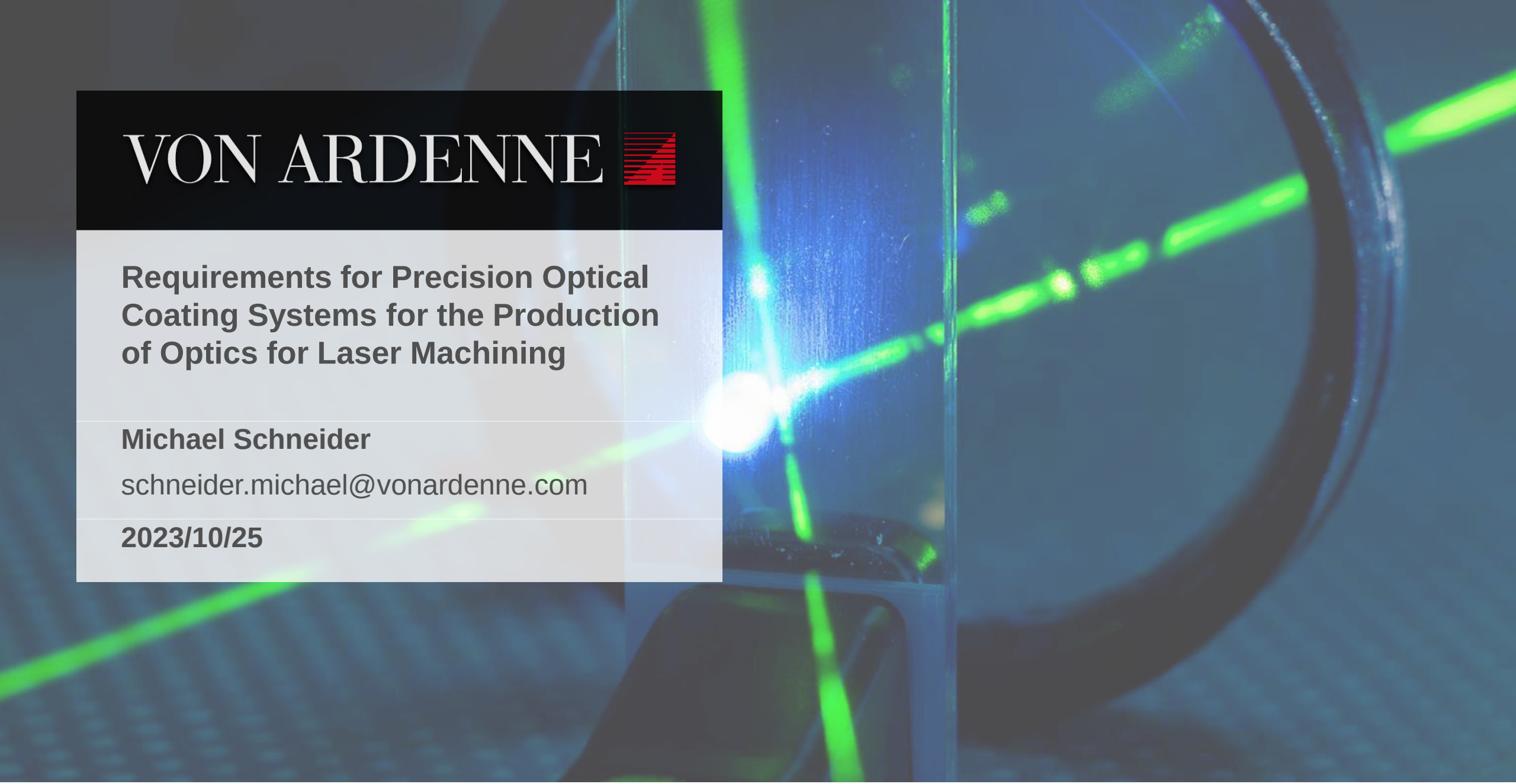

# Requirements for Precision Optical Coating Systems for the Production of Optics for Laser Machining

**Michael Schneider**

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**2023/10/25**

# OUTLINE

## Requirements for Precision Optical Coating Systems for the Production of Optics for Laser Machining

EPIC Meeting on Laser Applications along Battery Manufacturing Process, Stuttgart

- ☐ **About us**
- ☐ **Requirements for the Coating Process**
- ☐ **Requirements for the Substrate Geometry**
- ☐ **Conclusion**

# FROM SMALL TOOLS TO HIGH-VOLUME MANUFACTURING EQUIPMENT

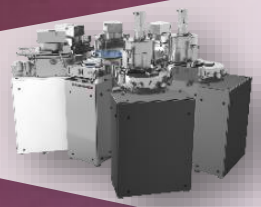
**CAPEX**
- Substrate width
- Throughput
- Footprint

