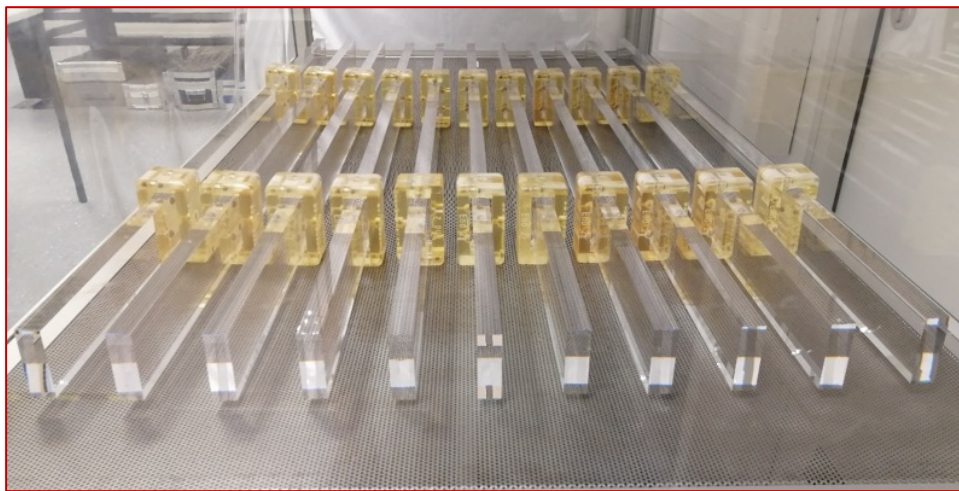


QA of Nikon Radiator Bars Status

G. Schepers, PANDA Collaboration Meeting,
GSI Darmstadt, 09.03.2021

- Fabrication of DIRC bars at Nikon Corp, Japan finished
 - Received 98 originally ordered bars, ~5 months ahead of schedule
 - 14 additional bars are delivered as well. Thanks to collaborators!
- All bars meet fabrication specs, performing detailed QA in GSI DIRC lab



New bars in GSI DIRC lab

Nikon	Number	Polishing	Side	Length
P23595-1-04	1	1	1	1199.7
P23595-1-08	1	1	2	1199.7
P23595-1-18	1	1	2	1199.85
P23595-1-19	1	1	2	1199.87
P23595-1-20	1	1	1	1199.89
P23595-1-03	2	1	2	1199.82
P23595-1-05	2	1	10	1199.81
P23595-1-07	2	1	3	1199.76
P23595-1-09	2	1	3	1199.76
P23595-1-13	2	1	3	1199.91
P23595-1-15	2	1	5	1199.89
P23595-1-17	2	1	5	1199.91
P23598-1-01	2	2	13	1199.83
P23598-1-03	2	2	4	1199.85
P23598-1-04	2	2	17	1199.85
P23598-1-05	2	2	4	1199.86
P23598-1-06	2	2	4	1199.86
P23598-1-07	2	2	4	1199.87
P23598-1-08	2	2	8	1199.86
P23598-1-09	2	2	8	1199.87
P23598-1-10	2	2	8	1199.88
P23598-1-13	2	2	16	1199.81
P23598-1-14	2	2	8	1199.81
P23598-1-15	2	2	8	1199.84

Squareness

Date: 2020/11/27

Lot No. YK094317-8

Material lot No. P23607-1-03

Polishing lot No. 7-7-37-35-21-25

0.16
End 2
Face 1

0.19
Side 2

0.34
End 2
Face 1

0.35
Side 1

0.39
Face 2

0.01
End 2

0.02
End 2

0.00
Face to Side

0.29
Face 1
Side 1

0.35
Side 1

0.00
Face to End

0.20
End 1

0.20
Side 1

0.03
Face to End

0.03
End 1

0.03
Face 2

0.20
End 2

0.19
Face 2

Data Sheet

Date: 2020/11/27

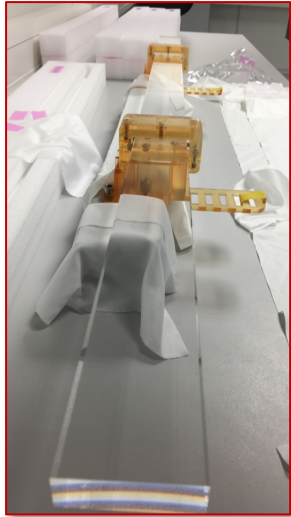
Lot No. YK094317-8

Material lot No. P23607-1-03

Polishing lot No. 7-7-37-35-21-25

Item	End / method	Result
Length [mm]	Specification	
Width [mm]	Specification	
Thickness [mm]	Specification	
Parallelism [mm]	Specification	
Squareness [mm]	Specification	
Surface roughness [A RMS]	Specification	
TTV [mm]	Specification	
Surface quality	Specification	

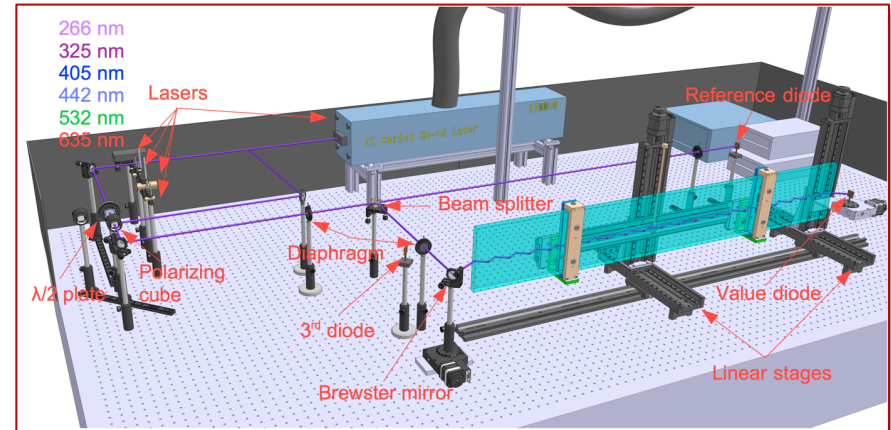
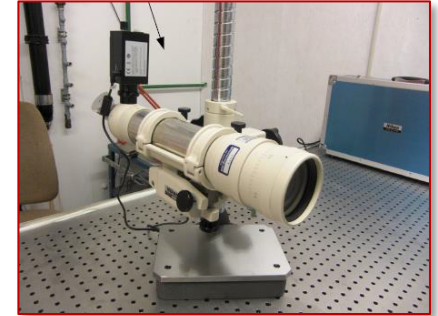
Lot No.	Face-End Squareness (Side1)				Face-End Squareness (Side2)			
	F1-E1	F1-E2	F2-E1	F2-E2	F1-E1	F1-E2	F2-E1	F2-E2
2020/11/27	0.15	0.16	0.26	0.11	0.26	0.11	0.08	0.19
	0.01	0.16	-0.02	0.25	0.01	0.26	-0.08	0.04
	0.06	0.02	0.13	0.02	0.14	0.02	0.01	0.07
	0.00	-0.02	0.05	-0.06	-0.05	0.06	0.03	0.02
	0.26	0.32	0.06	0.26	0.10	0.26	0.09	0.20
	0.40	0.00	0.40	0.20	0.17	0.20	0.17	0.13
	0.23	-0.08	0.24	-0.10	0.12	0.10	0.12	0.05
	-0.15	-0.12	0.15	-0.02	0.18	0.01	0.19	0.04
	-0.13	-0.10	0.13	0.02	0.09	-0.02	0.09	0.07
	0.05	-0.07	0.05	0.07	-0.30	0.04	0.30	0.05
	0.01	0.06	0.01	-0.06	0.07	0.04	0.06	-0.04
	-0.08	-0.05	0.08	0.05	0.02	0.02	-0.01	0.00
	0.07	0.03	0.07	-0.03	0.23	0.16	-0.23	0.16
	0.30	0.10	0.02	0.09	-0.02	0.20	0.37	0.20
	0.24	0.05	0.03	0.05	0.41	0.02	0.41	0.01
	0.29	0.00	-0.05	0.00	0.06	0.23	0.28	-0.23
	0.31	0.06	0.17	0.06	0.17	0.19	0.34	0.19
	0.19	0.04	-0.19	0.03	0.19	0.42	0.36	0.42
	0.43	0.00	0.01	0.00	0.21	0.21	0.22	0.26
	0.41	0.11	0.03	0.11	0.02	0.13	0.08	0.15
	0.16	0.13	0.07	0.13	0.07	-0.03	0.08	0.02

