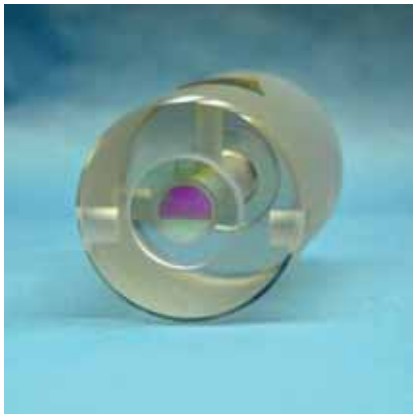
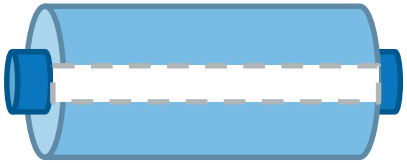
Swiss-made ultrastable high finesse optical cavities

OCLA 2018 Symposium
Buchs, 12.04.2018

E. Portuondo-Campa / B. Eiermann

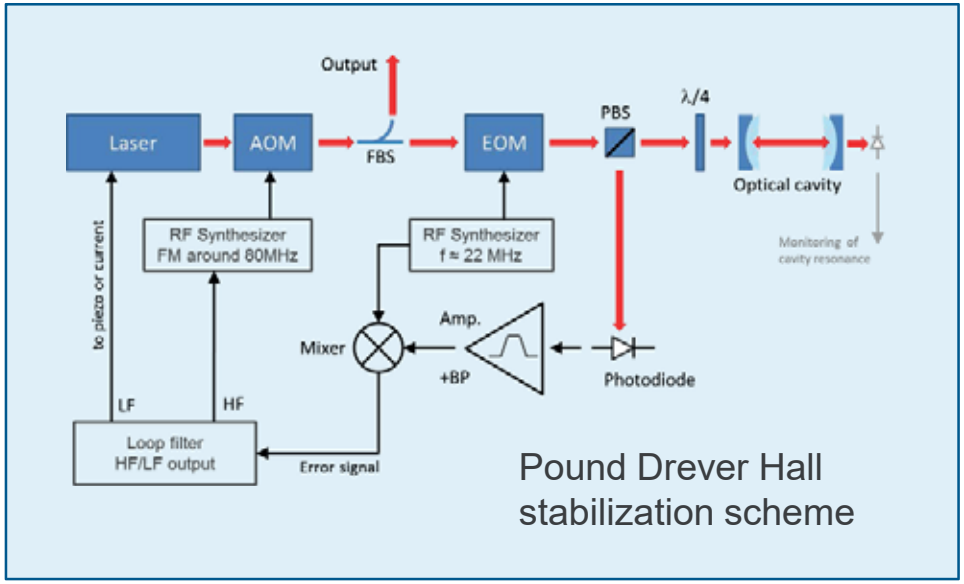
High-end optical coatings and frequency metrology



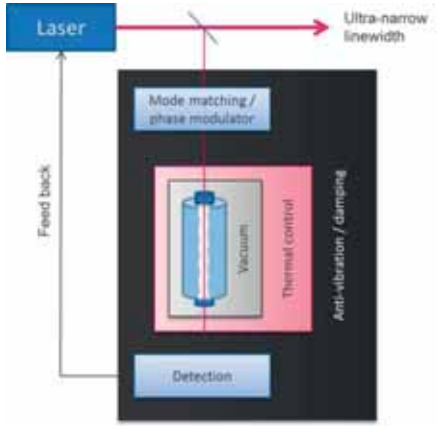


High reflectivity mirrors enable high-Q optical resonator

The length stability of the cavity is transferred as frequency stability of the laser through a feedback control (PDH scheme)



Pound Drever Hall stabilization scheme



The cavity length must be isolated from external perturbations

Ultrastable lasers: State of the art

The records

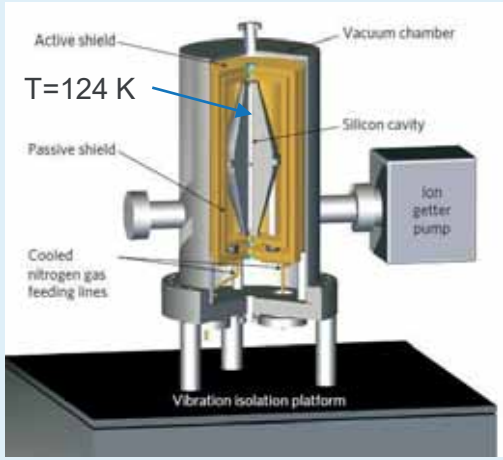
7 mHz optical linewidth

@ 1540 nm (195 THz)

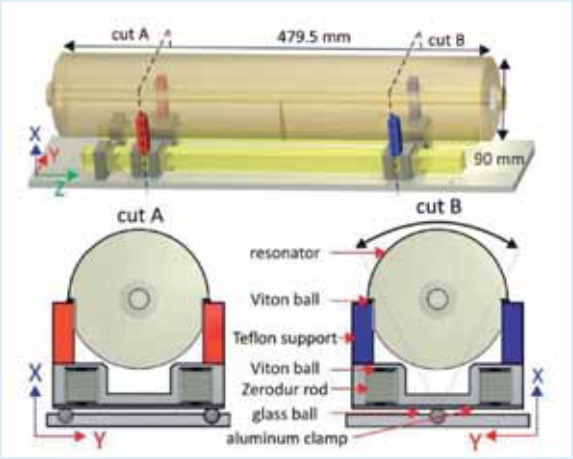
Relative freq. Stability = $4 \cdot 10^{-17}$

T_0 = 170 s (obs. time)

U. Sterr, J. Ye, et al. PRL **118**, 263202 (2017)



F. Riehle, J. Ye, et al. Nat.Phot. **6**, 687 (2012)



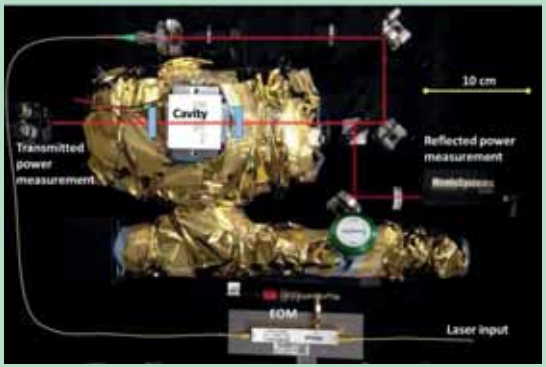
U. Sterr et al. Opt. Lett. **40**, 2112 (2015)

