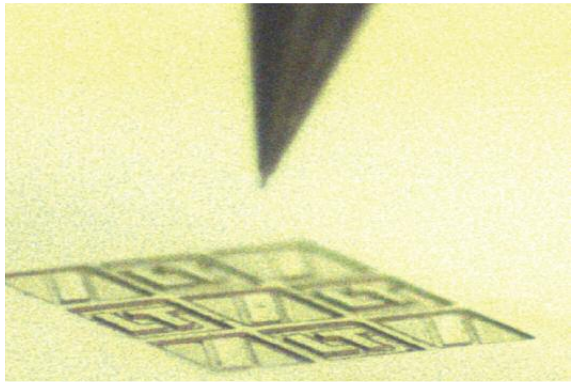


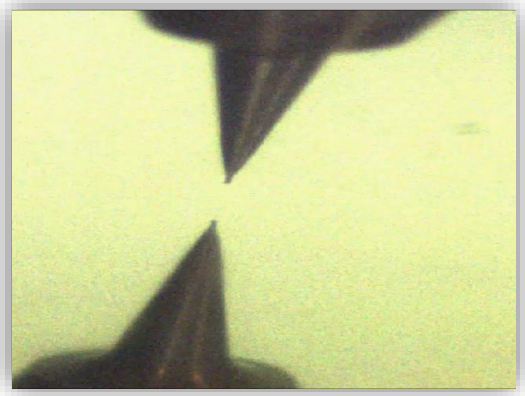


# Micromilling

- Microfluidics
  - D60 µm coated carbide tool
  - in NiP
- Micromilling
  - D60 µm carbide tool
  - in Brass



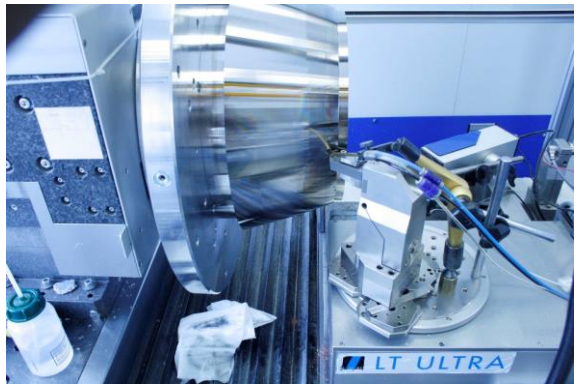




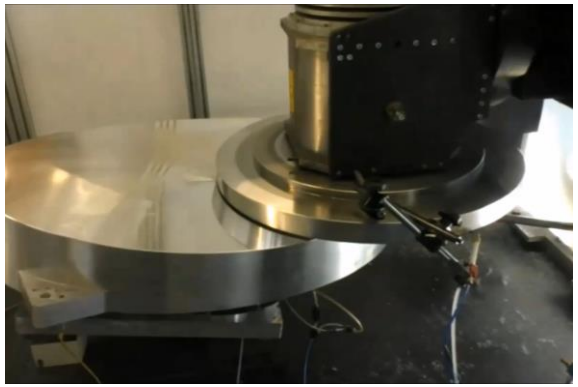
[4,6]

# Special Applications - Space

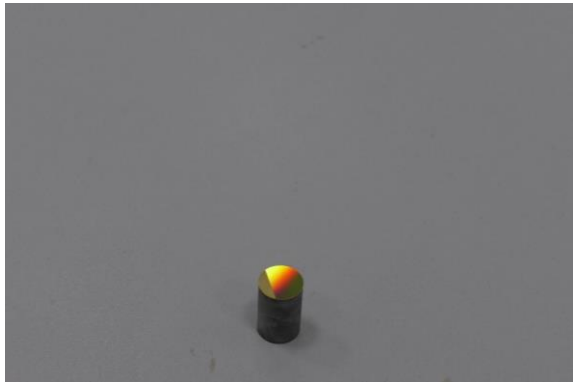
- Space telescopes
- Orbiter
- Terrestrial telescopes
- Laser based communication




eRosita (L2)



Ariel 1 (L2)



Grating, EXOMars (Mars)

ESA, beppiColombo (Mercury)

Magic

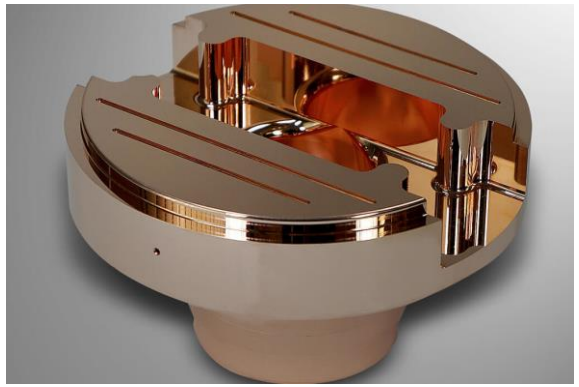
Laser communication, Sat.



