

# Laser processing of diamond tools for ceramic watch components

EPHJ: Photonics 4 Industry  
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Maximilian Warhanek  
IWF, ETH Zurich

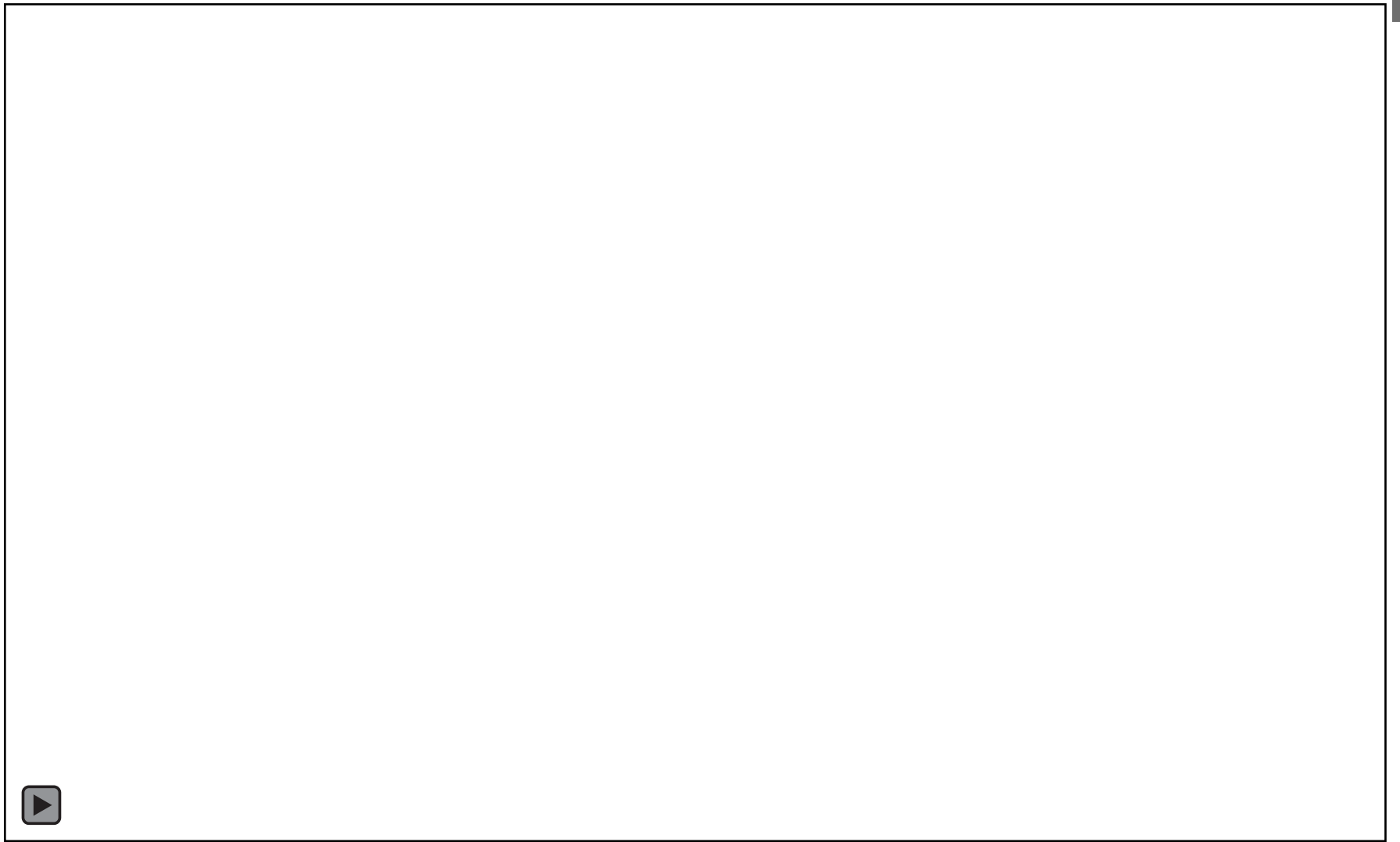
# Ceramic Watches



# Zirconia oxide

- Bio compatible
- Chemically stable
- Electric isolator
- Thermal isolator
- Light-weight
- Hard
  - Scratch resistant
  - Difficult to machine