The commercial systems

1 Hz linewidth @ T_0 = 1s

MenloSystems

Test setup at CSEM

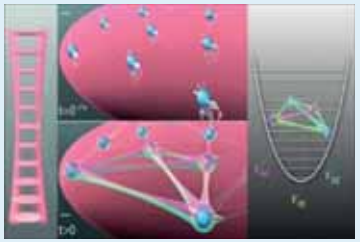


1 Hz linewidth @ T_0 = 1s

Applications of ultrastable lasers with high phase coherence

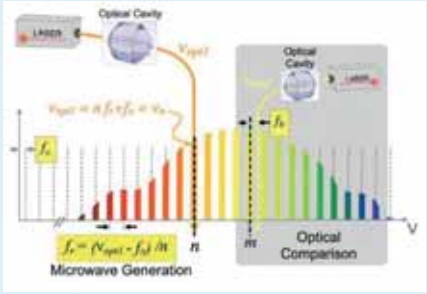
Present applications, scientific niche markets

Optical atomic clocks



Quantum physics

Gravitational waves



Ultra-pure microwave generation

Future, large markets

Telecom and Navigation satellites

Future Telecom

RADAR

Present situation:

Very few companies supply assembled external cavities serving these markets.
There is a strong demand for a reliable European supplier.

WZW and CSEM teamed up to develop and test this product, with the financial support of the KTI.

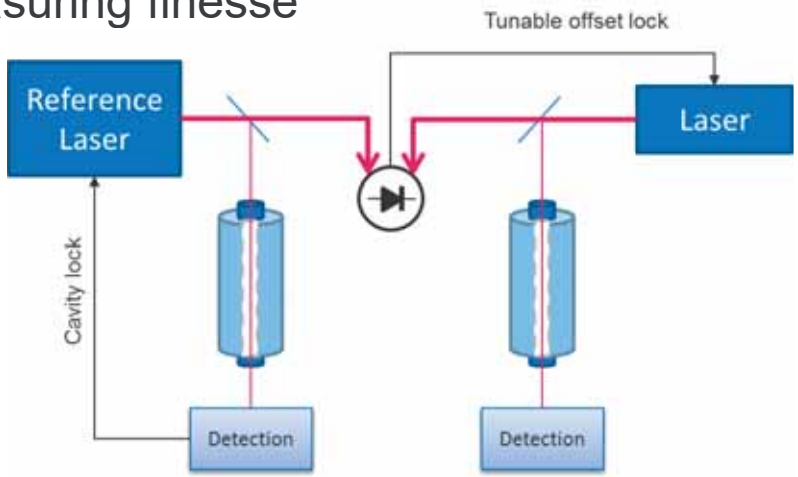
CTI –Project no. 18327.1 PFNM-NM (OptoReC)

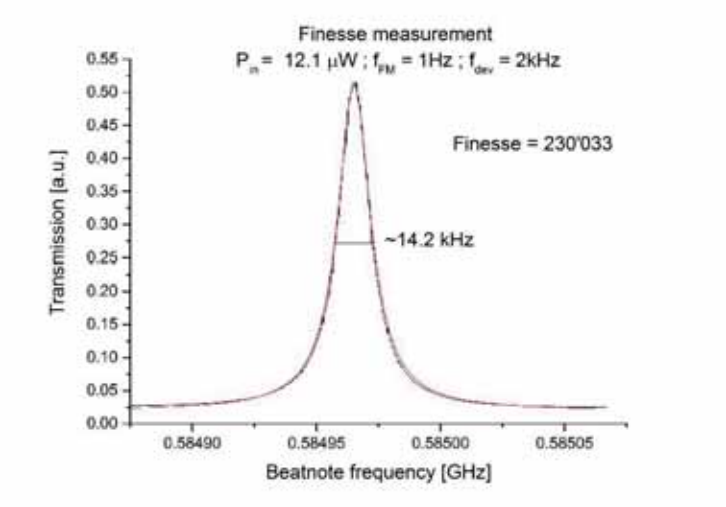
Expectations on cavity performance

Property	Target Value	Depends on:
High finesse	> 150’000	Mirror reflectivity R > 99.998 %
High throughput	> 20 %	Transmission vs Losses L < 10 ppm
Accessible 0-CTE point	> 25 °C	Spacer material
Low drift	< 50 mHz/s	Spacer material and cavity design