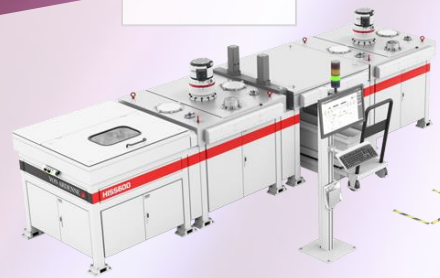
**R&D**

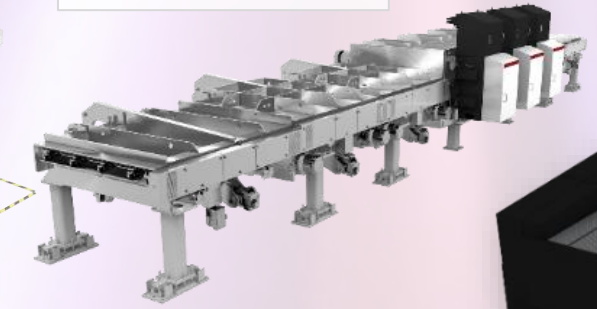
**Pilot**

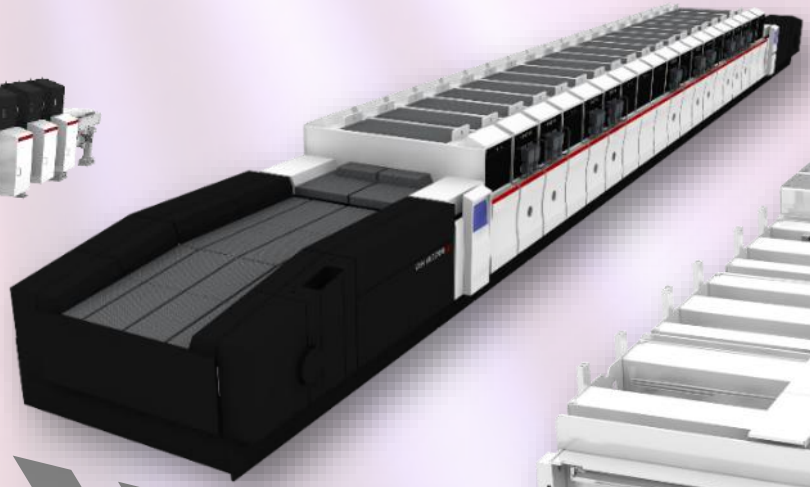
**Production**

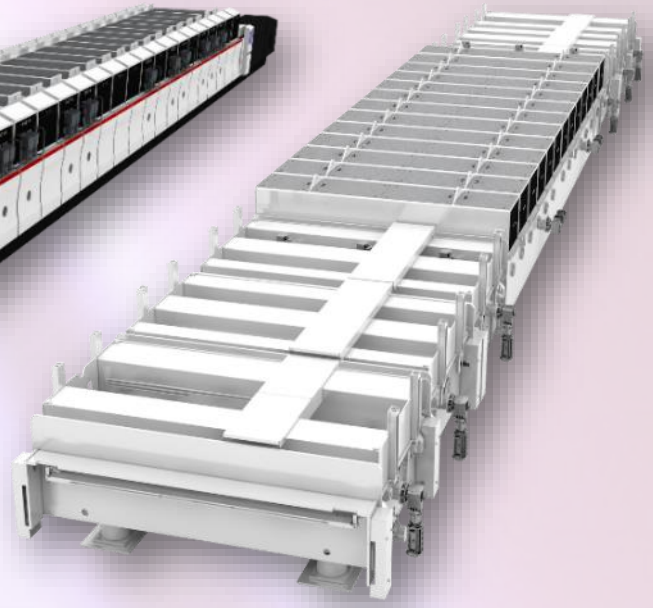
Scalability is Productivity











Cost per substrate

**OPEX**
- High-utilization magnetrons
- Advanced heating processes
- Homogeneity of coatings

# MANFRED VON ARDENNE

## Scientist, Inventor & Entrepreneur

1907 – 1997

### Key Inventions

**1964** Installations for evaporation coating of thin films in a high vacuum for industrial applications

**1959** The 45 KW electron beam multi-chamber furnace (EMO) for vacuum melting and refinement of reactive and refractory metals

**1937** Scanning electron microscope

**1930** First transmission of fully electronic television

His inventions laid the foundation for our work today in the fields of vacuum, plasma and electron beam technology.

## VON ARDENNE Company History

Established 1928


Company campus in Dresden, Germany

### Milestones

**Today** VON ARDENNE Group (Dresden)

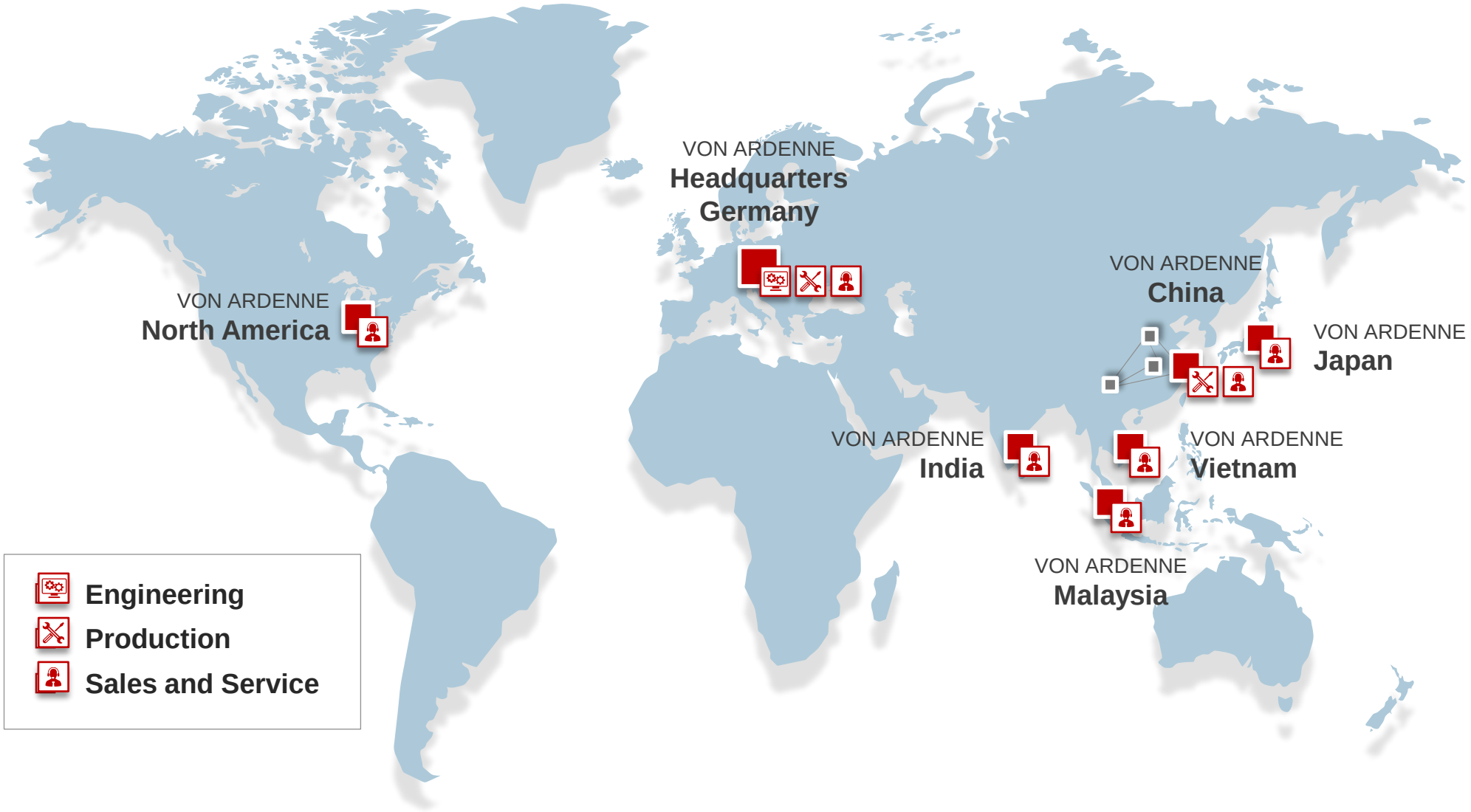
**1991** VON ARDENNE Anlagentechnik GmbH (1991 - 2013)