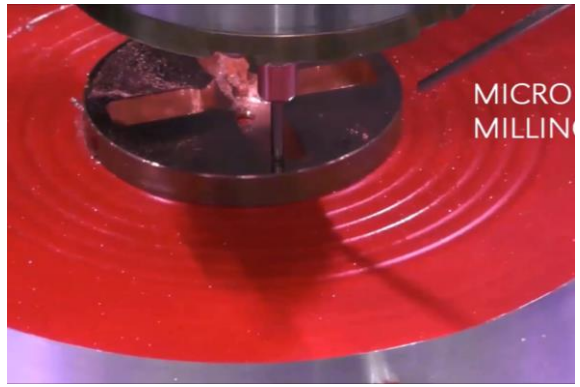
[1,9,10]

# Special Applications – Research/ Comm./Energy

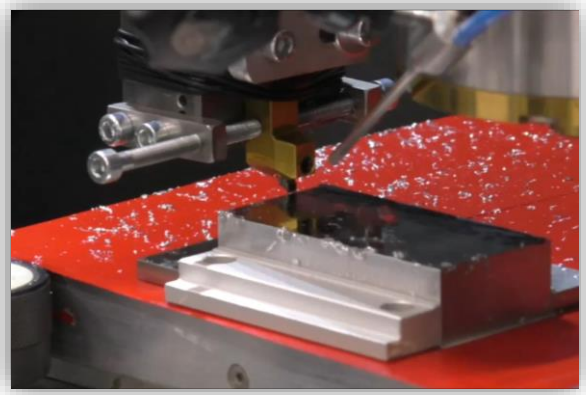
- Accelerator Discs
- Planing of freeform surfaces
- Planing of DOEs (Blaze on Sphere)
- Large mirrors > 1 m² for power applications



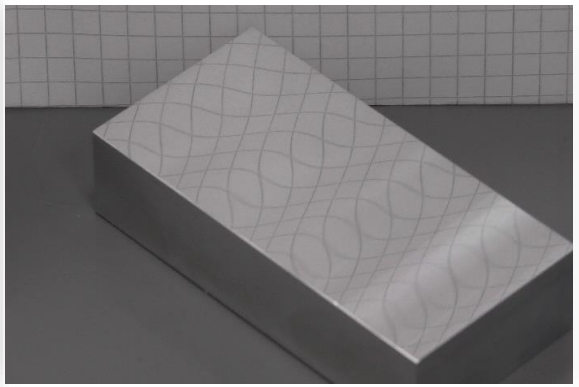
Accelerator




Accelerator



Freeform, planing



Freeform

DOE, Blaze on Sphere

Solar thermal power plant



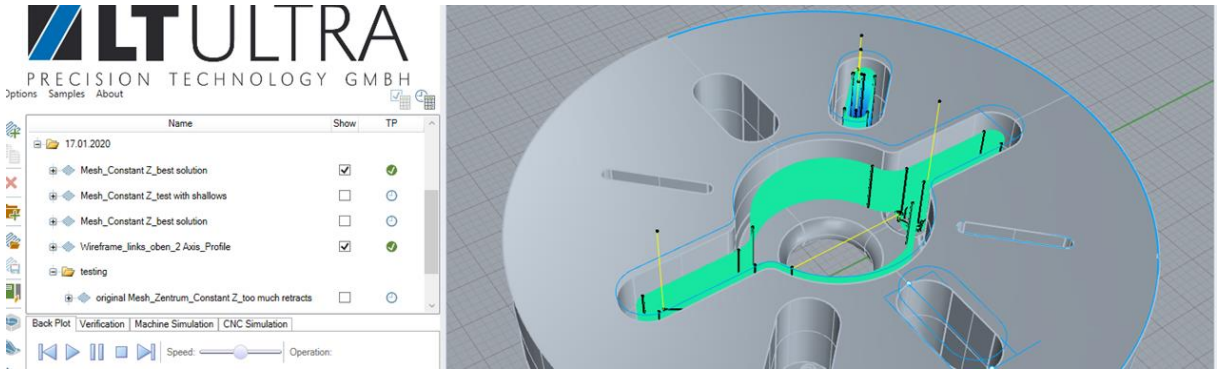
[2,3,4,6,7,11]

