

# Scaling Photonic Integrated Circuits via Optical Coatings and Ion Beam Trimming solutions

EPIC Technology Meeting on Microelectronics &  
Photonics – Two Sides of One Coin

Daniel Sa Pereira - Sales Manager  
daniel.sa\_pereira@buhlergroup.com  
+49 (0) 151 72516233



# Leybold Optics at a glance



## Leybold Optics Hub – Raleigh, USA

- Machine refurbishing
- Application center

## Center of Competence – Owatonna

- Sputtering components

## Leybold Optics Hub – Alzenau, Germany

- Machine manufacturing
- Application center

## Center of Competence Leipzig

- Ion Beam figuring & trimming
- Measurement technology

## Center of Components Hasselroth

- Fabrication of key technology components


## Leybold Optics Hub – Beijing, China

- Machine manufacturing
- Application center



  
300 mCHF  
Turnover

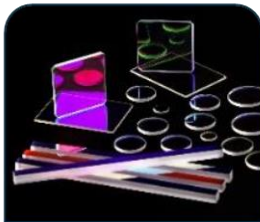
  
600  
FTE employees  
worldwide

  
3500+  
Installed system

  
7%  
of turnover for  
innovation

BU Optics

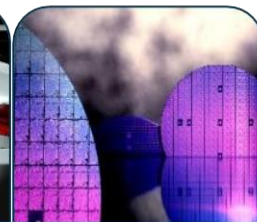
BU Energy



Precision



Automotive



Semiconductor



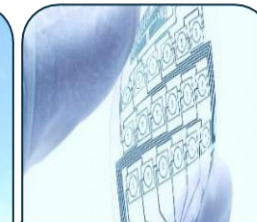
Consumer



Ophthalmic



Glass

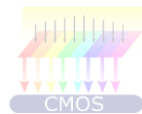


Flexible

# Leybold Optics Semiconductor

## Sensing ●●●●

Proximity Sensors, Ambient Sensors, Facial Recognition, Hyperspectral Imaging, Solid State LiDAR, CIS



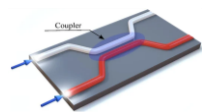
## Lighting and Display ●●

LED, microLED, VCSEL, EEL, LCoS



## Photonic Integration ●●●

PICs, Metasurfaces, Augmented Reality, Waveguides, Optical Modulators, Datacom, Diffractive Optical Elements



