Enabling New Developments in Automotive

Dr. Roman Trattnig

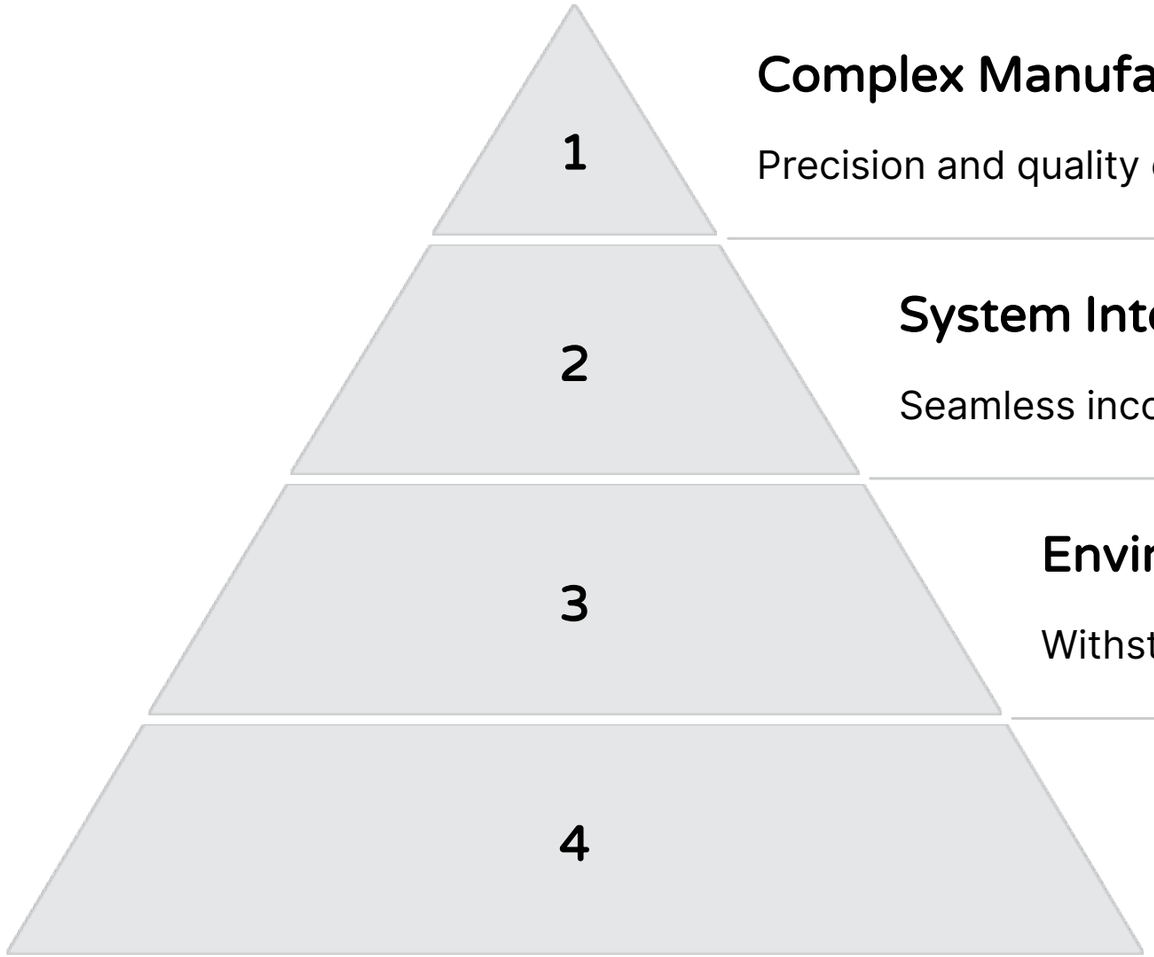
Amsterdam, 02.12.2024

JOANNEUM RESEARCH MATERIALS

The Potential of Micro-Optics in Automotive

- **Enhanced Lighting Systems**
  - Micro-optics enable adaptive headlights and advanced signal lights for improved visibility.
- **Advanced Sensor Systems**
  - Micro-optic sensors boost safety and autonomous driving capabilities in modern vehicles.
- **Interior Enhancements**
  - Aesthetic and functional improvements in vehicle interiors are achieved through micro-optics.