**1955** Manfred von Ardenne Research Institute (Dresden)

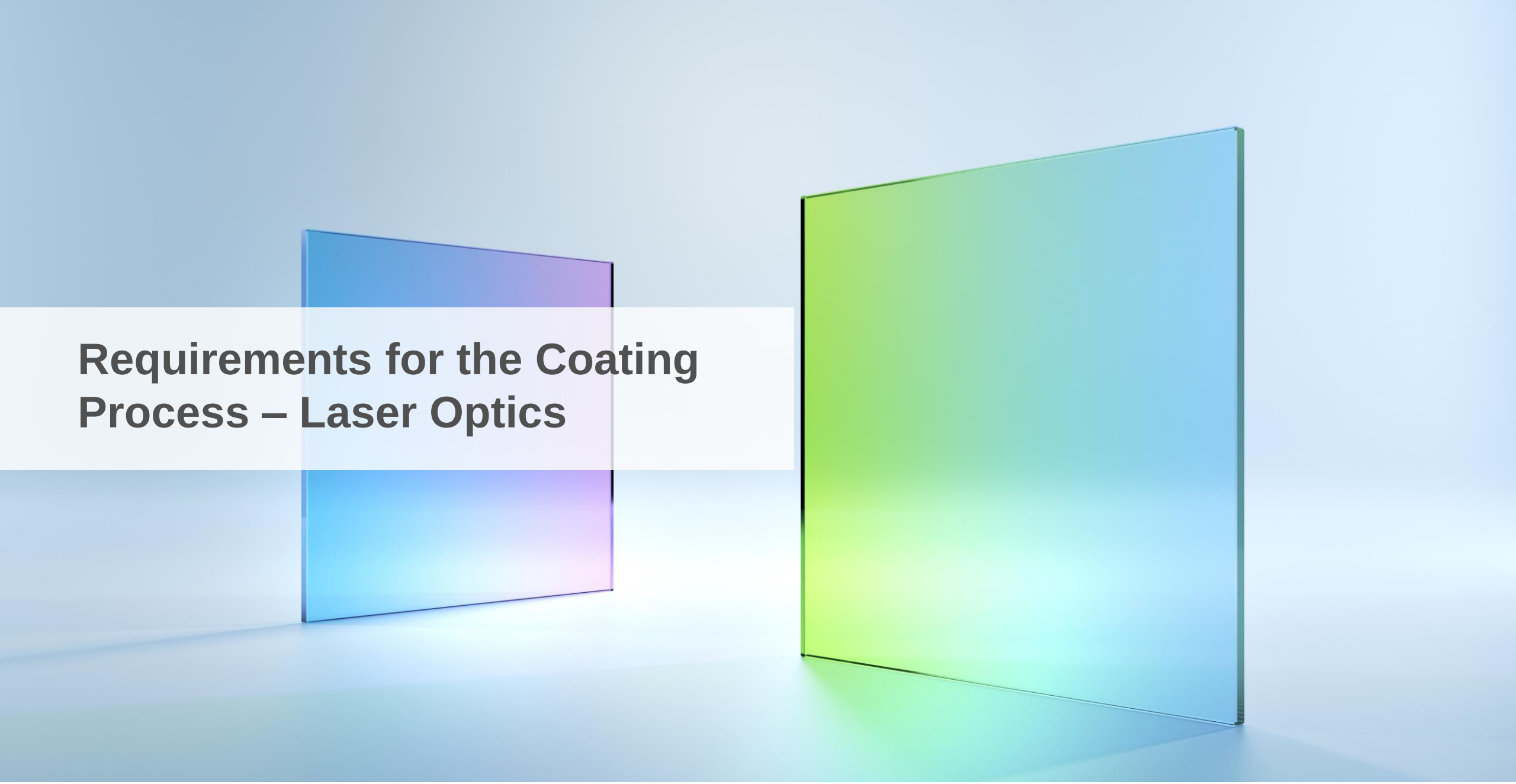
**1945** Institute for Industrial Isotope Separation (Suchumi)

**1928** VON ARDENNE Laboratory for Electron Physics (Berlin)

# VON ARDENNE – A GLOBAL COMPANY

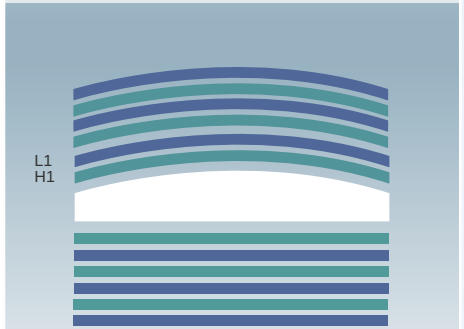


# Requirements for the Coating Process – Laser Optics



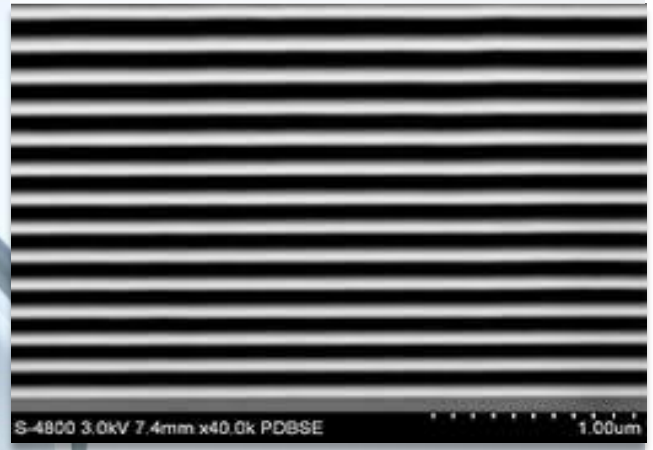
# PRECISION OPTICAL COATINGS

Substrate side view

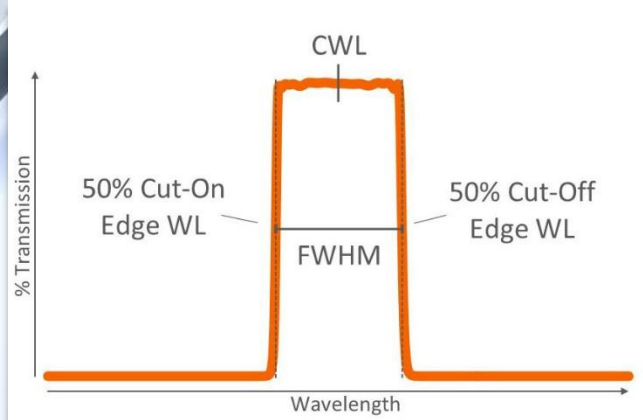



**Flat-convex lens**
Layer stack: [HL]^500

High precision multilayer coating




Optical filter



# LASER OPTICS CHALLENGE

## Low-loss Optical Coatings

Light energy-resistant filters and mirrors

### Desired layer properties

- ☐ Lowest losses (absorption, scattering)
- ☐ Low stress
- ☐ Defect-free
- ☐ Dense film structure

### Avoiding extrinsic defects

- ☐ Particle contamination - substrate pre-cleaning, unclean handling, equipment cleaning condition, carrier cleanliness, particles from process, flitter

### Specific coating design

- ☐ Coating material (band gap)
- ☐ Electric field standing wave
- ☐ Transition of incident medium into layer stack
- ☐ Interface tuning

### Avoiding intrinsic defects

- ☐ Microstructural defects such as pores, cracks, incomplete stoichiometry, columnar microstructure, multicrystalline phases
- ☐ Mechanism of layer growth

