Conditioning of Hard Tools by Ultra Short Pulsed Lasers

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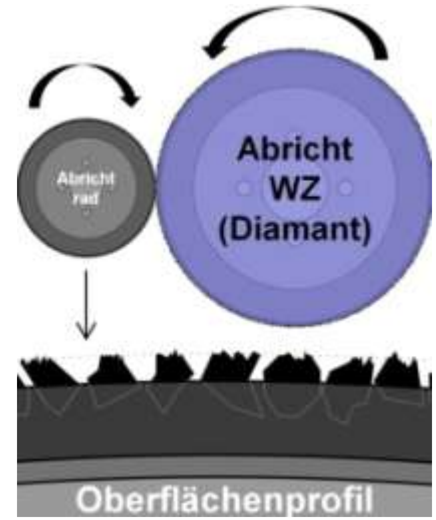
C. Dold, Chr. Walter, G. Eberle,
U. Maradia, J. Stirnimann

Topics

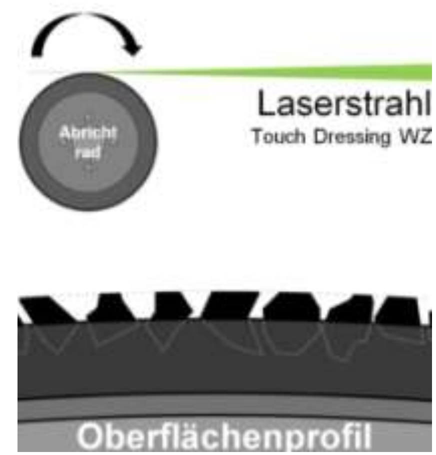
- Laser touching of dressing wheels
- Laser machining of PCD-tools
- Laser ablation of diamonds
- Laser conditioning of grinding wheels
- Laser structuring of cutting inserts
- Laser process simulation
- Conclusions

Laser touching of dressing wheels

Comparison of conventional- & laser-dressing process:



- Conventional grinding machining:
  - Machining sequence: Dressing tool → dressing wheel → grinding wheel
  - Diamond to diamond machining
  - Material removal by micro cracks and grain break out



- Laser machining:
  - Machining sequence: Laser beam → dressing wheel → grinding wheel
  - Laser beam tangential to the dressing wheel
  - Diamond grains are precisely cuted (no cracking!)
  - Goals:
    - Adjusting a defined contact area → cutting of grain tips
    - Machining of a defined topography on the outer surface
    - Remove negative flank angles from the grain

Laser touching of dressing wheels

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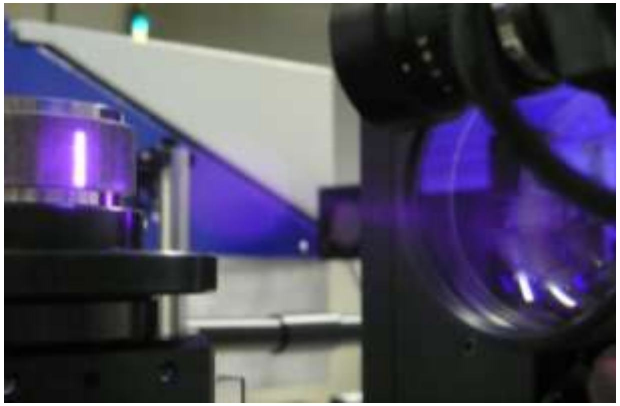
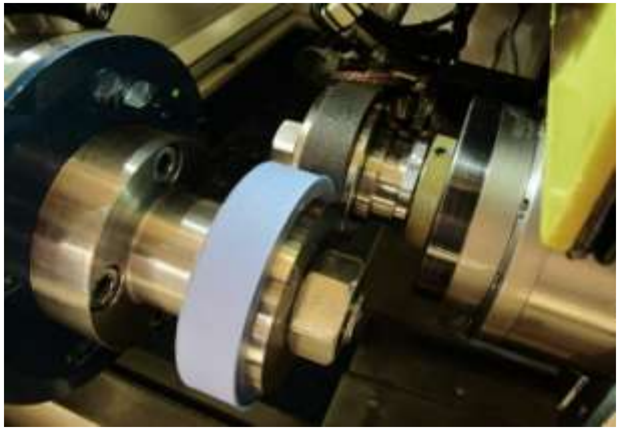
Evaluation of touch dressed wheels:

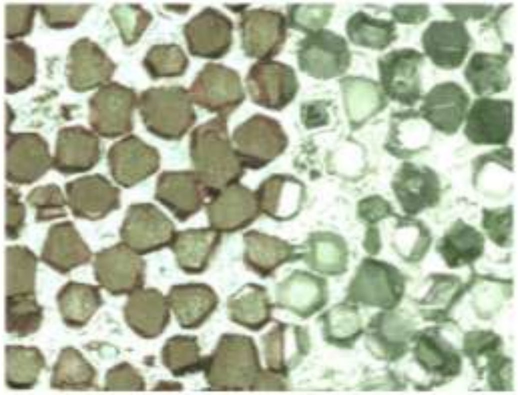
- Cylinder roll / material:
  - Industry diamond Type IIa
  - Grain size D181
  - Nickel bonded
- Tangential laser machining:
  - Cutting of the grain protrusion
  - The bonding layer is not touched
  - Used wavelength: λ = 343, 1030 nm
- Dressing of a grinding wheel:
  - Grinding machine: Studer S31
  - Dressing a SiC-grinding wheel
  - Force measurements by a rotating Dynamometer

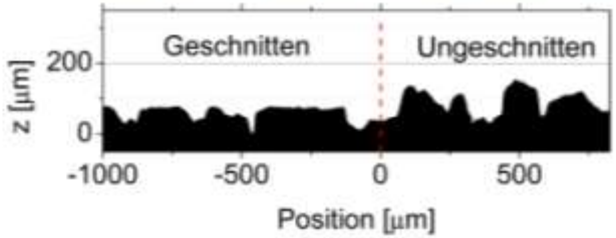




Results of the evaluation:

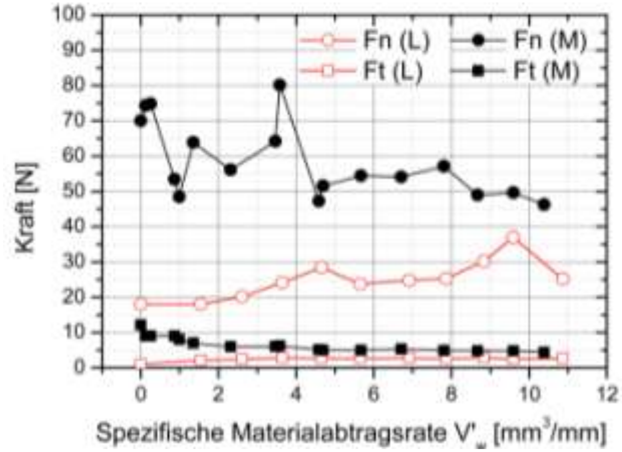
- Selective machining of the area:
  - Problem-free machining by laser
  - All grains are machined with positive flank angle & without micro cracks
  - Process speed > 2 – 5 x higher than conventional dressing
  - No thermal nor mechanical damage of bonding layer





- Analysis of surface roughness:
  - Laser machined dressing tools shows slightly better results

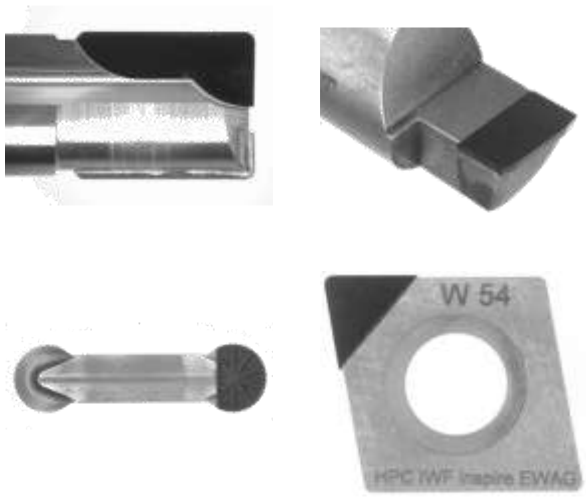
- Process forces:
  - Tangential forces: Laser < Mechanical dressing
  - Normal forces: Laser << Mechanical dressing



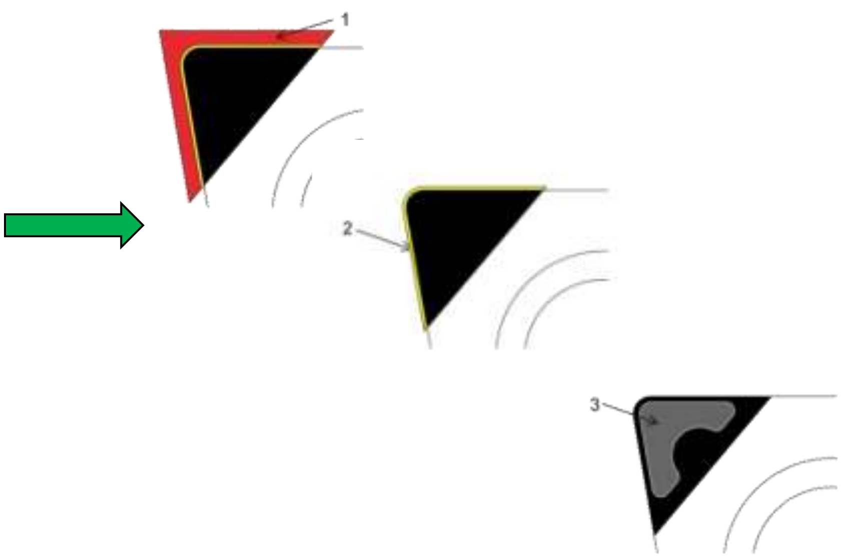
Laser machining of PCD-tools

- High performance tools often shielded / coated by PCD, CVD, cBN

- Advantages of laser machining of PCD tools & inserts:
  - Individual adaptation to defined process → unlimited variety
  - Cutting geometry in 2D & 3D possible
  - Complex chip surface & chip breaking area in 3D-machining
  - Mostly single stage process compared to conventional process