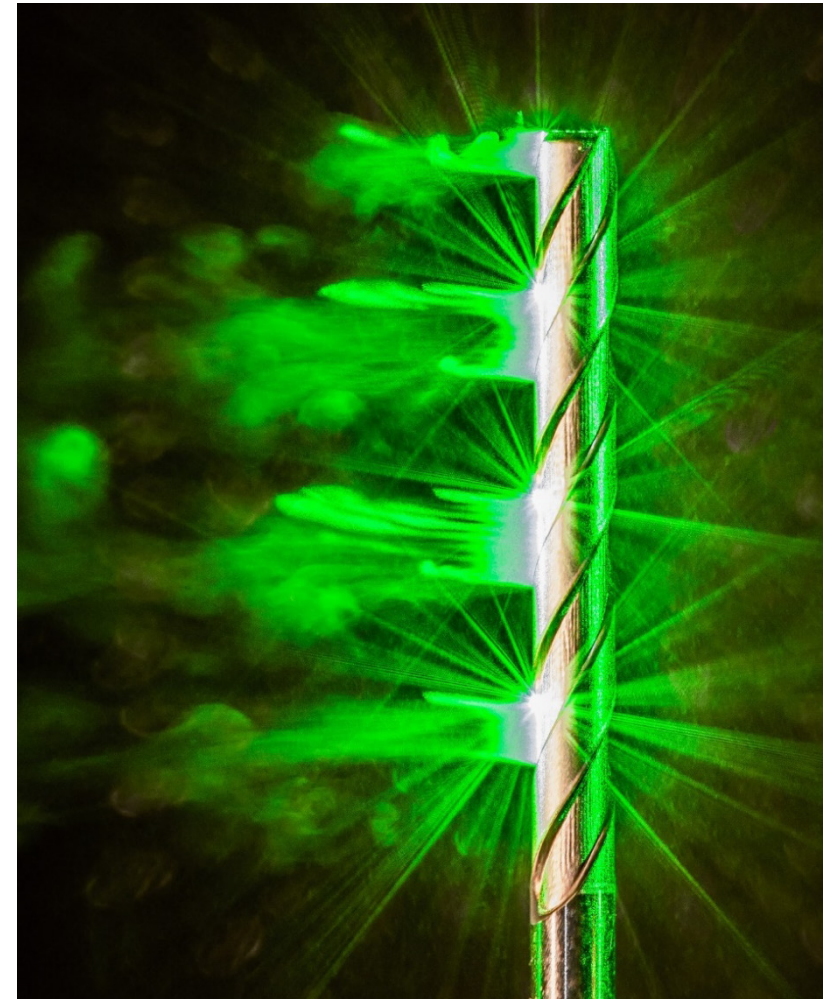
Milling

Drilling



# Technology

Mineral	Mohs	Image
Talc	1	
Gypsum	2	
Calcite	3	
Fluorite	4	
Apatite	5	
Feldspar	6	
Quartz	7	
<u>Topaz/ZrO2</u>	8	
Corundum	9	
<u>Diamond</u>	10	
<u>??</u>	<u>??</u>	<u>??</u>



Laser processing

# Laser-processed Solid Diamond Tools



Drill



Thread Mill



Core drill



Mill

# Laser-processed Solid Diamond Tools

## Diamond coated tools and grinding tools

- High wear
- Low tool life time
- + Established process

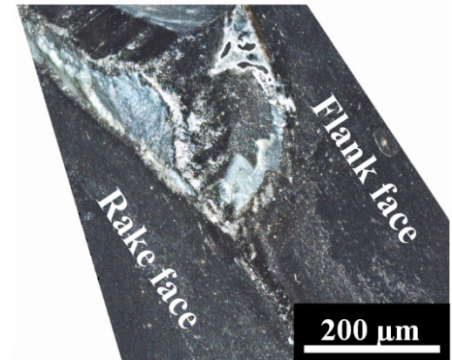
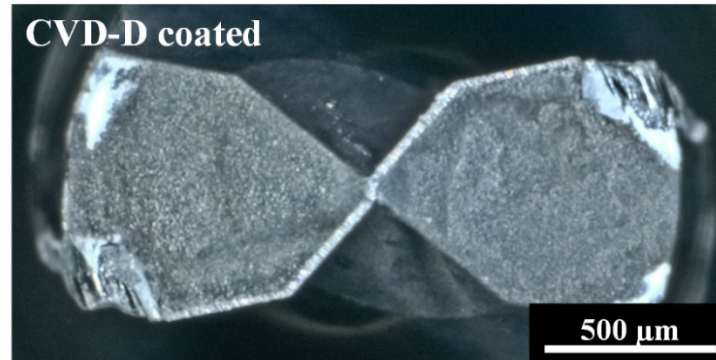


Figure A: Wear after 15 bores, n: 3500min<sup>-1</sup> f: 4mm/min; t: 3mm

## Solid PCD tools

- + 5 -10x higher tool life times
- + Precision
- + Process stability

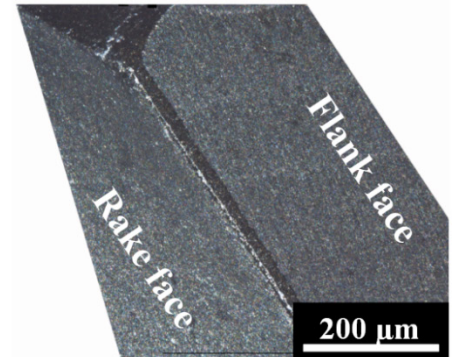
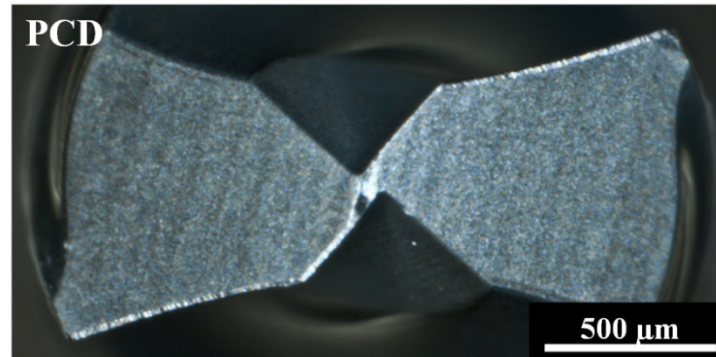


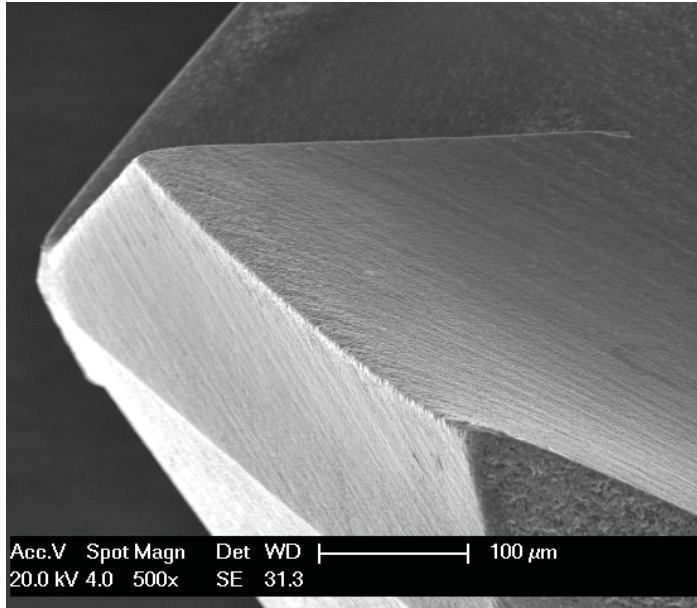
Figure B: Wear after 15 bores, n: 3500min<sup>-1</sup> f: 4mm/min; t: 3mm



