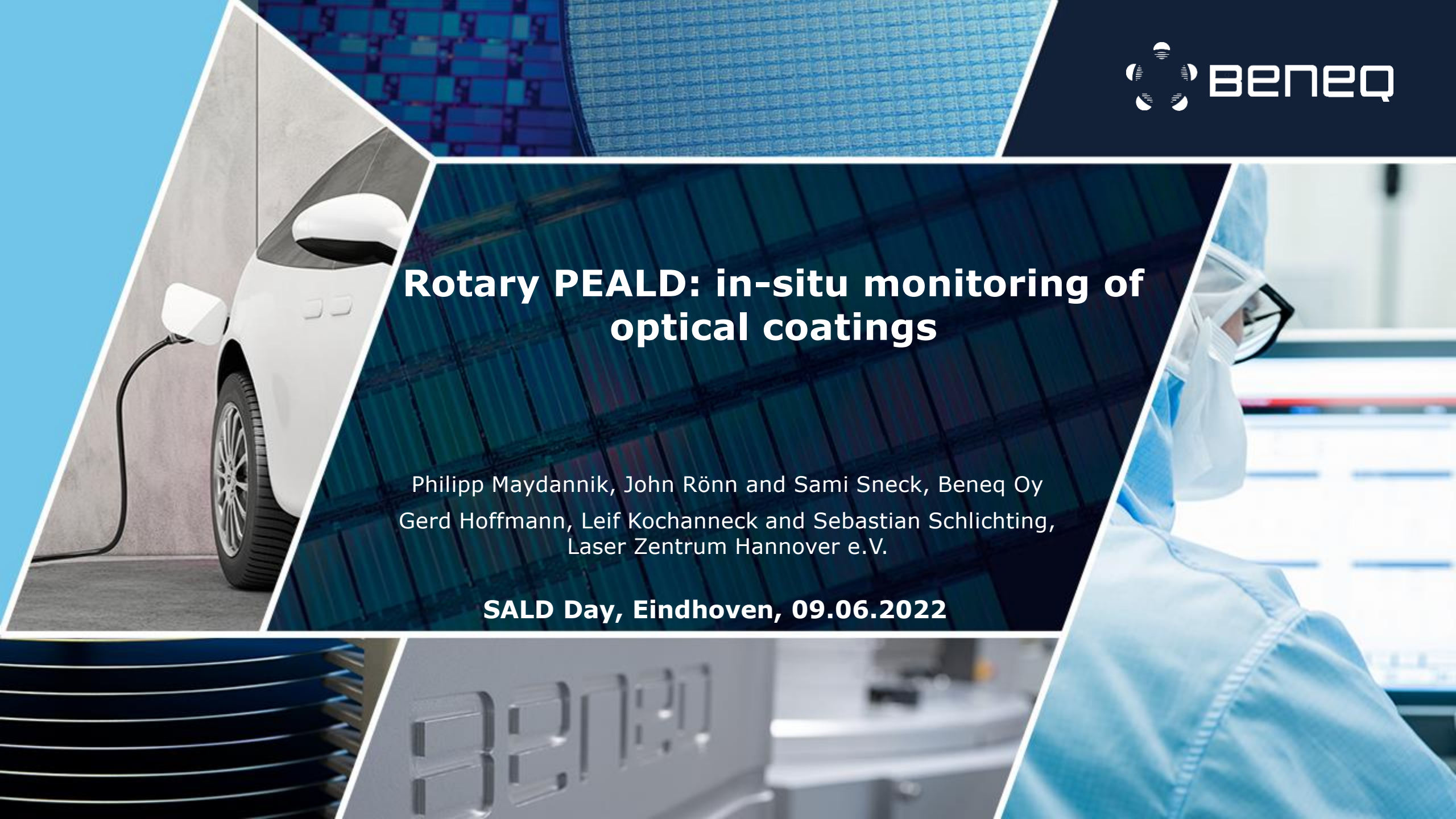


Rotary PEALD: in-situ monitoring of optical coatings

Philipp Maydannik, John Rönn and Sami Sneck, Beneq Oy

Gerd Hoffmann, Leif Kochanneck and Sebastian Schlichting, Laser Zentrum Hannover e.V.

SALD Day, Eindhoven, 09.06.2022

Beneq is the Home of ALD

The world’s first industrial production using atomic layer deposition (ALD), since 1984.