# CAM Requirements and Solutions

- High Point density
  - High calculation performance
  - Big NC-files (up to 10 GB)
- Heigh calculation precision
  - << 10 nm (1-2 µm with regular Softw.)
- Easy customizable kinematic setup
- Jobs/Operation → special for UP
- CAD import
- Point Cloud import
- Analytic functions
- Simulation

→

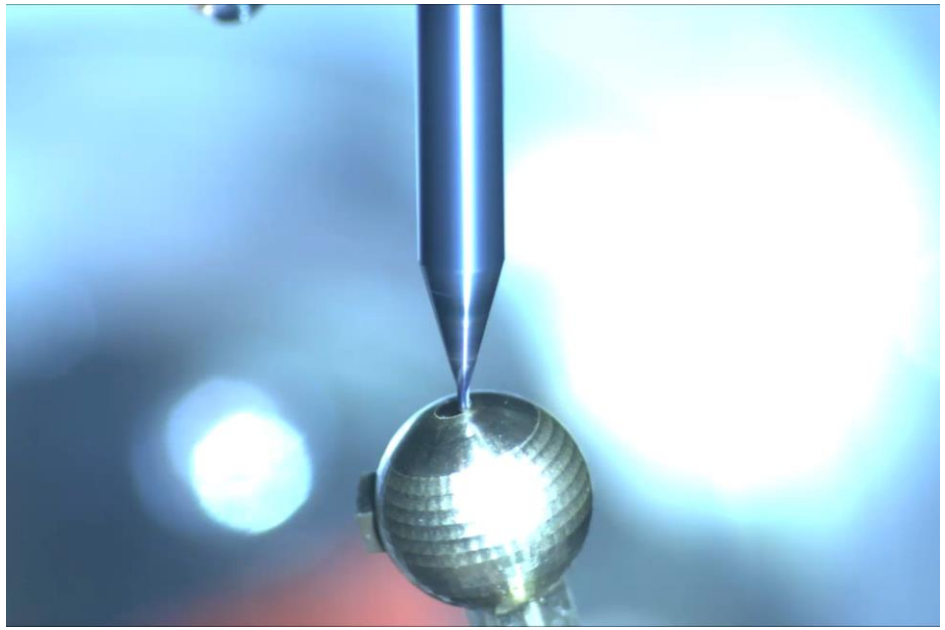
- LT-CAM 4 Versions
  - UP-Turning regular /advanced
  - UP-Milling 3 / 5-Axis
- LT-Machine CAM
- CUSTOMized

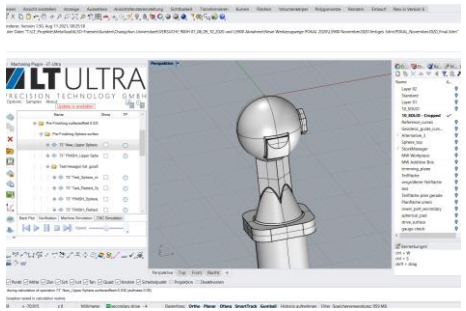


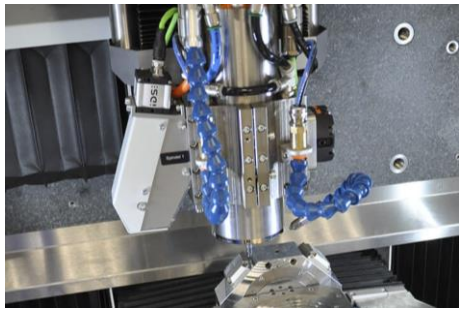

LT-CAM powered by ModuleWorks

# 5-Axis UP-Milling

- Complex part
- Video with roughing and some finishing -->
  - Roughing with carbide tool
  - Finishing with diamond
- → Accuracy ~ 1 µm
- → Roughness ~ 10 - 15 nm