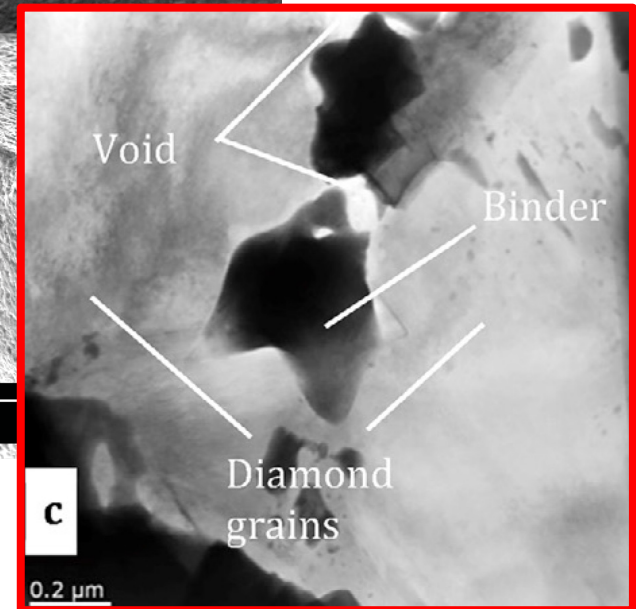
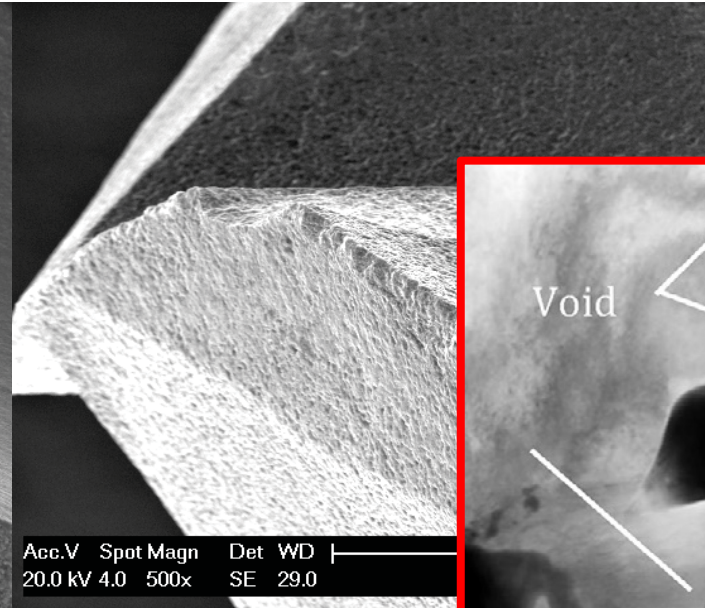
# Laser-processed Solid Diamond Tools

## Tool state after 300 bores in CMC

Laser-processed tool



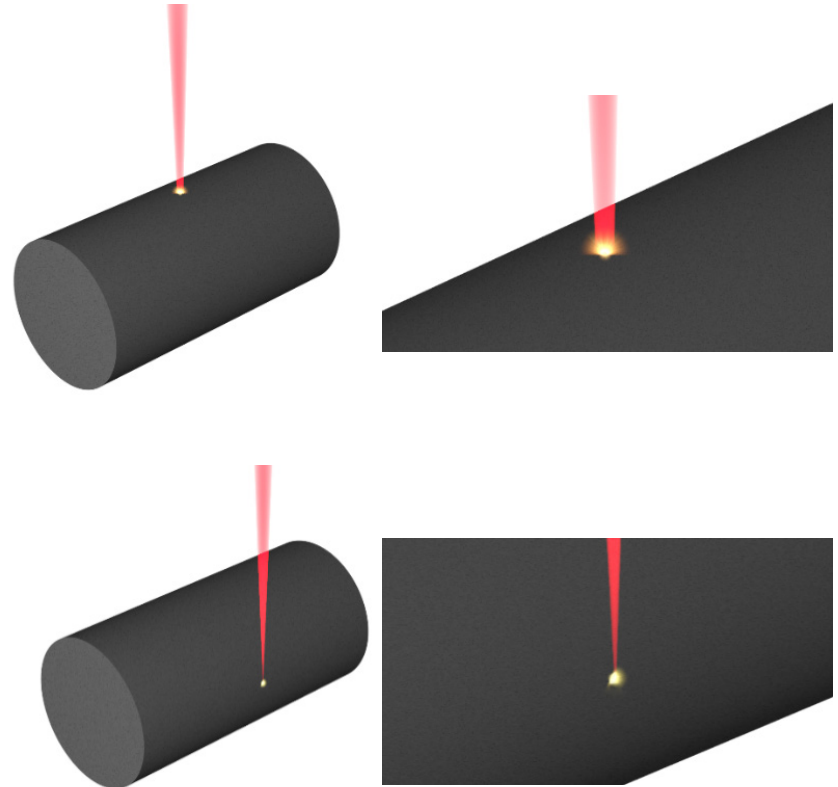
EDM-processed tool



Source: Butler-Smith et al. CIRP Annals - The influences of pulsed-laser-ablation and electro-discharge-grinding processes on the cutting performances of polycrystalline diamond micro-drills Manufacturing Technology 65 (2016) 105–108

# Laser Processing Kinematics on Rotary Tools

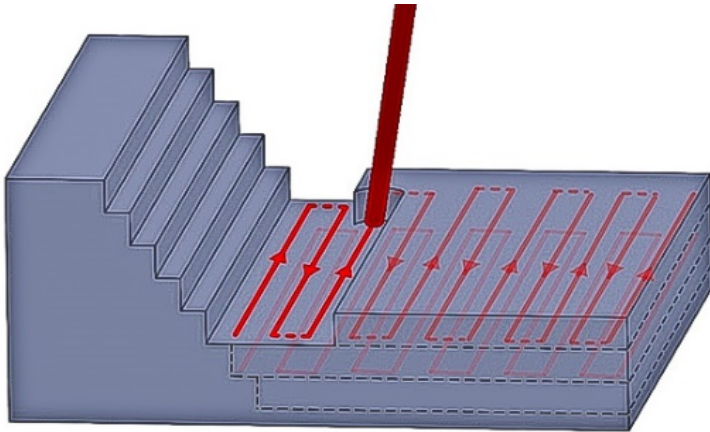
- Radial
  - Efficiency
  - Geometrical flexibility
- Tangential
  - Precision / Repeatability
  - Surface quality





