Fraunhofer IWU

Fraunhofer Institute for Machine Tools and Forming Technology IWU

FLOIM: Flexible Optical Injection Moulding of optoelectronic devices

Challenges in the machining of micro-optical mould inserts

Profile of Fraunhofer IWU
Research under the heading “Resource-Efficient Production“

Founded July 1st 1991

Currently approx. 690 employees

Approx. € 45 million annual budget

Locations: Chemnitz (headquarters), Dresden, Zittau, Wolfsburg, Leipzig

3 scientific fields:

Functional Integration and System Integration	Production Systems and Factory Automation	Process Technology

Profile of Fraunhofer IWU
Your benefits

Custom-fit solutions

System modules, which can be **individually composed** according to your **initial situation,** allow for **optimal adaption** considering the **desired outcome.**

Specific benefits

Our **aim** is the creation of smart and efficient **solutions of production technology** with **concrete added value** regarding your specific requirements.

Fraunhofer – key to success

The constantly updated **scientific input**, as well as the **close cooperation** and the **cross-linking with the industry**, support the successful development of **solutions suitable for series production**.

Profile of Fraunhofer IWU
Competence from A to Z

- Automation
- Sheet metal forming
- Additive manufacturing processes
- Industrie 4.0
- Determining characteristic values and material characterization
- Lightweight construction
- Bulk metal forming
- Mechatronics and adaptronics
- Medical engineering
- Micro and precison manufacturing
- Assembly technology and robotics
- Production management

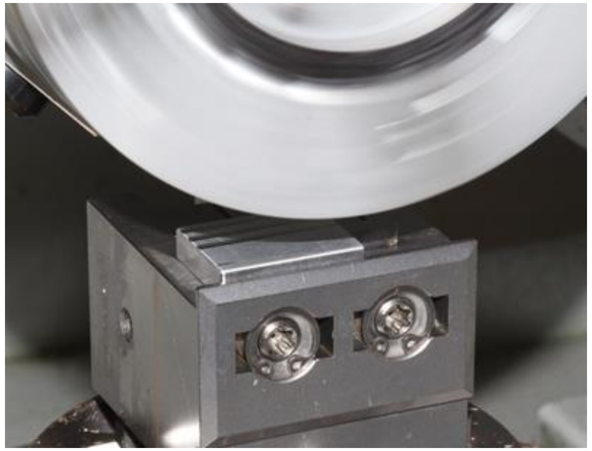
- Hydrogen and fuel cell production
- Simulation
- Cutting and removal
- Acoustical engineering
- Thermal and mechanical joining
- Virtual and augmented reality
- Machine tool
- Tool and mold making

Fraunhofer IWU in FLOIM project

Three main topics in the R&D framework

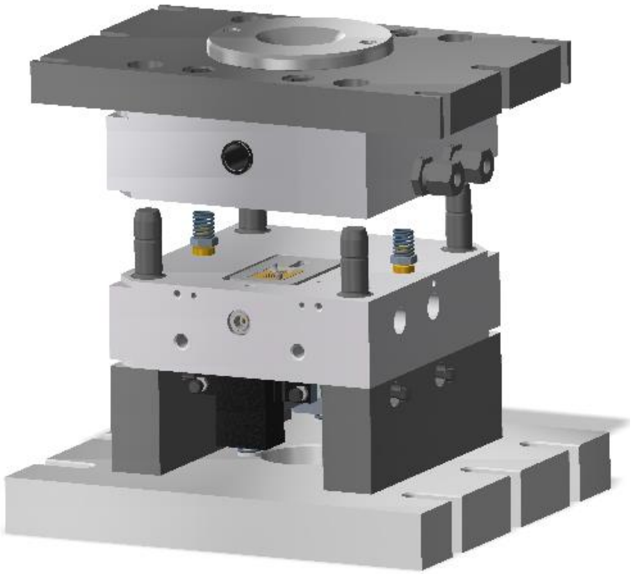
Structuring of mould inserts with optical features by machining

- micro milling, laser machining and laser structuring are combined for producing micron and sub-micron features on moulds in cooperation with further partners



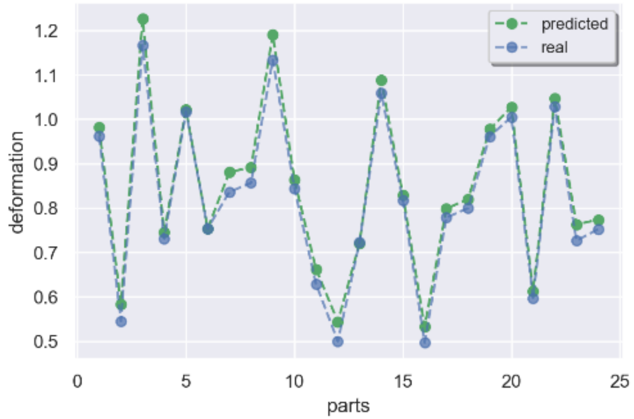
Modular mechatronic component for fine positioning

- compensate for insertion errors and geometric tolerances of the components to be overmoulded