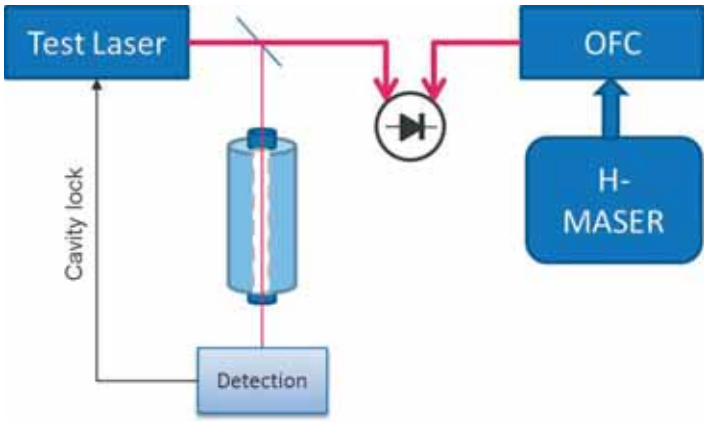
Measuring cavity performance

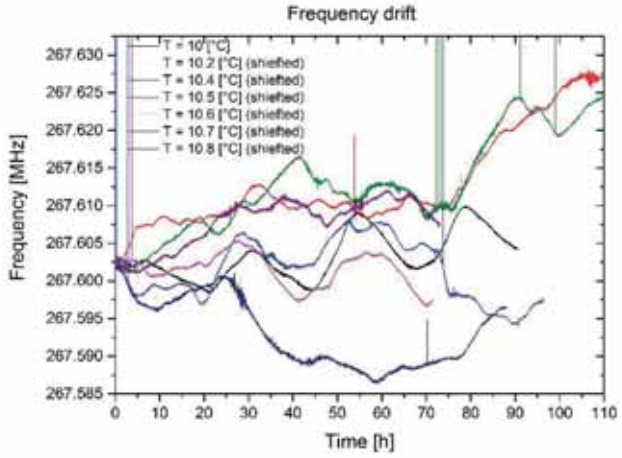
Measuring finesse



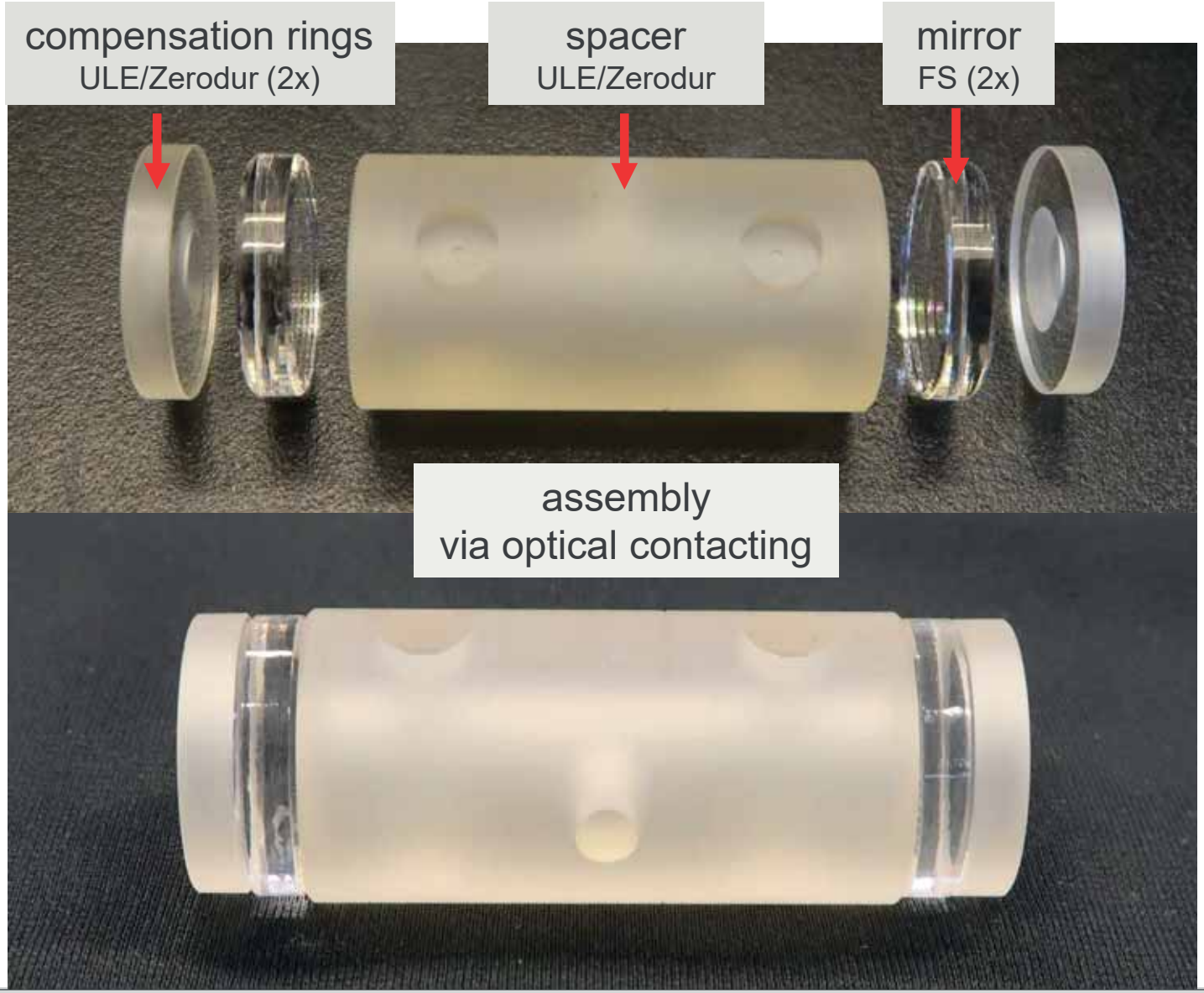


Measuring drift, 0-CTE

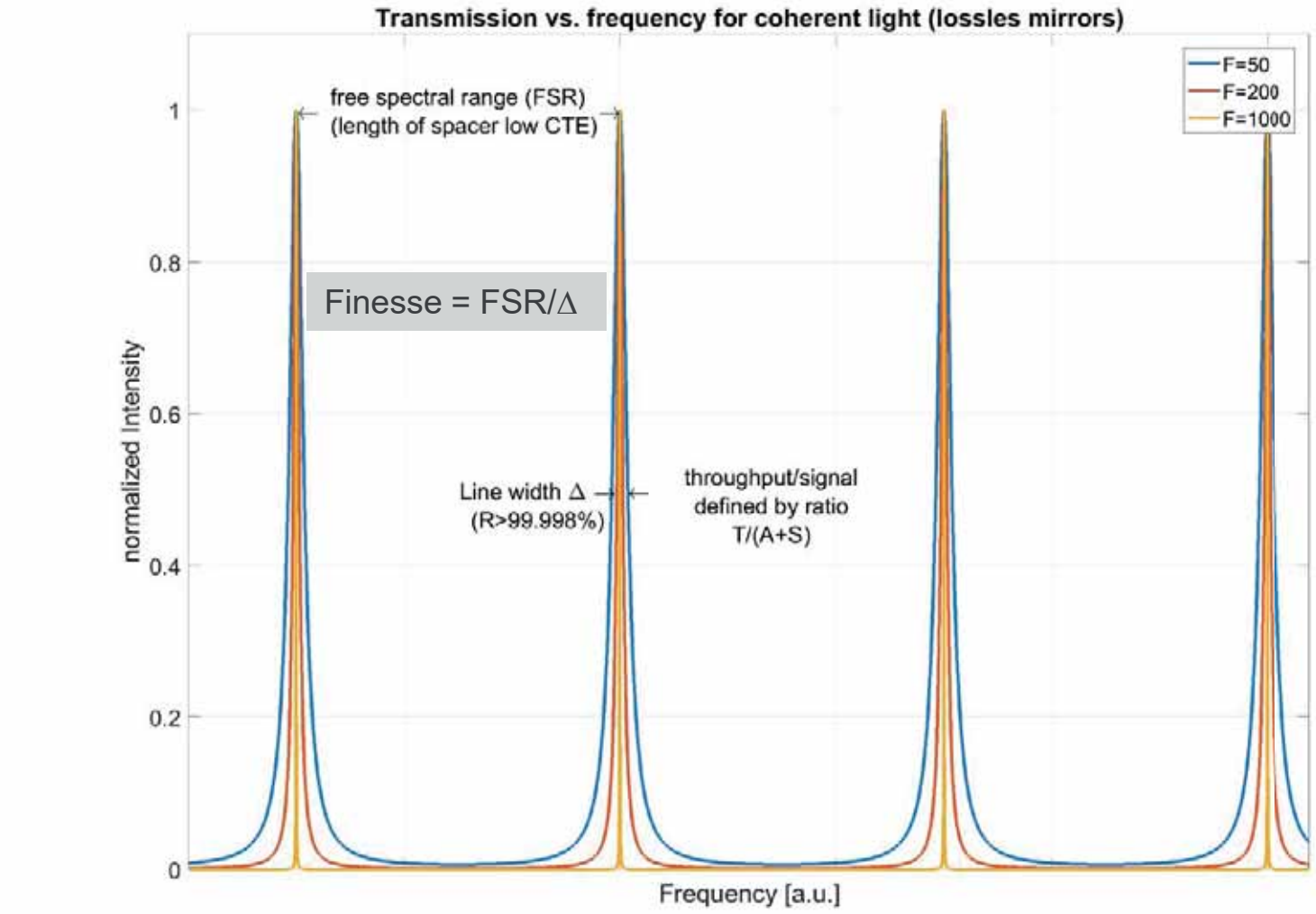




How does it look like? – Dimension is Ø20 x 50mm



Longitudinal modes of resonator (low finesse)



Some frequencies are transmitted (modes) although laser sees two reflective interfaces!

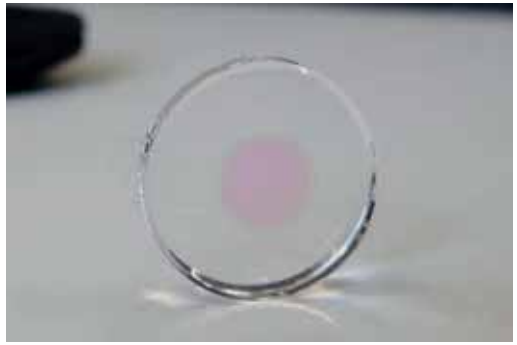
Challenging parts are the mirrors

Rings & spacers are not challenging

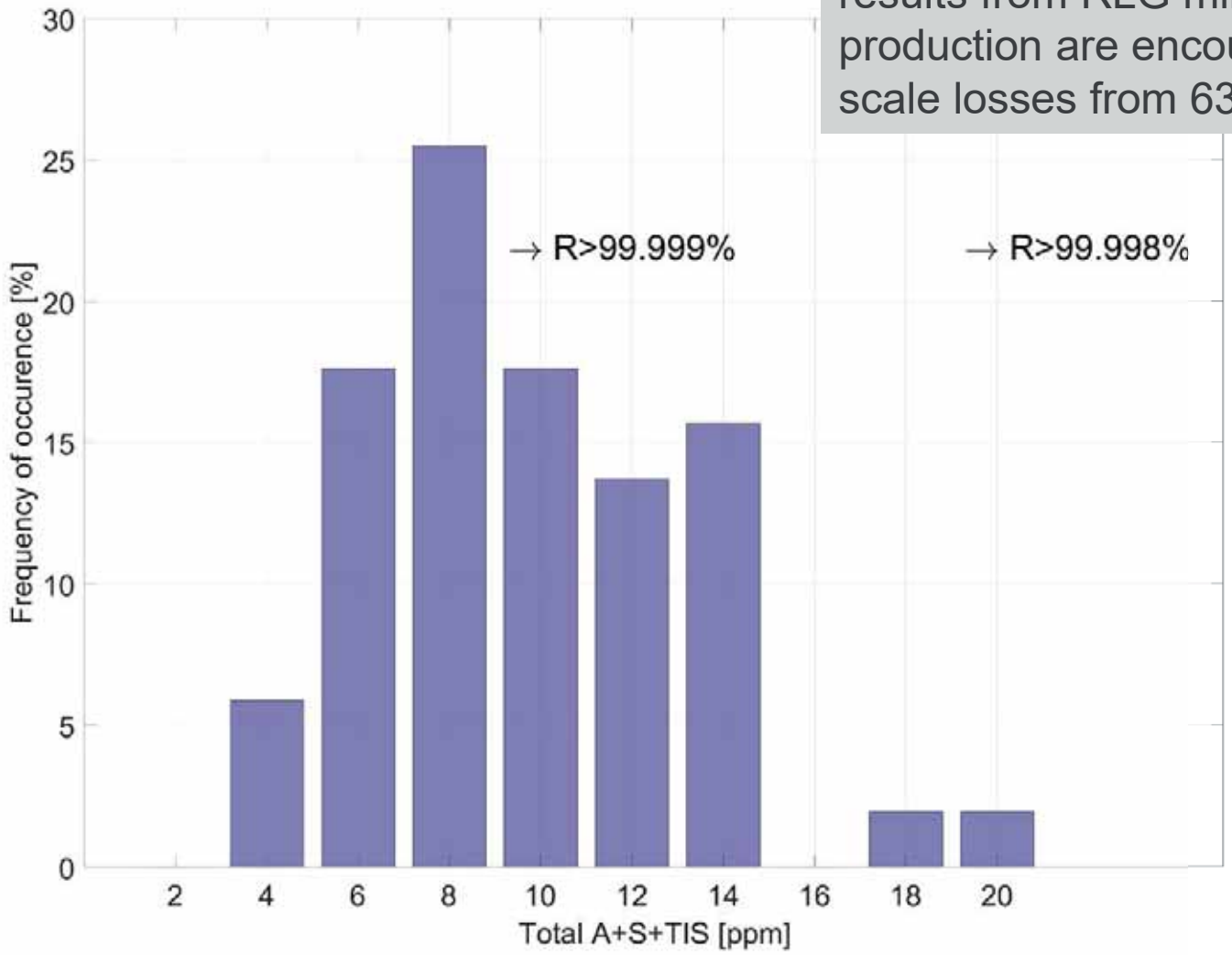
- «standard» materials
- «standard» laser grade finish σ(rms) <5Å & $\lambda/4$ flatness sufficient
- easy geometry, low dimensional accuracy
- laser beam does not «see» these items (bores)

Mirros are critical

- still «standard» materials
- still easy geometry, low dimensional accuracy
- Rear-side AR -> R<0.1% @1560nm (no problem)
- 2 types, one flat/flat mirror & one pcv mirror (R=1m)
- superpolishing needed: σ(rms) <1Å to minimize scatter
- low loss coating needed: absorption+scatter < 5ppm @1560nm
- Transmission > losses: T=10 ± 1 ppm @1560nm



Histogram of total losses by CRD – HR mirror@633nm (T<4ppm)



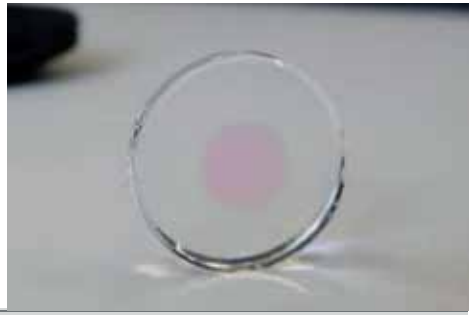
results from RLG mirror production are encouraging scale losses from 633 to 1560nm!