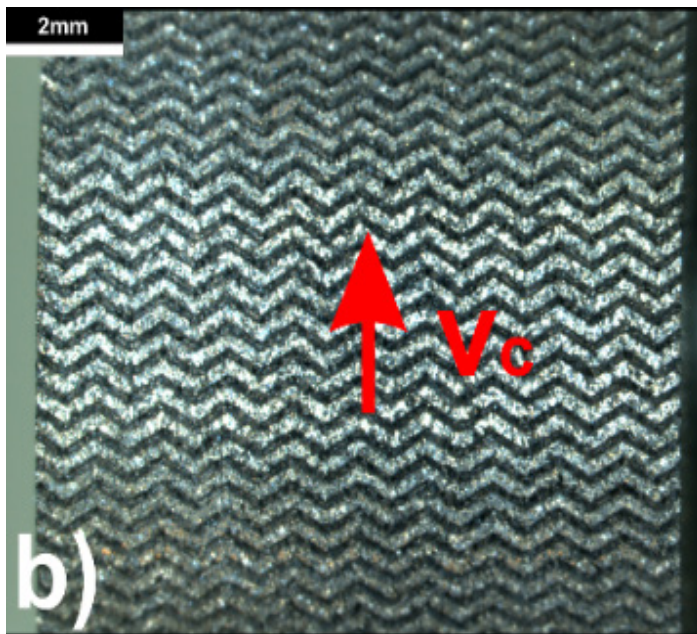
# Radial Laser Processing: 2.5D Volume Ablation

- Material removal in layers
- Orthogonal beam incidence
- + Geometrical flexibility
- + Laser power efficiency

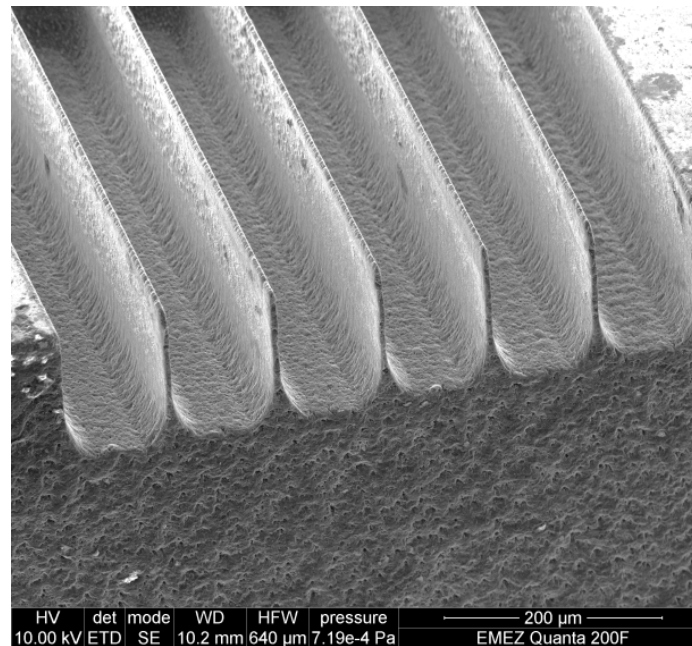


# Radial Laser Processing: 2.5D Volume Ablation

## Diamond processing by 2.5D volume ablation



Source: Christian Walter, ETH Zurich



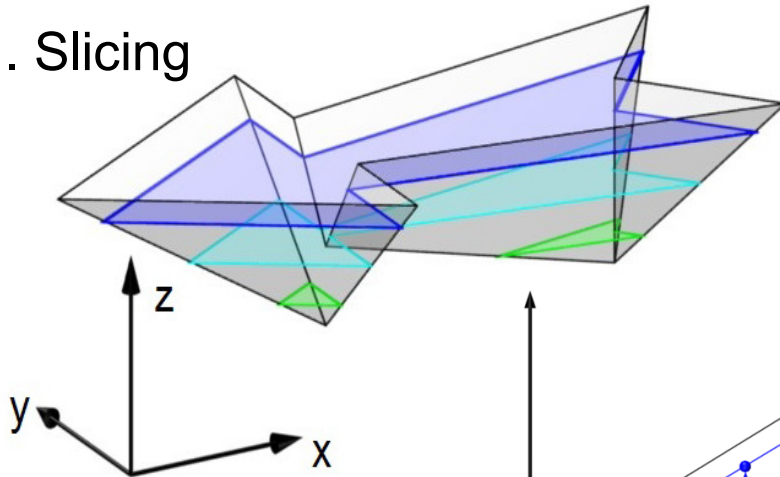
Source: Gregory Eberle, inspire AG



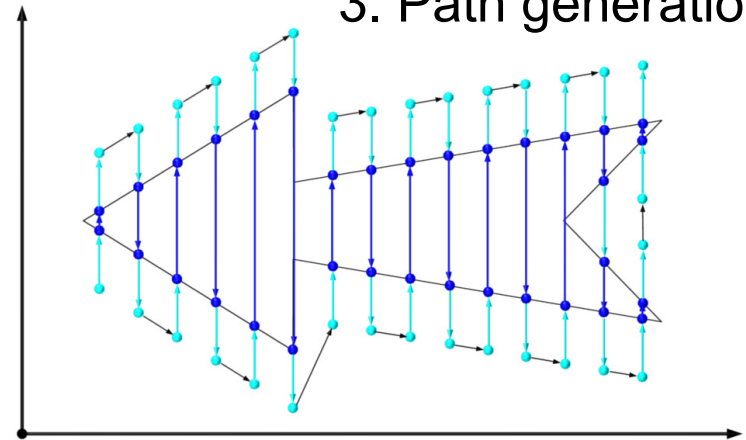
# Radial Laser Processing: 2.5D Volume Ablation