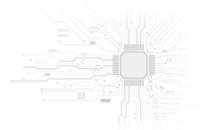
## RF-front end connectivity ●●●

SAW/BAW filters, Wafer Bonding, POI



## Frontend Semiconductor ●●

Hard Masks, HAMR, Encapsulation, Trench Fillings, Gate Oxides



HELIOS Series



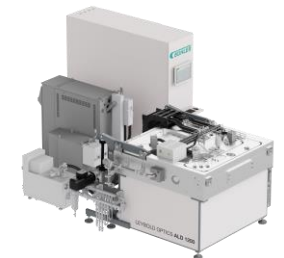
IBT Series



ARES Series



ALD 1200

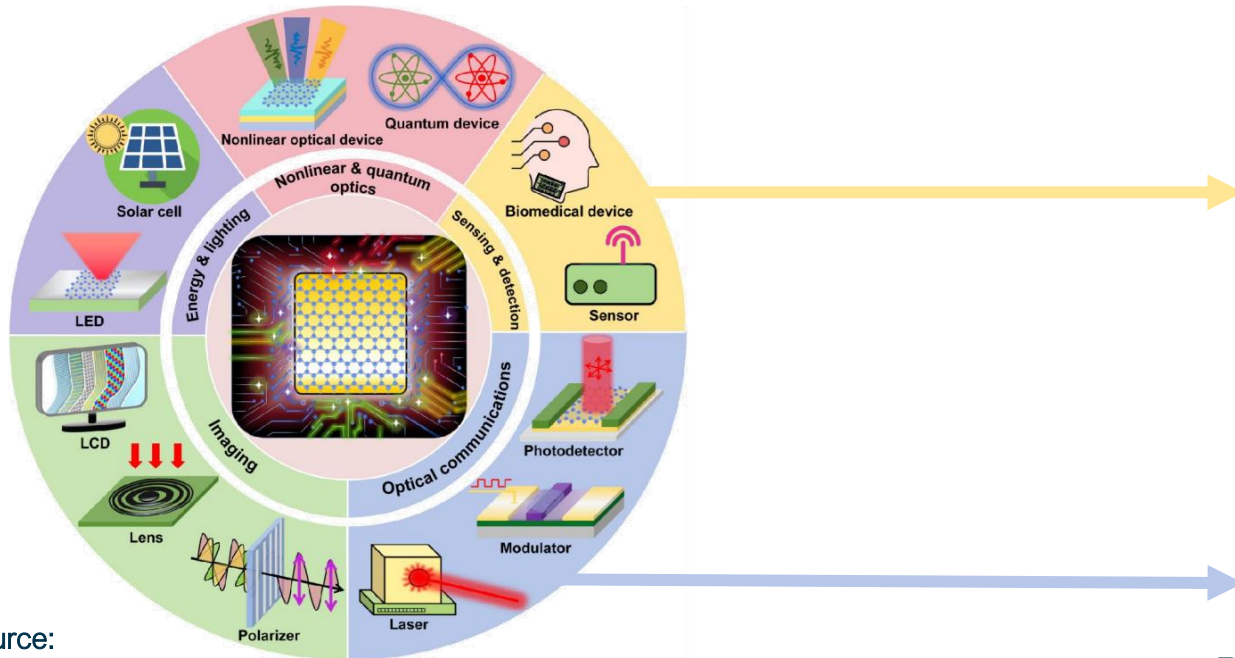


LTE Series

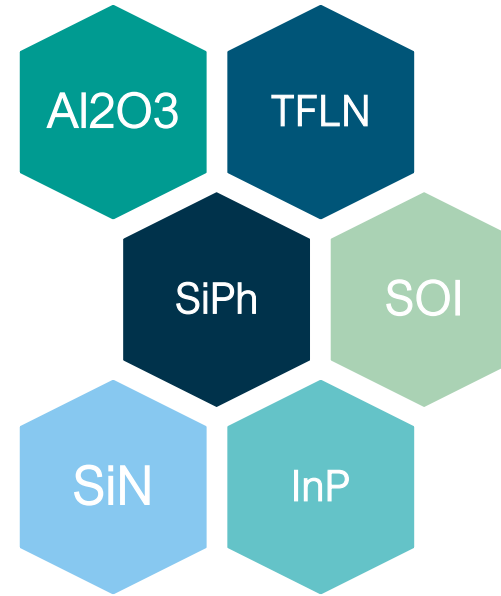


- Magnetron Sputtering
- Evaporation
- Ion Beam Trimming
- Atomic Layer Deposition

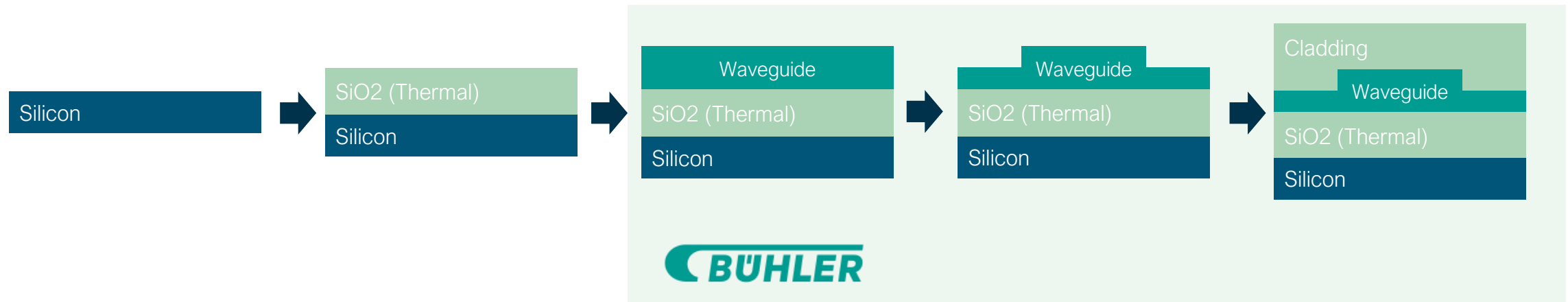
# The Rise of Mass Production of Integrated Photonics



Source:  
Moss, David. (2024)  
Integrated photonics incorporating 2D materials for practical applications.



PIC Platforms with Mass Production Potential





# HELIOS Series

Magnetron Sputtering



# HELIOS Series

## Request from Semiconductor Market.

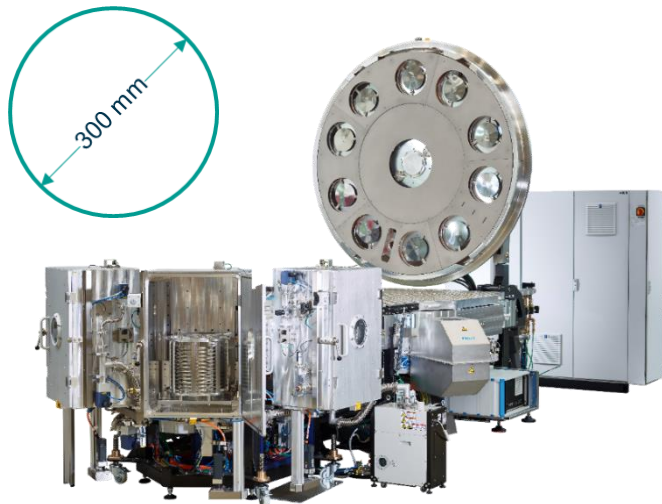
- In-situ control for highest reproducibility and uniformity
- High deposition rates
- High material flexibility and target utilization
- Low particle level
- Low deposition temperature