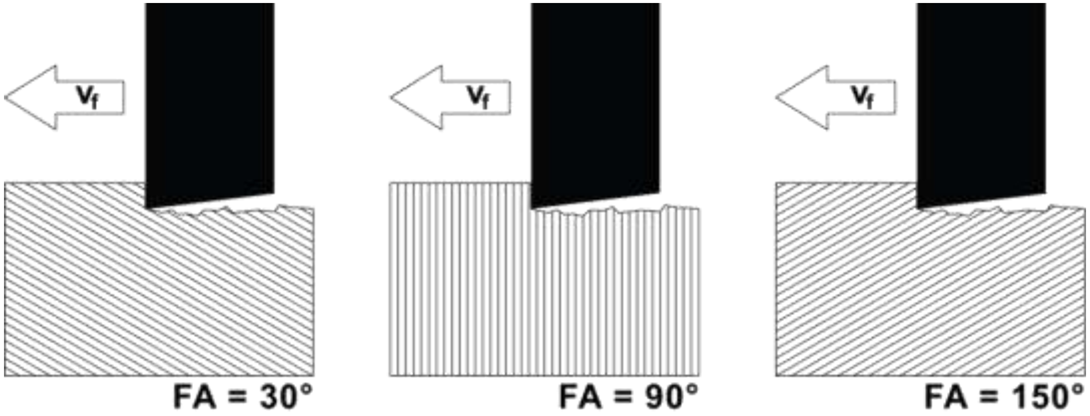


- Sequence of laser machining an insert:
  1. Removing of overlaying contour
  2. Machining of the cutting edge geometry:
     - Flank face
     - Rounding of the cutting edge
  3. Machining of optional geometry elements:
     - Rake face
     - Chip breaker
     - Chamfer radius



Validation & comparison of laser- & conventional-machined PCD tools:

- Comparison of grinded & lasered inserts
- Validation by means of turning CRP material with 3 different fiber orientations
- Evaluating of:
  - cutting forces
  - cutting edges
  - machining time



Laser machining of PCD-tools

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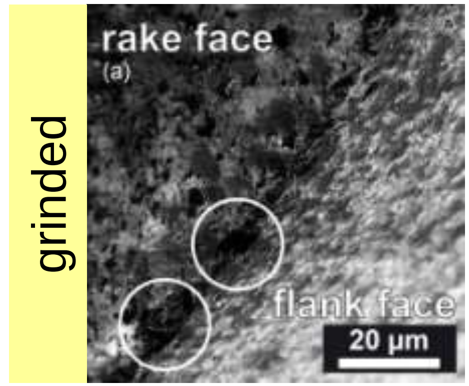
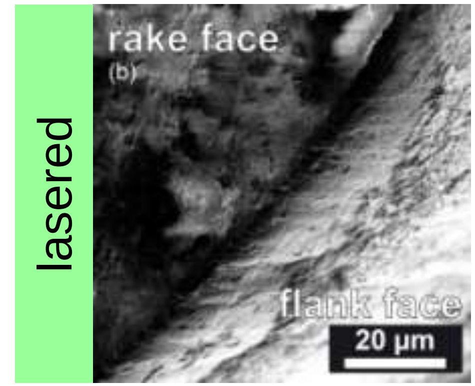
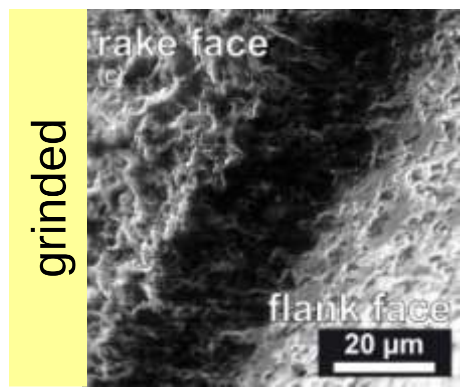
Results of the validation:

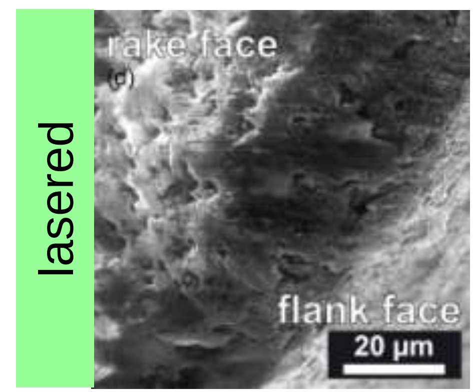
- New grinded cutting edges:
  - Grain breakout → size of ½ grain
- New lasered cutting edges:
  - No grain breakout
  - Good chipping of the cutting edge