Challenges in Automotive Micro-Optics



Complex Manufacturing

Precision and quality control in production processes.

System Integration

Seamless incorporation with existing automotive technologies.

Environmental Durability

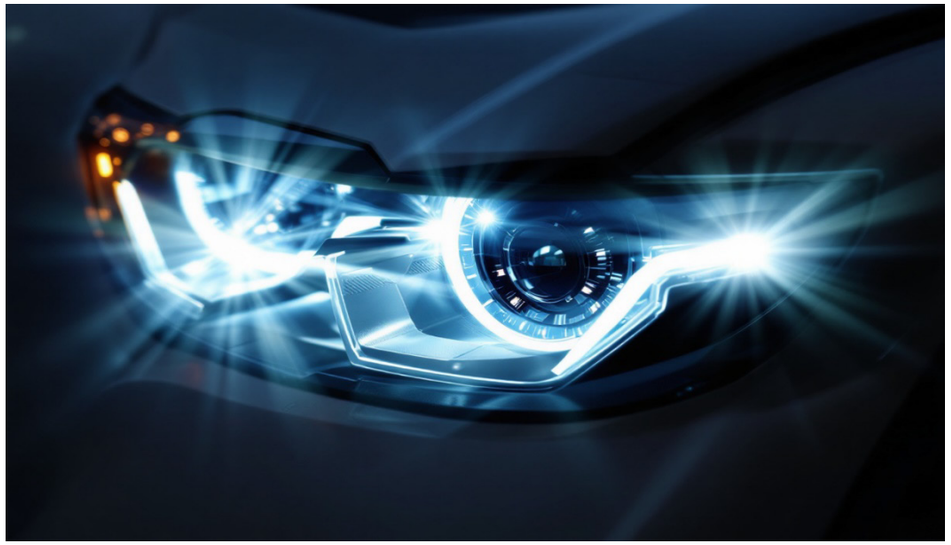
Withstanding harsh automotive conditions over time.

Scalability

Maintaining high quality in large-scale production.

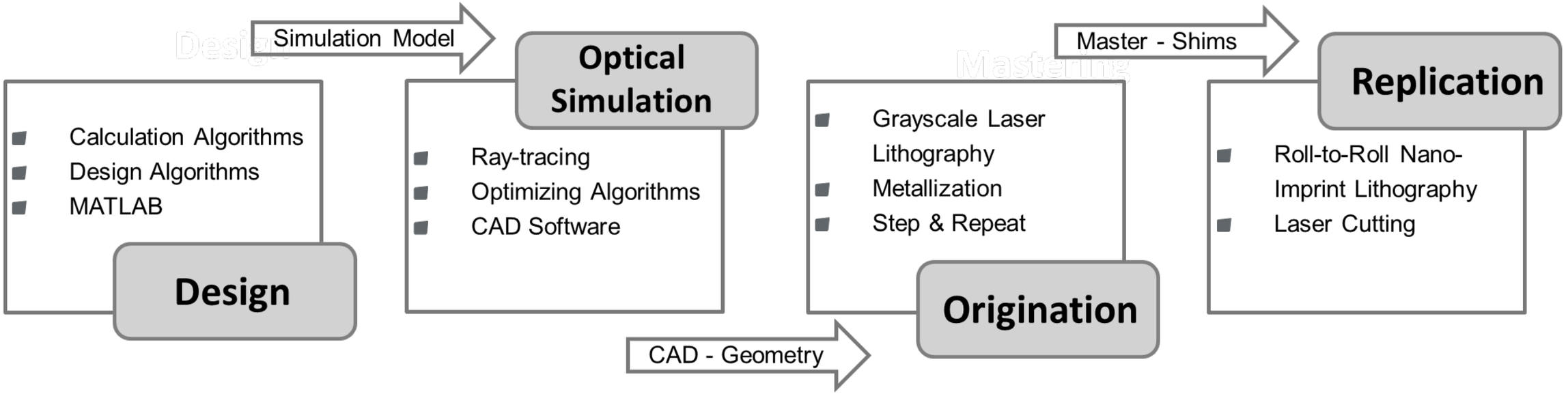
Why Free-Form Optics?