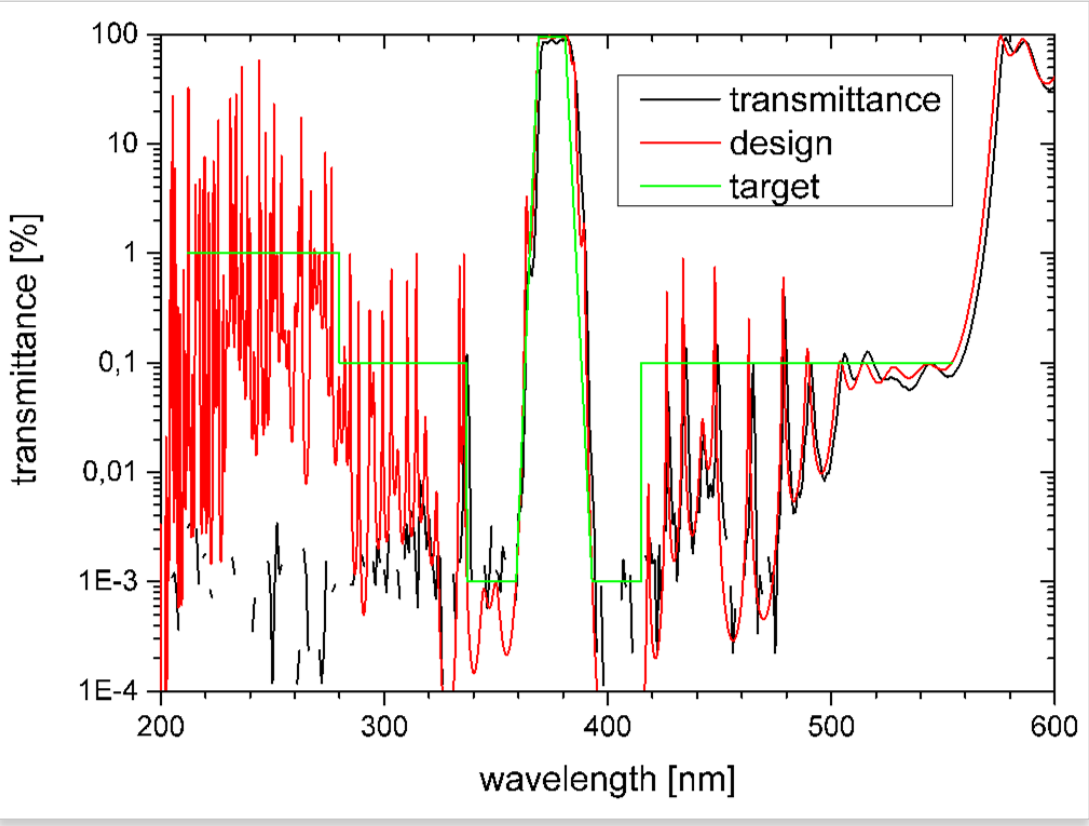
### Desired process properties

- ☐ Precise and uniform
- ☐ Long-term stable
- ☐ Automated
- ☐ Low maintenance, low cost

# COATING EXAMPLE

## Laser Optics – Clean-up Filter

Transmittance measurement



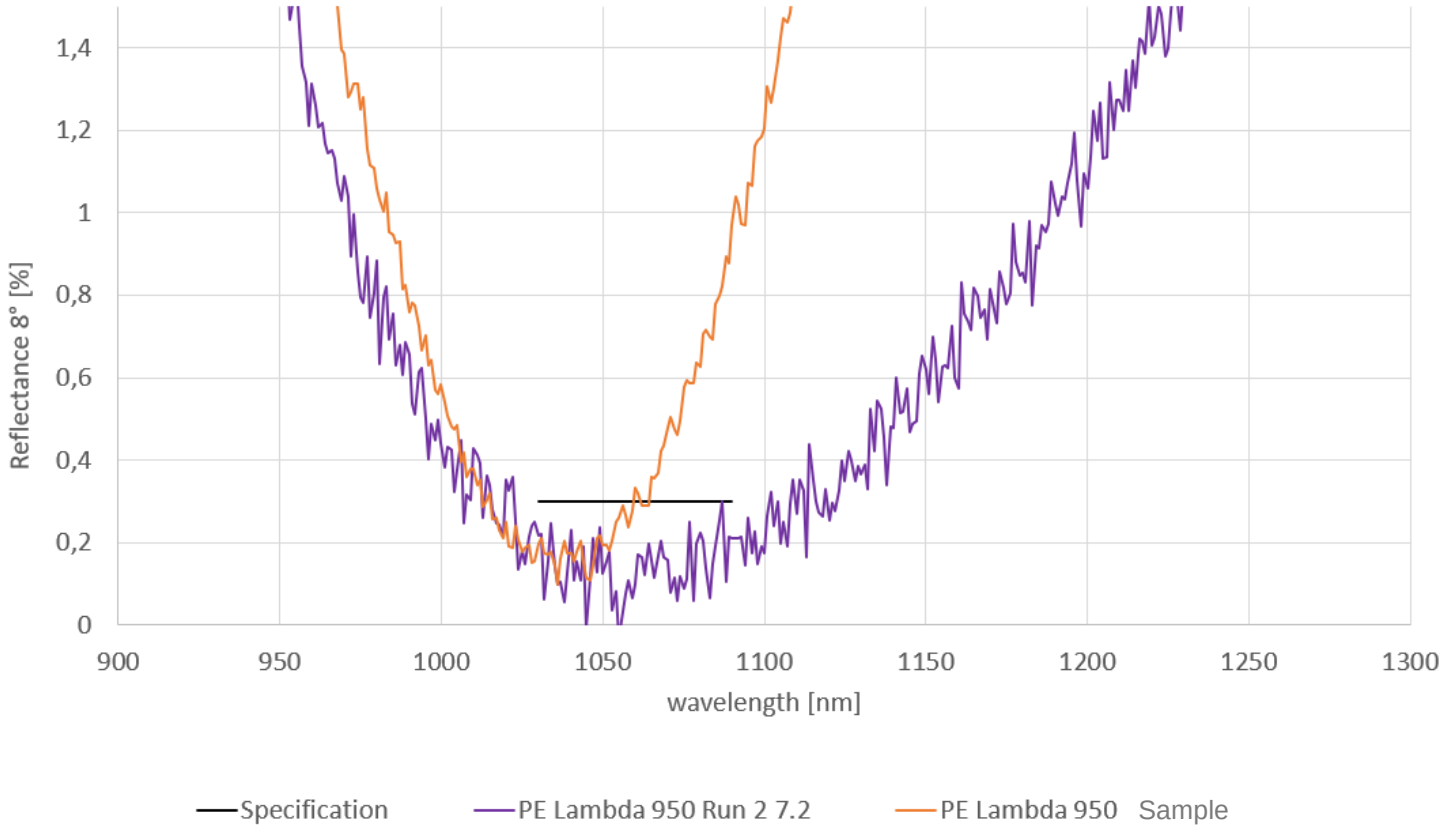

- T(avg) > 90% 372-378 nm
- OD(avg) > 5 @ 337-359 nm, 393-415 nm
- OD(avg) > 3 @ 212-265 nm, 385-554 nm
- Coating without test run and without AR on backside

*In collaboration with Fraunhofer IST*

# COATING EXAMPLE

## Laser Protective Glass

Reflectance measurement (AOI 8°)




**OPTA X**

☐ R <0,3% @ 1030-1090nm

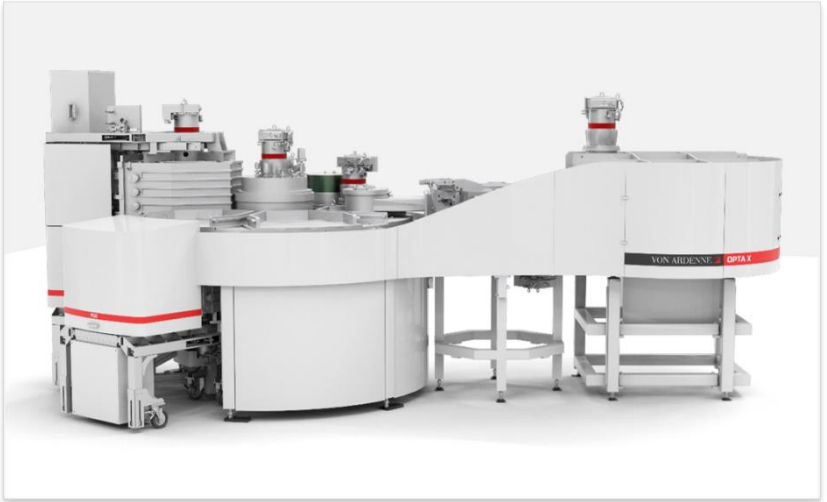
**Commercial Sample**

☐ R <1,0% @ 1030-1090nm

## OPTA X – Rotary Disk Coating System

Enhanced sputtering system for optical interference coatings

OPTA X – Rotary Disk System




### Flexible platform configuration

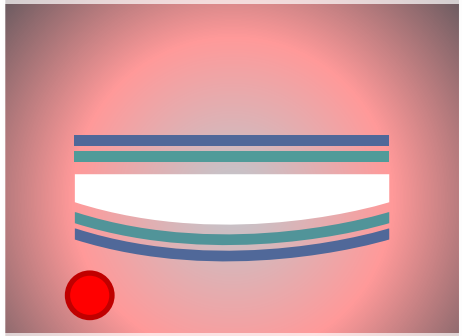
- ☐ Sputter-up coating
- ☐ Sputter-down coating
- ☐ Double-sided coatings, simultaneous