## Technology.

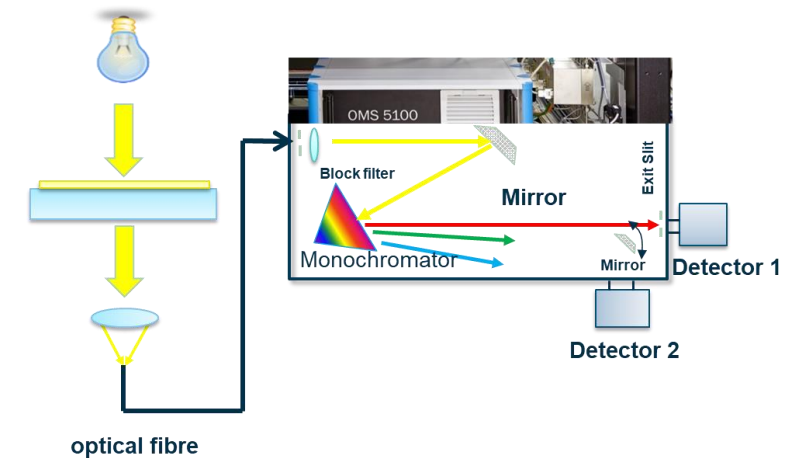
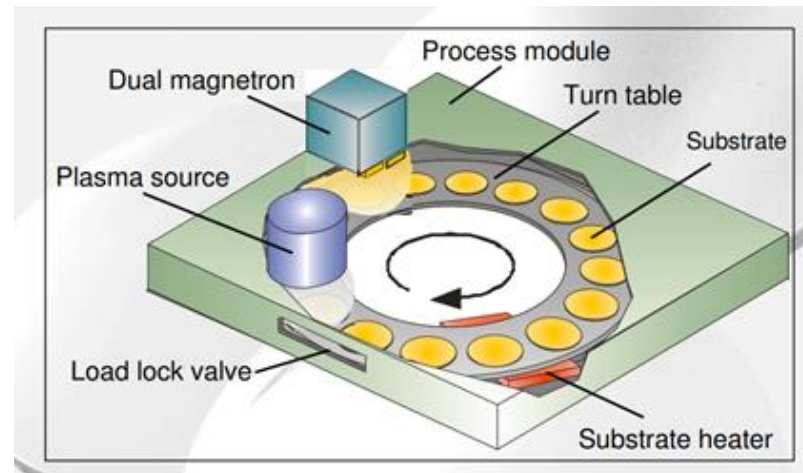
- PARMS+: Plasma Assisted Reactive Magnetron Sputtering
- OMS: Optical Monitoring System



HELIOS800

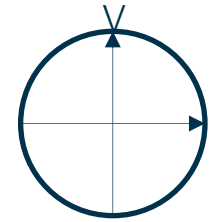
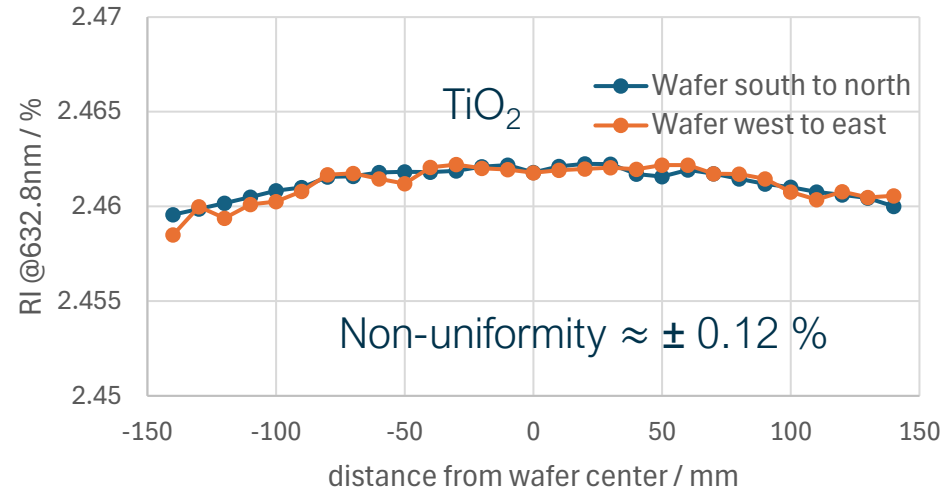
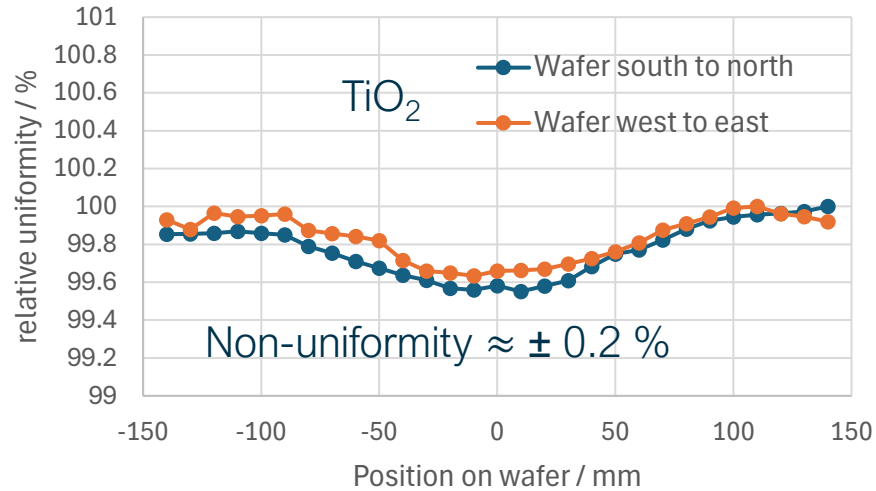