## LaserCAM

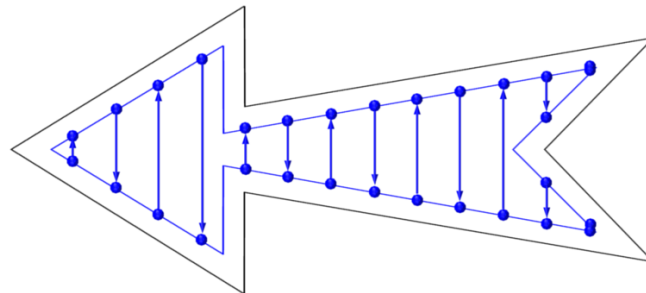
1. Slicing



3. Path generation



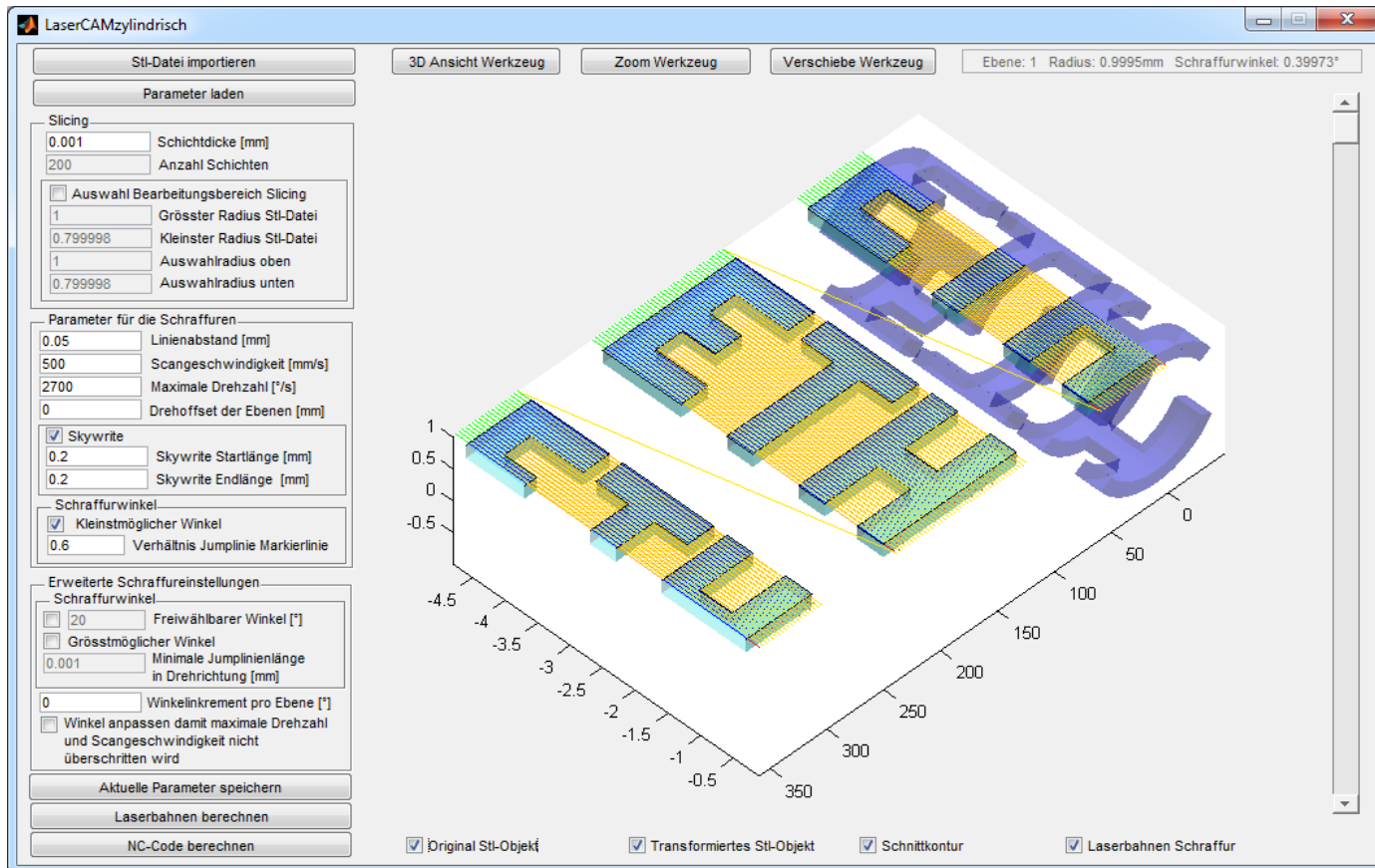
2. Contour offset



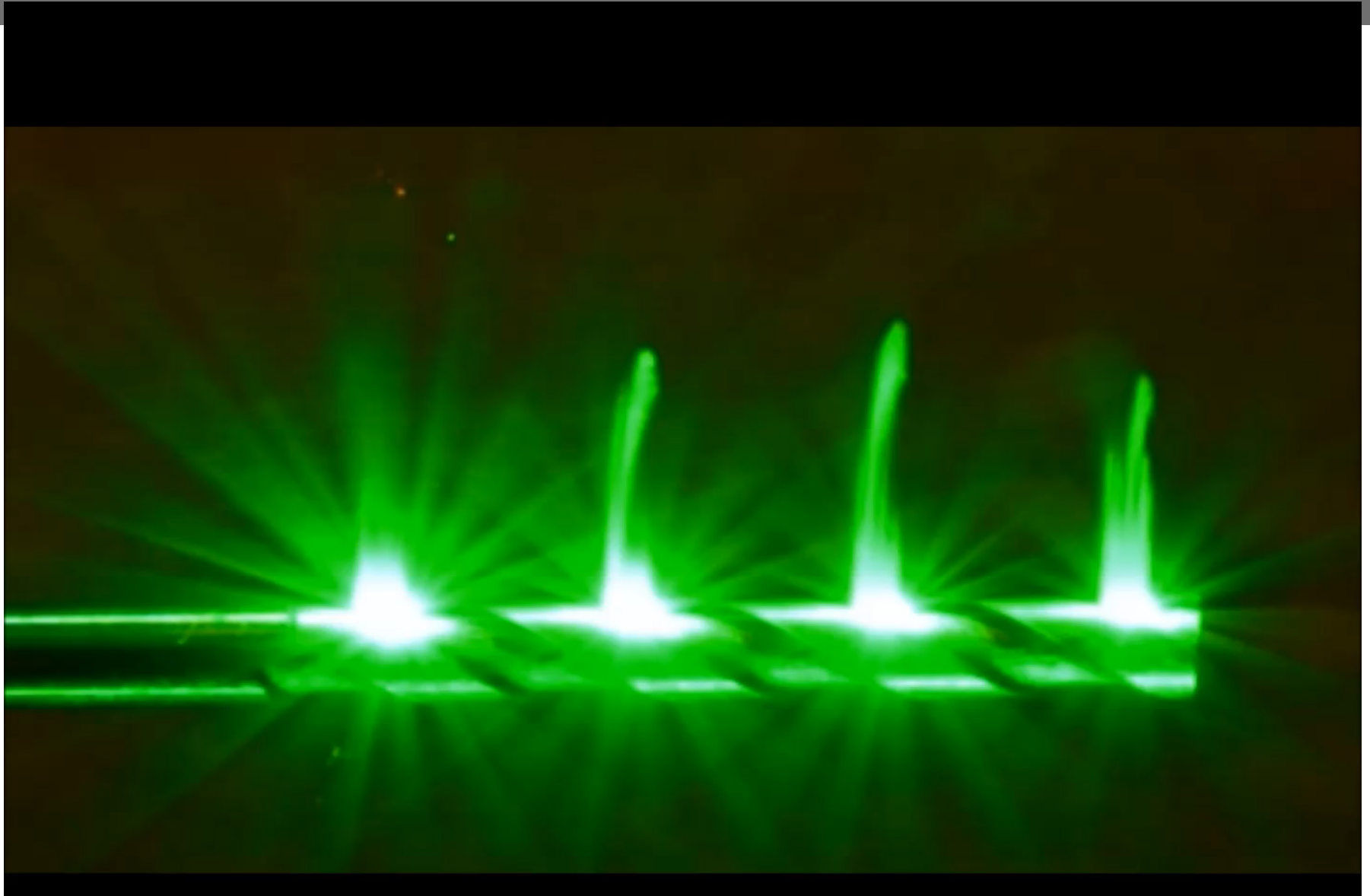
Source: Johannes Gysel, ETH Zurich

# Radial Laser Processing: 2.5D Volume Ablation

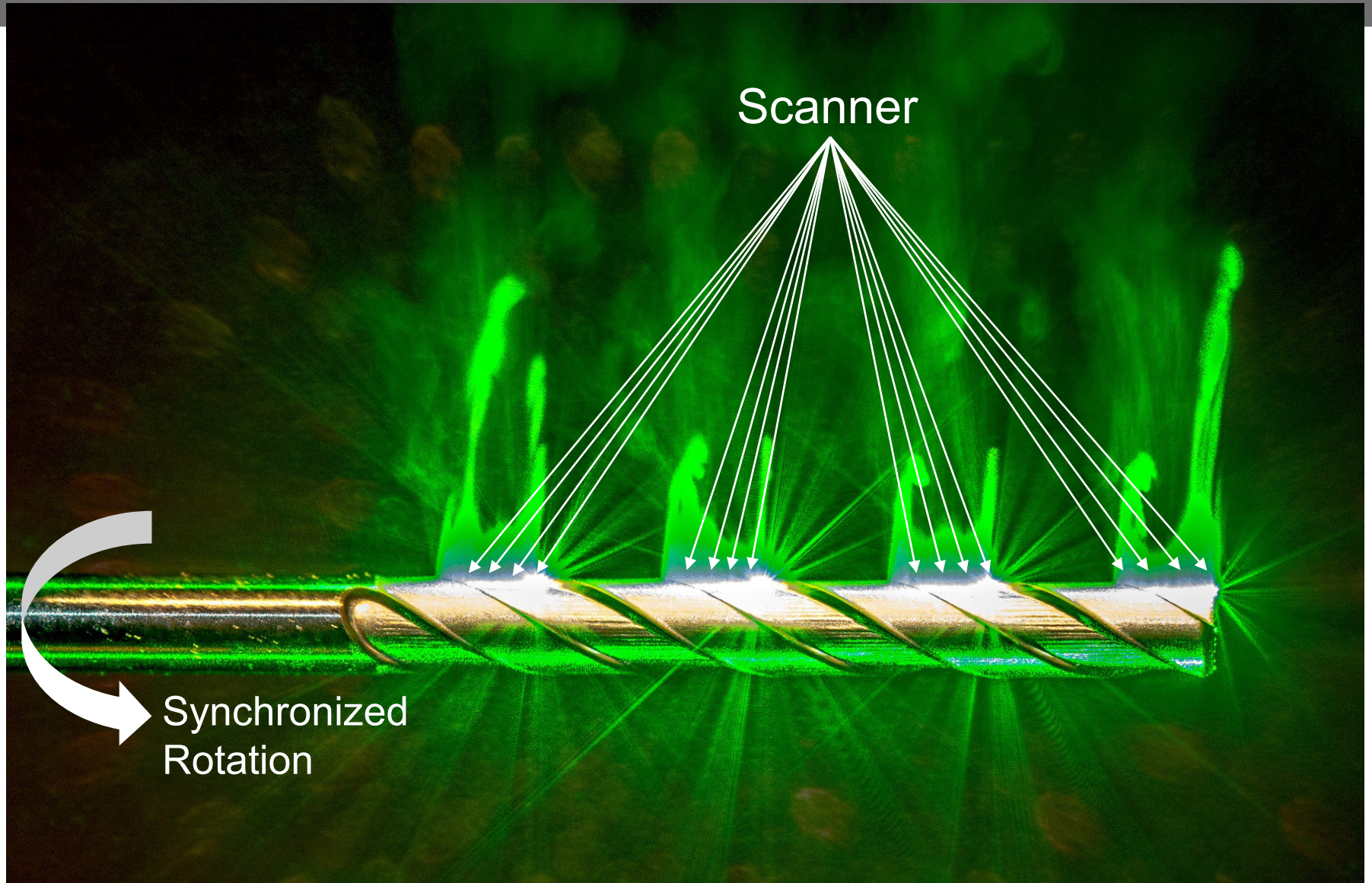