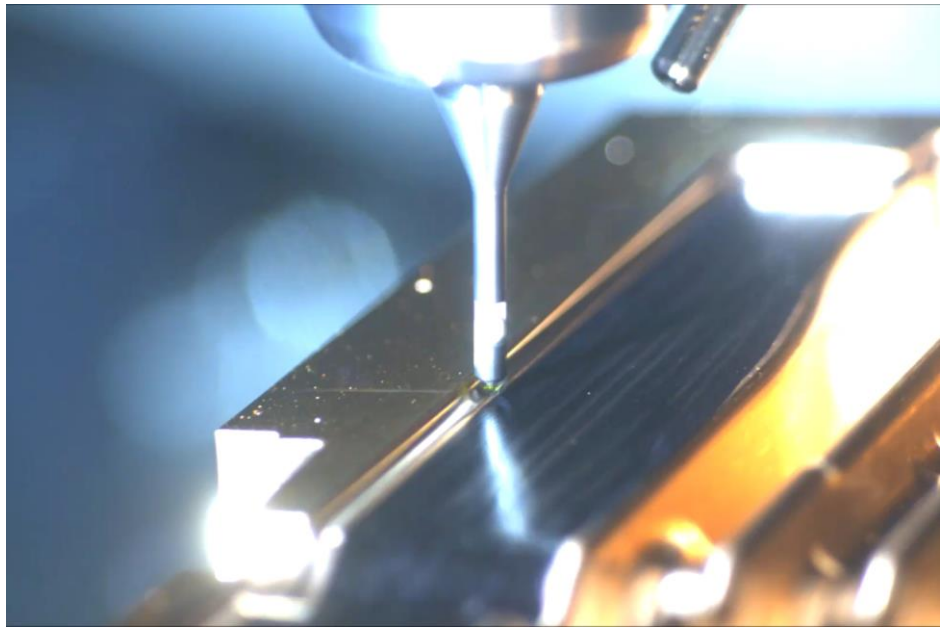


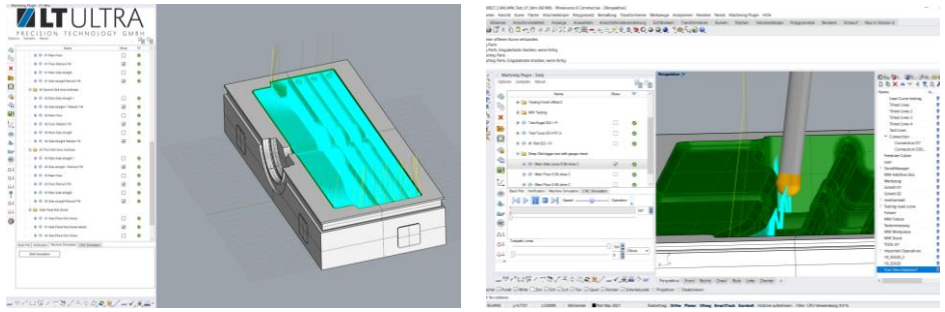


# 5-Axis UP-Milling

- “NEW” Accelerator Parts for CLIC (CERN) in progress
- Freeform 5-Axis Diamond tooling
- In OFHC-Cu
- Accuracy < 1 µm
- Roughness: not relevant