# OPTA X

## Operation Principle

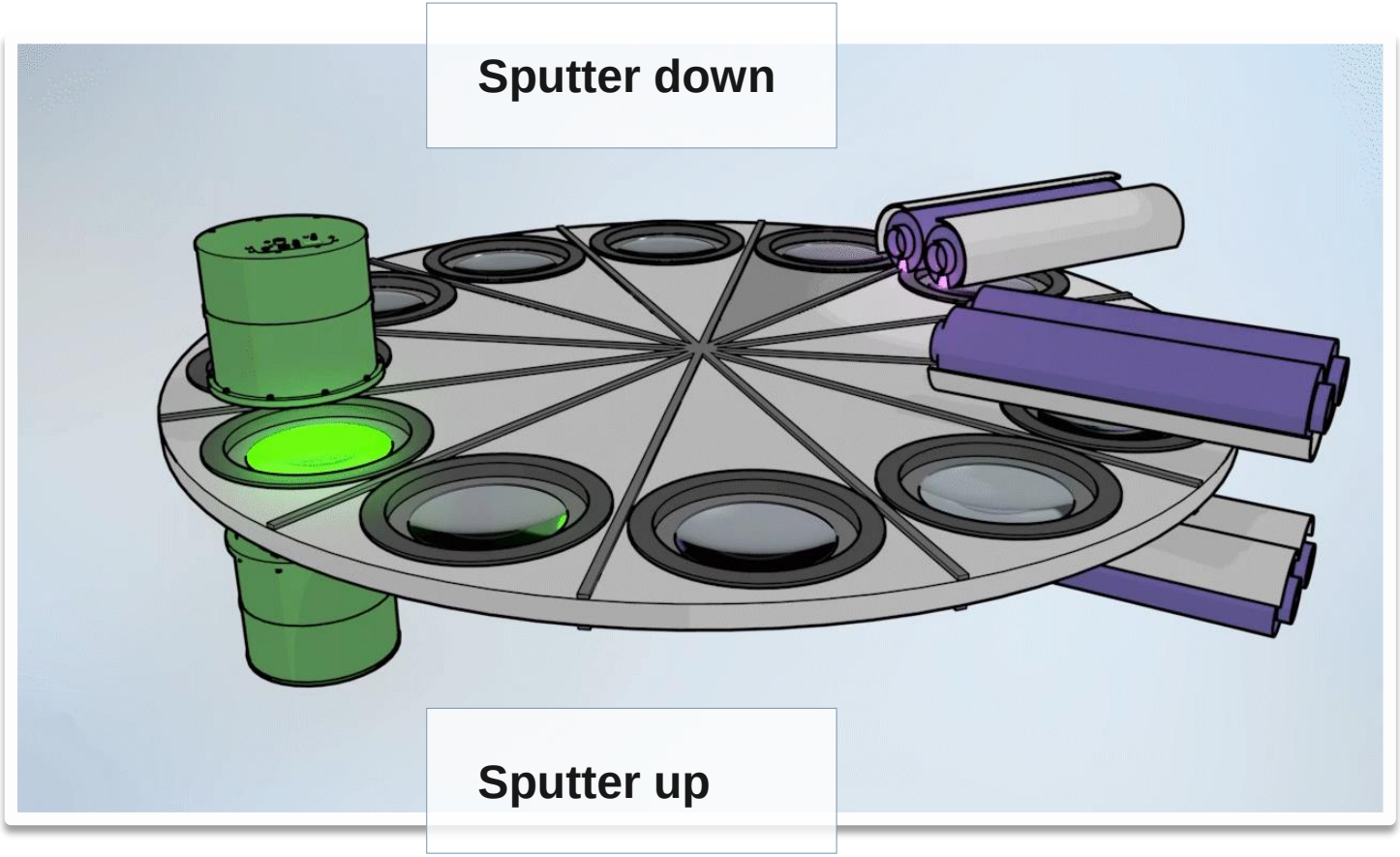
Simultaneous double sided coatings

Substrate sideview



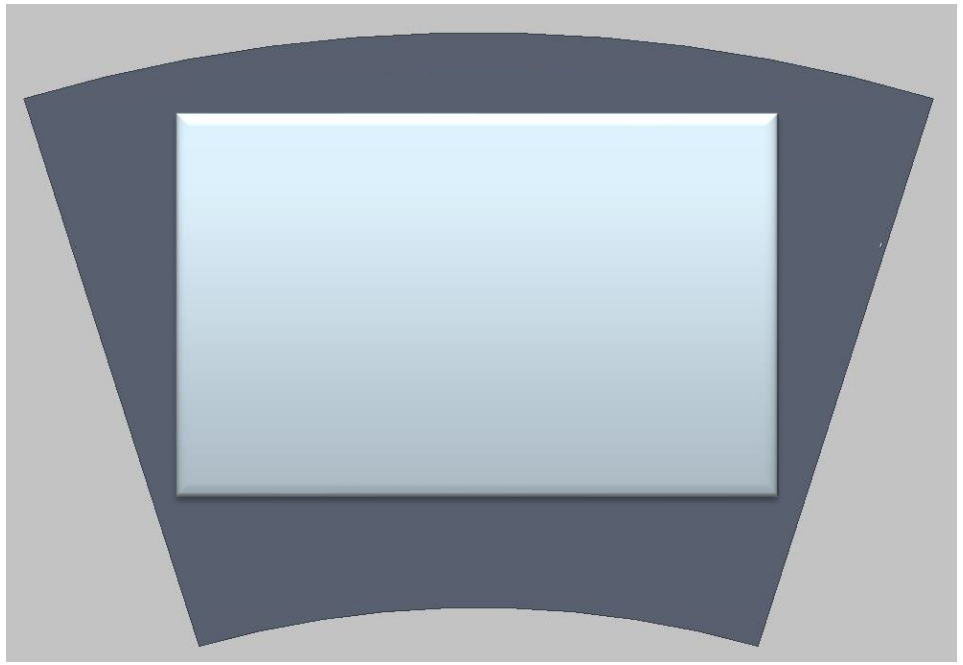
Double sided coating