- Worn cutting edges:
  - Similar for grinded & lasered inserts:
    - Flank-wear land width
    - Wear behavior
    - At a cutting depth of 1 grain size → identical wear





- Identical machining time for grinding and lasering an insert

Enabling advanced functionalities of D̲iamond and other ultra-hard materials by I̲ntegrated P̲ulsed L̲aser A̲blation T̲echnologies

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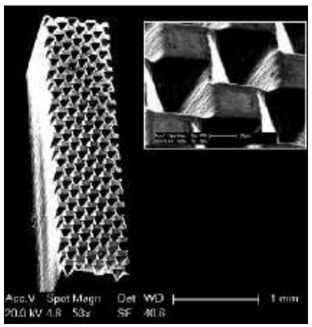

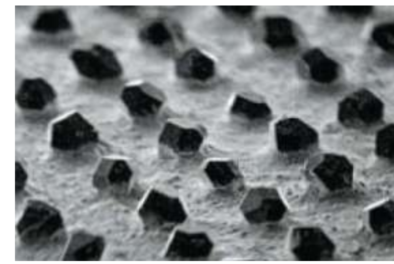

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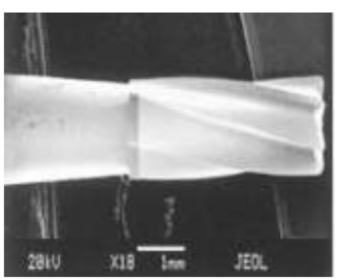
Coordinator contact: **Christian Walter**
walter@iwf.mavt.ethz.ch



FP7-2012-NMP-ICT-FoF
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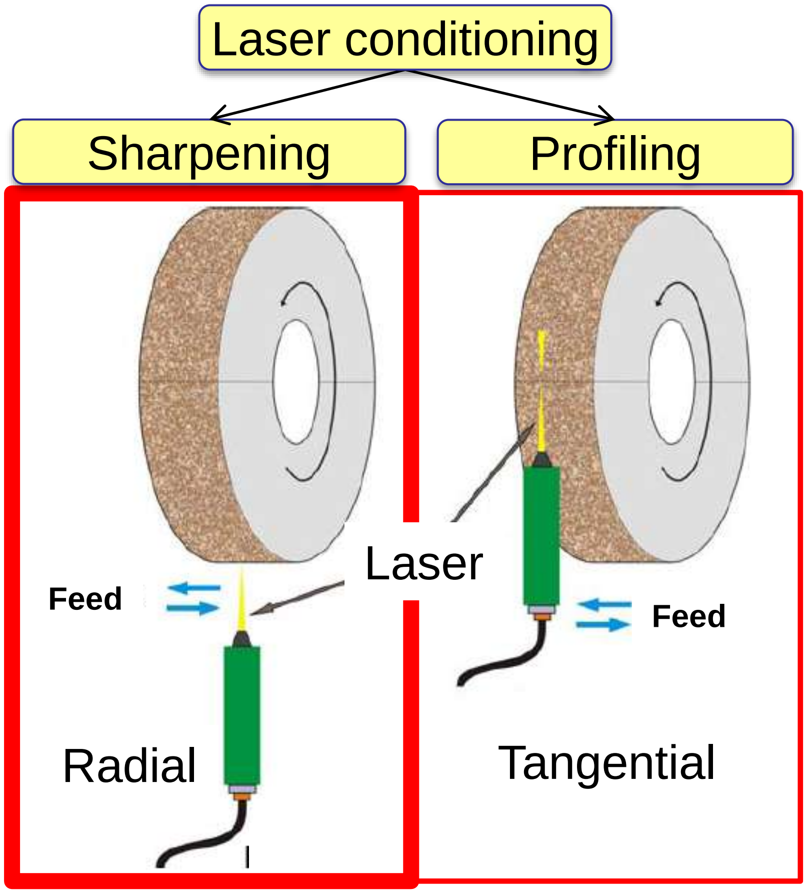
SEVENTH FRAMEWORK PROGRAMME

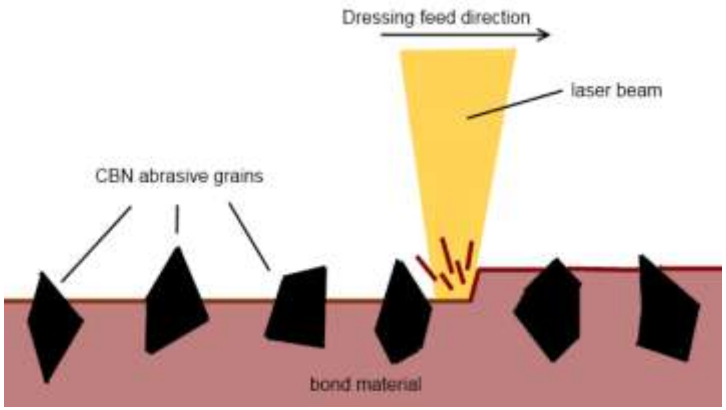
- **Goal: Generate a cBN grinding wheel topography by laser machining**