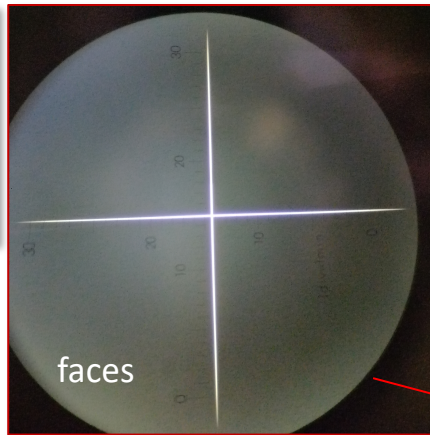
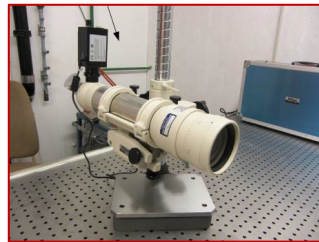


- **Visible inspection**
 - Clean surfaces, no residue from cleaning nor packing, sharp corners?

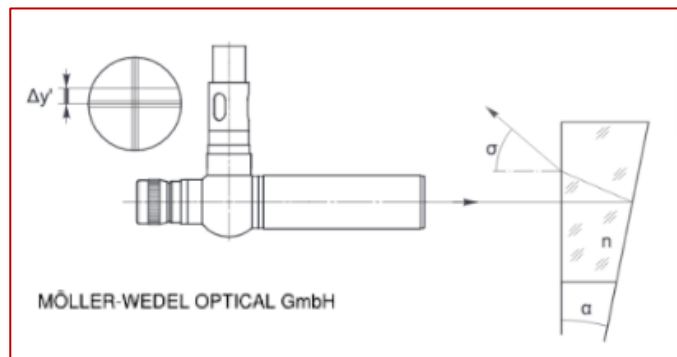
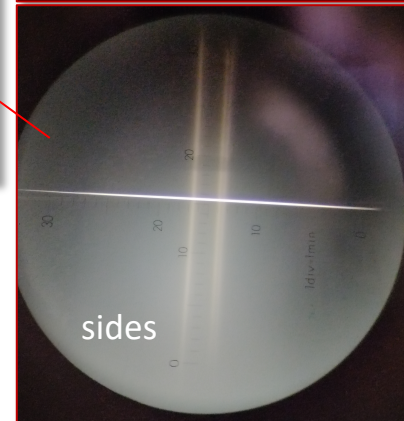
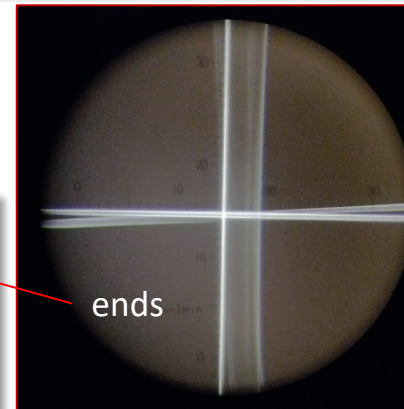
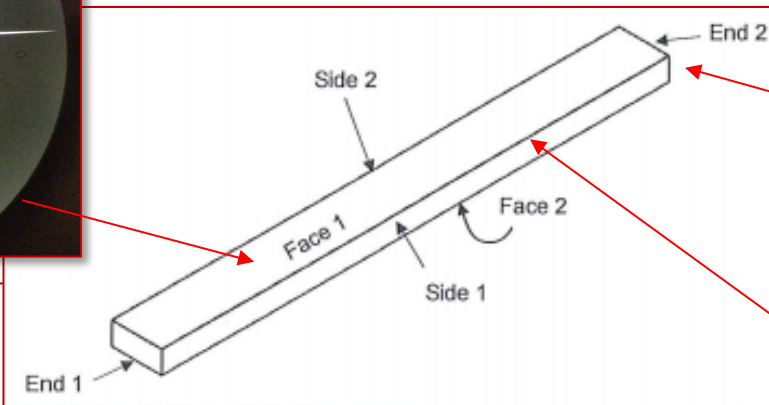
- **Autocollimator**
 - Shape, parallelism, squareness

- **Laser setup**
 - Internal reflection for:
 - Bulk absorption
 - Reflection coefficient
 - Subsurface damage
 - **External reflection**
 - Shape





Faces show “perfect” parallelism



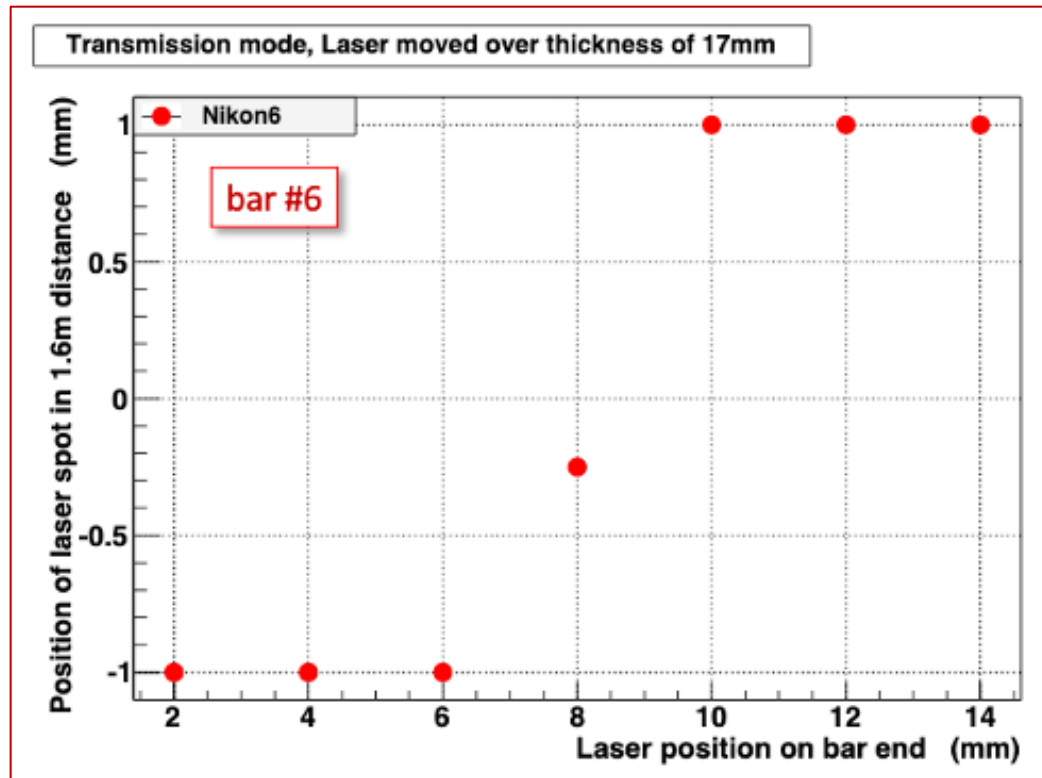
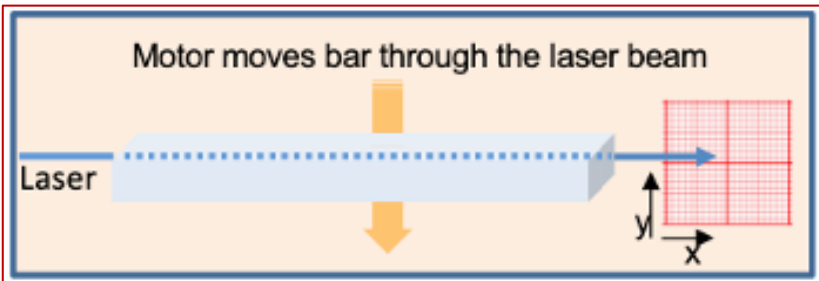
Ends and sides show “fuzzy” image

- Striae and/or shape deviations
- No squareness determination possible

When the laser beam passes straight through the bar, the shape of the sides has no influence.