**Backside coating with sputter-down possible**

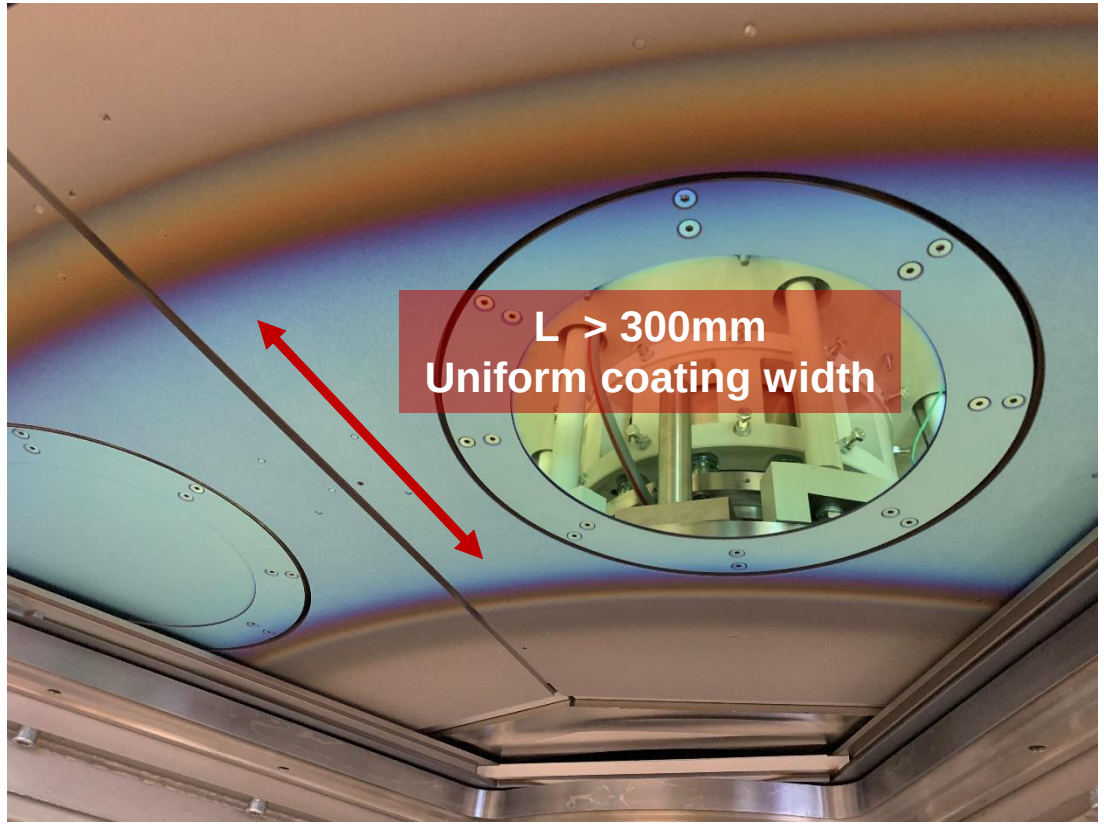


## Various Substrate Formats

Customized carrier design



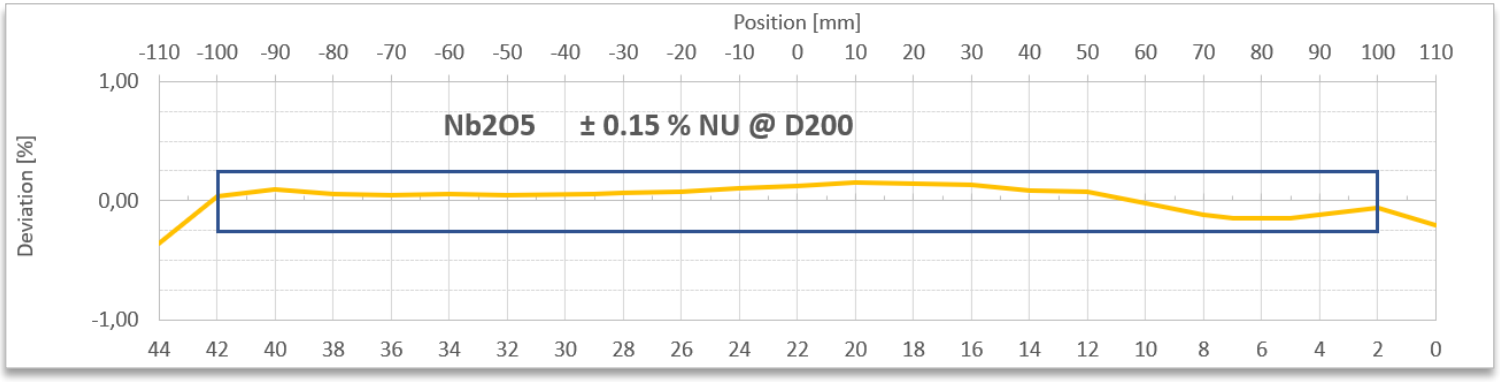
- Substrate sizes up to approx. 300 x 400 mm²