- **Arbitrary Surface Shapes:**
  - Free-form optics allow nearly unlimited surface flexibility.
- **Enhanced Performance:**
  - Tailored light distributions improve system efficiency.
- **Functionality Integration:**
  - Combine multiple optical elements into one surface.
- **Broad Range of Applications:**
  - Automotive lighting, AR/VR, imaging,…



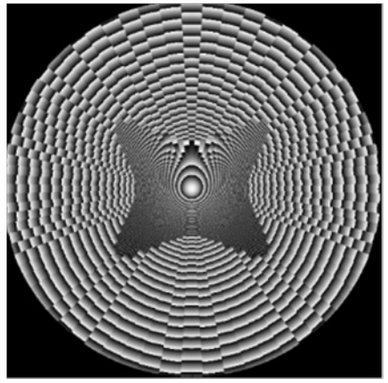
Joanneum Research's Value Chain for Developing Free-Form Micro-Optical Elements

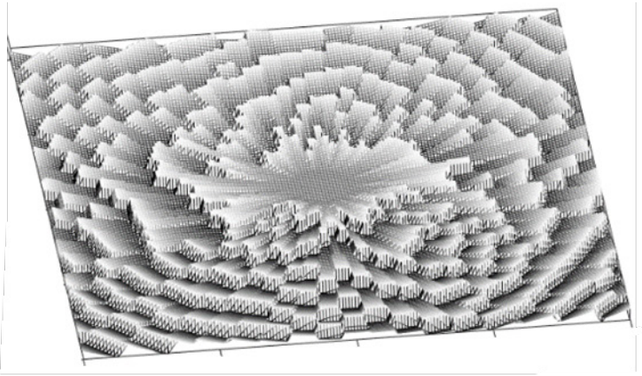
Our Value Chain comprises all necessary steps from the idea to the manufactured structures on a foil. In detail, it can be subdived into the **Design**, the **Optical Simulation**, the **Origination** and the **Replication** process.

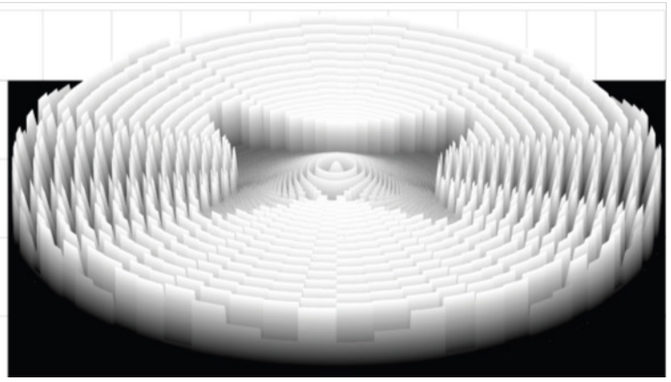


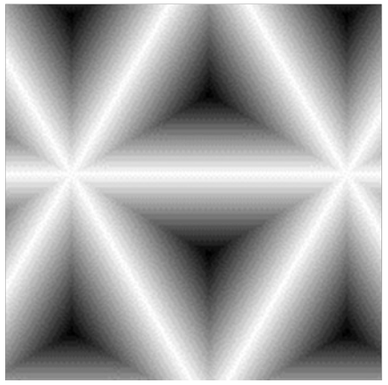
Optical Design and Simulation

- **Design Excellence**
  - Advanced CAD software and MATLAB implementation using proprietary algorithms for complex optical requirements
  - Custom-tailored solutions for specific functions
  - Precise geometric specifications for each component
- **Virtual Validation**
  - Comprehensive ray-tracing simulations
  - Early detection of potential performance issues
  - Pre-production verification of component functionality
- **Iterative Optimization**
  - Continuous refinement through feedback loops
  - Value chain optimization from design to manufacturing