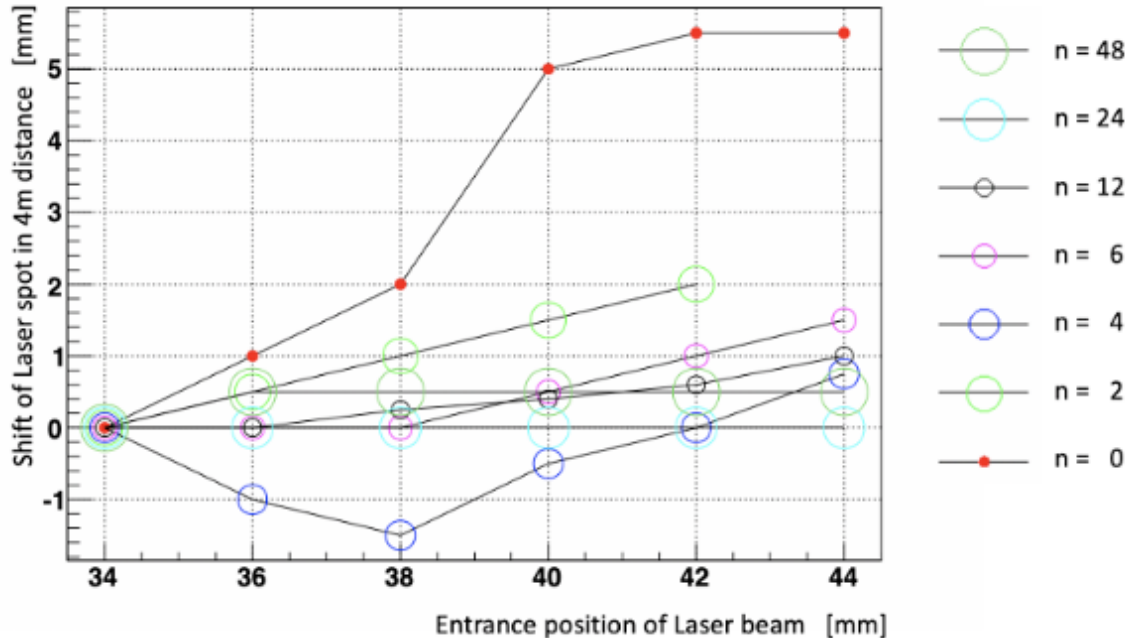
Any deviation of the laser spot position on the wall from the initial position provides hints regarding refractive index variations over the bulk.
(note that the bar ends were found to be flat)

The deviation can be in x- and/or y-direction



Observed position shift during thickness (17mm) scan

Primary photon propagation in a DIRC is along the length of the bar -
 Check if the effect is larger or similar for photons bouncing many times

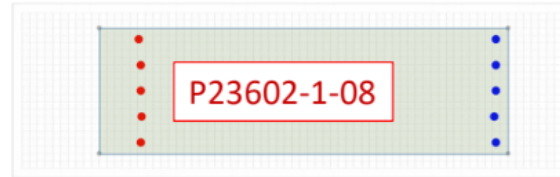
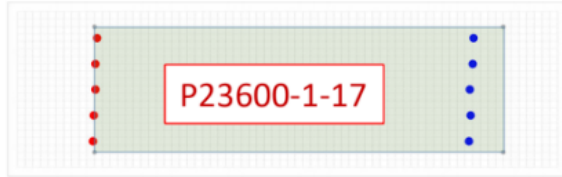
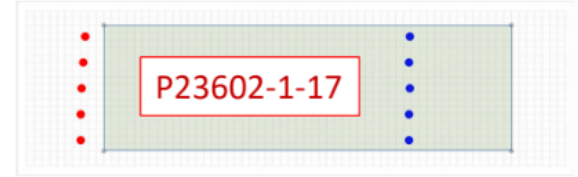
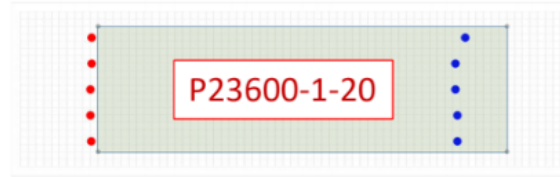
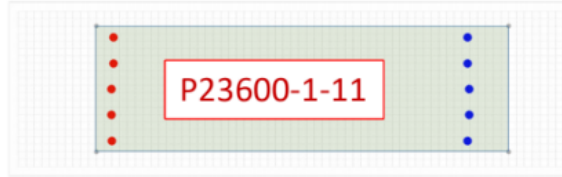
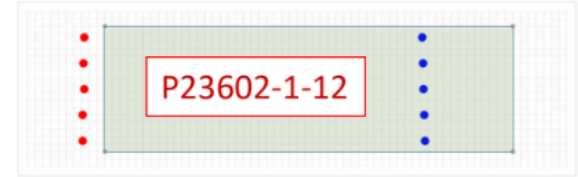
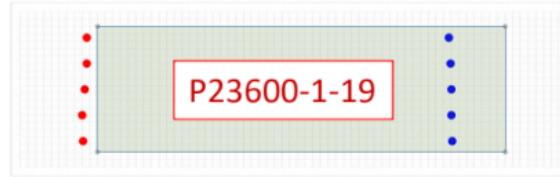
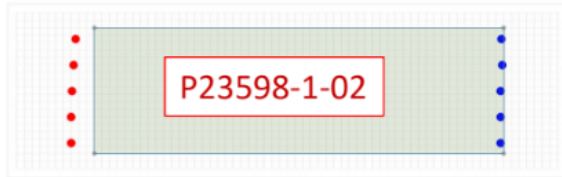


- n: number of internal reflections
- The bar was scanned over its thickness from face2 to face 1
- The shift is shown relative to the spot position of each first laser entrance

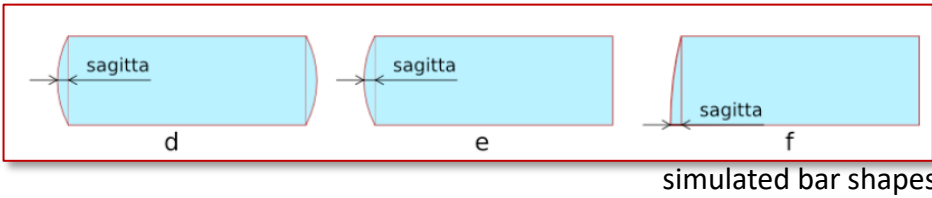
Impact of effect is smaller for larger photon angles



Deviations from ideal bar shape shown
for narrow sides, position 3mm from End 2
(Nikon CMM data, deviation scaled by factor 1000.)

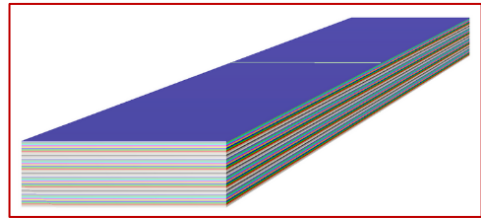
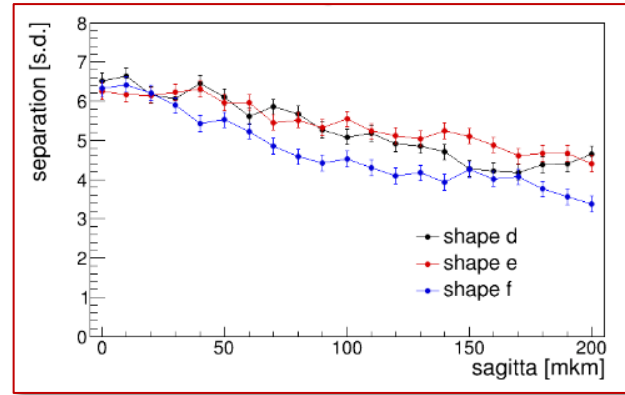


Deviations from ideal bar shape shown
for narrow sides, position 3mm from End 2
(Nikon CMM data: 200717_surface shape data,
deviation scaled by factor 1000.)