Headquarters and ALD fabrication in Espoo, Finland, with 40+ ALD systems for R&D and services.

Global operations and services in Japan, Taiwan, China, USA, and EU.

Rapid growth of more than 50% in headcount and revenue, year-on-year.

SALD technology at Beneq

C2R PEALD

Roll-to-roll ALD

Beneq SALD equipment evolution

WCS 500

Genesis ALD

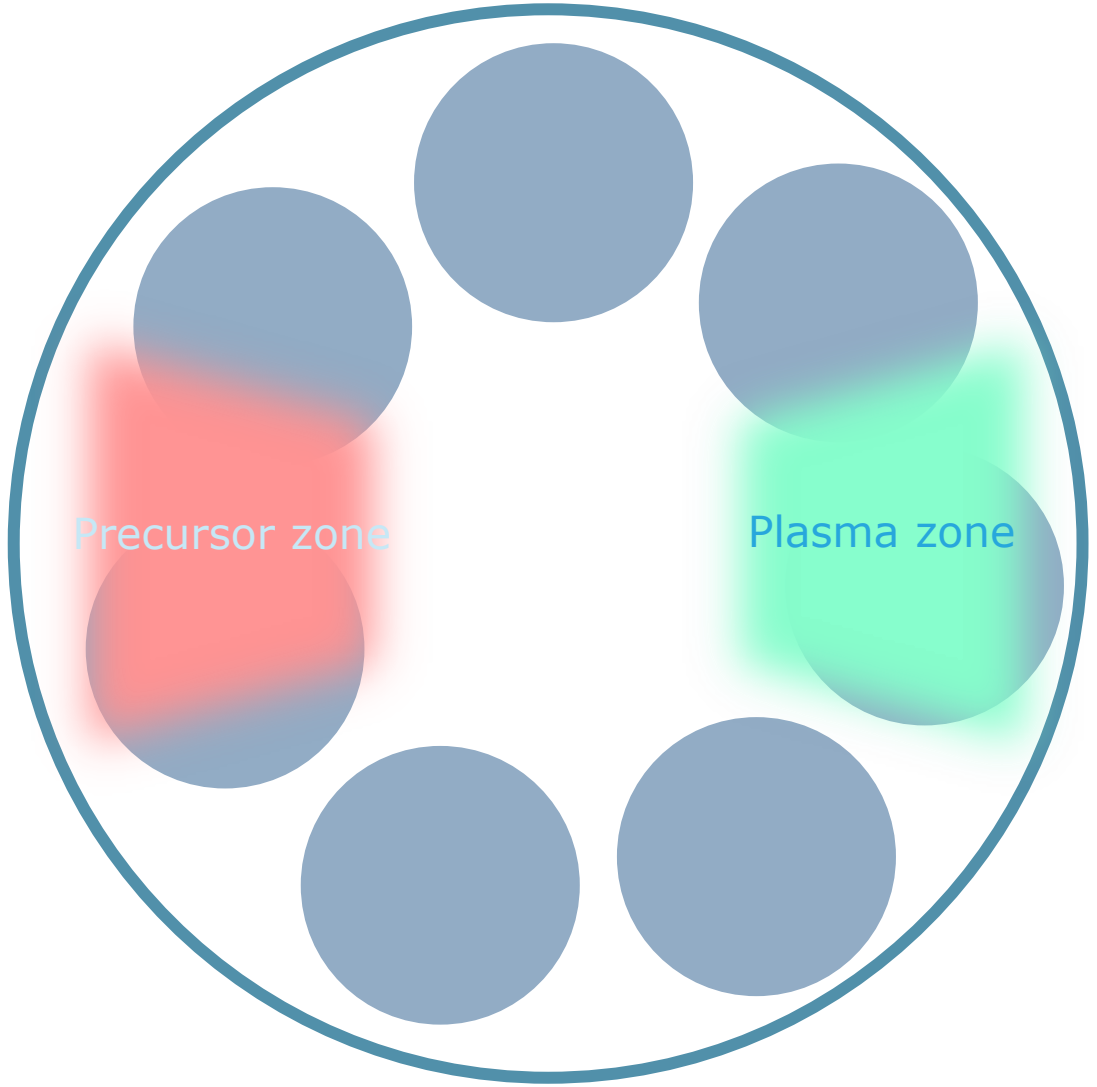
TFS 200R

WCS 600

C2R PEALD

2009 2013 2014 2019 2021->

Rotary PEALD



Rotary PEALD

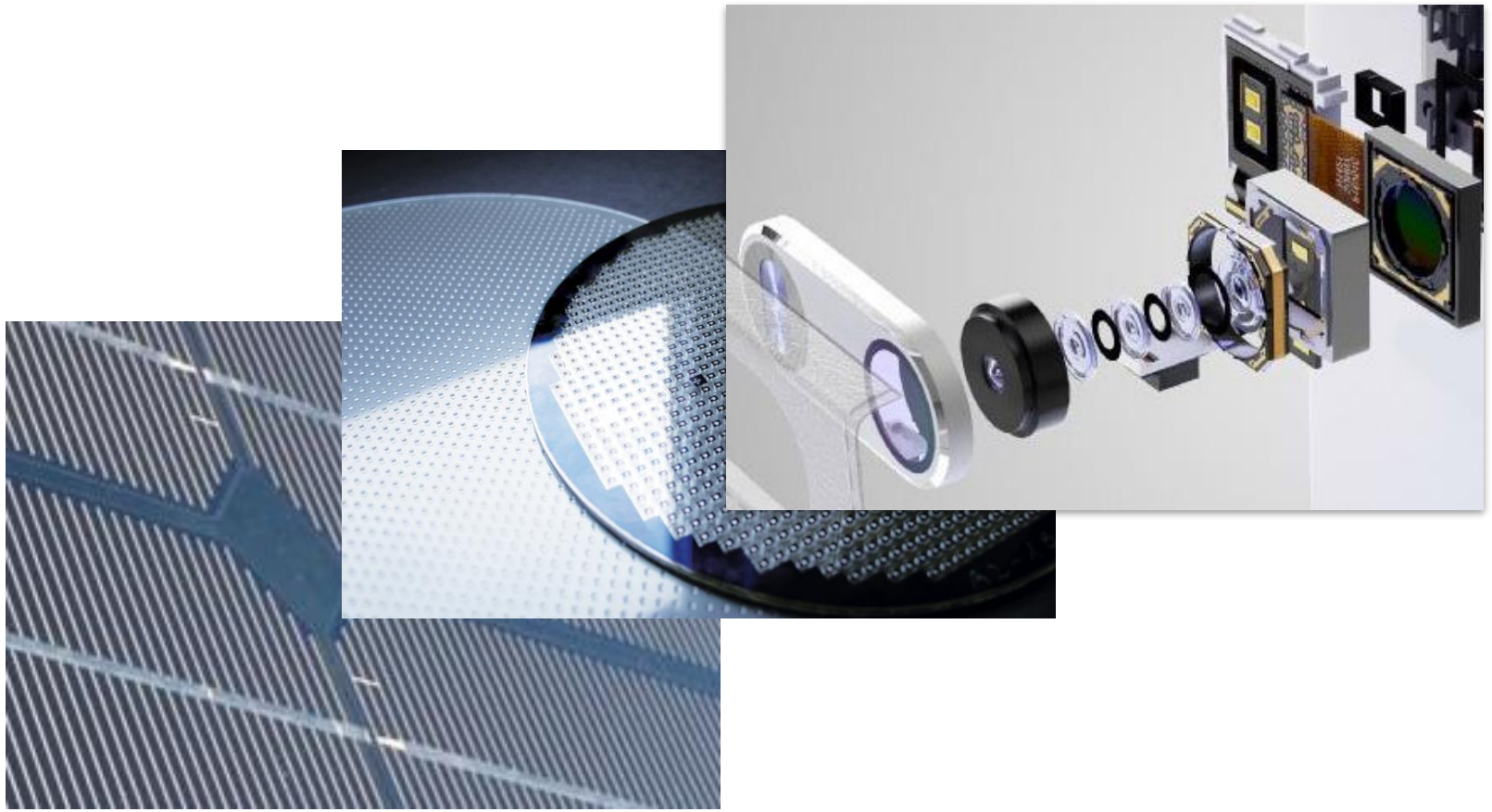
beneq

Rotary PEALD

- Compact size
- Relative straight-forward design and hence high reliability
- Both thermal and plasma modes
- High RPMs => high deposition rates
- Flexibility: adjustable gap between substrate and precursor distribution plate
- Flexibility: plasma parameter gives additional opportunity adjust coating’s property (e.g. RI, stress)
- Substrate plasma pretreatment possible
- Instant process stop by switching the plasma off
- Inherits all advantages of ALD process e.g. uniformity

Optical coatings

- Antireflective
- High reflective
- Filter coatings
- Optical Phased Arrays
- Waveguides
- Beam splitters
- Flat optics/metasurfaces
- etc



Optical coatings

- Thick – from few hundred nanometers to several micrometers
- Complex structures - tens of layers

Even higher precision is needed!