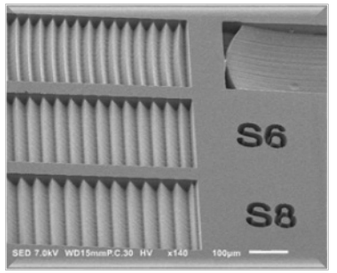


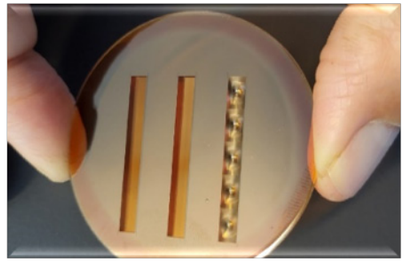


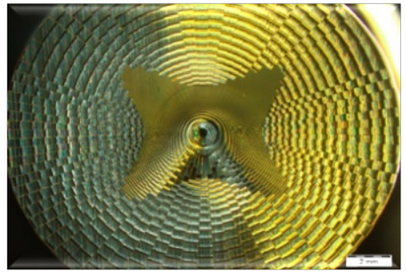
Origination Process: From CAD to Master for Replication

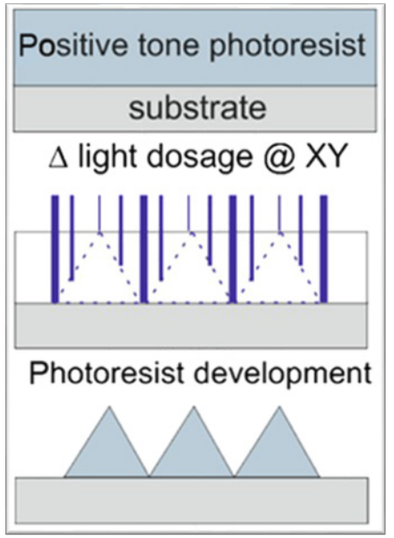
Translating optical designs into physical structures for replication.

- CAD Geometry Conversion:
  - Transformation of designs into a virtual photomask with light dosage mapped to each x,y,z coordinate.
- Grayscale Laser Lithography:
  - Controlled light doses applied to a positive photoresist, creating precise 3D structures.
  - Optimization of light exposure patterns for accuracy.
- Resist Removal:
  - Exposed areas of the photoresist are removed, revealing intricate 3D shapes.
- Nickel Plating:
  - Electroplating of developed structures creates robust metal master stamps, durable and ready for up-scaling..



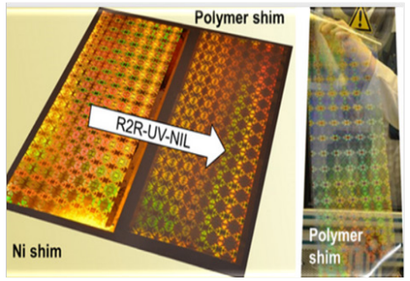


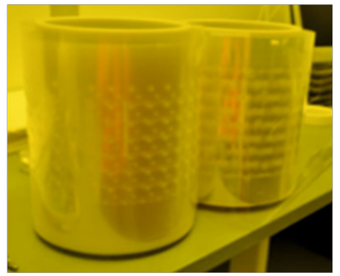


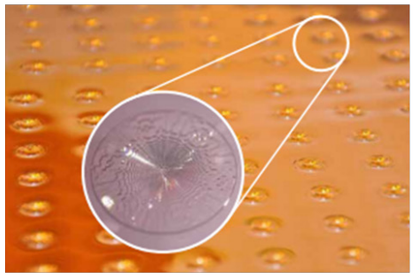


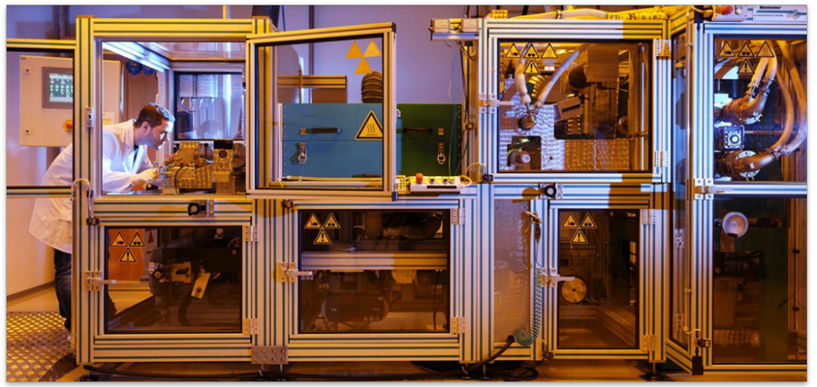
Up-Scaling Free-Form Optics with R2R Technology