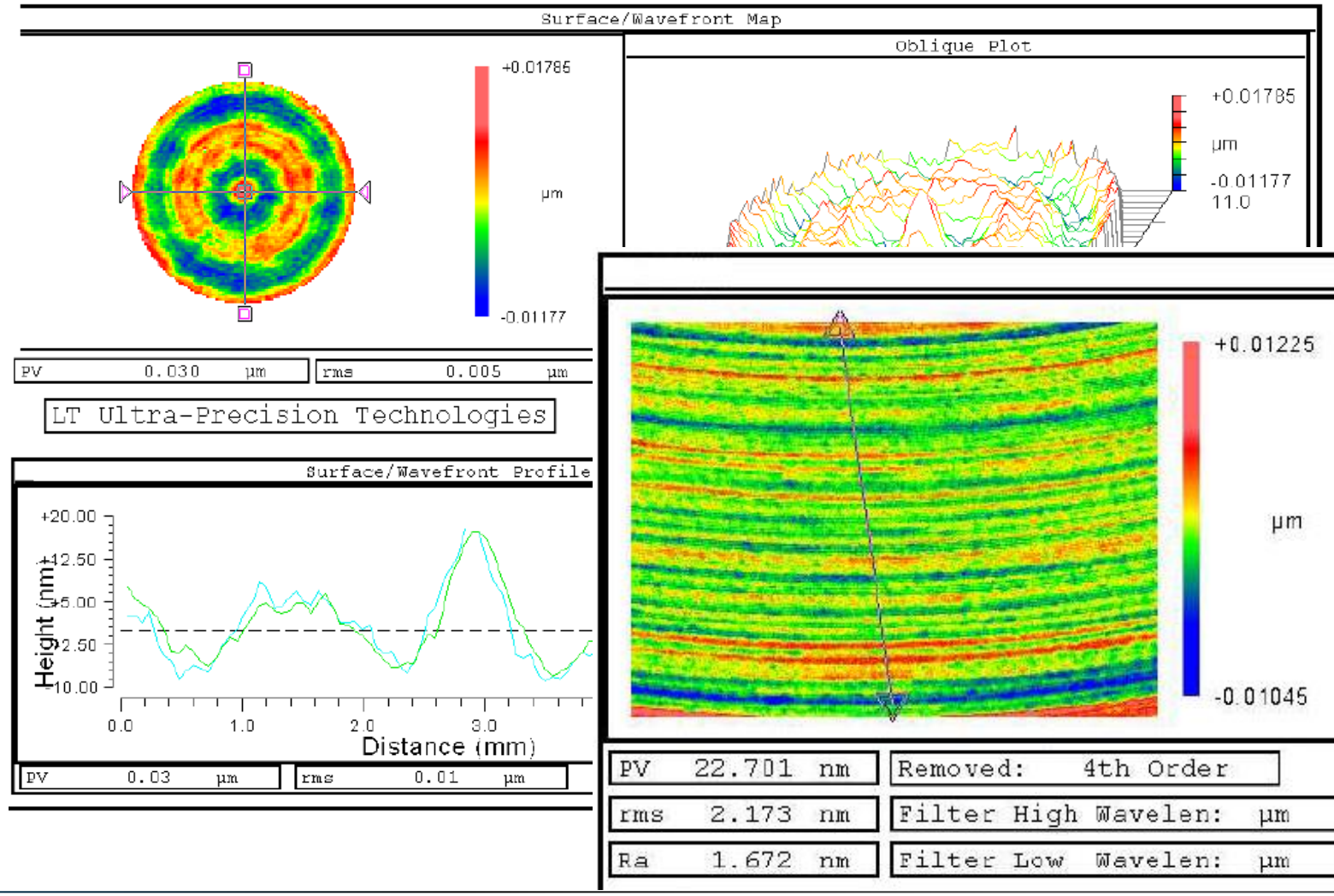


# UP-Turning – Medical

- Medical applications

  IOL (Ø 6 mm) →

  “special” polymer
- Freeform
- FastTool

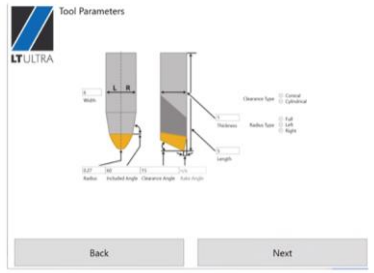


# Template CAM on Machine (LT-Machine CAM)

- CAM running on machine PC
- Import of Point Clouds / analytic
- Automatic communication between machine HMI and CAM
- Optimized calculation time


- Development for Customer:

Highly automated procedure with only barcode scanning and no additional operator interaction

# Reference


[1] Schmidt, K.: Teil 8: Großflächige Ultrapräzisionsbearbeitung, in: Wirtschaftliche Mikrobearbeitung (Langenbeck, P.; Hanser 2009)

[2] Haskic, K.: Verfahren zur mechanischen Erzeugung periodischer nanoptischer Strukturen mit monokristallinen Diamantwerkzeugen am Beispiel von Blazegittern (Fraunhofer, 2015)

[3] Schmidt, K.; Haskic, K.: Automation für Genauigkeiten im Sub-µm-Bereich (Mikroproduktion, 6/15)

[4] Schmidt, K.; Haskic, K.: Automation for accuracies in the sub-micron range (microPRODUCTION, 1/16)

[5] Schmidt, K.; Haskic, K.: Ultraschallunterstütztes Zerspanen von Stählen (Mikroproduktion, 4/16)

[6] Schmidt, K.; Haskic, K.: Formnestfertigung in UP-Qualität (Mikroproduktion, 6/17)

[7] Schmidt, K.; Haskic, K.: Mould cavity production in UP quality (microPRODUCTION 01/18)