Data-driven methodologies for quality and functionality control

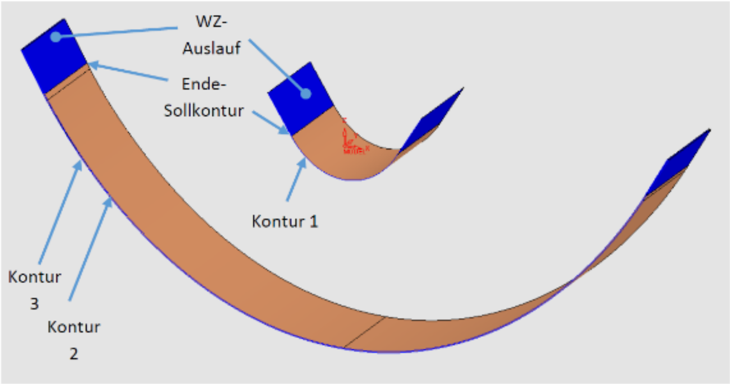
- machine learning algorithms for process prognosis and improvement
- system architectures for cognitive control powered quality assurance



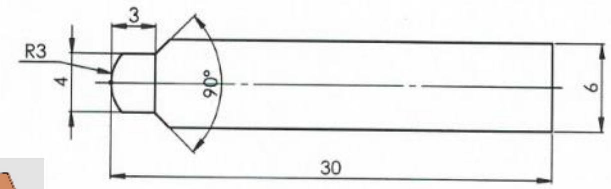
Machining of cylindrical lenses for optical encoder demo

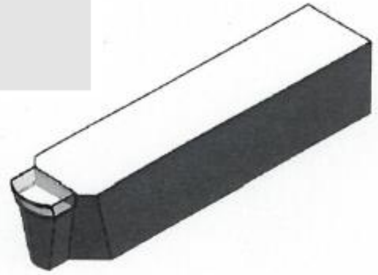
Tool strategies, design and procurement

- Two types of diamond tools for precision machining of the lens geometry
  - Contour based tool for direct milling
  - Radius tool for line milling
- Definition of tool requirements/design for small and big lens
- Radius tools R3mm and R0.5mm available for machining of lens geometries
- Transfer of lens geometry on known mould inserts (22x28mm)
- CAM-based NC-coding for line machining with small cutting depths and cutting widths of only some micrometer

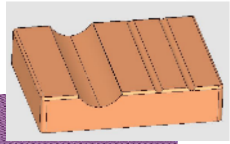


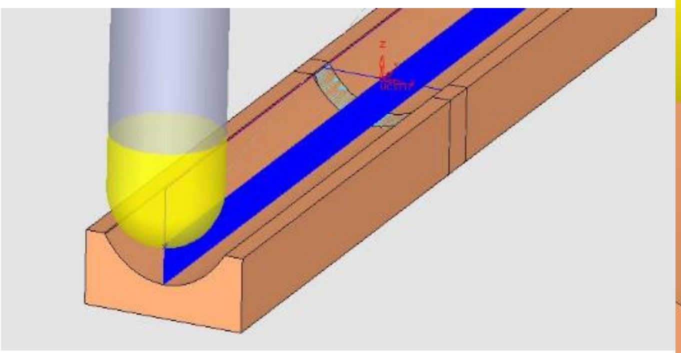
Definition of tool requirements

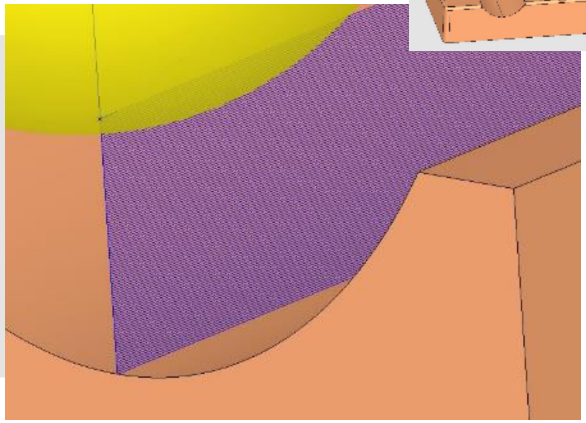




Example diamond tool design for R3 mm

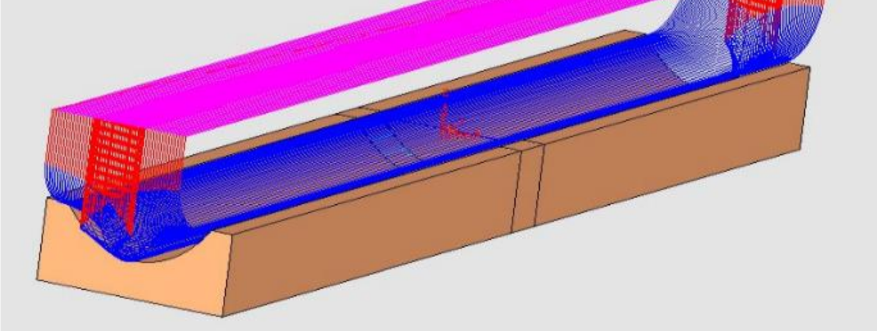






Diamond tool pre-machining in Z-direction only

Diamond tool finish-machining in line milling (for illustration with higher depths/widths)