## LaserCAM for rotary 2.5D geometries





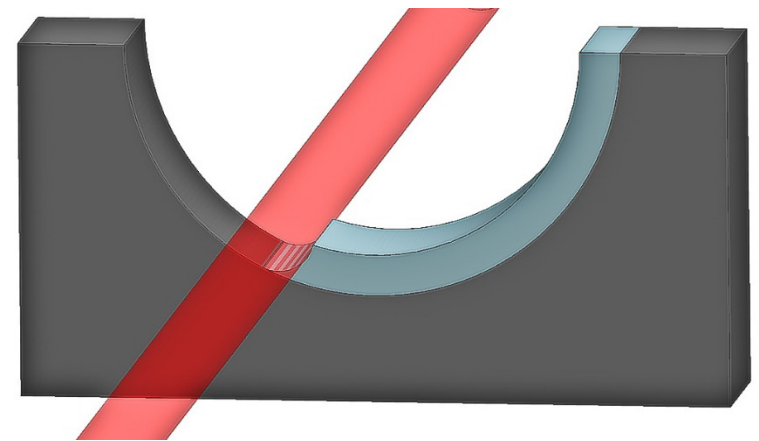
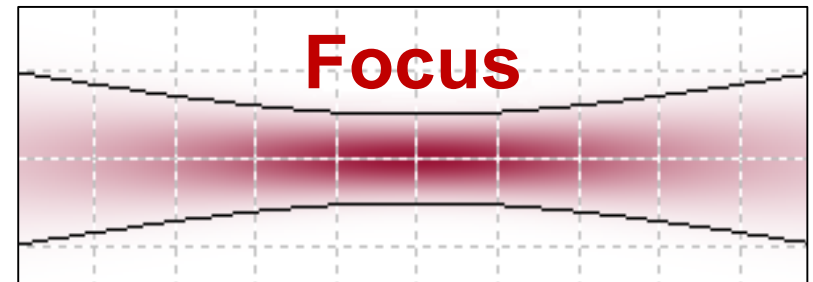






# Tangential Laser Processing

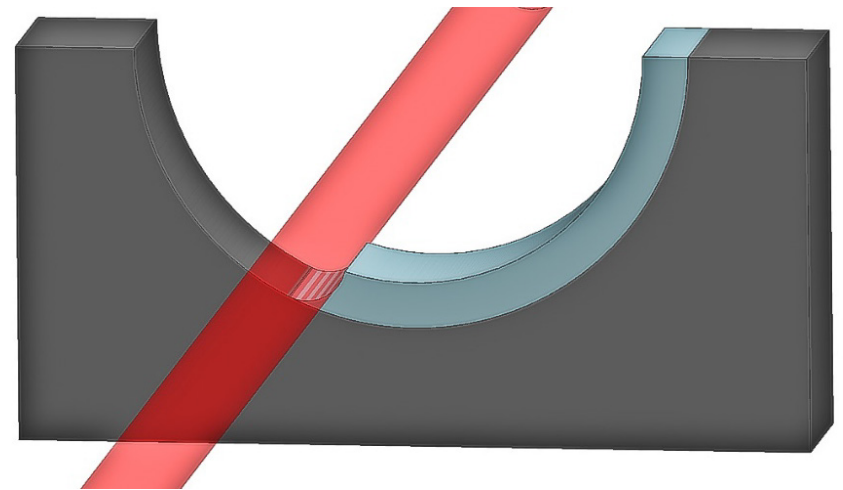
- Material removal orthogonal to beam direction  
→ Defined geometrical limits
- Final contour is defined only by the relative motion between laser and workpiece
- [Timmer 2001]: *True profiling*