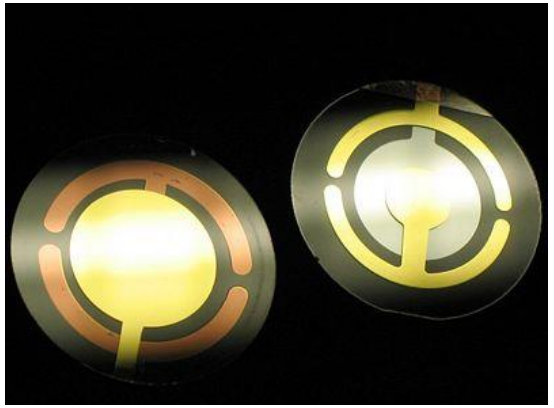
Sources of deviation

- Precursor concentration due to bottle filling level – full vs. half empty vs. almost empty
- Ambient temperature variation
- Substrate - growth rate during nucleation period
- Stabilization at the start of the process
- HW malfunction
- Etc.

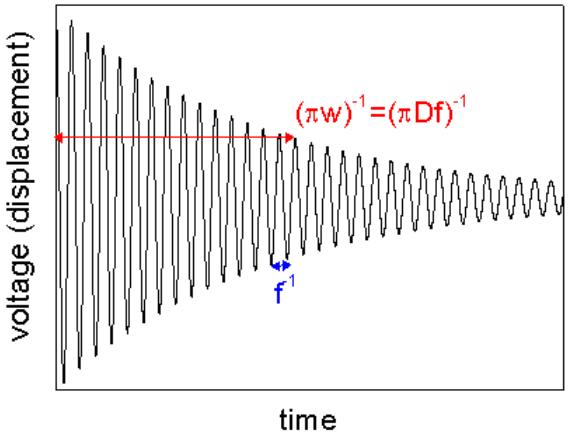
ALD in-situ process monitoring tools

QCM

- Difficulties reading electrical signal from moving parts
- Difficulties with heat stabilization