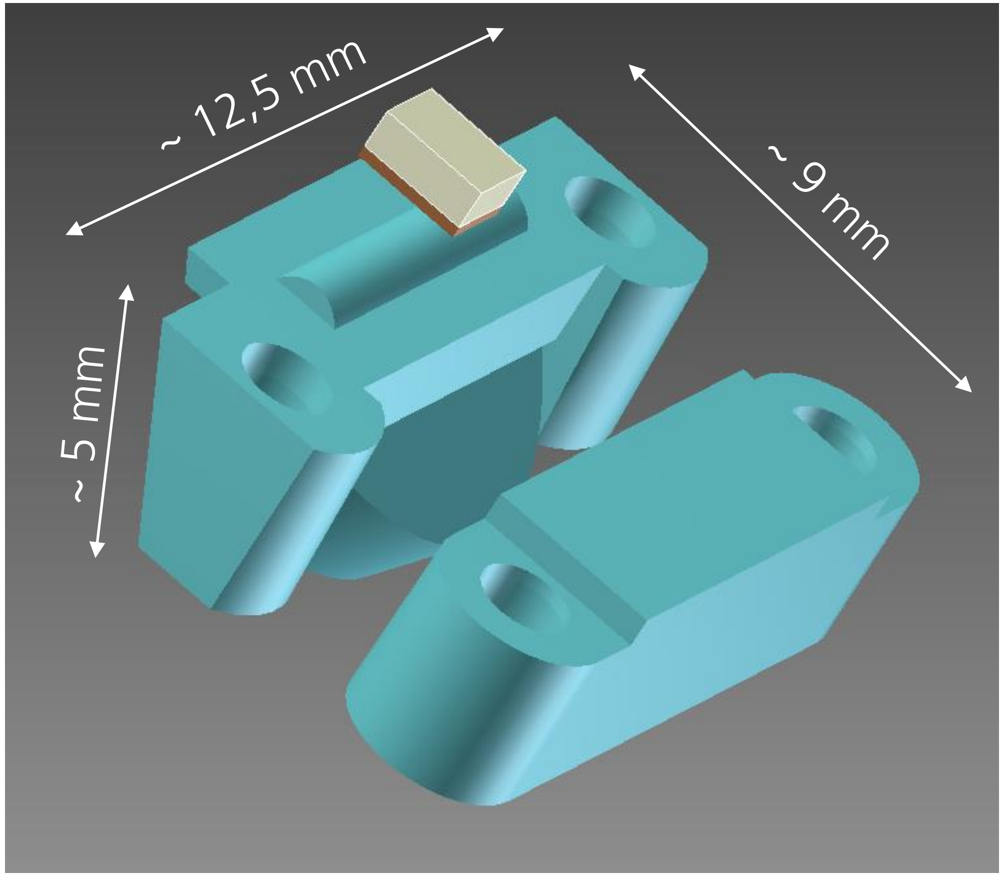
Machining of cylindrical lenses for optical encoder demo

Shrinkage estimation for mould insert manufacturing

- Systematic dimensional deviations between mould and injection moulded part
- Influences have their origin in material properties of the tool, the plastic and the process control
  → form deviations between mould and part geometry
- Compensation by scalar correction factor K for the tool geometry

- Shrinkage of polycarbonate PC typically 0,5..0,8 %
- For high surface qualities a high mould temperature is assumed, therefore the **shrinkage estimation** is calculated with **0,5 %** for demo application

Injection moulded optical part dimensions 12,5 x 9 x 5 mm³	Estimated Shrinkage 62,5 x 45 x 25 µm³

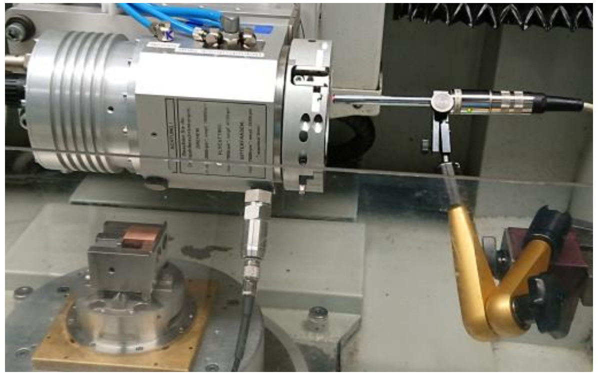


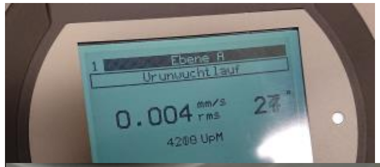
Machining of cylindrical lenses for optical encoder demo

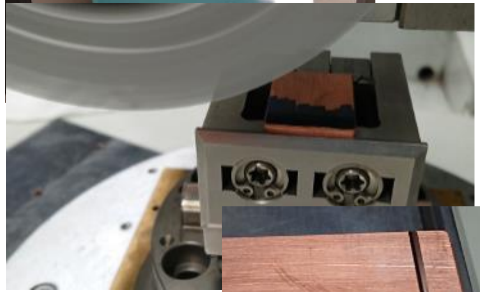
Milling tests

- Set-up micromachining center for diamond machining
- Diamond tool adaption requires high accurate balancing of air bearing spindle system with less than 0.02 mm/s
- Diamond machining with most suitable parameters of the pre-test especially on OF-OK Cu mold inserts (also Ms58, AlMgSi1 …)
- Target is machining of real lens geometries under consideration of requirements on accuracy of geometry and surface quality