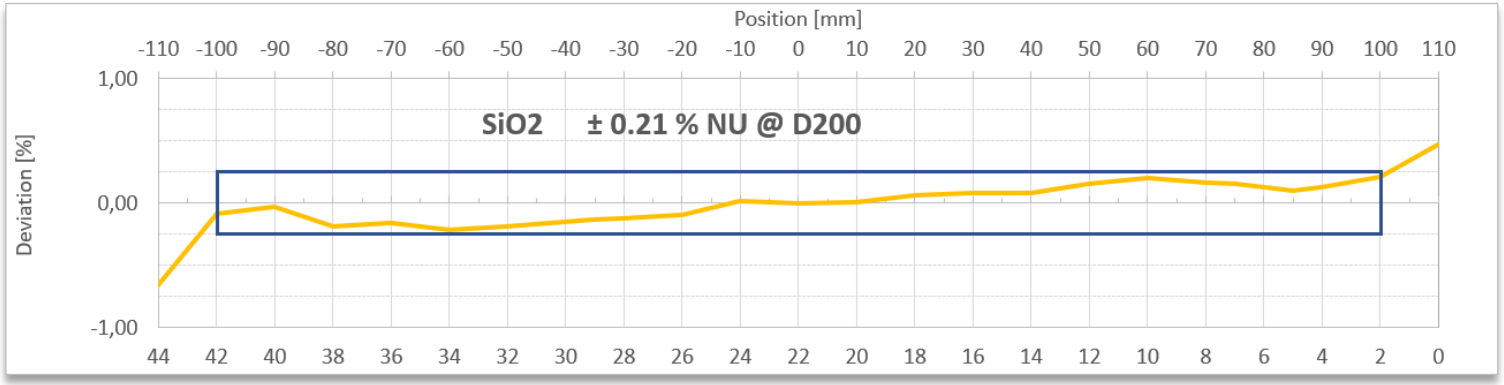


# TECHNOLOGY HIGHLIGHT

## Non-Uniformity of Layer Thickness

Stable repeatability from run to run

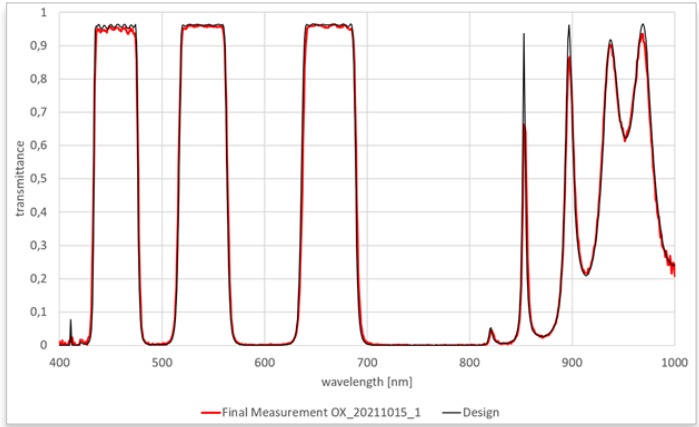


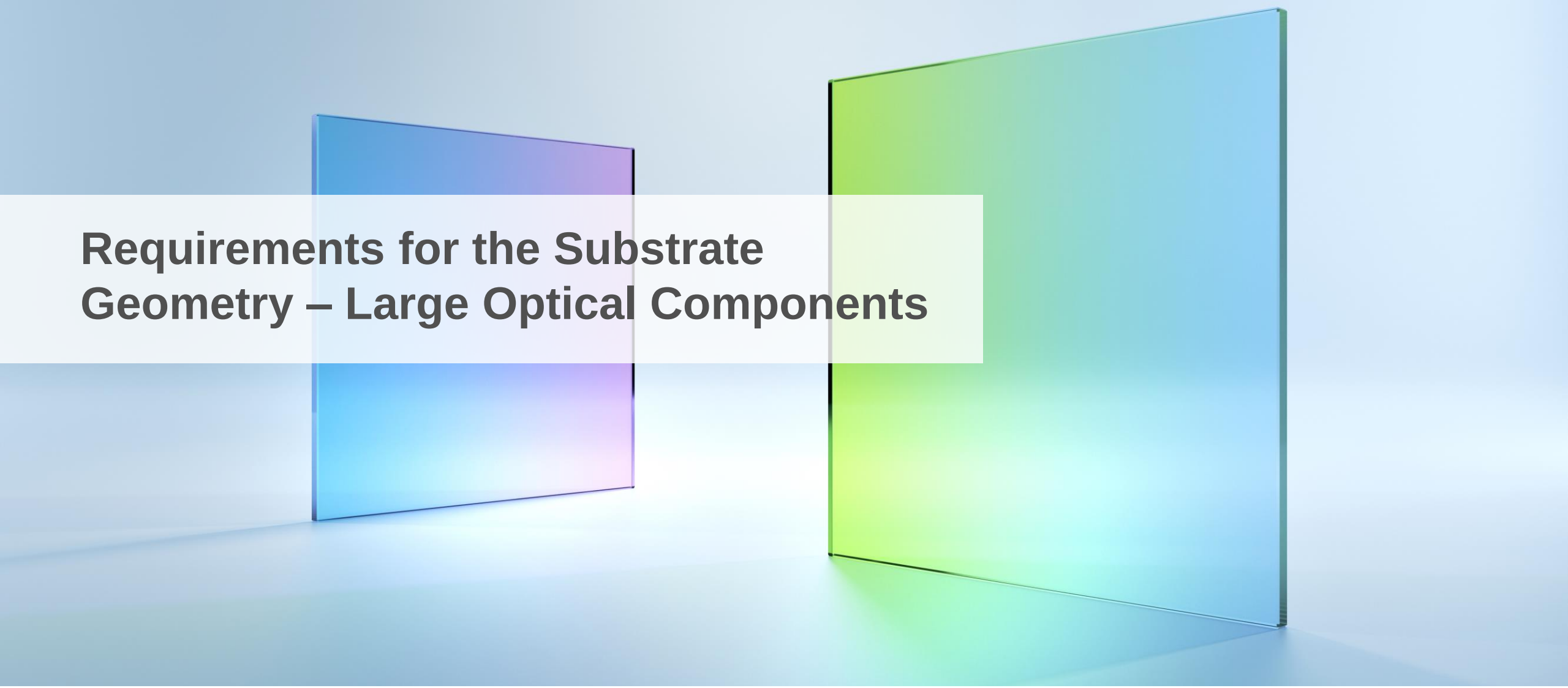

**WITHIN CARRIER THICKNESS DISTRIBUTION**

- ☐ ± 0.25 %
- ☐ Diameter 200 mm

Optical interference filter e.g. BPF



# Requirements for the Substrate Geometry – Large Optical Components



# PRECISION OPTICAL COATING ON LARGE AREA

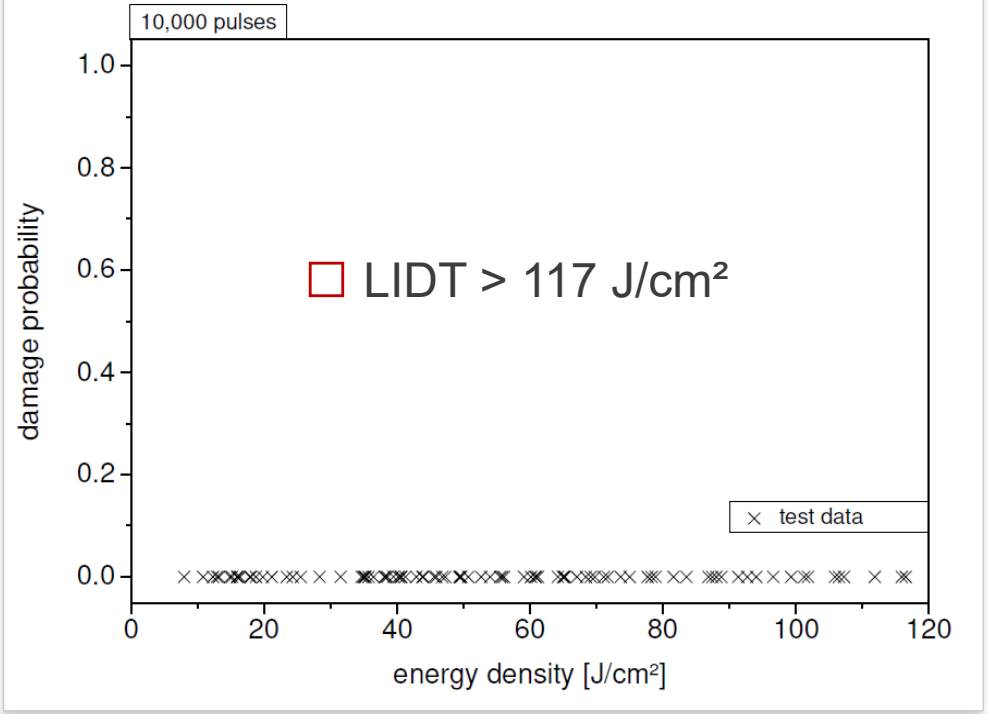
## Large Optics for Laser Applications

Coating requirement: Dielectric mirror @ 1064 nm wavelength

- Substrate geometries: up to 600 x 2400 x 60 mm³
- Substrate weights: typically 10 kg ... 100 kg
- Coating material e.g. HfO2, SiO2
- LIDT test: S-on-1 at 1064 nm (100 Hz, 8 ns)

*Courtesy of Berliner Glas*

HR@1064 / Damage probability for 10000 pulses



## VISS – Vertical Inline Sputter System

Large Optics for Laser Applications


VISS – Vertical Inline Sputter System

### Available system configurations

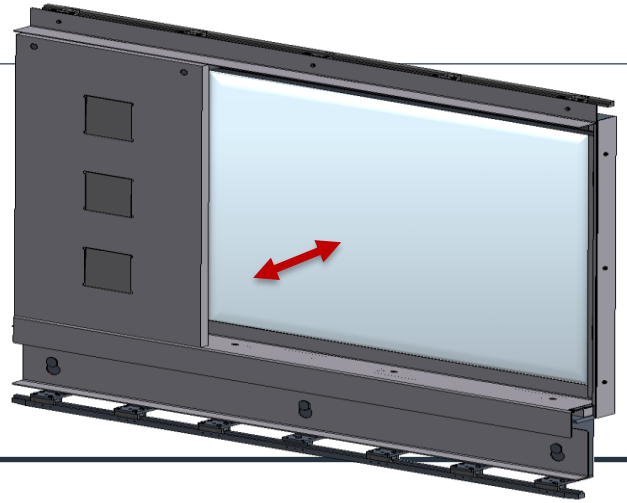
- ☐ Batch
- ☐ Single-end
- ☐ Real Inline-System
  - Carrier-Return-System
  - Automated substrate loading/unloading