Mirror characterisation

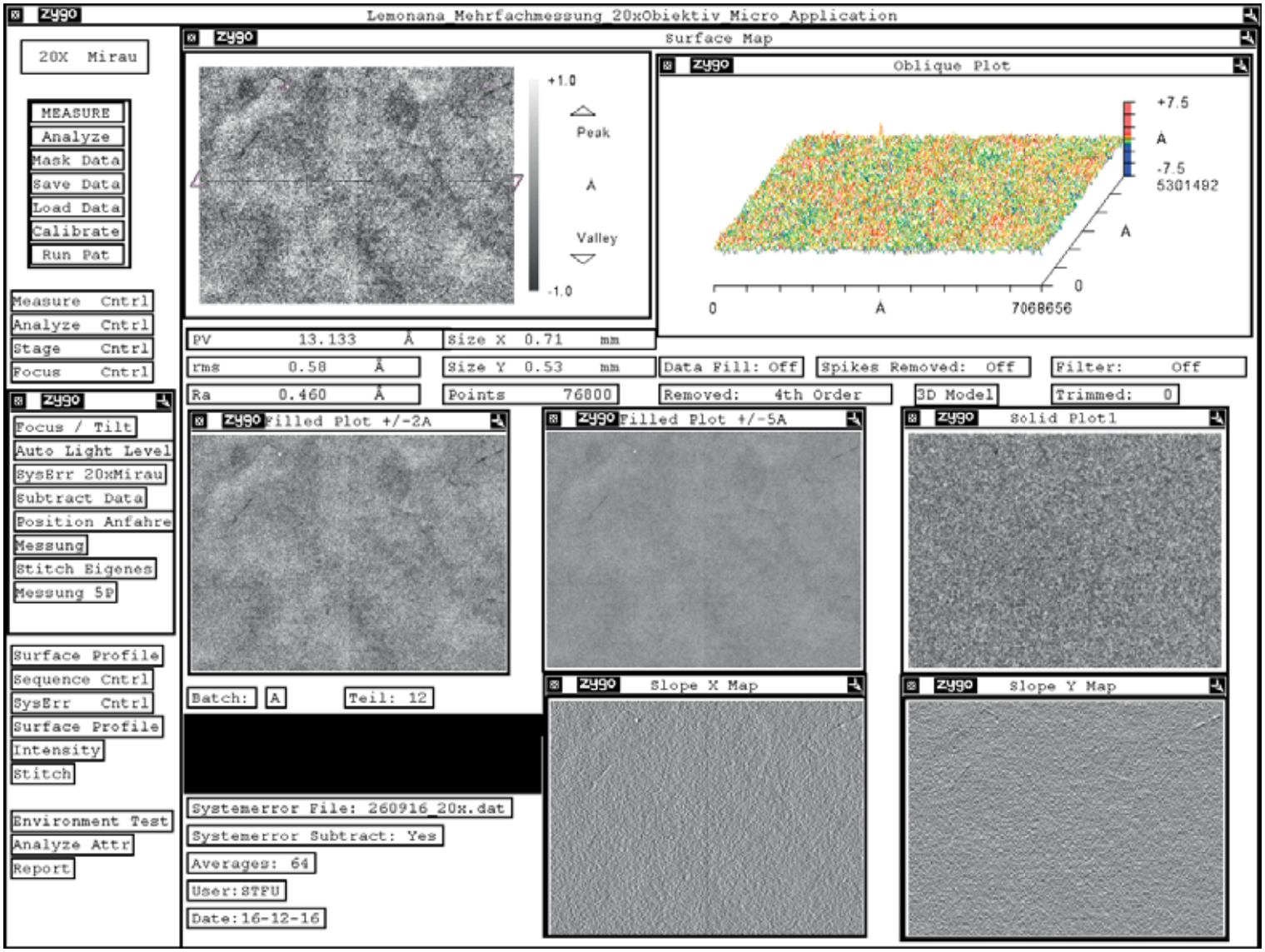
Only few measurements needed:

- Surface roughness (by white-light interferometer)
- Cleanliness – laser scanning microscope Olympus Lext 4100
- Scattered light – adapted WZW internal device «Streuli» - after coating
- Transmission – scanning spectrometer Perkin Elmer Lambda 900
- CRD currently not possible (no setup available)