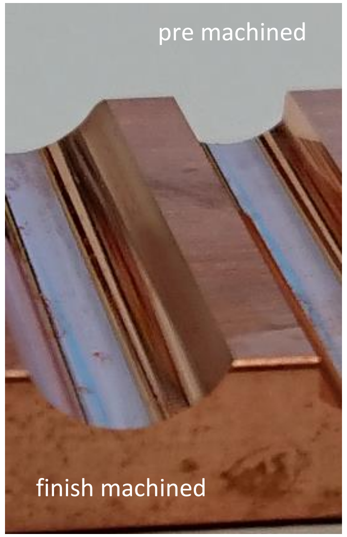

Diamond tool alignment

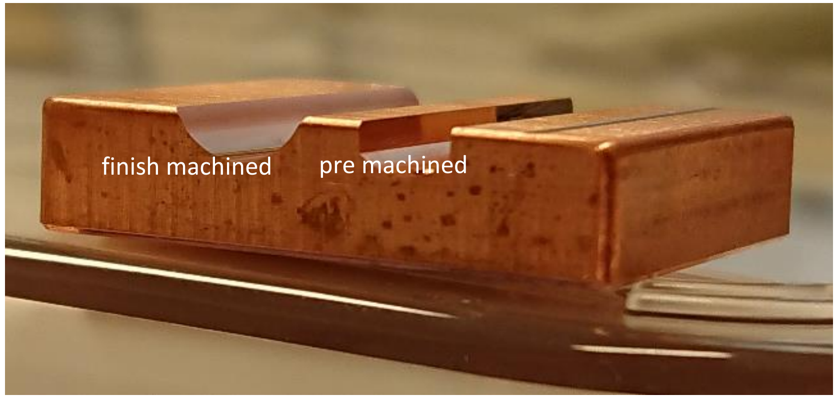

Set-up for balancing and machining


Balancing control unit report less than 0.02mm/s

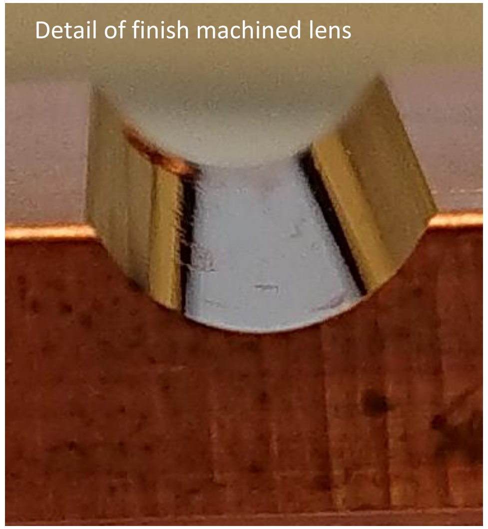

Z-Level definition


Test machining after setup





Example of complete lens geometry

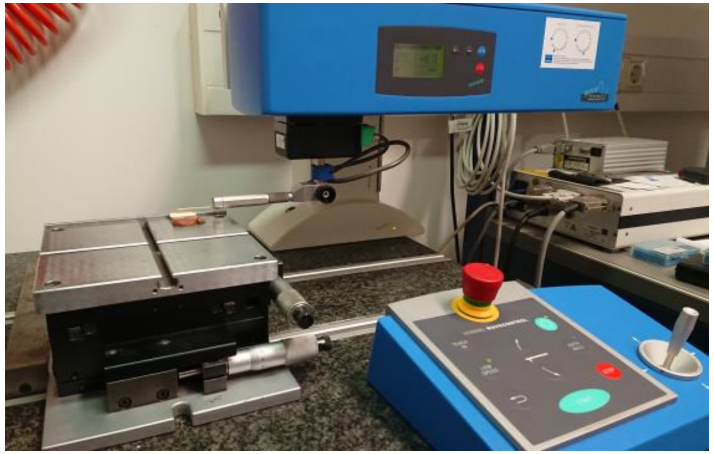


Machining of cylindrical lenses for optical encoder demo

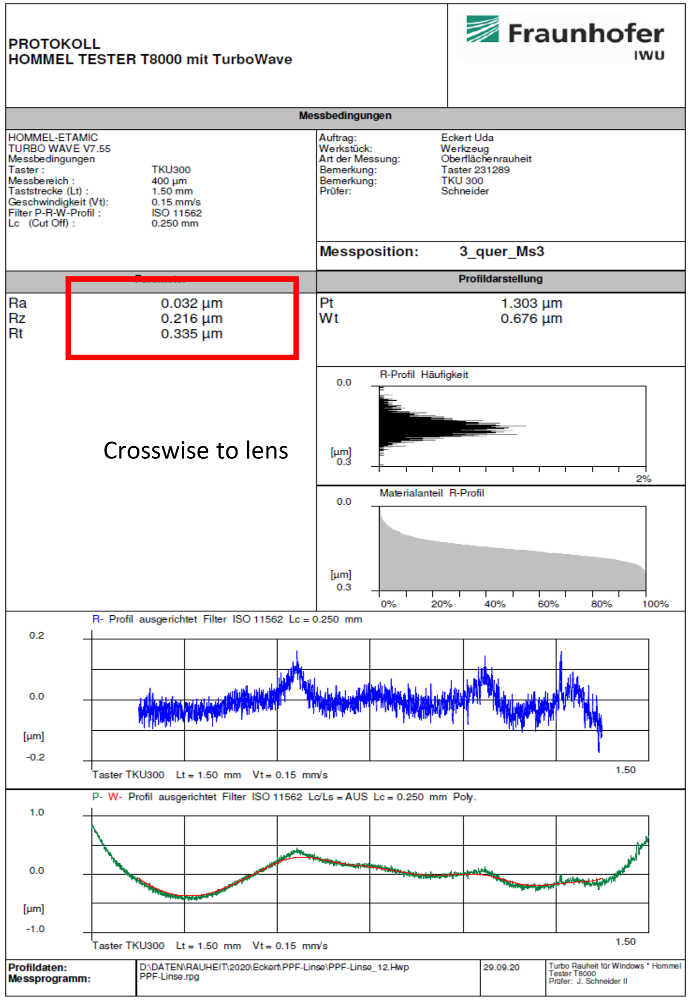
Quality control

- Tactile measurement of the surface quality confirm results of the pre-test
- Roughness level in Ra and Rz constant for all three variants of machining strategies
- High repeatability of the results
- Contour line measurement of the lens geometry following a comparison with lenses 3D-model

	Text	Ra	Rz
test machining	1_Ms1	0,023	0,158