- **Step-and-Repeat (S&R) Upscaling**
  - Successive UV nanoimprints to replicate Micro-optical patterns across large surfaces.
  - First polymer shims are created.
  - Metallized shims are produced for high volume replication.
- **Roll-to-Roll nanoimprint lithography (R2R-NIL)**
  - Continuous production process that demonstrated high-resolution micro- and nanostructures via imprinting
  - Cost-effective scaling of free-form optics and high-volume production with consistent quality.



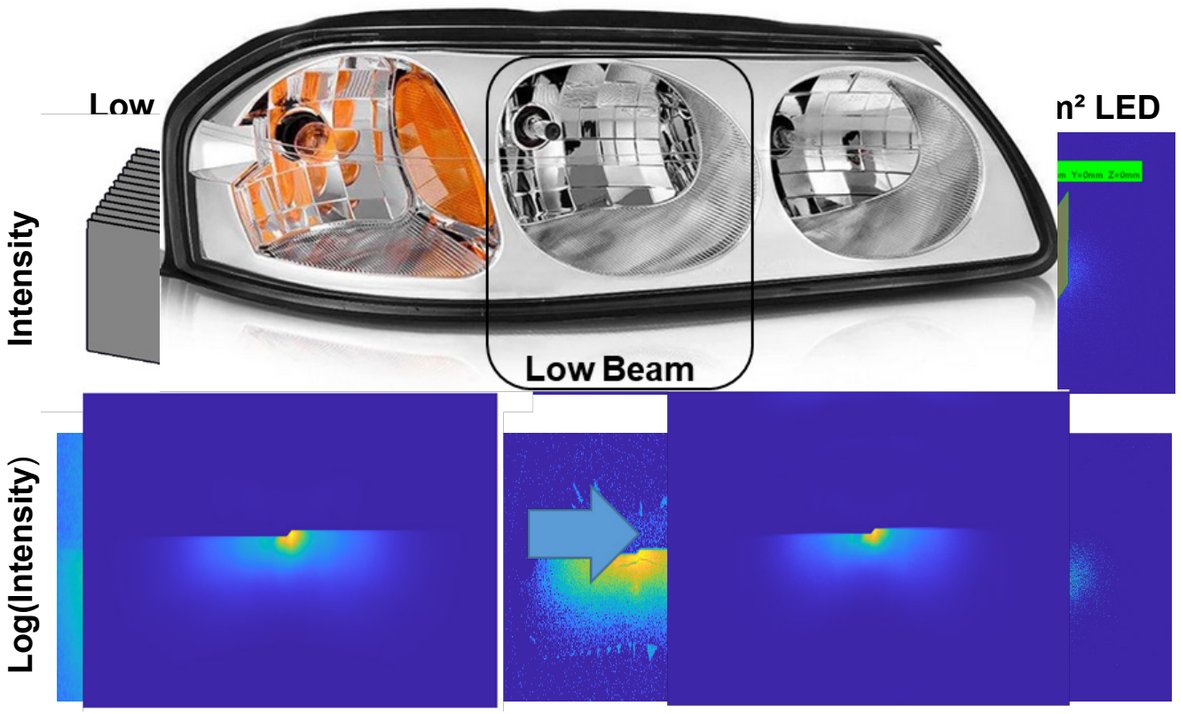






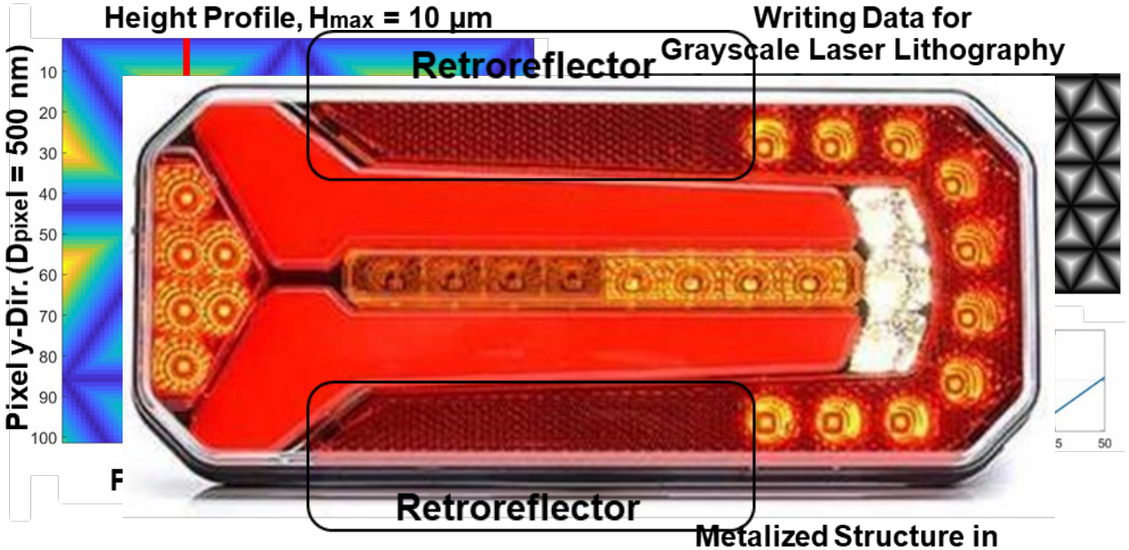