Principle:



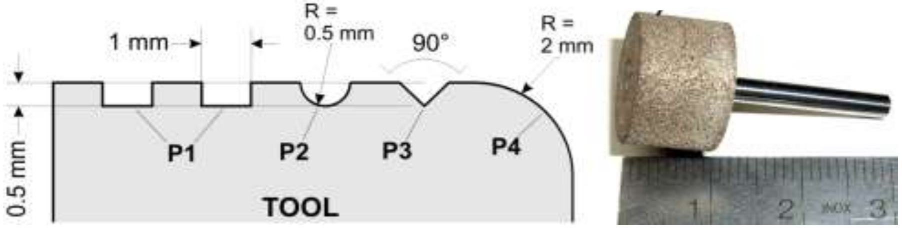
- **Laser source:**
  - Short puls fiber laser: Rofin Lasag QFS 50
  - P = 50 W, tP = 150 – 200 ns
  - eP = 1 mJ @ 50 Hz

- **Cutting head:**
  - Fixed focal length with process gas
  - f = 150 mm, dfoc = 50 µm
  - Process gas: Pressured air (5 bar)

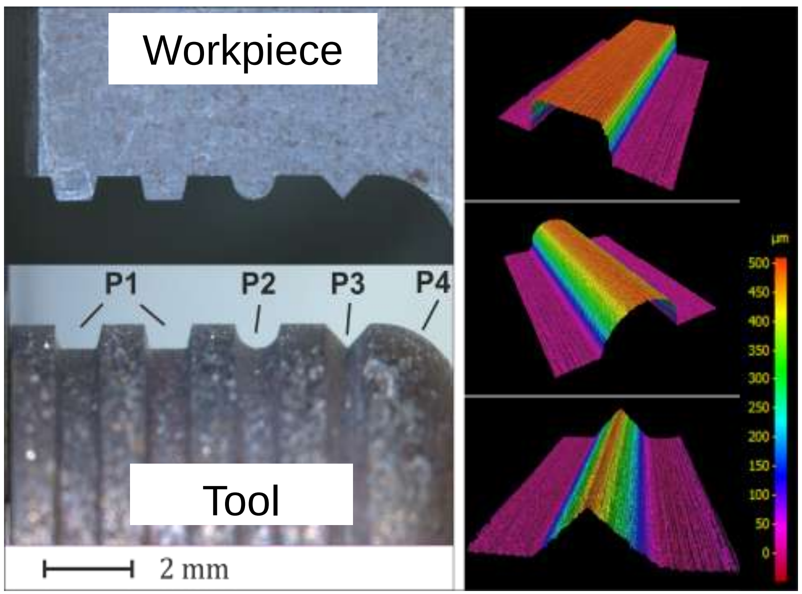


Example: Laser conditioning of a cBN grinding pin

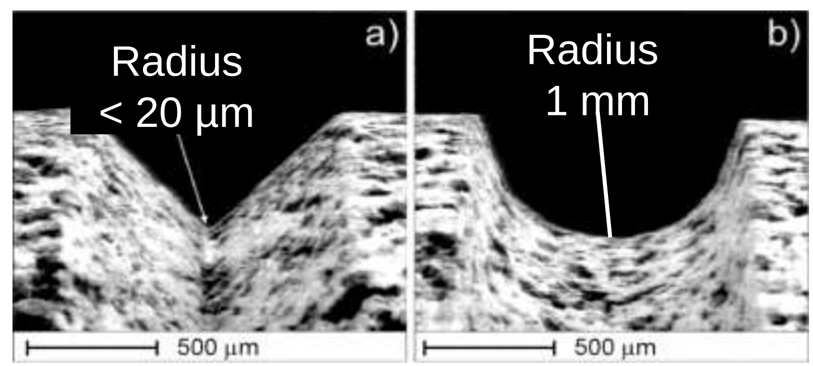
Tool geometry:



Tool & Workpiece after machining:



Details of the lasered tool:



Laser conditioning of grinding wheels

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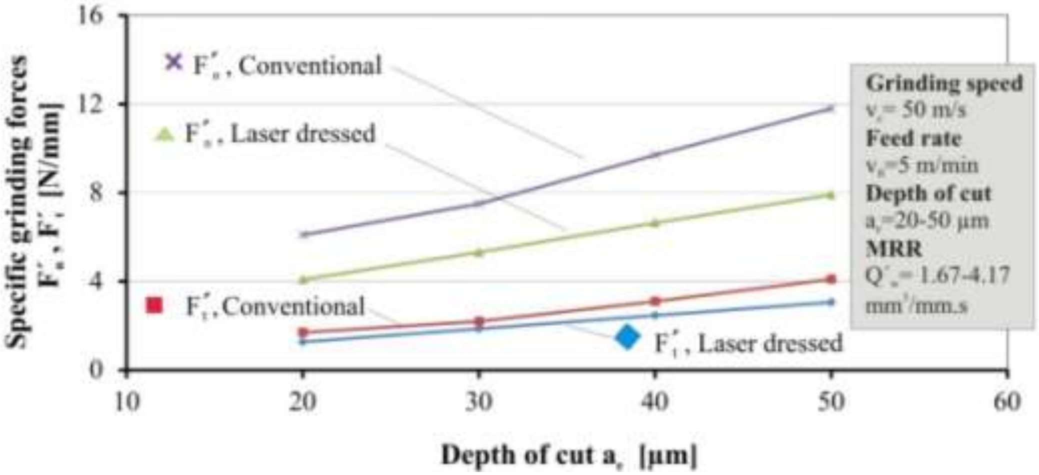
Results of laser conditioning process:

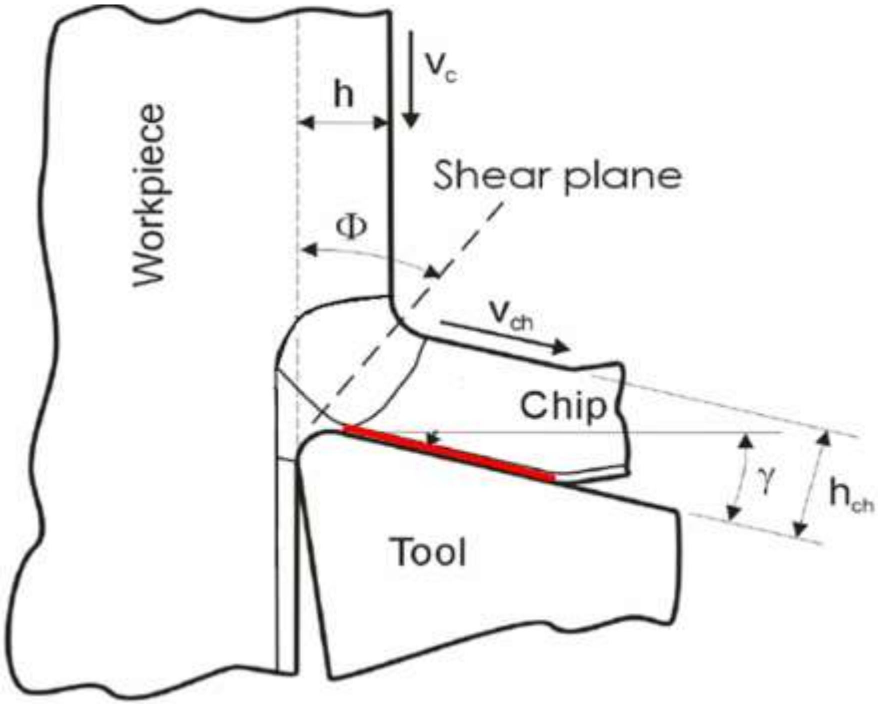
- Tangential- and normal forces (Ft, Fn)
  - Clearly lower compared to conventional process
  - Identical difference to conventional force curves even at high material removal rates
  - Slightly higher wear due to higher grain protrusion