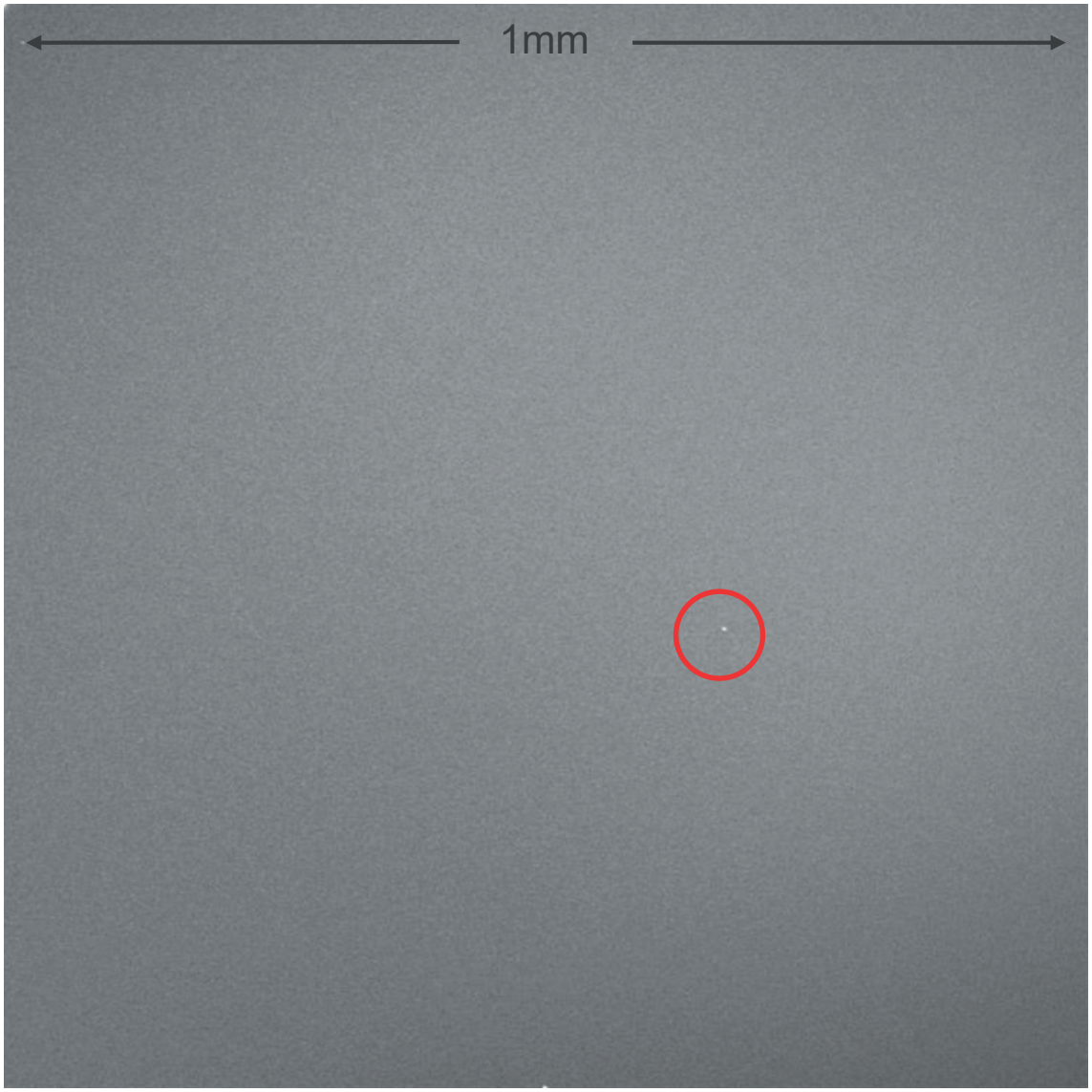
Memo: $\underline{R} = 1 - \underline{T} - \underline{TIS} - A$



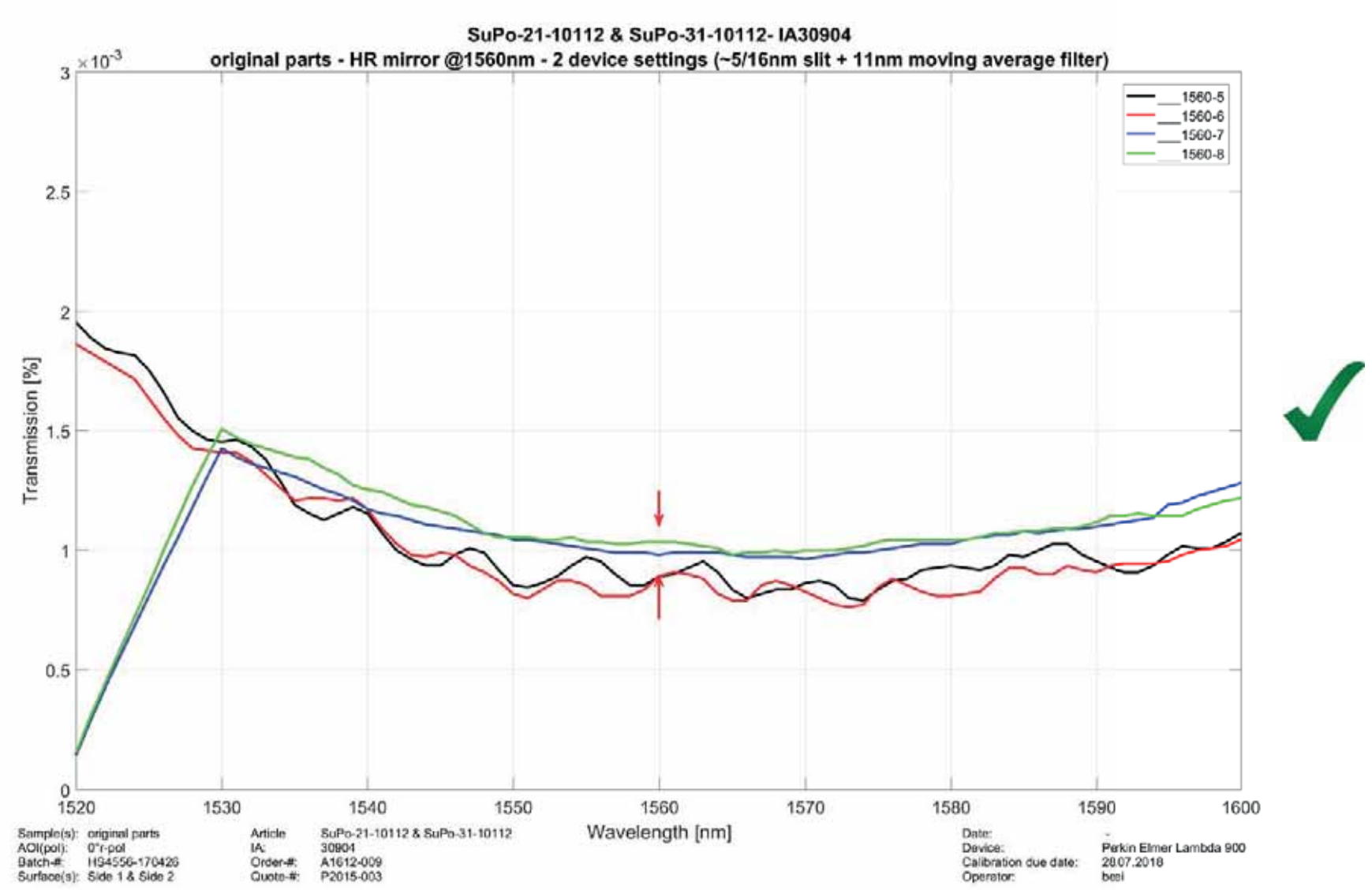
Results: roughness measurement (Zygo NewView 6300)