HELIOS1200

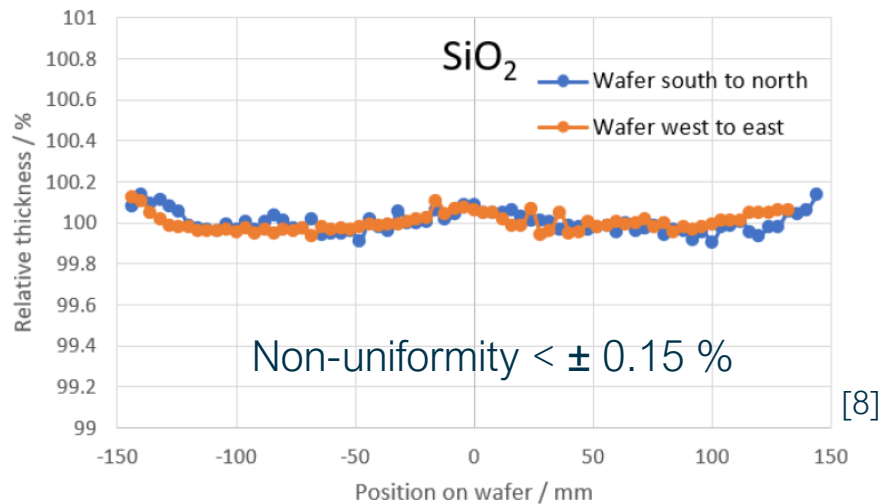


# HELIOS Series

## Thickness non-uniformity, Results as deposited



Measurement pattern



TTV  $< \pm 0.6$  nm possible for 400 nm thin films on  $\varnothing$  300 mm

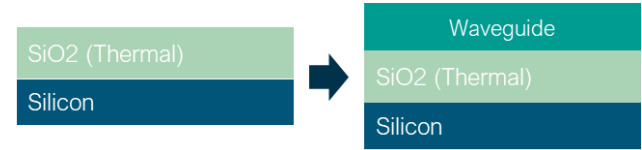


HELIOS 1200

# HELIOS Series

## Propagation Loss of deposited waveguides

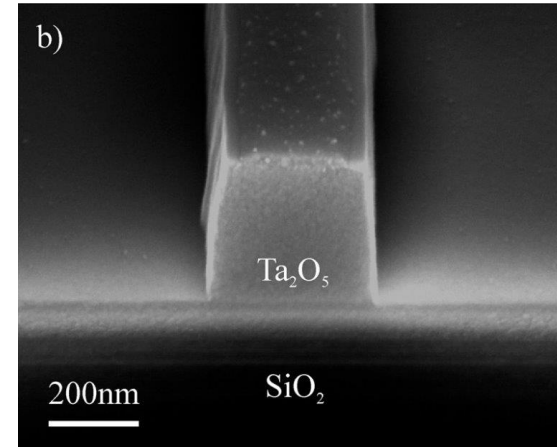
Ta2O5



**Table 1**  
Reactive sputtering process parameters for each metal target. The argon flow rate in the cathode target was kept constant at 35 sccm and the additional plasma source was constant at 1.5 kW power and 15 sccm oxygen.