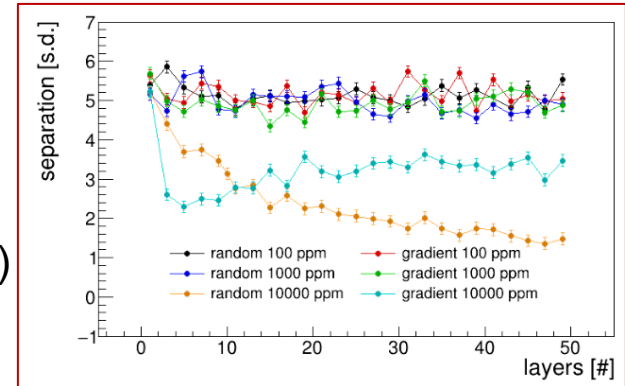
Maximal Sagitta around $10\mu\text{m}$ (Nikon)

➤ minor influence



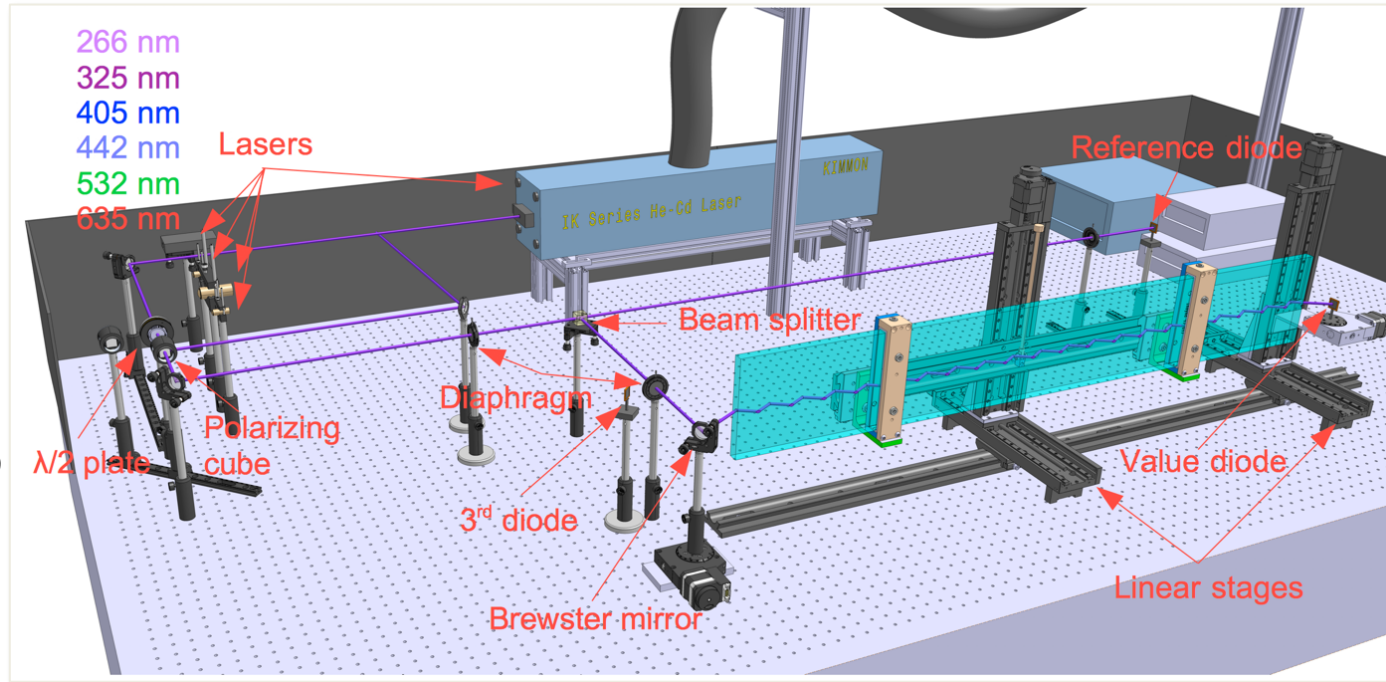
Maximal Variation of Refractive Index: = 7 ppm (Nikon)

➤ minor influence



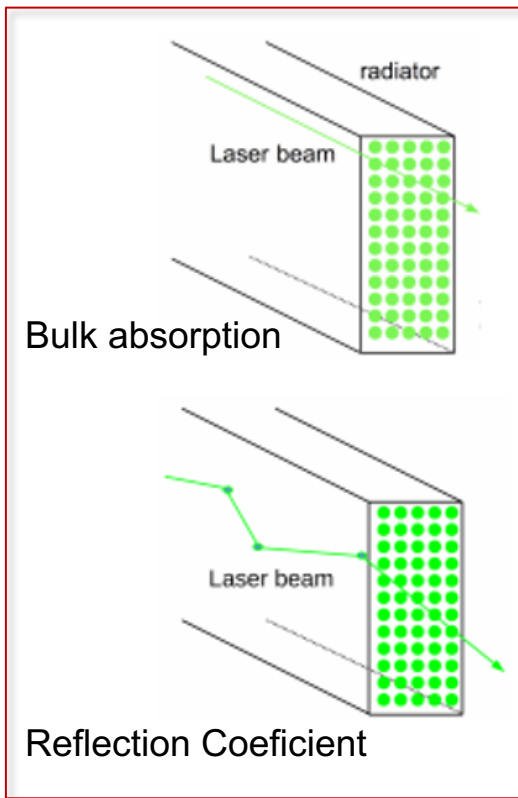
Producer is not able to measure internal reflection

Measurement of the wavelength dependent reflection coefficient gives access (via SST) to the surface roughness and thus to possible subsurface damage by the production method



Motor-controlled laser scanning system

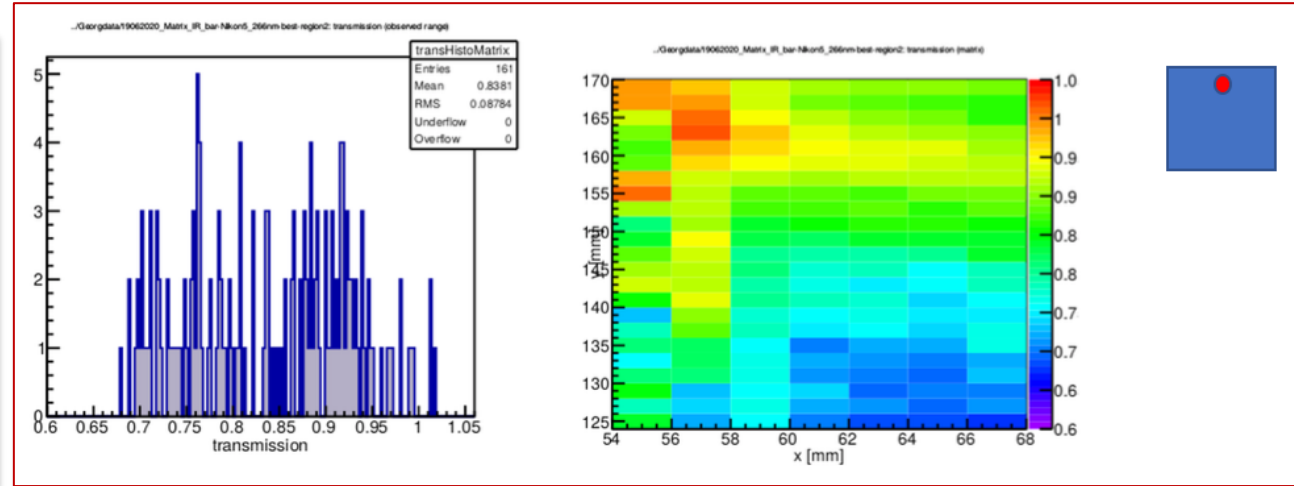
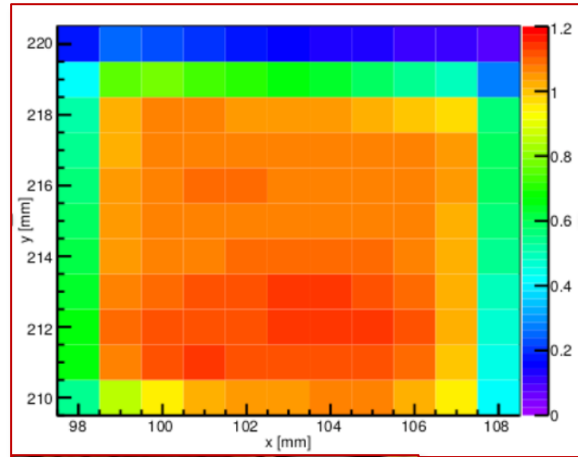
SST: scalar scattering theory