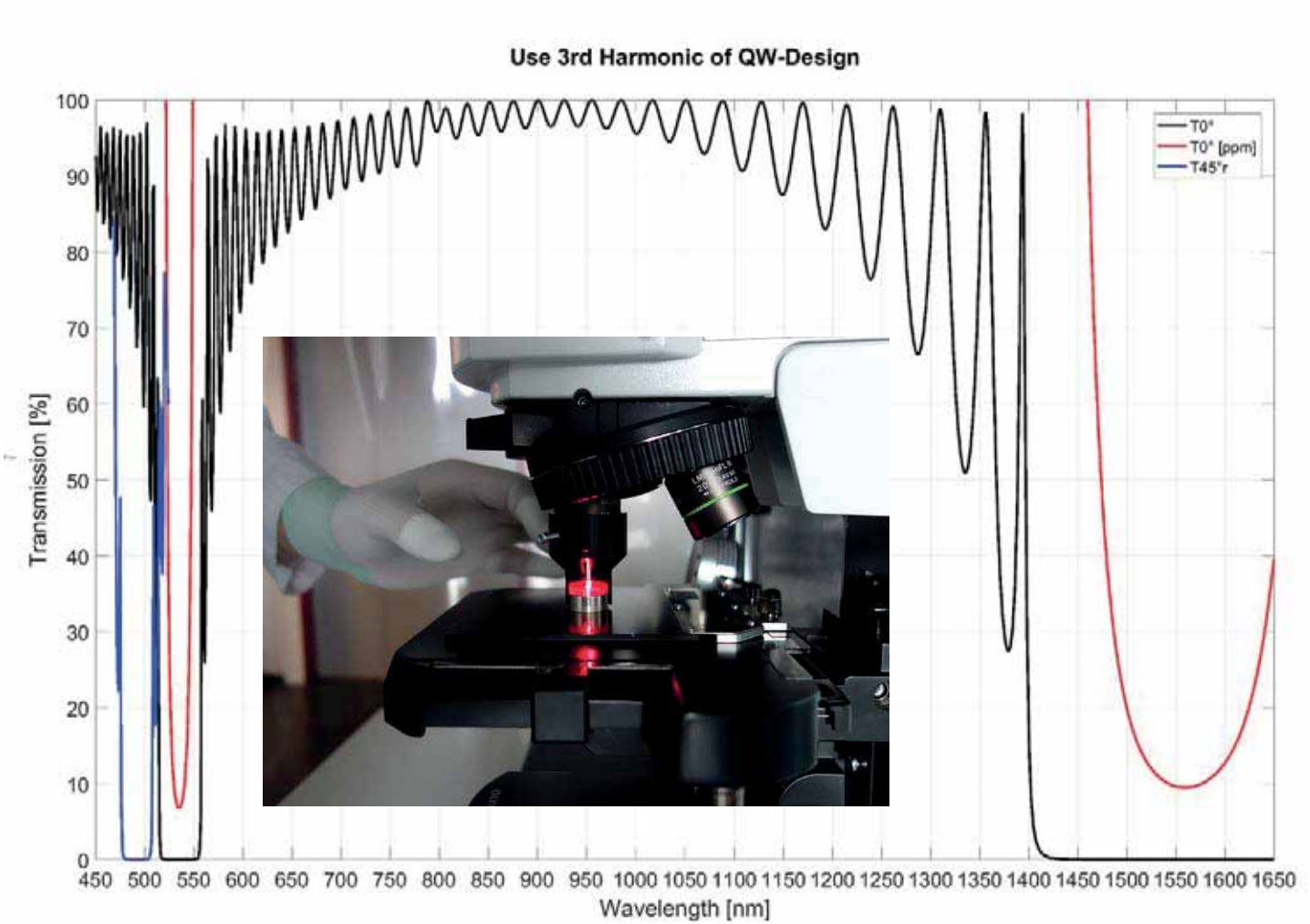
Results: Surface quality (Olympus Lext 4100)



Results: transmission measurement (Perkin Elmer L900)