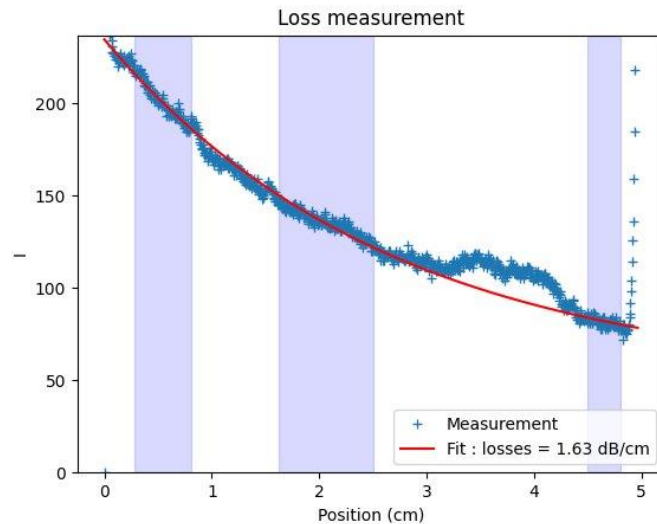
Material	Al <sub>2</sub> O <sub>3</sub>			Ta <sub>2</sub> O <sub>5</sub>		TiO <sub>2</sub>		Y <sub>2</sub> O <sub>3</sub>		ZrO <sub>2</sub>		
	(i)	(ii)	(iii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(iii)
Cathode O <sub>2</sub> (sccm)	30	20	10	72.5	37	20	10	16.4	6.3	53	27.6	12.2
Cathode power (kW)	8.5	4.1	2.6	8.5	4	4	2	4	2	8.5	4	2
Lambda voltage (mV)		340		306	315	379.4		384	381.9		345	
Thickness (nm)	556	352	564	732	770	480	509	664	715	525	614	720
Deposition rate (nm/s)	0.371	0.234	0.128	0.732	0.385	0.480	0.255	0.332	0.179	0.525	0.307	0.18
Roughness RMS (nm)	0.199	0.211	0.239	0.179	0.186	7.49	7.40	0.375	0.643	0.878	0.982	1.96
Refractive index												
500 nm	1.671	1.658	1.656	2.230	2.238	2.680	2.674	1.959	1.958	2.246	2.242	2.262
800 nm	1.658	1.646	1.643	2.162	2.171	2.505	2.493	1.930	1.928	2.204	2.195	2.212
1000 nm	1.655	1.644	1.641	2.150	2.159	2.479	2.466	1.923	1.921	2.196	2.185	2.202
Waveguide loss (dB/cm)												
633 nm	35	50	26	1	1	-	-	-	-	-	-	-
833 nm	15	10	6	1	1	-	-	-	-	-	-	19
1320 nm	10	10	5	1	1	-	-	2	3	-	18	10
1552 nm	10	10	4	1	1	-	-	2	4	-	11	5
Atomic ratio	1.81	1.80	1.77	3.17	3.27	2.04	2.06	2.15	2.47	3.14	2.77	2.74

Surface & Coatings Technology 206 (2012) 4930–4939



UNIVERSITY OF  
**Southampton**

Si3N4



**EPFL** **ETH** zürich

Material

Losses / dB/cm

	at 1547 nm	at 983 nm
Si <sub>3</sub> N <sub>4</sub> (as deposited)	2.2	3.0
Si <sub>3</sub> N <sub>4</sub> (annealed)	0.5	1.6

\*Also suitable for Al<sub>2</sub>O<sub>3</sub> waveguides

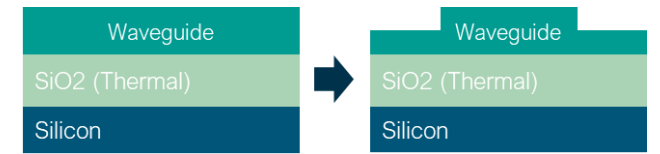


# Leybold Optics IBT Series

Ion Beam Trimming

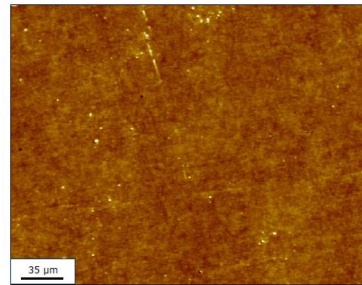
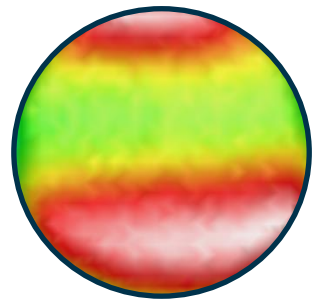