[8] Haskic, K.; Schmidt, K.: Serienmäßig mit Sub-µm-Genauigkeit (Mikroproduktion, 4/18)

[9] Haskic, K.: eROSITA startet zur Erkundung des Weltalls - Mit an Board: Technologie von LT Ultra, (Whitepaper, LT Ultra-Precision Technology, 22.07.2019)

[10] Haskic, K.: Von der Mikrozerspanung bis zur Ultrapräzision, (Mikroproduktion 4-5/21)

[11] Haskic, K.; Oberschmidt, D.: Ultrapräzise Maschinen für hybridoptische Elemente (Mikroproduktion, 4/19)

[12] Haskic, K.: Der dynamische Achsmodus in der UP-Bearbeitung (Whitepaper, LT Ultra-Precision Technology, 27.07.2020 )

[13] Haskic, K.: Temperierung für ultrapräzise Maschinen (Mikroproduktion 04/20)


→ [3-13] are available at www.lt-ultra.com in the download section

→ **Manufacturing Videos (free access)** https://www.youtube.com/channel/UCcqWTp4AiQGCBHYowU2_saQ

# Thank You!

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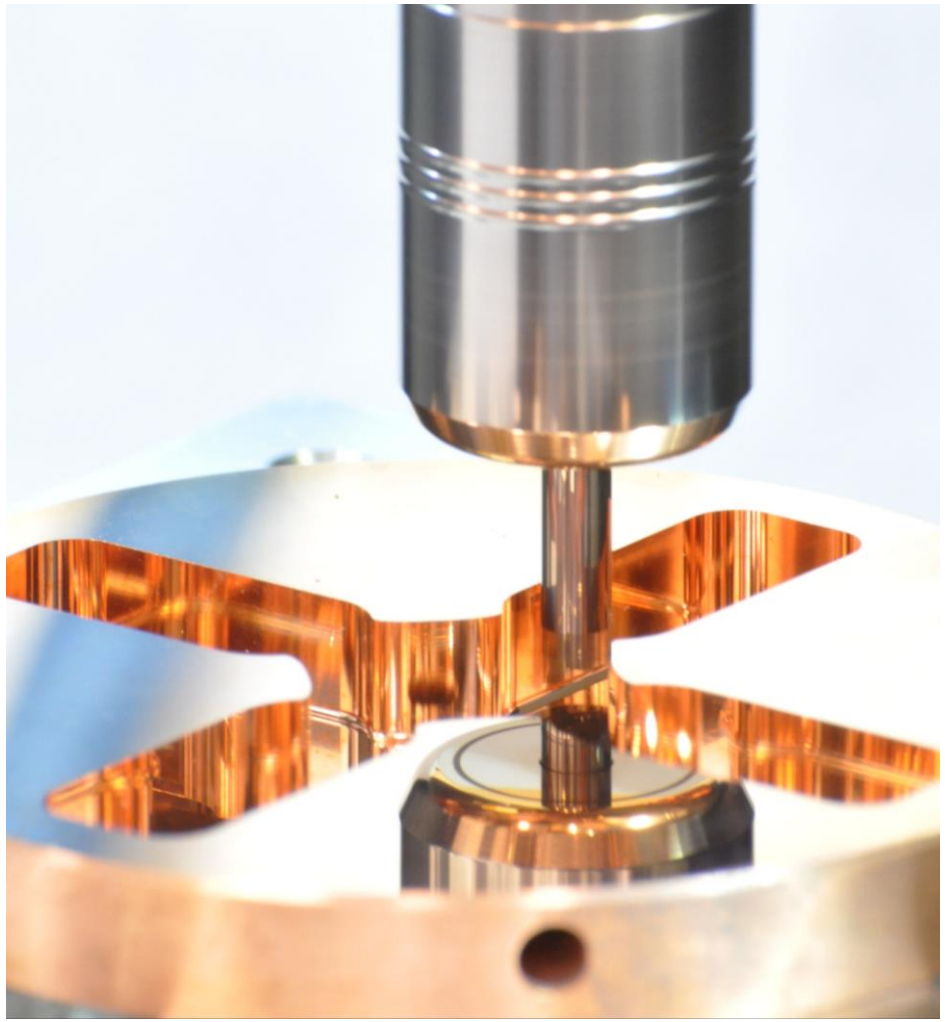

# Multi Axis Machining of Ultraprecision Parts

MIC -2022 (Module Works Insider Conference)

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OUR PROFESSION IS PRECISION