Scanning of a matrix of positions on the bar to cover the highest portion of the material/surface

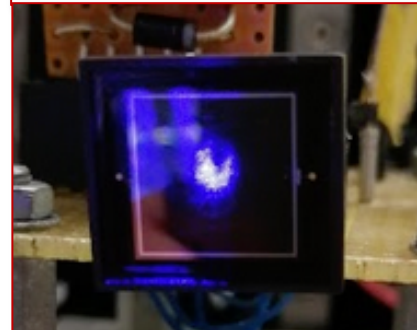
Prerequisite:
Laser spot hits always the same region on the photosensor

Photodiode 10x10mm

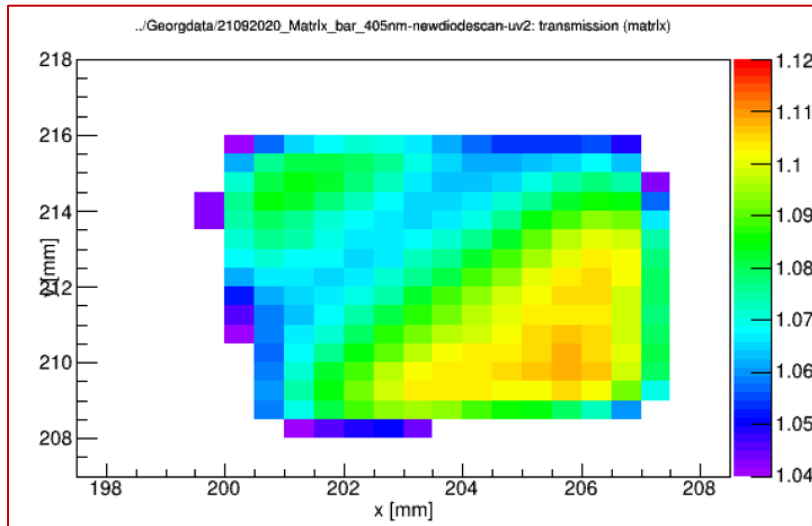


Measurement of Transmission with Nikon bar #5 extremely broad

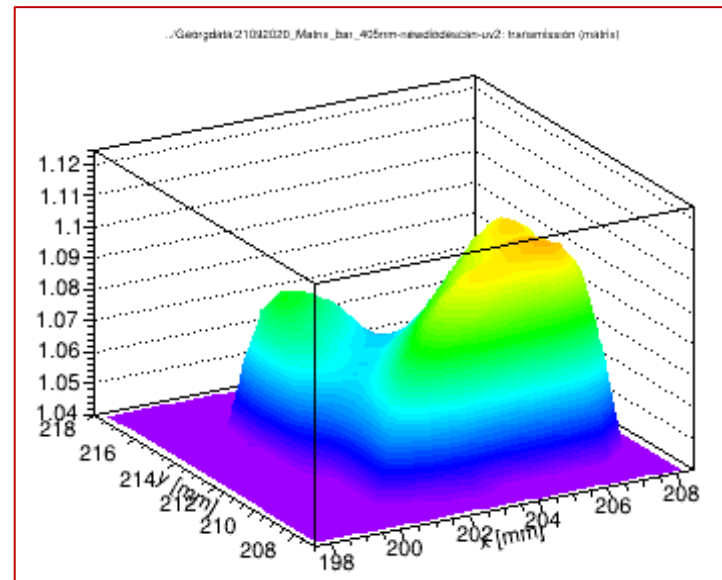
Scan of the Si photodiode shows much more Inhomogeneity than the specified 2% (for the inner 80% of the diode)



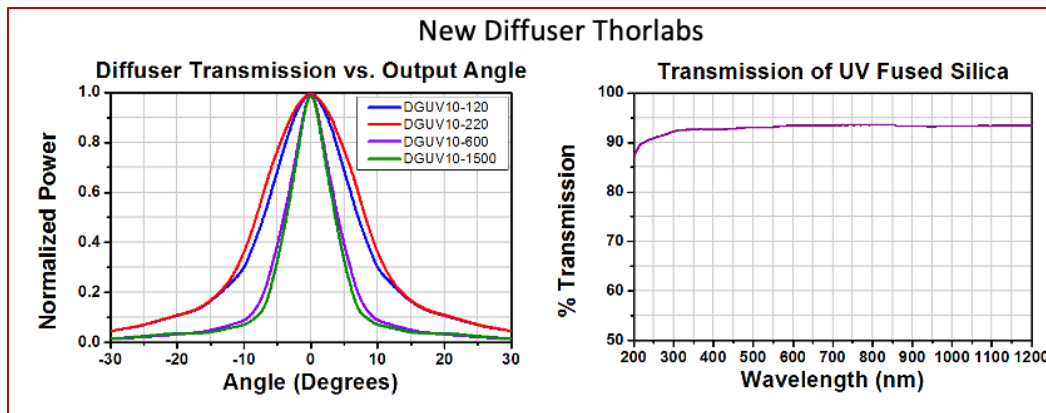
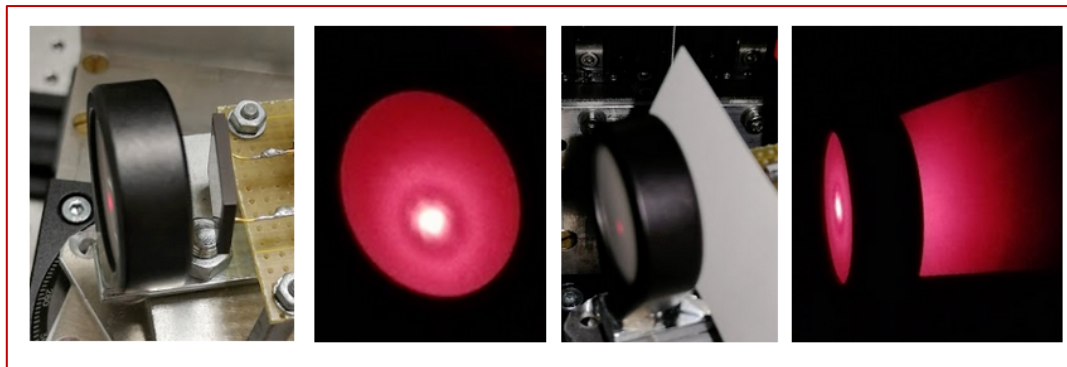
Homogeneity:
Scan with laser (405nm) in 0.5mm steps