# Bühler Leybold Optics Ion Beam Trimming (IBT)

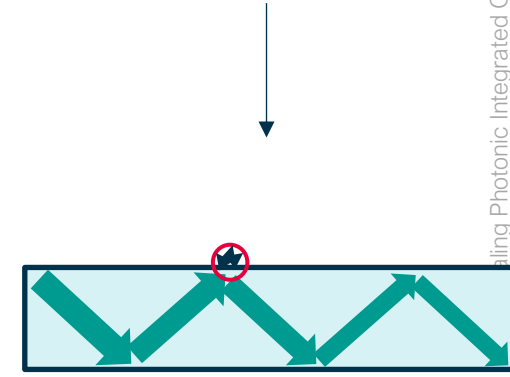
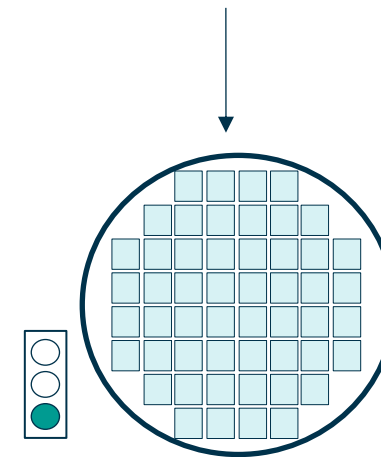
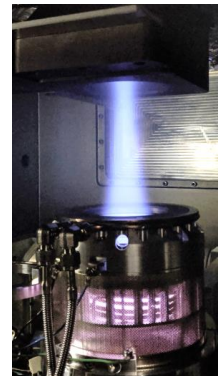
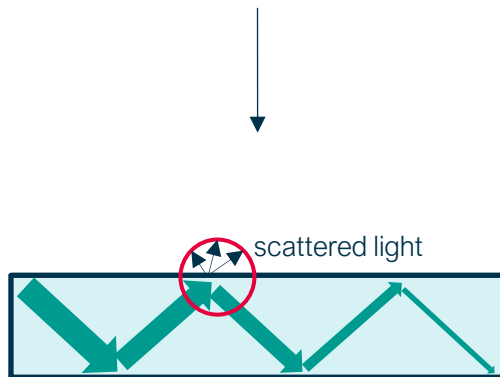
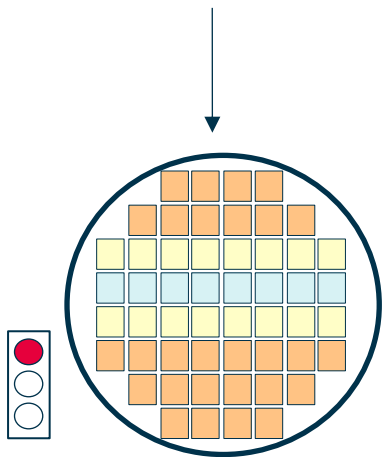
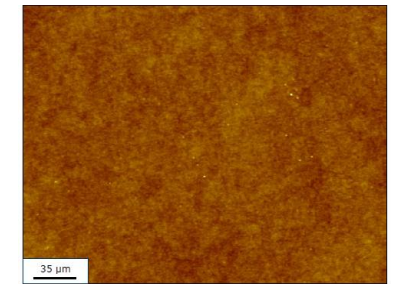
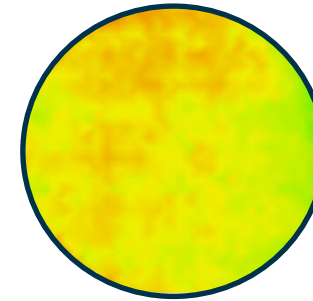


## Waveguide Uniformity and Roughness Optimization

Process after CMP: TTV typically ~30nm; rms > 0.5nm



Process after IBT: TTV typically ~5nm; rms < 0.5 nm



# Bühler Leybold Optics Ion Beam Trimming (IBT)

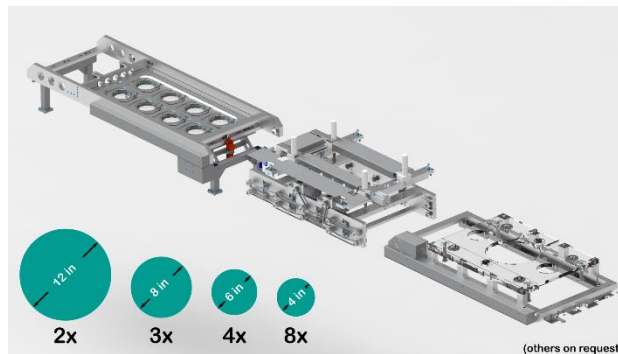
High precision uniformity improvement and thickness adjustment on wafer-level surfaces