Application - Low Beam Headlight

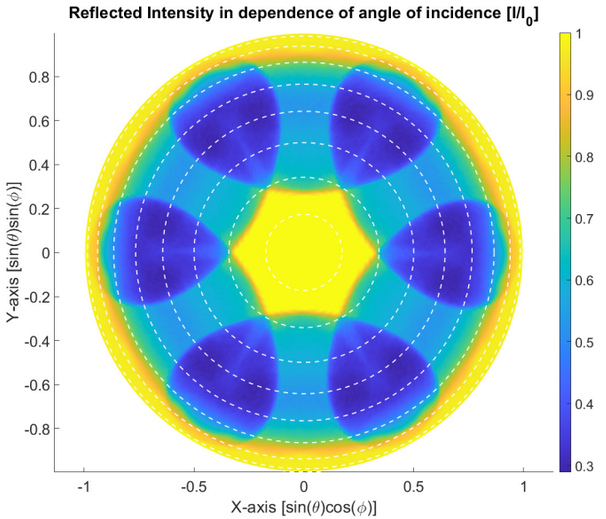
- Optimizing Low Beam Headlights with FF-MOE Technology
- **Design Challenges:**
  - Strong asymmetries (top vs. bottom), with wide horizontal spread and a narrow vertical spread.
  - Sharp cut-off line - maximum gradient of 0.3 to 0.35 degrees in the central region.
  - High concentration of light in the central area (horizontal ±10 degrees, vertical 0–5 degrees).
- **Feasibility:**
  - Complete transformation using FF-MOEs cold not be achieved
  - Promising for partial adaptations. (projection lens)