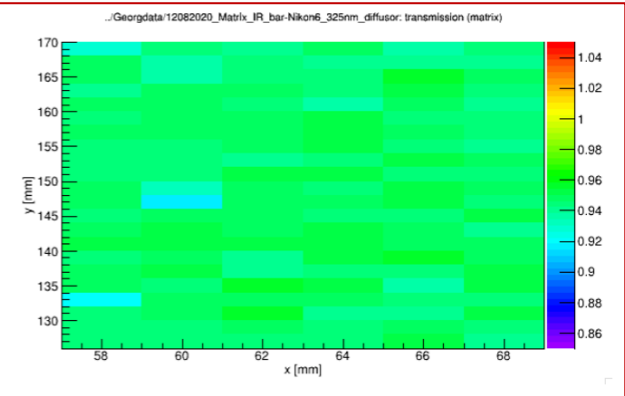
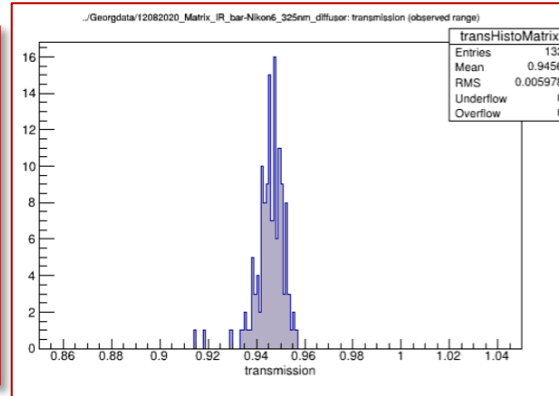
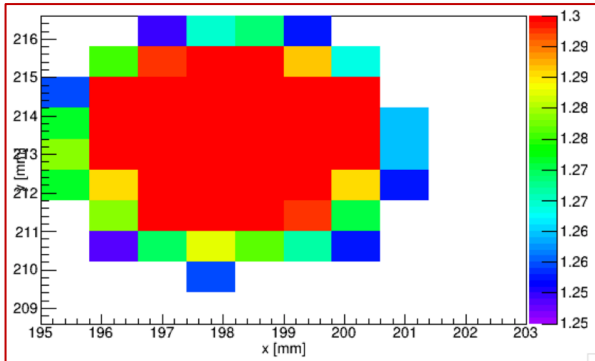


New Diode 2



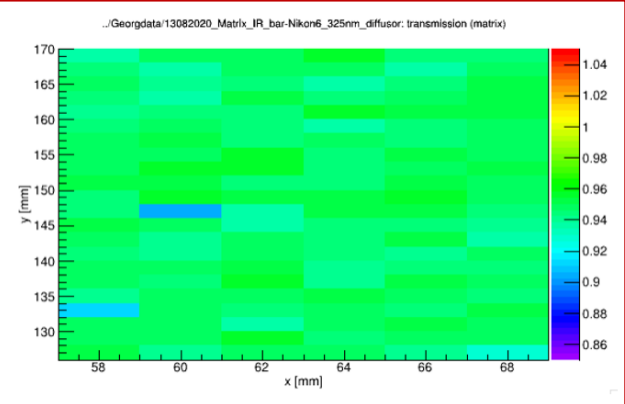
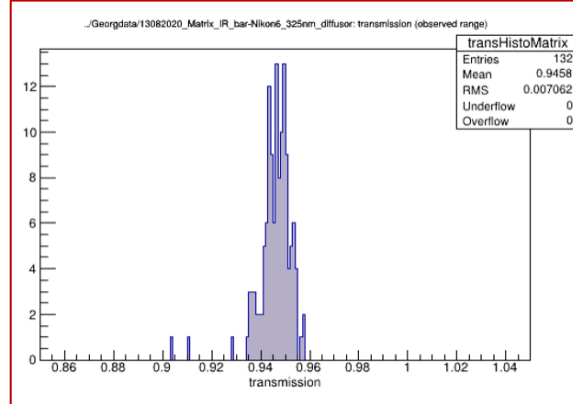
Not a better performance than the “old” sensors





Scan of the UV-photodiode behind the diffuser

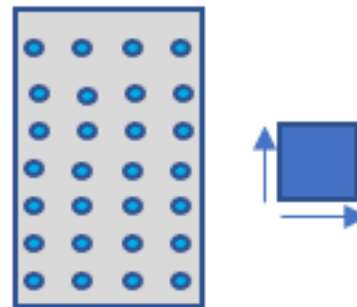
Now reproducible results:
Between both measurements
Laser spot was moved by
1mm in x- and y- direction
on the UV-photodiode



Reminder: Nikon bars shift the beam spot on the photodiode after inner reflection

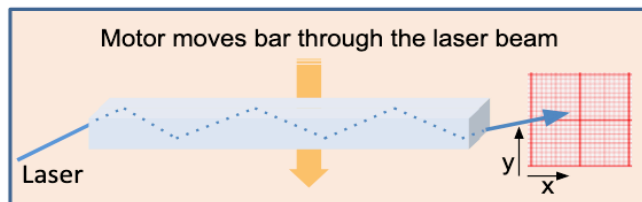
- Independence from the beam spot position on the diode
- Diffuser
- Photodiode
- Integrating Sphere
- Maximum Intensity Method**

Scan the beam spot with the photodiode to find for each position on the bar end the maximal measured intensity (Value diode/ Reference diode)



Bar(17mmx53mm. Diode (10mmx10mm)

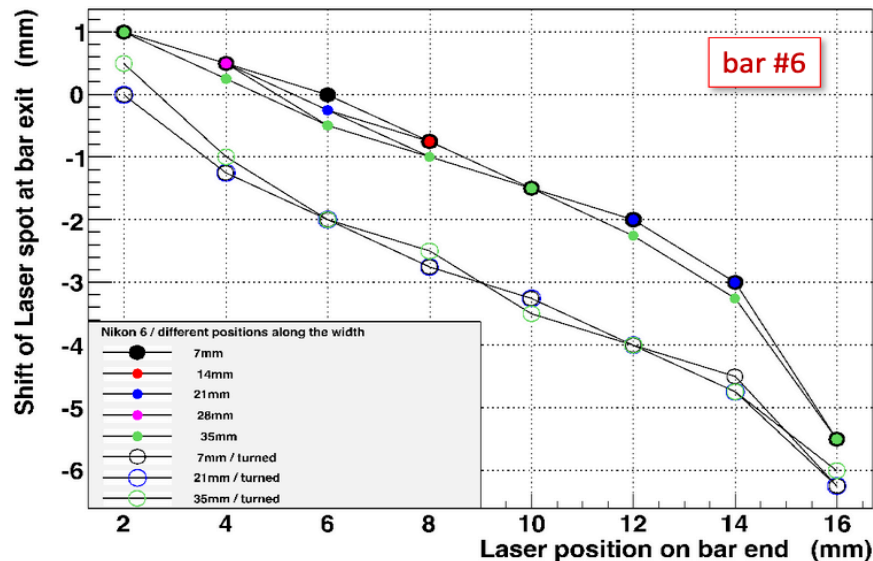
Shift of Internally Reflected Laser Beam



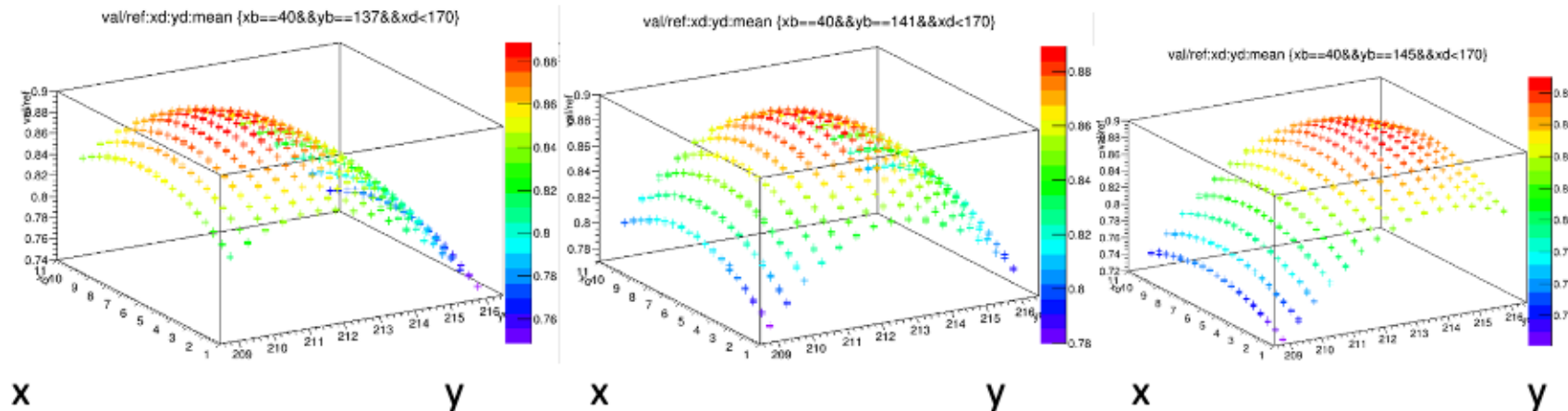
Detailed scan for bar #6, different laser entry positions
No significant dependence of entry position along width
Consistent result if bar is turned (end 1 -> end 2)

Observed “**beam steering**” results for all Nikon bars
consistent with reflections from **non-flat surfaces**
and/or steering from layers of varying refractive
indices (**striae**) (*cannot be distinguished by this method*).