OTFP +  
Robotic Handling

Double  
Load Lock

Process Chamber +  
Operation



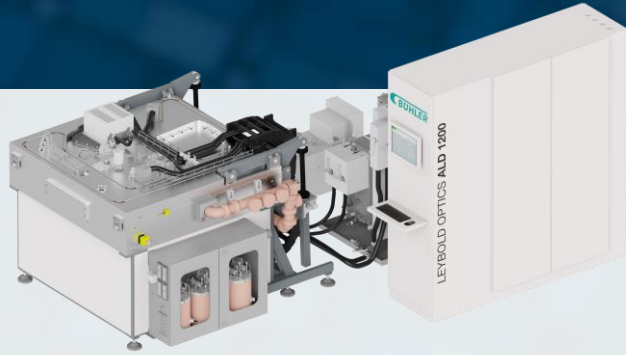
(others on request)

## Optimized for High Throughput

Material	Before	After	Process
$\text{Si}_3\text{N}_4$	TTV 19.7 rms 4.1	TTV 4.6nm rms 0.5nm	12" wafer beam size 20mm 15 min
$\text{LiTaO}_3$	TTV 48.9 nm rms 6.4nm	TTV 10.1nm Rms 1.4nm	4" wafer beam sizes 20mm & 4mm 45min
$\text{LiNbO}_3$	TTV 17.9nm rms 2.6nm	TTV 5.9nm rms 0.66nm	4" wafer beam size 5mm 20min
$\text{SiO}_2$	TTV 19.3nm rms 1.9nm	TTV 4.9nm rms 0.3nm	4" wafer beam sizes 8mm 7min
Si	TTV 64.5nm rms 9.3nm	TTV 13.5nm rms 1.7nm	8" wafer beam sizes 20mm & 5mm 90min

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Product Announcement



# Leybold Optics ALD 1200

Atomic Layer Deposition




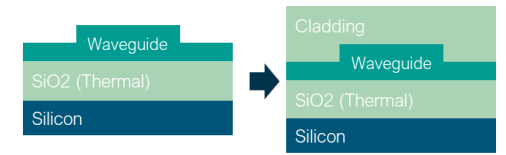
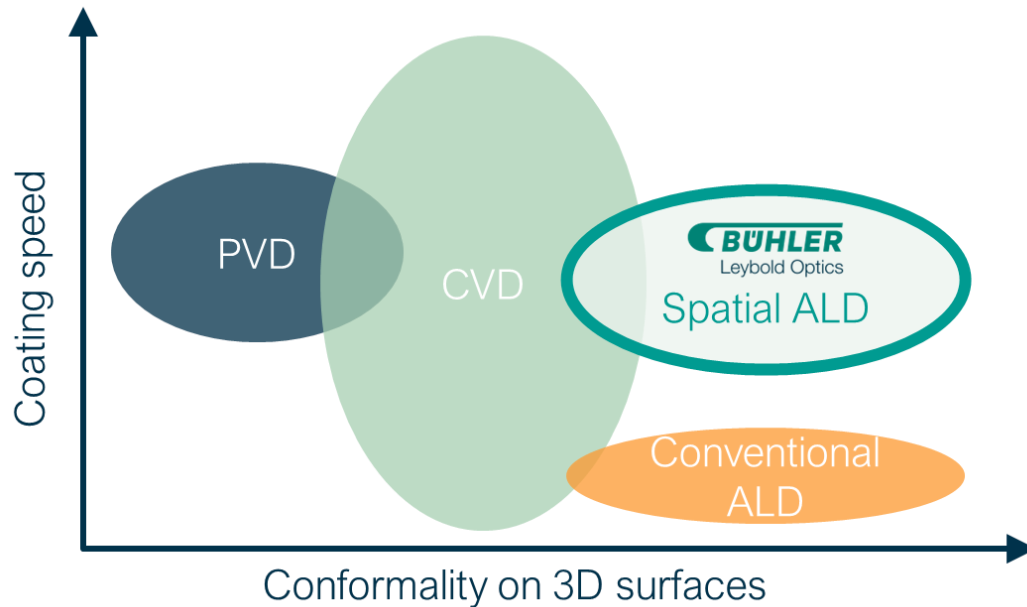
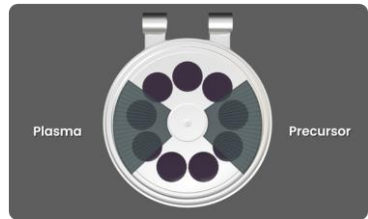
# Leybold Optics ALD 1200