	1_Ms2	0,021	0,146
	1_Ms3	0,023	0,162
pre machining	2_Ms1	0,024	0,157
	2_Ms2	0,021	0,146
	2_Ms3	0,023	0,179
finish machining	3_Ms1	0,023	0,178
	3_Ms2	0,023	0,152
	3_Ms3	0,022	0,167



Measurement set-up on HOMMEL T8000 for roughness and contour line measurement



Crosswise to lens

along to lens

Manufacturing of gratings on molding inserts

Machining strategies

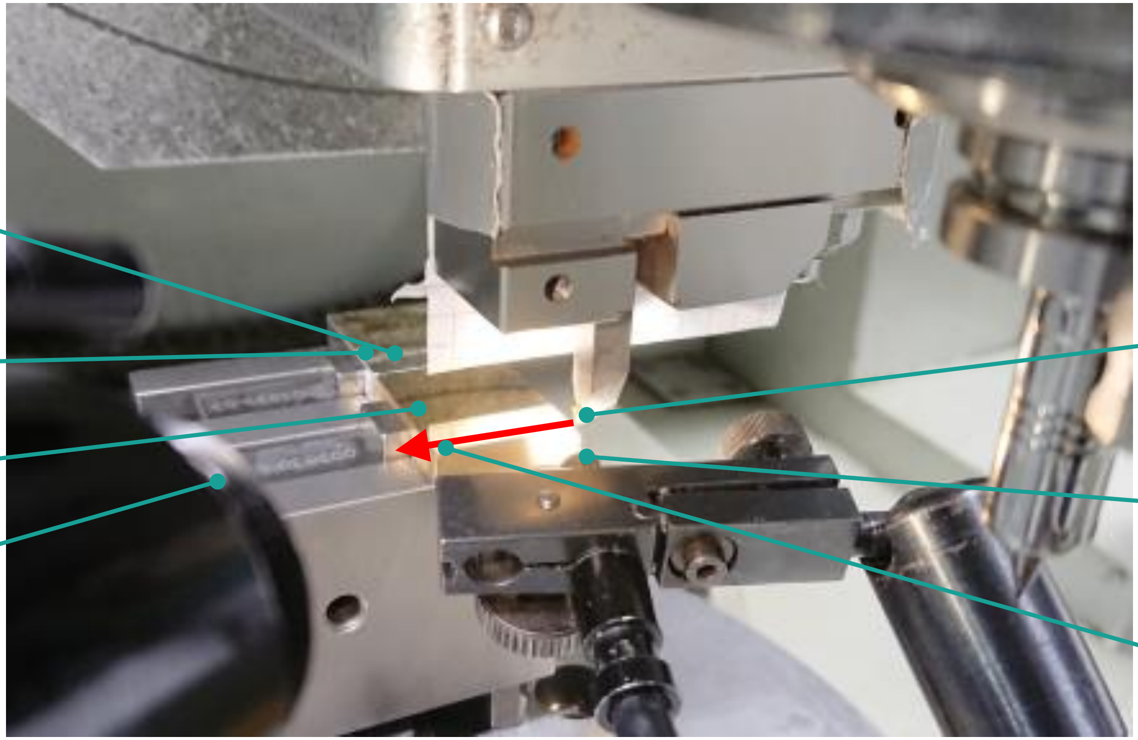
- Two options available
  - Fly-Cutting in grid milling version → precision problems regarding zero definition and thermal effects
  - Plane machining (Planing) with NON rotating diamond tool on diamond pre-machined surface
- Test setup for plane machining:

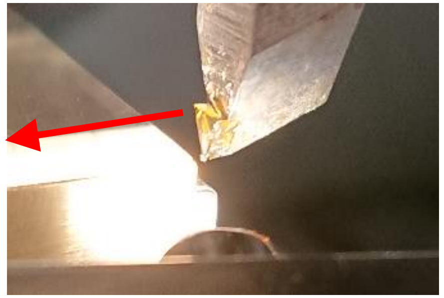
Rear projection for improvement of lighting and lattice for optimized contrast on surface