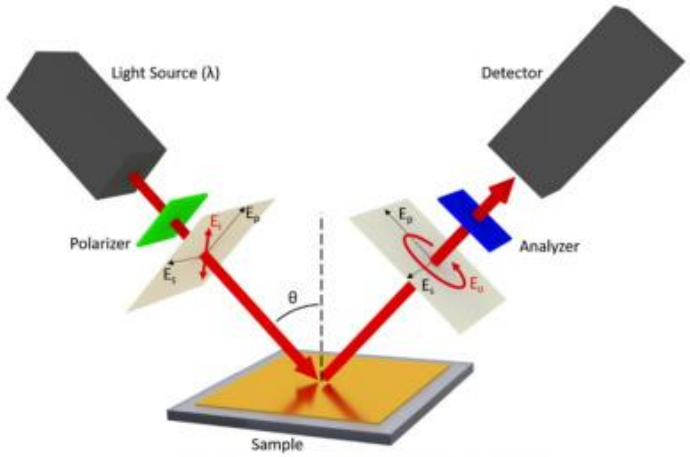


Opposite sides of a quartz crystal resonator
Credit: Beaker via Wikipedia



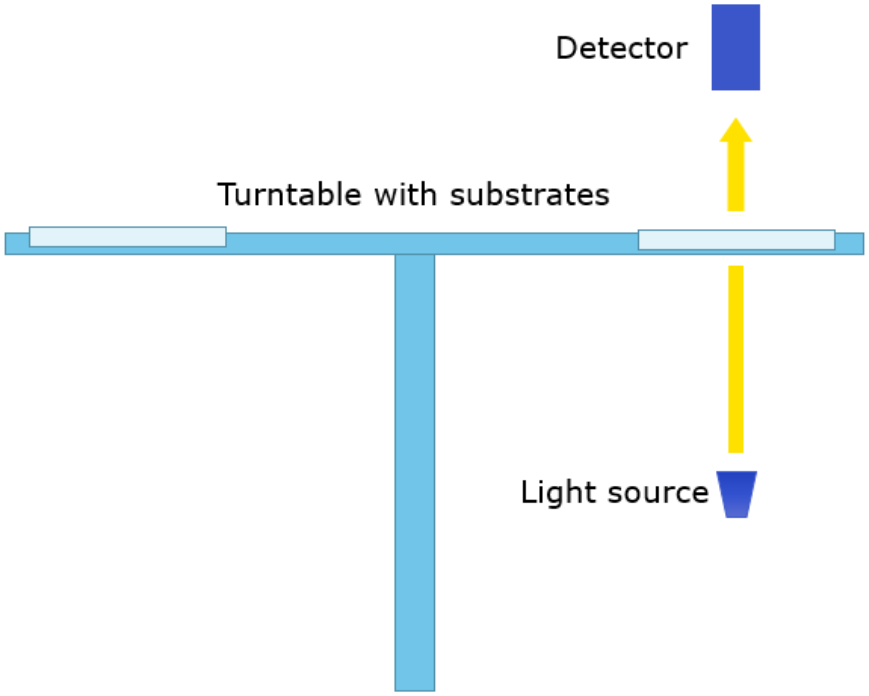
Reflectometry/Ellipsometry

- Difficulties to align and keep good alignment while substrate is moving



R. Secondo, D. Fomra, N. Izyumskaya, V. Avrutin, J. N Hilfiker, A. Martin, Ü. Özgür, and N. Kinsey
https://doi.org/10.1364/OME.9.000760

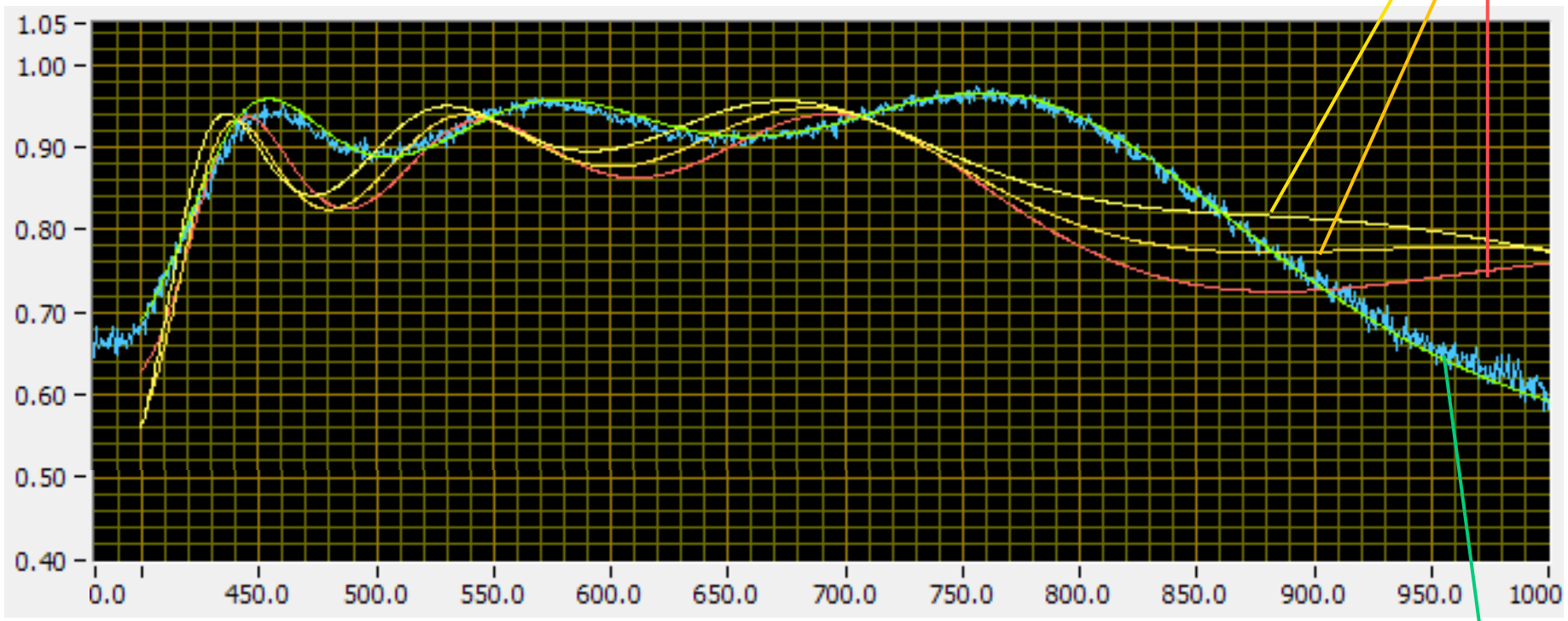
Broad Band Monitoring (BBM)