## Conformal Coatings meet High Throughput

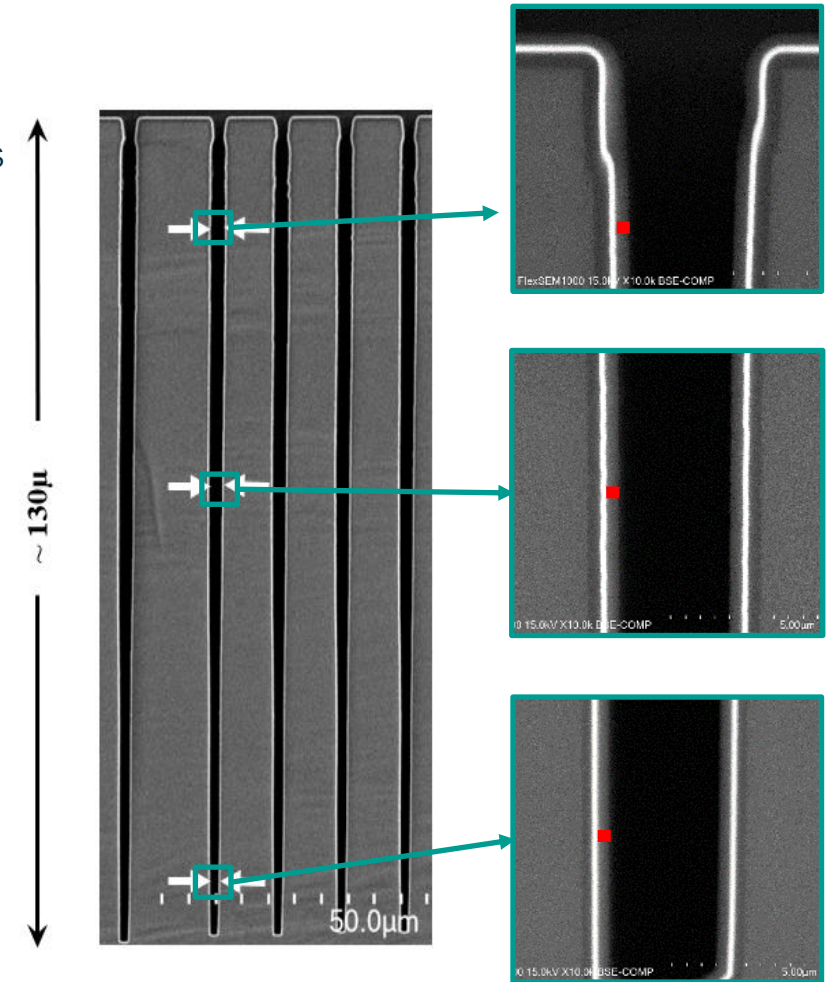
- Conformal coating of deep trenches possible with ALD technology
- Spatial ALD together with Multi-wafer coating leads to increased WPH

## ALD coating of SiO<sub>2</sub> cladding material for PICs

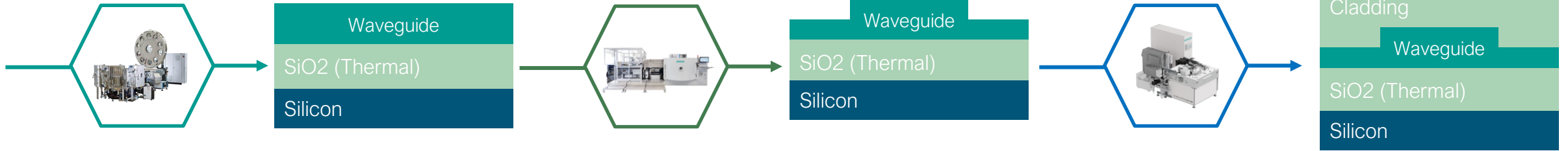
- Superior RI control to optimize light modes in LN waveguides
- Eliminating air voids in directional couplers increasing design freedom and allow for tighter specs
  - Under evaluation with Lionix International 
- Strategy for TFLN, POI platforms



## SiO<sub>2</sub> trench filling with the ALD 1200



# Conclusion



## HELIOS Series:

- Si<sub>3</sub>N<sub>4</sub>, Ta<sub>2</sub>O<sub>5</sub> or Al<sub>2</sub>O<sub>3</sub> waveguide sputtering
- No H<sub>2</sub> assisted gas during production of films → important for 1550 nm PICs
- Low deposition temperature, High Non-uniformity and Losses below 1 DB/cm (@1550 nm)

## IBT Series:

- Localized removal or wafer trimming of PIC materials (LN, LT, SiO<sub>2</sub>, SiN,...) with improved Total Thickness Variation (TTV)
- Decrease in rms leads to decreased propagation loss of waveguide materials

## ALD 1200:

- Superior RI control to optimize light modes in LN waveguides
- Conformal coating avoids airgaps adding optical loss
- Passivation layers to protect PIC performance



is looking for partners in the landscape of PICs

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Thank you for your attention

Daniel Sa Pereira - Sales Manager  
daniel.sa\_pereira@buhlergroup.com  
+49 (0) 151 72516233