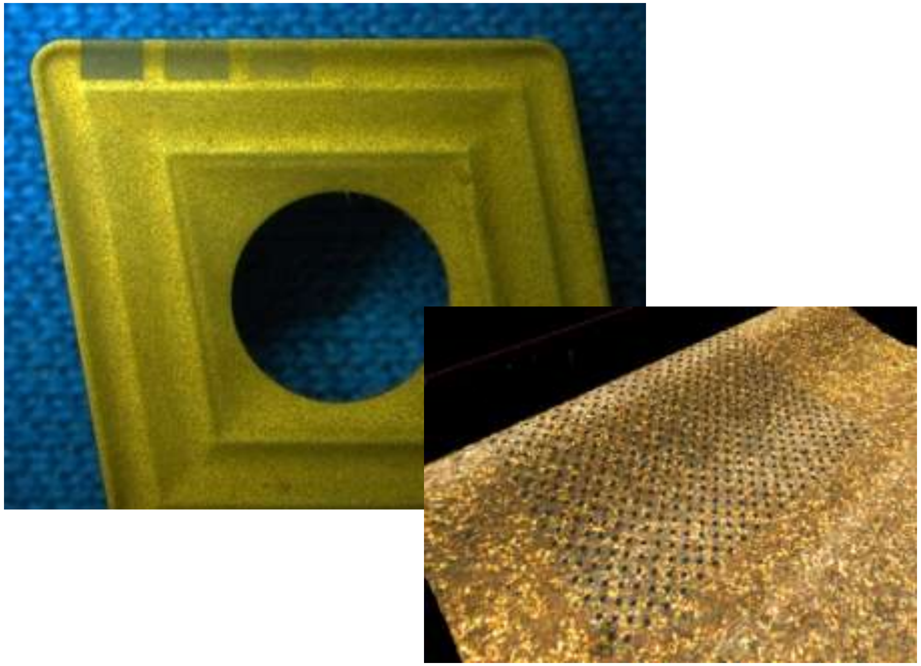


- Stable grinding conditions after run in
- Compact surface due to tangential profiling
- No grain damage in consequence of laser machining

Laser structuring of cutting inserts

- Goal: Minimizing of chip friction on cutting inserts
  - → Wear reduction
  - → Better chip flow
  - → Better surface quality
- Task: Structuring of the chip surface to built lubricant pockets





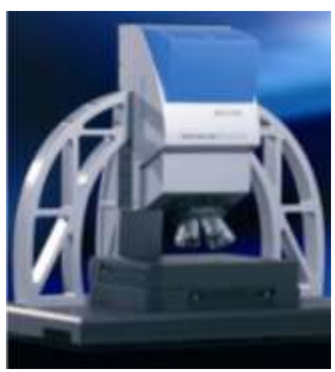
Laser structuring of cutting inserts

Laser machine TRUMPF VC5

- Hardware specification
  - λ : 355 nm
  - Laser type: Nd: YVO4
  - f : 160 mm
  - Focus dia.: ~25 µm
- Software
  - Marking software
  - CAD editor
  - Laser parameter administration