Workpiece AlMgSi1

Workpiece MS58

Camera for process observation





Diamond tool with V-shape in 53.1°

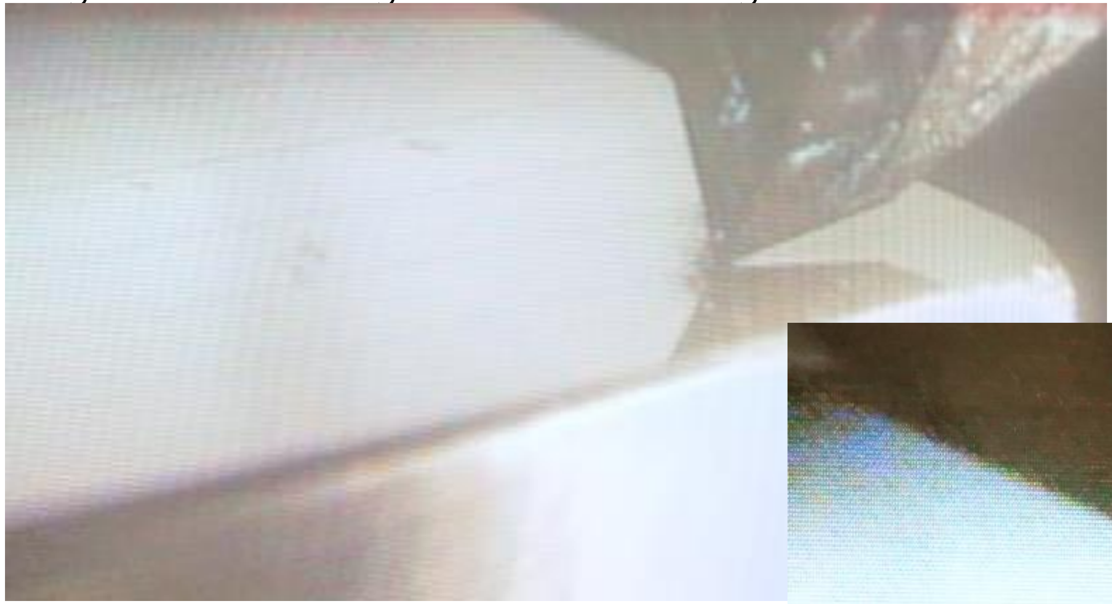
Lighting

Machining direction

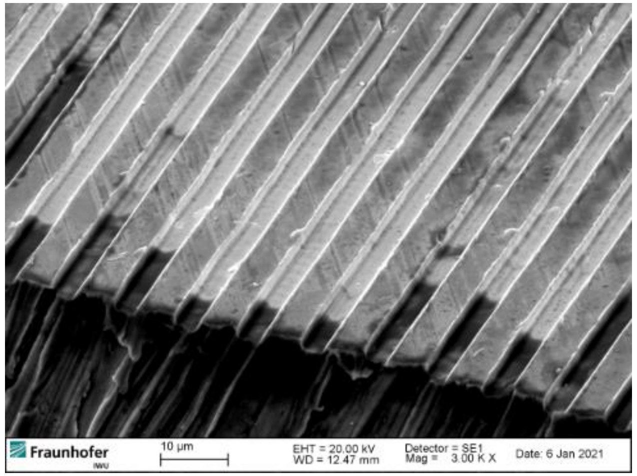
Manufacturing of gratings on molding inserts

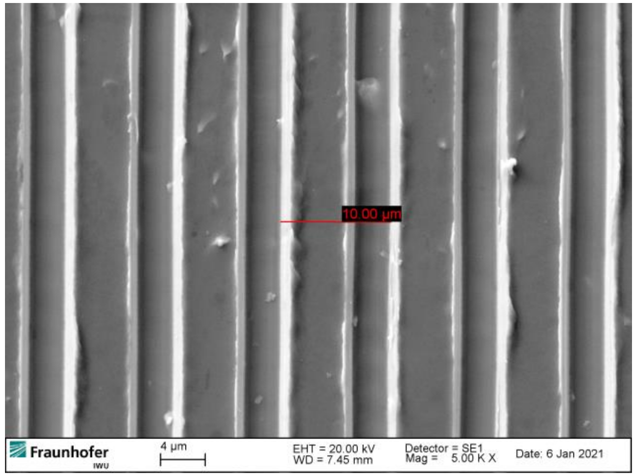
Impressions on realization of plane machining