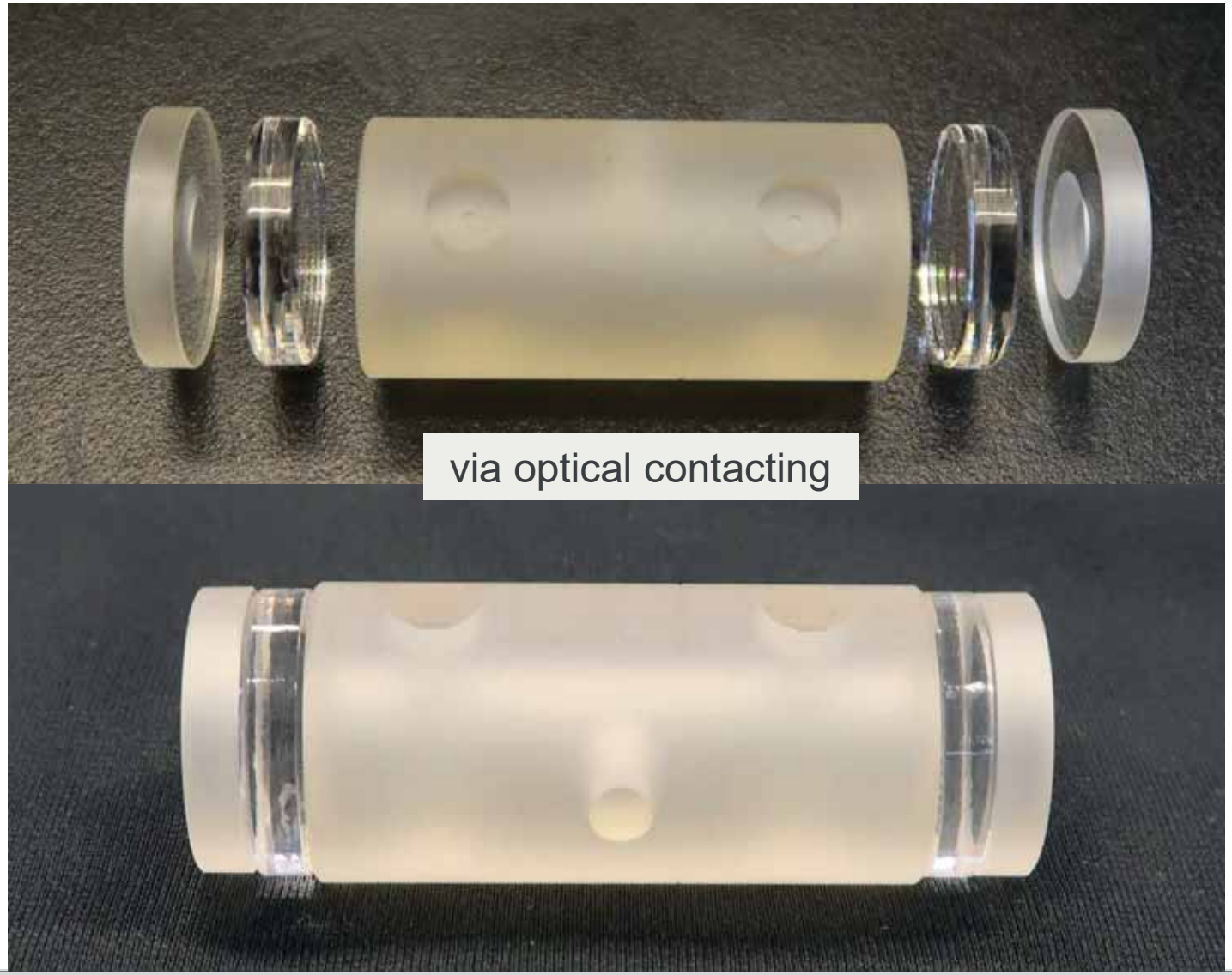


Results: measure scatter of 3rd harmonic (AOI 45°) @480nm

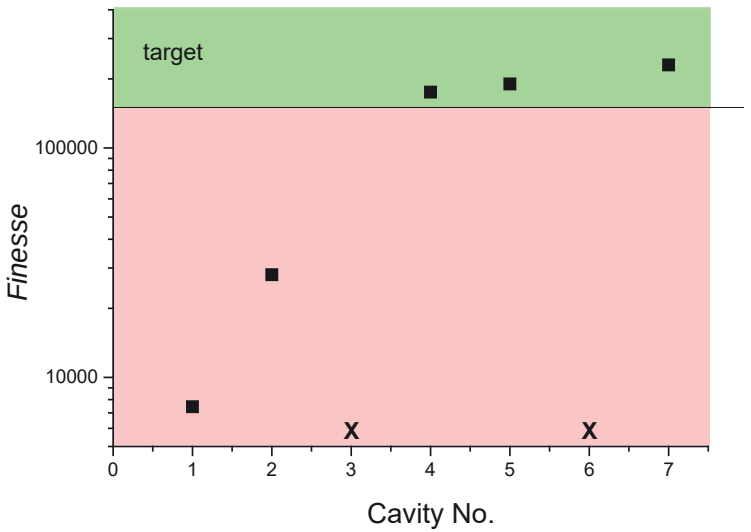


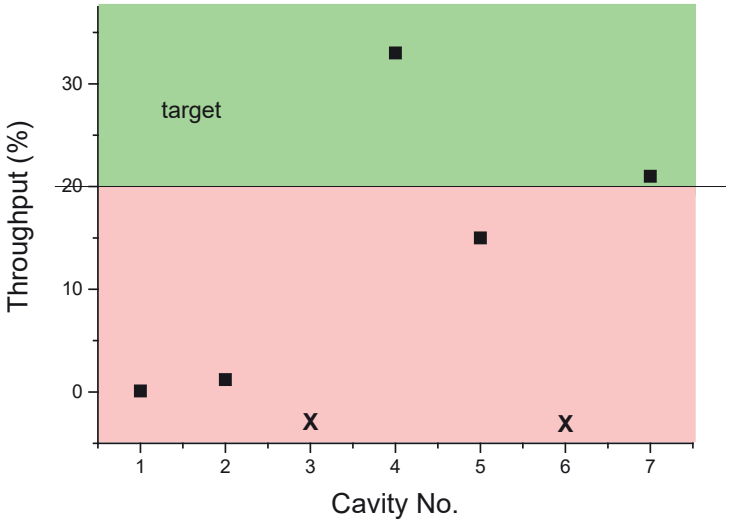
Scattered light @ 480nm~25ppm -> scales to ~2.5ppm @1560

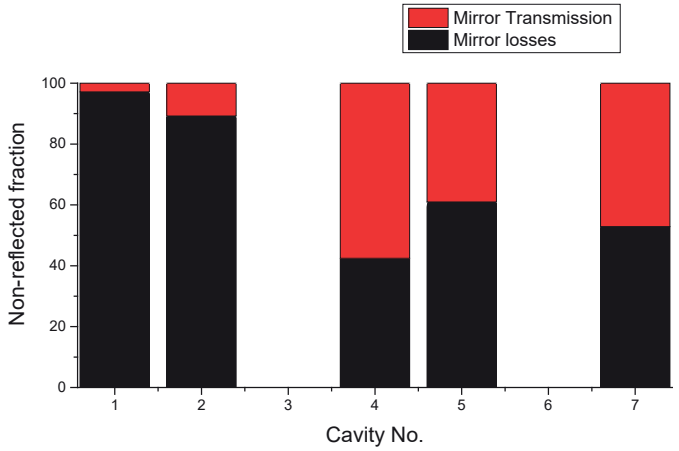
What's left? Assembly!

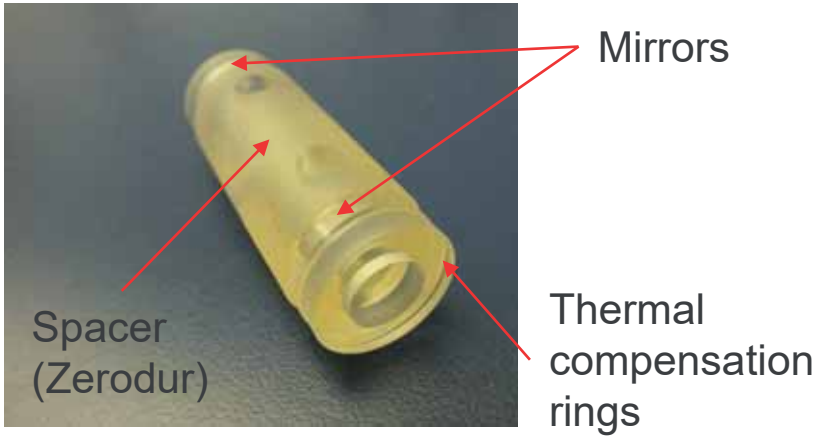


Results on characterization of assembled resonators









Conclusions

- Mirror feasibility demonstrated
- reliability of assembly process still to be improved (focus on cleanliness)
- Improve quality control after assembly
- Goal: stable production with reasonable (predictable) yield (not world record)

- 0-CTE setpoint and drift measurements on-going

Outlook:

- IBS coatings in-house @WZW
- «Full» characterisation of the assemblies prior to shipment to future customers

Thank you for your attention!
Questions?