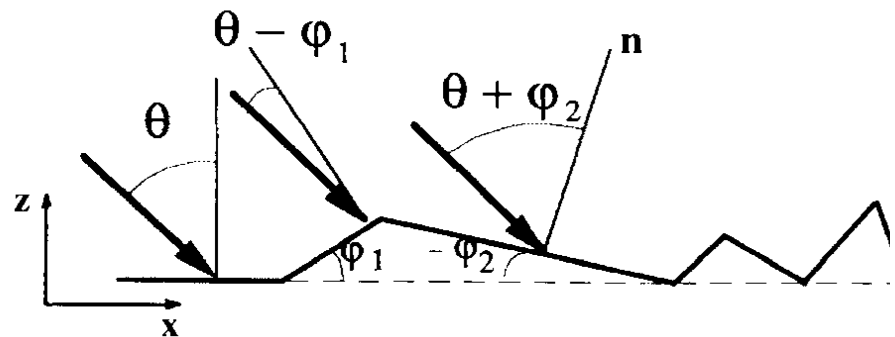
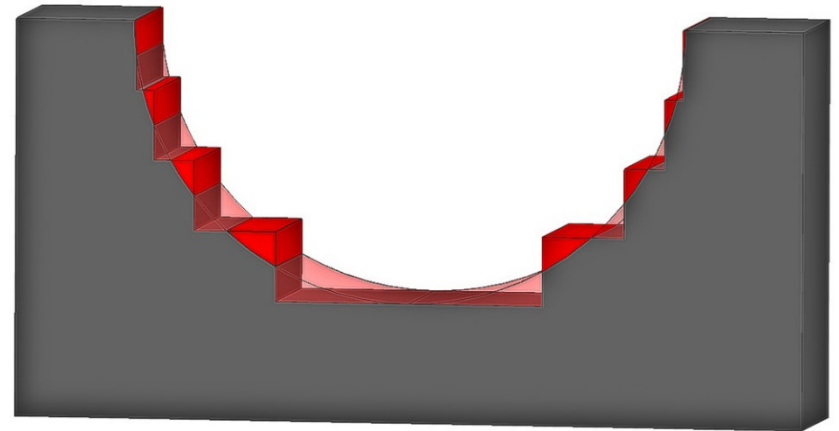
# Tangential Laser Processing: Advantages

- Precision / Repeatability  
Less sensitive to:
  - Raw material tolerances
  - Laser power fluctuations
  - Irregular material composition (PCD)
  - Irradiation time
- Preceding roughing process possible