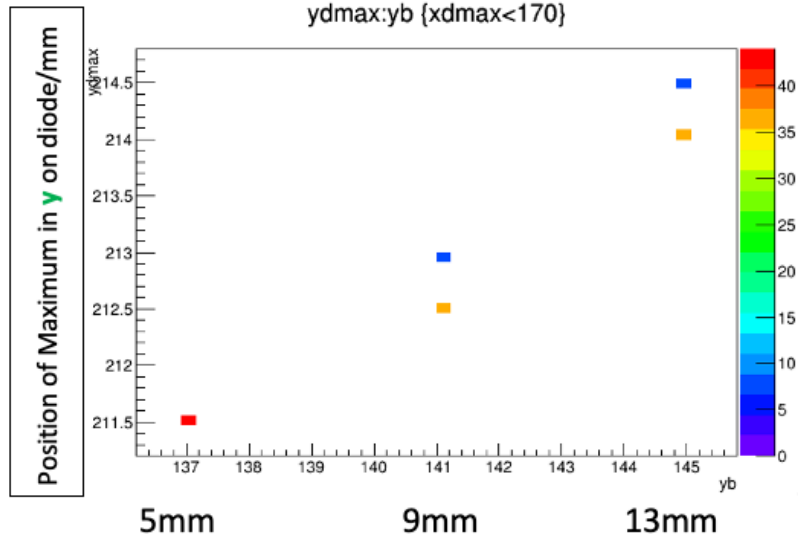
Shift after 16 reflections from the sides of the Nikon bar 6 at bar exit



Diode scan for maximum position

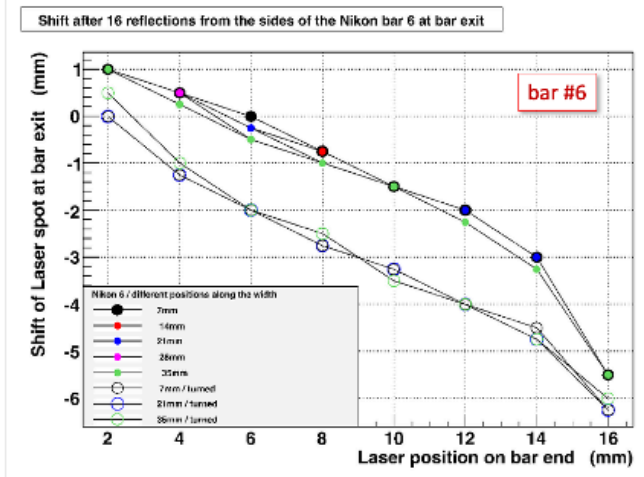


Laser entrance position into the bar in y-direction (width of the bar 17mm)



5mm 9mm 13mm

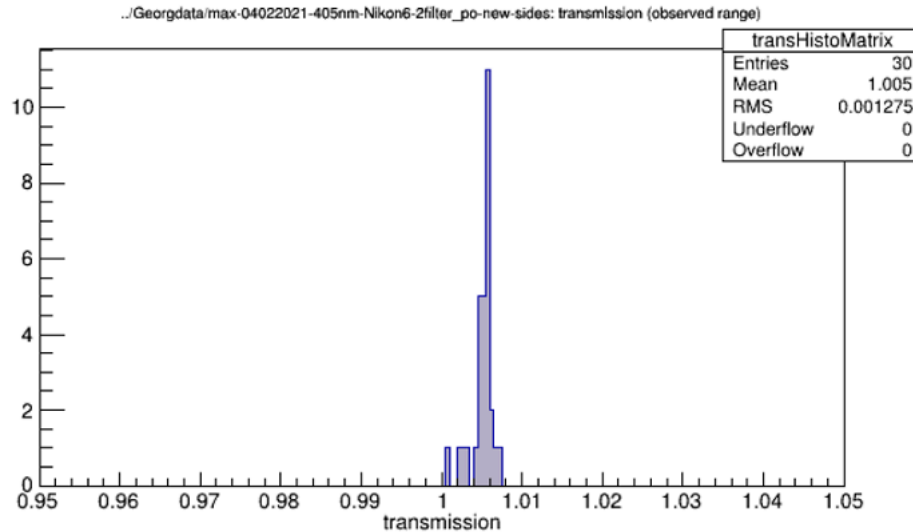
Change of entrance point into the bar in