Single line machining in MS58 for setting zero level



Grating
machining
in MS58

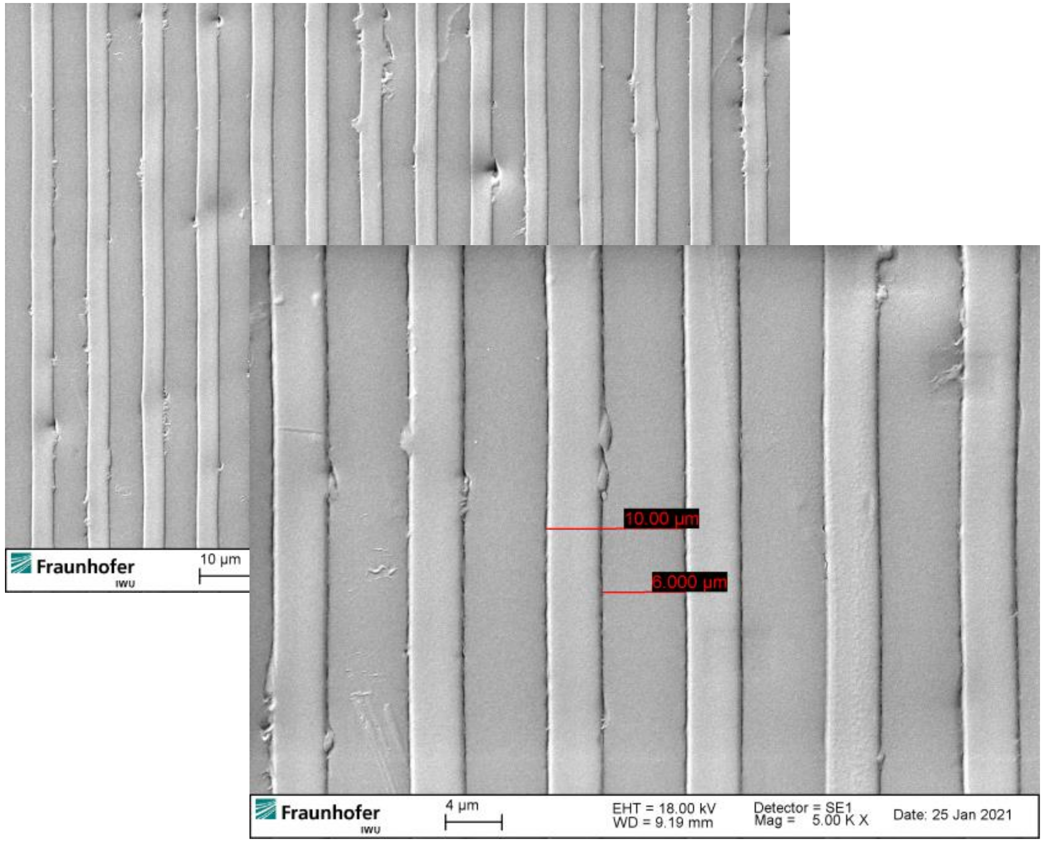




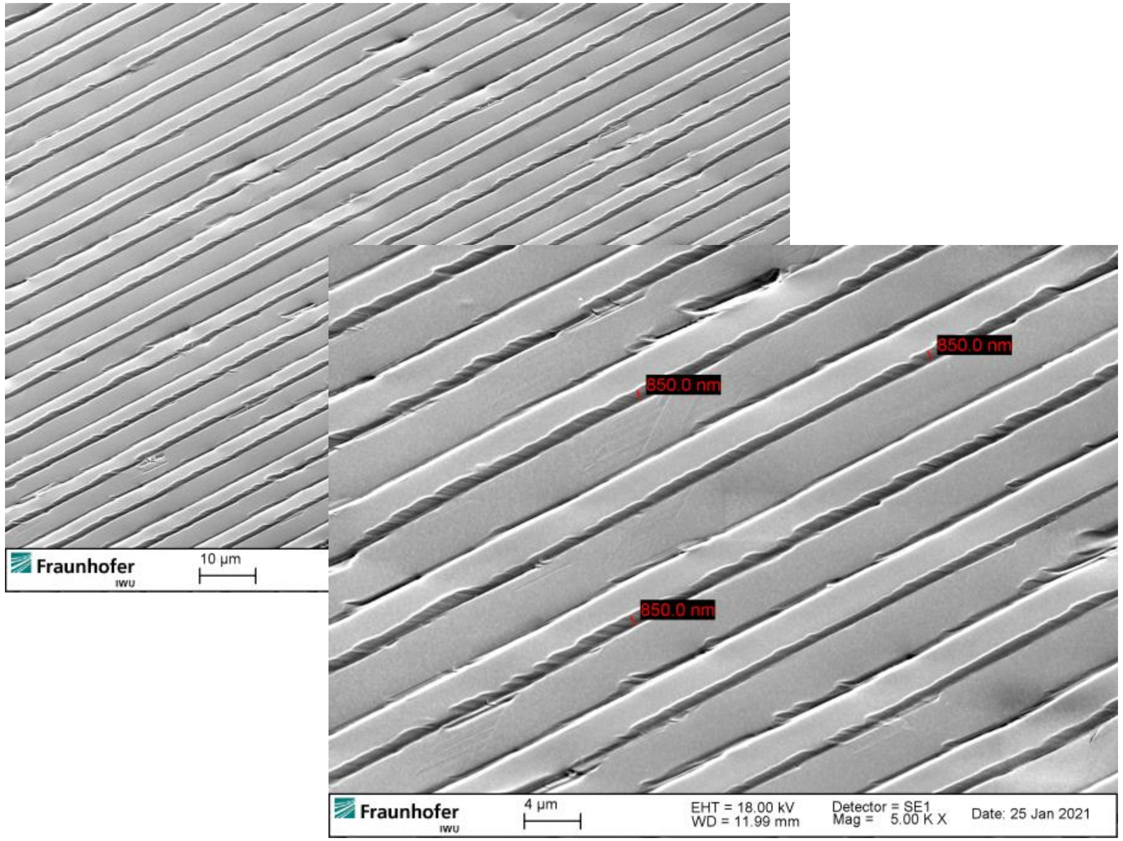
Manufacturing of gratings on molding inserts