Optical measurement

- Alicona Infinite focus

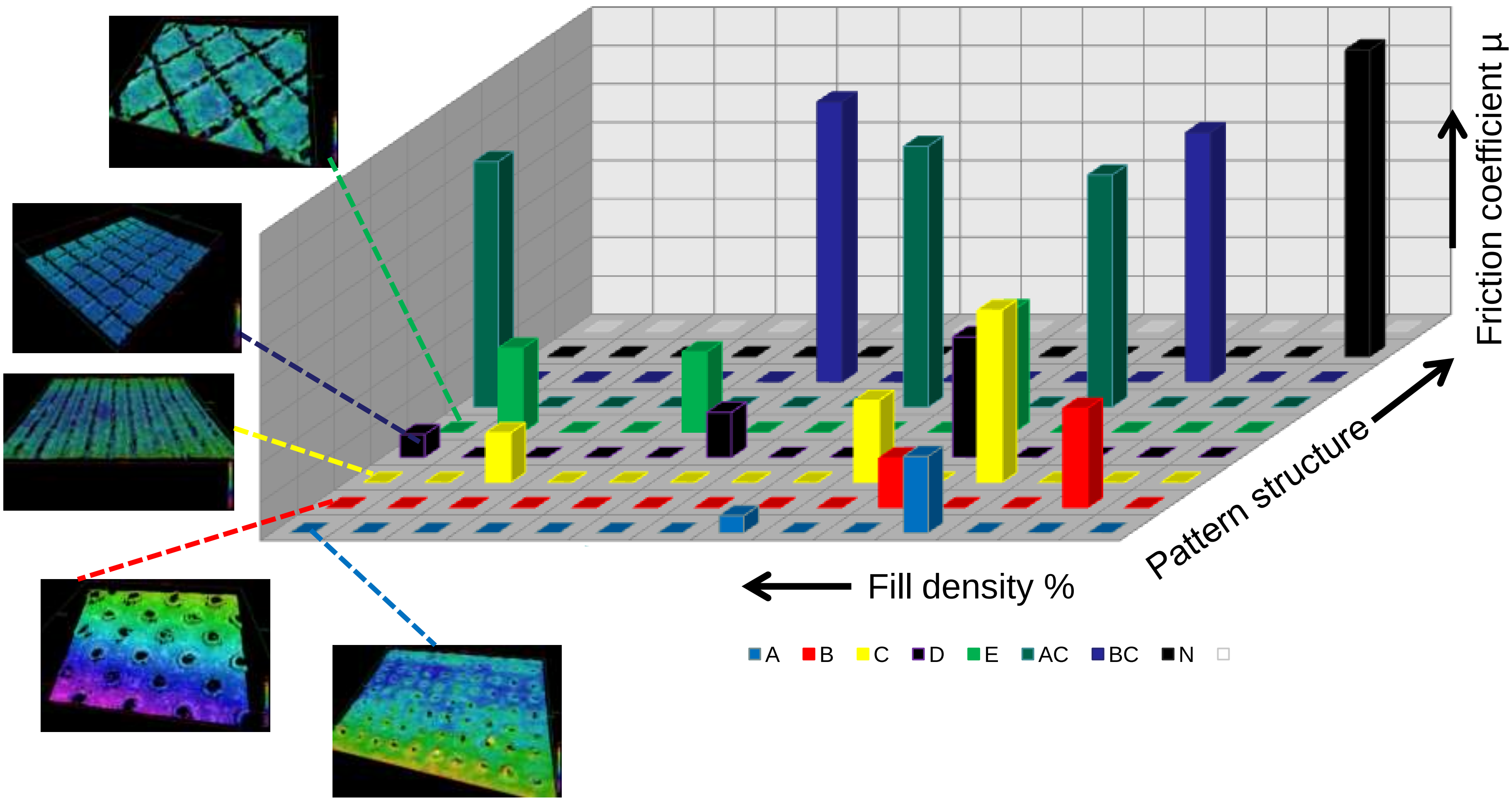


Tasks for structuring optimisation

- Focal plane and beam diameter:
  - Ellipticity
  - Energy density
- Optimization of laser parameters:
  - Power
  - Velocity
  - Frequency
  - Pulse width and number of pulses
  - Internal laser parameter
  - Precision
  - Hatching
- Multiple marking and controlling depth
- Change of optics

Results of cutting experiments:

- Relation between fill density, pattern structure & friction coefficient



Simulation of USP-Laser Processes

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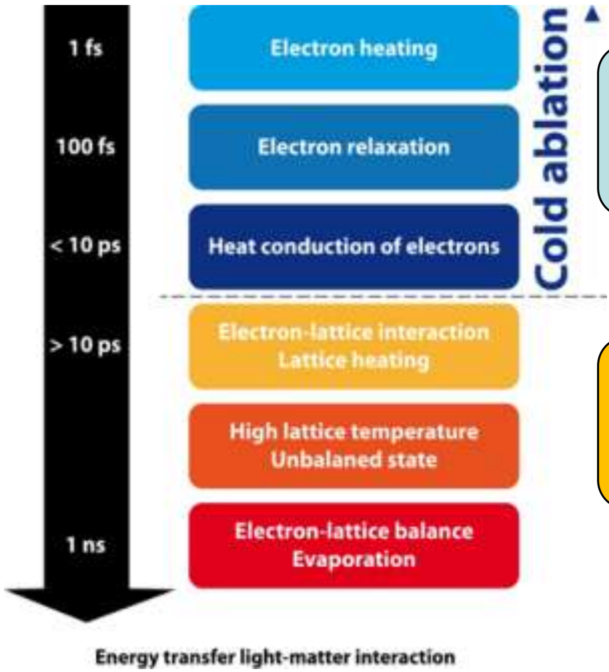
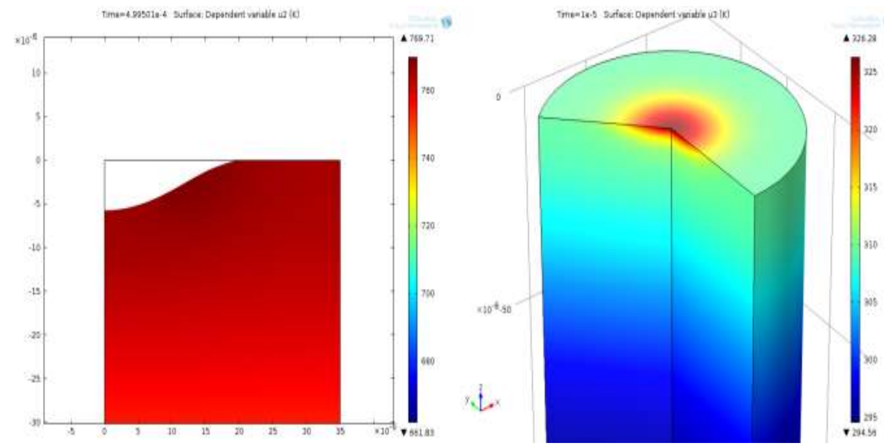
Pulse time dependent ablation characteristic:



Two-temperature modell

Classical heat conduction equation

Simulation result of a 10 ps-laser process:



Conclusions

- Conclusions for laser ultra short pulse machining of ultra hard surfaces:
  - The process is convenient for grain and insert geometries
  - Smallest cutting edge radii accessible:
    - Single grain type IIa   rK > 4 µm
    - PCD, CVD-D   rK > 2 µm
  - Surface roughness   Ra < 0.2 µm
  - No thermal damage of the machined material → best cutting edge quality

- Trends for laser process development:
  - From tool inserts to highly complex 3D geometries
  - Laser beam guidance:
    - Higher scanning velocities
    - Accuracy of tool center point (TCP)
    - Synchronisation (time) with CNC axes

Many thanks to …

Schweizerische Eidgenossenschaft
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Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER
Commission for Technology and Innovation CTI
Innovation Promotion Agency

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SEVENTH FRAMEWORK PROGRAMME

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… for supporting us!

Thank you for your attention !