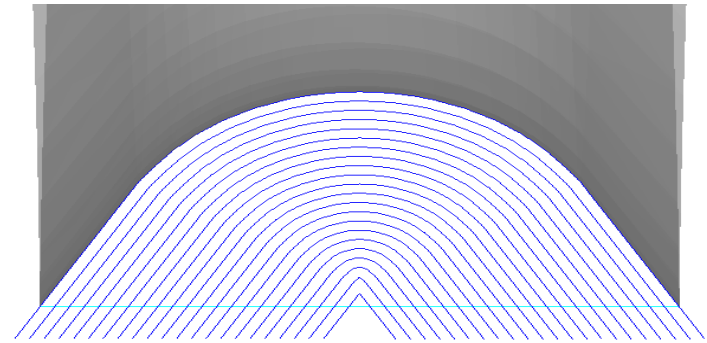
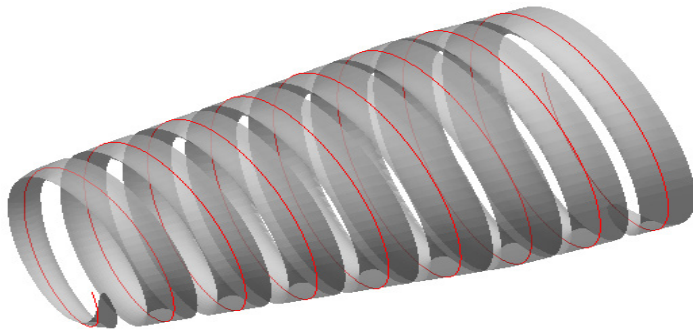
# Tangential Laser Processing: Advantages

- Surface quality
  - No discretization error
  - Less trade-off between surface quality and process time
  
- Polishing effect
  - [Tokarev et al. 1994]
  - Composite materials
  - Roughing
  
- $R_a < 35\text{nm}$  on carbide

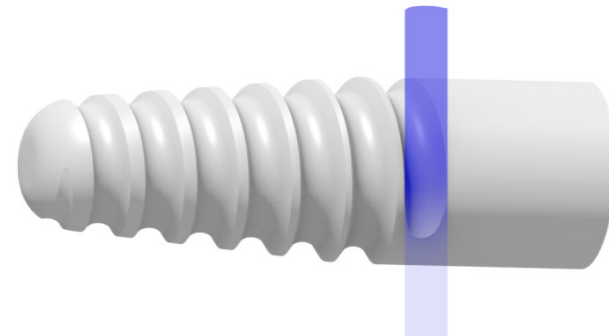
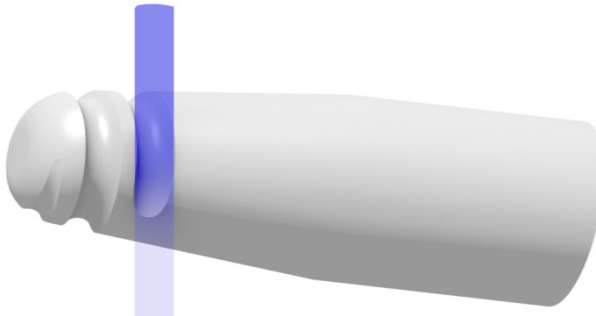


# Tangential Laser Processing

## LaserCAM for tangential laser processing



- Synchronous laser processing with 5+2 axes







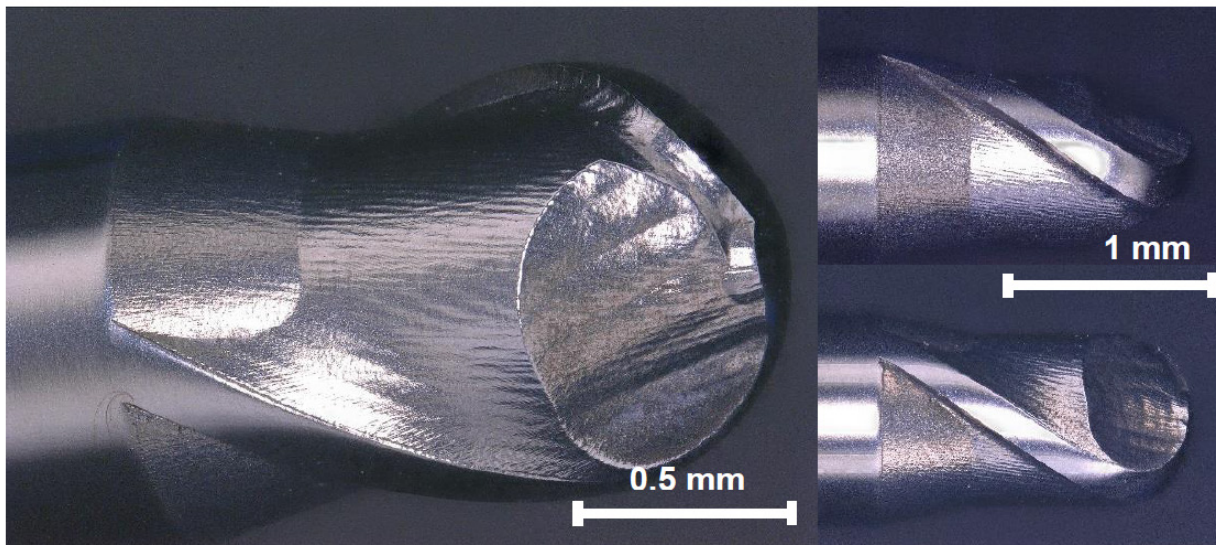
# Radial & Tangential Laser Processes

## Radial

- Geometric flexibility / Simple
- $R_a > 500\text{nm}$
- Precision depends on blank quality and number of layers

## Tangential

- No concave surfaces
- $R_a < 40\text{nm}$  possible
- High repeatability allows precision in  $\mu\text{m}$ -range



**Thank you for your kind attention!**

**Solid diamond tools available at: [www.6c-tools.ch](http://www.6c-tools.ch)**

**LaserCAM software available at:  
<https://github.com/Hannes333/Computer-Aided-Manufacturing-Programm-for-2.5D-Laser-Ablation-Version-2.0>**