Molding results - SEM analysis of molded parts in polycarbonate

Field 3 – top view

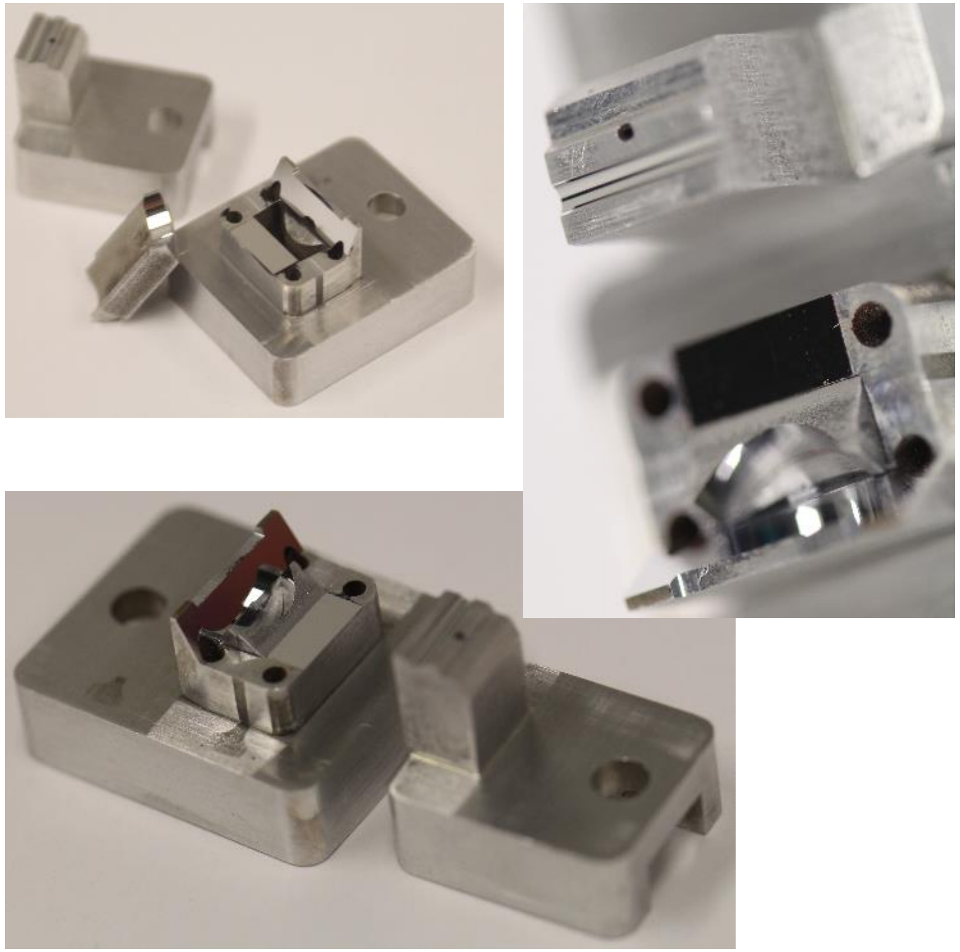


Field 3 – isometric view



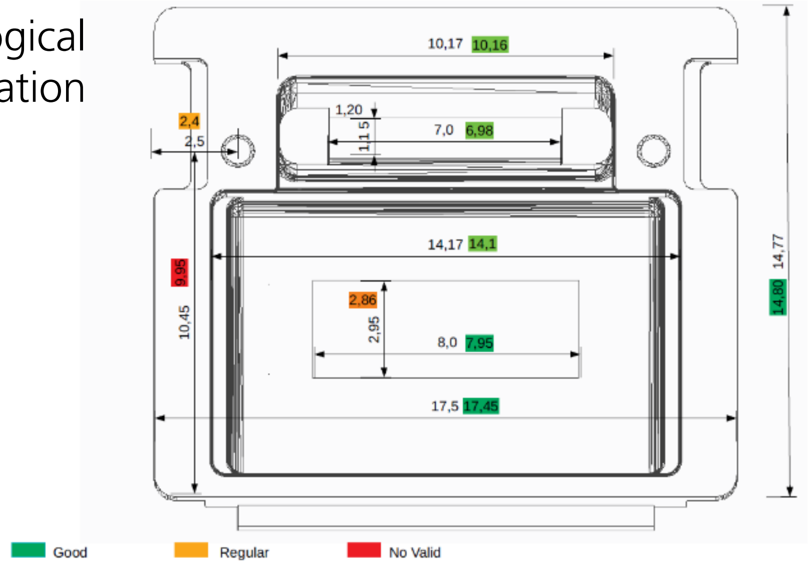
Mould inserts for Optical Encoder Demo

Impressions of first Demostrator tests

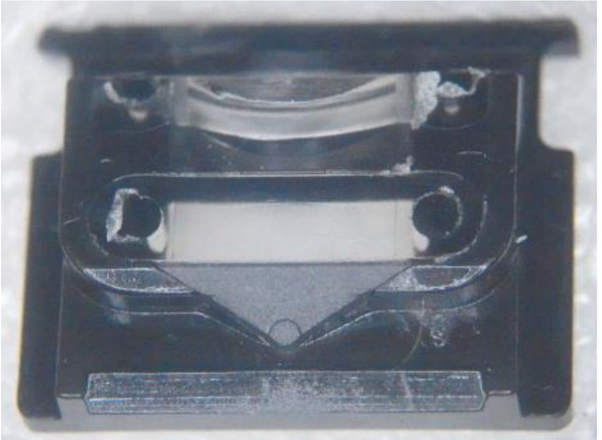


Structured Mould Inserts

Metrological evaluation



Injection Moulding result



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