Advantages of BBM

- Easy alignment
- Broadband
- Quick measurement -> high rotation speeds possible
- Optical transmission measurement, derivation of dispersion data (RI) and extinction coefficient (k)
- Layer structure re-optimization during coating process
- Deeper insight into the process -> informed and rapid process development

BBM – working principle



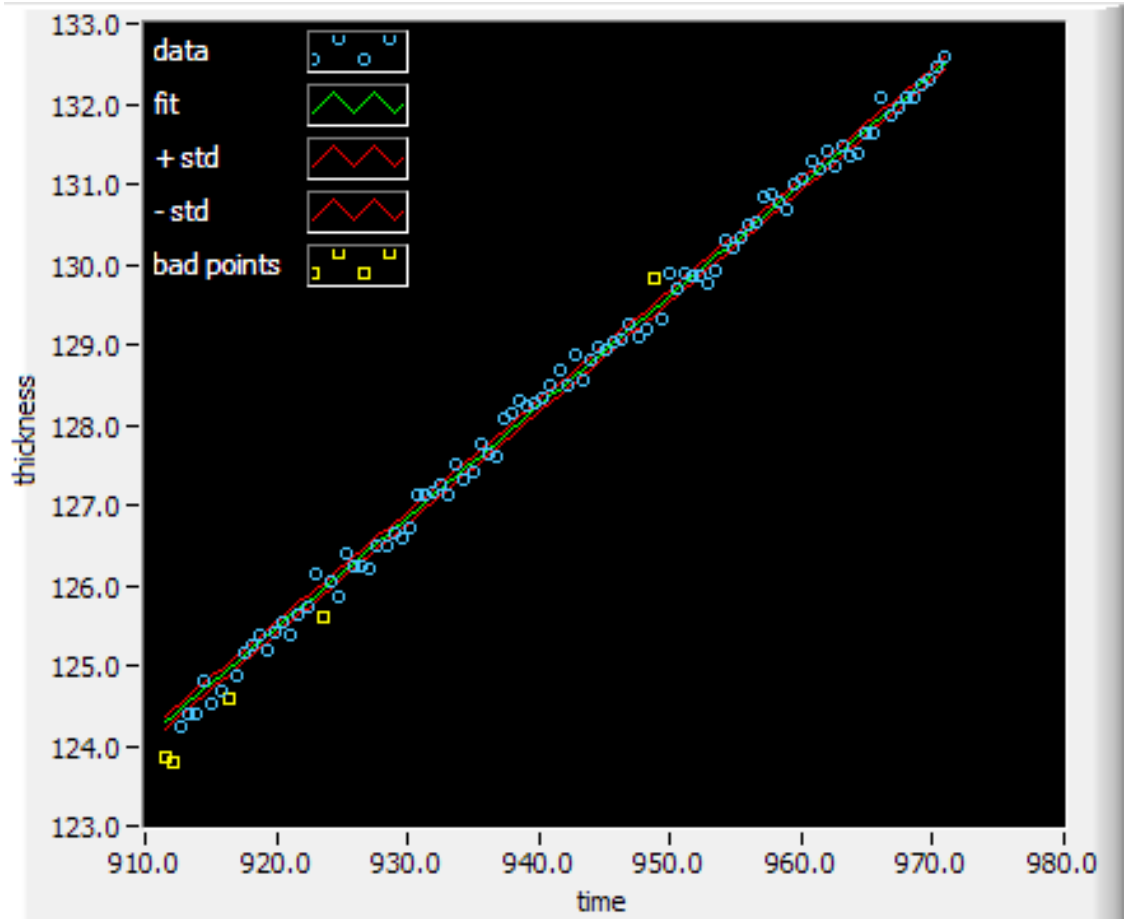
Layer 4 of 23 (SiO_2)