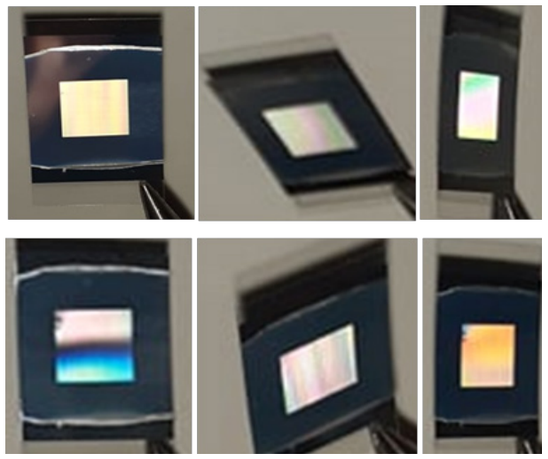


Application -Microstructured Retroreflectors

- Study and fabrication of microstructured retroreflector for enhanced reflectivity and aestthetics.
- **Design Specifications:**
  - Pyramid shapes with three surfaces forming 90° angles.
  - Pixel resolution: 500 nm.
  - Maximum structure height: <50 µm.
  - Structured area: 1 cm² with approximately 48k pyramids.
- **Material and Visibility:**
  - At 50 µm, structures appear homogeneous to the naked eye, ensuring aesthetics without compromising functionality.
  - Structures can further be aluminum-coated for enhanced reflectivity.







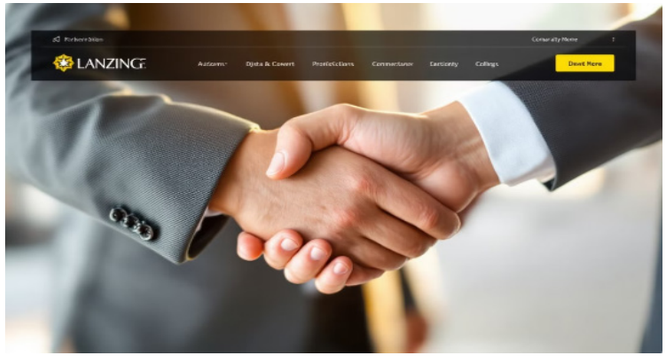
Key Benefits and Vision for Free-Form Micro-Optics

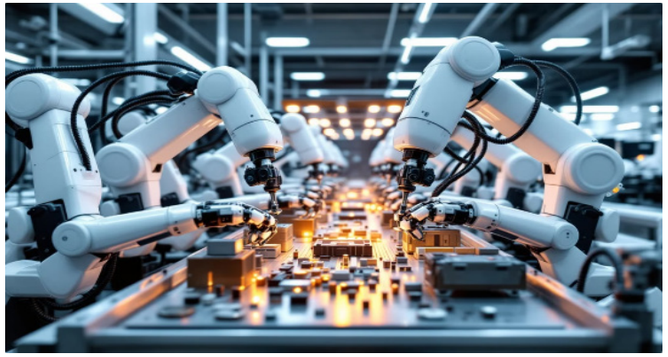
- Results display nicely:
  - Free-form micro-optics provide new solutions for tailored light distributions.
  - Compact, multifunctional optical systems for diverse applications are possible
  - Cost-effective replication enabled by R2R-NIL and Step-and-Repeat techniques.

- Potential Future Perspectives:
  - Integration with emerging technologies like AI-driven optical design streamlining the design process
  - Expansion into green technologies: solar energy and energy-efficient lighting.
  - Free-form micro-optics offers transformative solutions for technological innovation and sustainability.
  - Continued research and collaboration are essential to unlock the full potential of free-form micro-optics.

Comprehensive Service Offerings - Let's innovate together

- **Design & Simulation**
  - Advanced optical modeling and optimization for your specific needs.
- **Advanced Origination**
  - Cutting-edge grayscale laser lithography
- **Prototyping and Pilot Production**
  - Rapid prototyping and testing of micro-optic components.
  - Scalable pilot-production solutions for high-quality micro-optic elements.
- **Proprietary Resins**
  - Custom UV imprint resins tailored to meet stringent requirements for durability and performance.
- **Strong Partnership – The Phabulous Pilot Line**
  - Extended Expertise: Access advanced capabilities and scalable manufacturing through our partner network.
  - Comprehensive Solutions: Collaborative approach to deliver tailored, end-to-end solutions for evolving market needs.





Shaping the future, together!

JOANNEUM RESEARCH
Forschungsgesellschaft mbH

MATERIALS
Institute for Sensors, Photonics and Manufacturing Technologies

Franz-Pichler-Strasse 30
8160 Weiz

Phone: +43 316 876-3000
materials@joanneum.at

www.joanneum.at/materials

JOANNEUM RESEARCH
MATERIALS