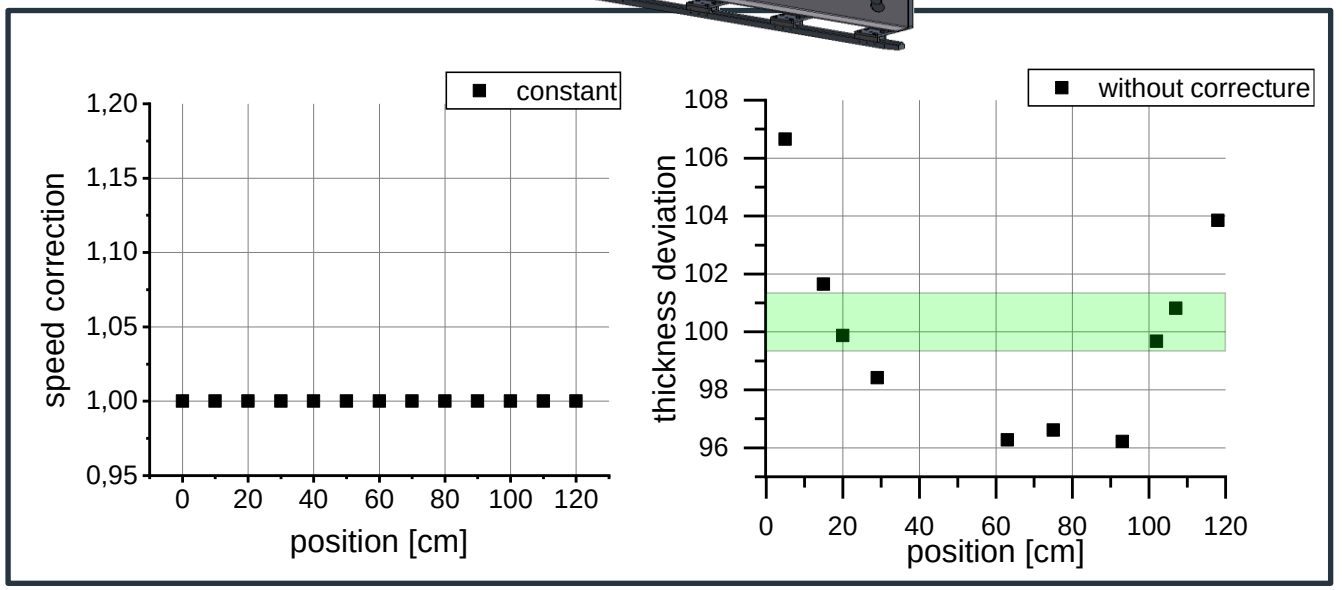
# TECHNOLOGY HIGHLIGHT

## Substrate Handling and Transport

VISS – Vertical Inline Sputter System

- Substrate carrier with inlays (tooling) for highest form flexibility
- Variable substrate level for TSD adjustment and 3D-substrates
- Mechanical connection of two carriers for large substrates
- Programmable position-speed profiles for homogeneity correction in machine direction, specially on 3D-substrates





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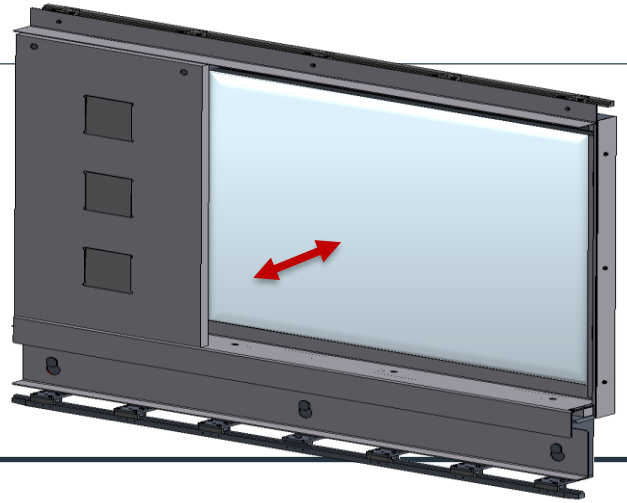

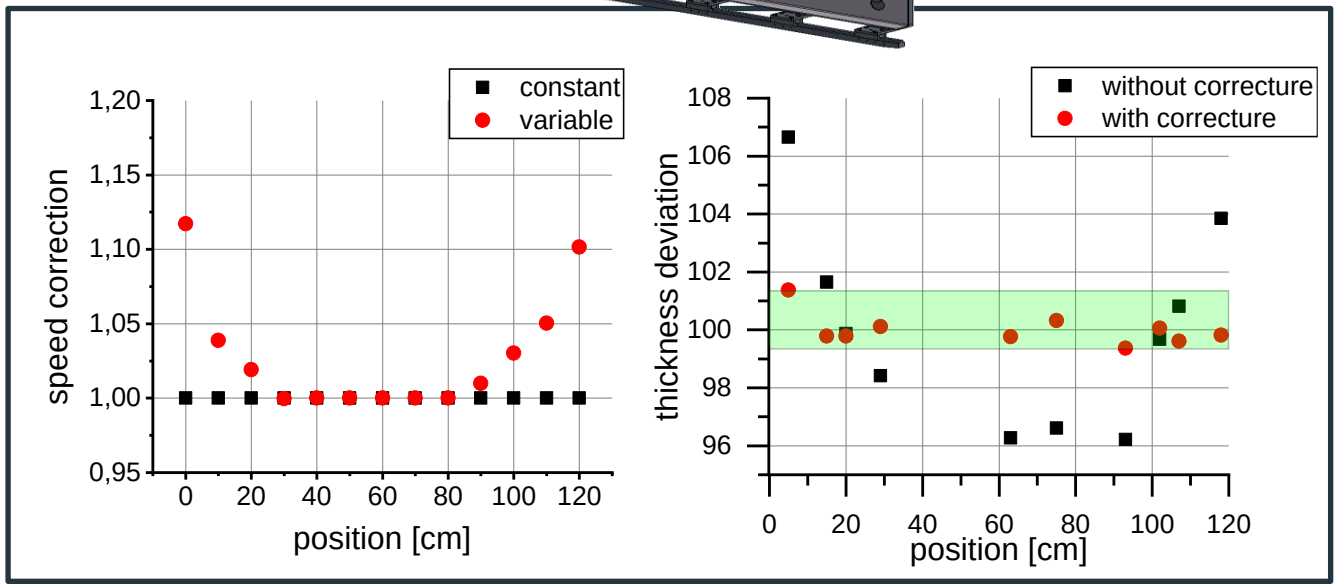

# CONCLUSION

## Wrap-up of the Talk

- For optical components in laser systems, high-precision coating processes of sufficient quality are available to deposit functional coatings such as AR, HR and specific filters
- With advanced equipment technology, even very large substrate geometries can be coated, e.g. flat surfaces up to 300 x 400 $mm^2$ or heavy cylinder optics up to 600 x 2400 x 60 $mm^3$
- Out of the box: Connecting points in the production chain through laser integration – first optical coating on large surfaces, then laser cutting of final product geometry