Current thickness – 58.16nm

Target thickness – 186.30nm

BBM – deposition rate monitoring

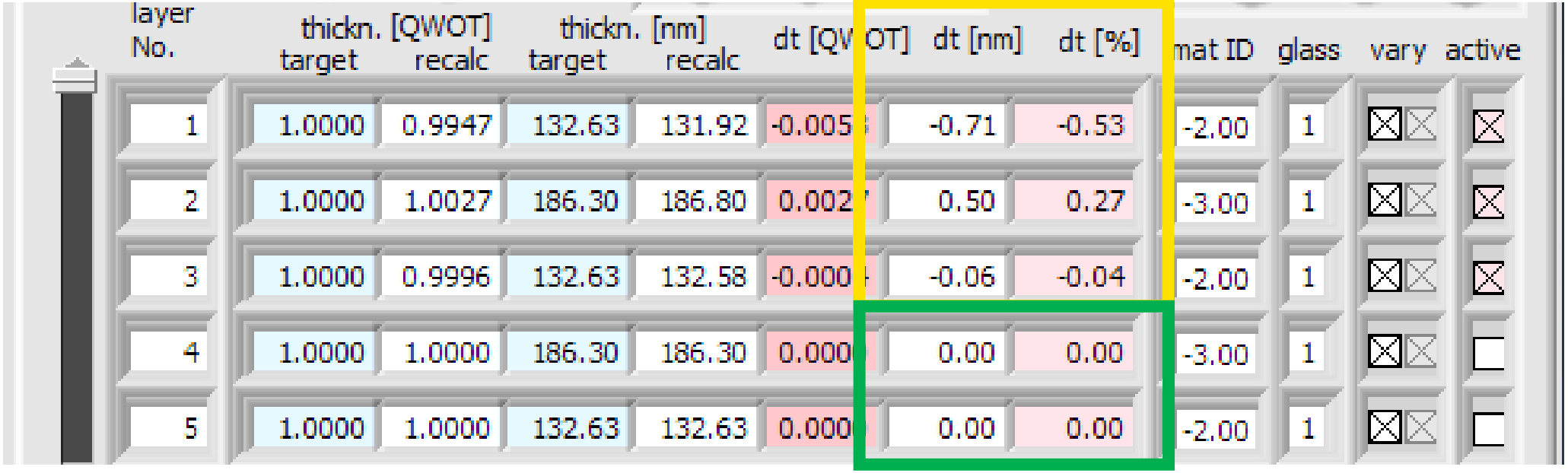
Layer thickness vs. process time



- Real-time process diagnostic information
- Run-to-run process health monitoring

Current deposition rate: 0.118 nm/s Average deposition rate: 0.117 nm/s

BBM – Reoptimization



layer No.	thickn. [QWOT] target	thickn. [QWOT] recalc	thickn. [nm] target	thickn. [nm] recalc	dt [QWOT]	dt [nm]	dt [%]	mat ID	glass	vary	active
1	1.0000	0.9947	132.63	131.92	-0.005	-0.71	-0.53	-2.00	1	☒	☒
2	1.0000	1.0027	186.30	186.80	0.002	0.50	0.27	-3.00	1	☒	☒
3	1.0000	0.9996	132.63	132.58	-0.000	-0.06	-0.04	-2.00	1	☒	☒
4	1.0000	1.0000	186.30	186.30	0.000	0.00	0.00	-3.00	1	☒	☐
5	1.0000	1.0000	132.63	132.63	0.000	0.00	0.00	-2.00	1	☒	☐

Small thickness errors can be alleviated by reoptimization of optical stack. Thickness of the following layers will be recalculated to maintain optical function of the layer stack.

Conclusion

- Rotary PEALD is a perfect technique for depositing optical coatings
  - High deposition rates
  - High precision
  - Deposition on structured surfaces and high-aspect ratio substrates
- Broad Band Monitoring allows:
  - In-situ monitoring of deposition rate.
  - Measurement of optical function of the coating
  - Process diagnostics
  - Thickness error calculation and reoptimization of layer stack during the process


Thank You!