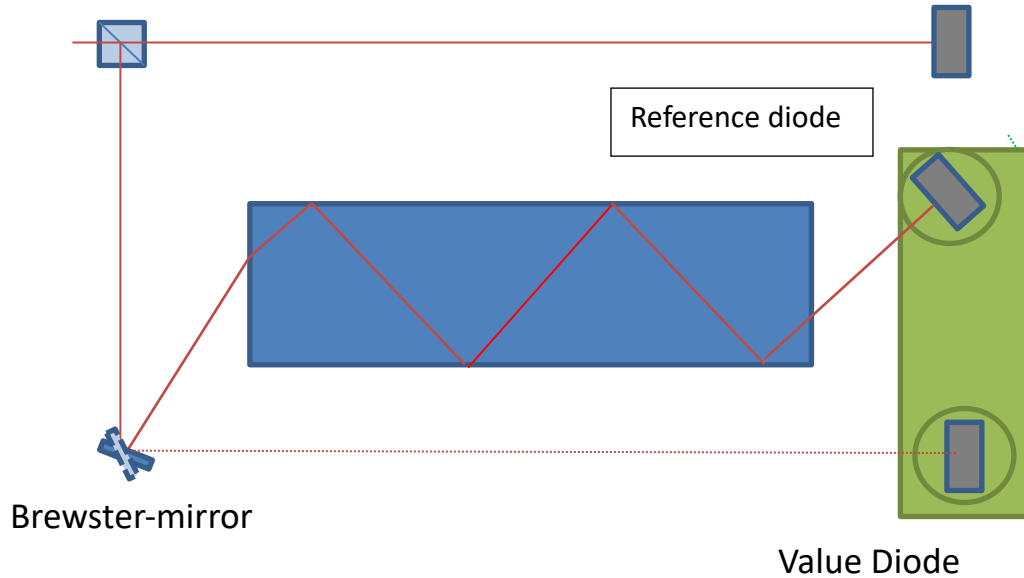


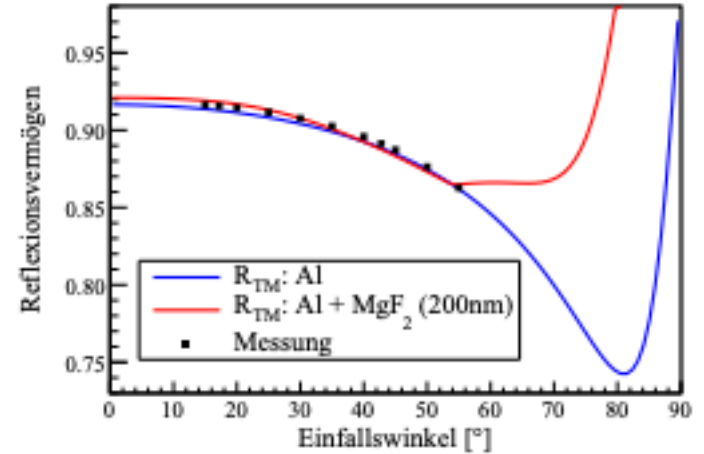
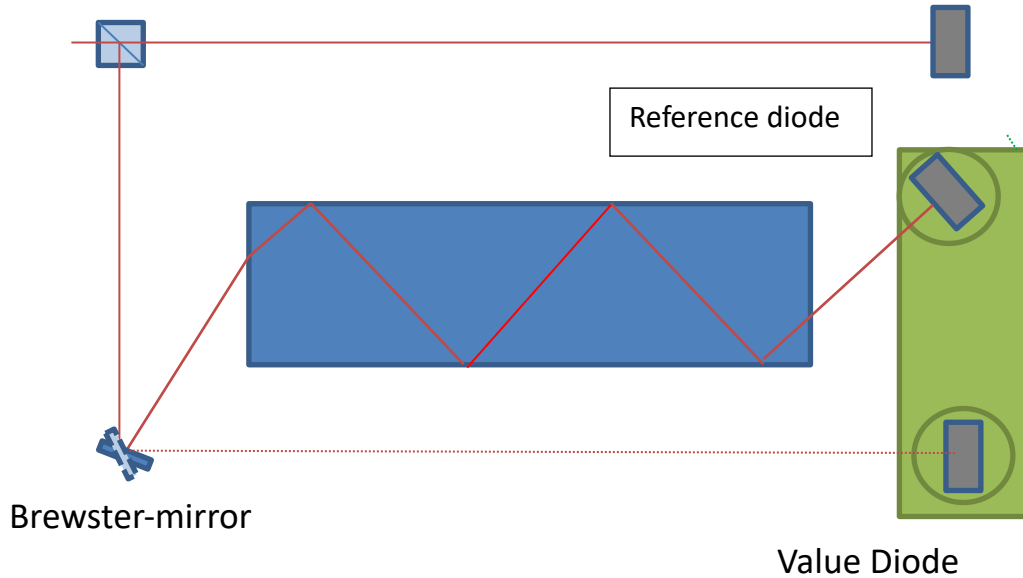
The two measurements are in accordance:

- Old measurement: Shift of laser spot on a **fix scale paper** at bar exit (2cm) -> **shift negative**
 - o Shift of -2.5mm when laser entrance point is changed by 8mm
- New measurement: Shift of laser point on diode in 5cm distance -> **diode has to be moved** in **positive direction**
 - o Shift of 3.mm when laser entrance point is changed by 8mm

Transmission is larger than 1

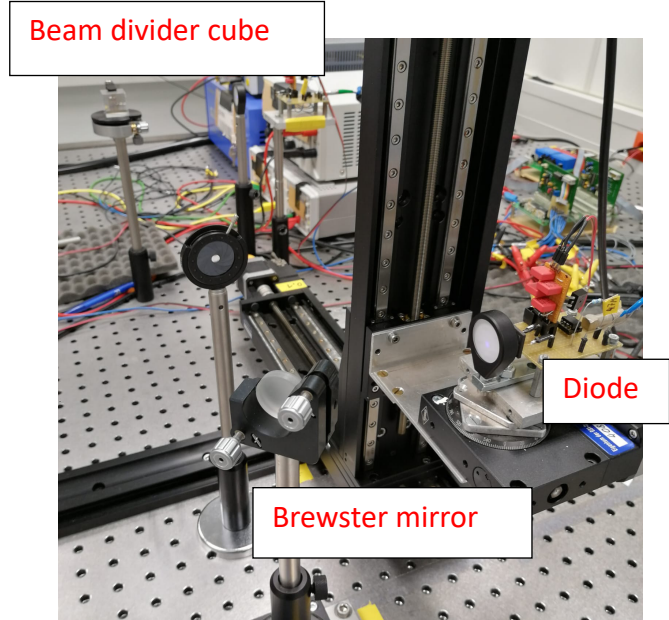
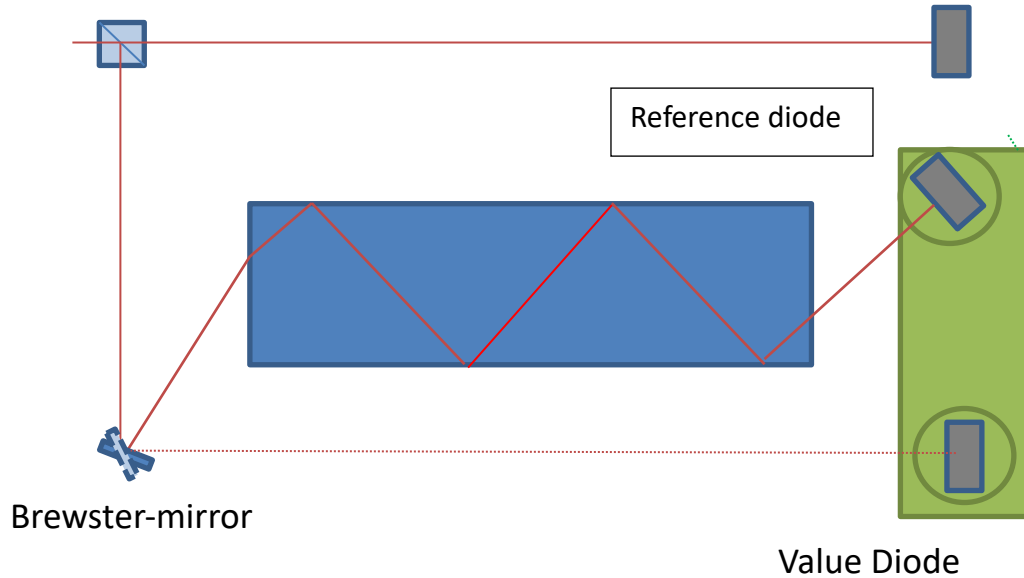


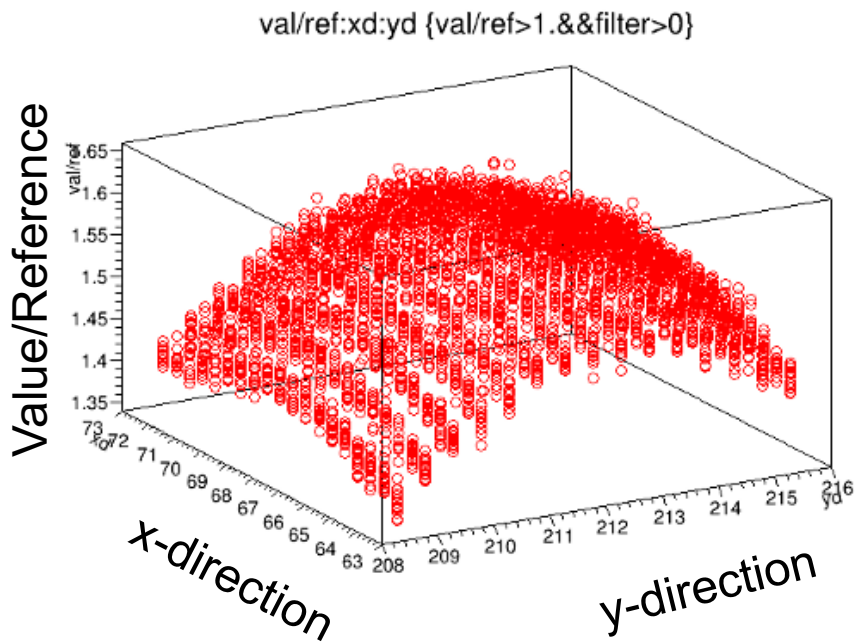




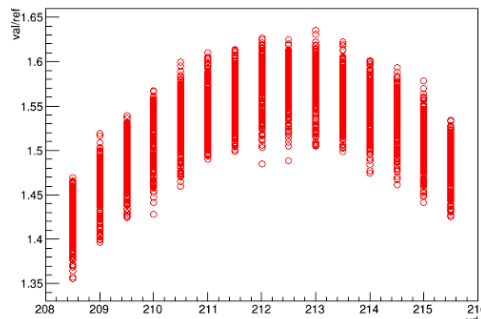
(b) 532 nm

Reflectivity of Aluminum-mirror with MgF_2 layer
 Roland Hohler, PhD 2011

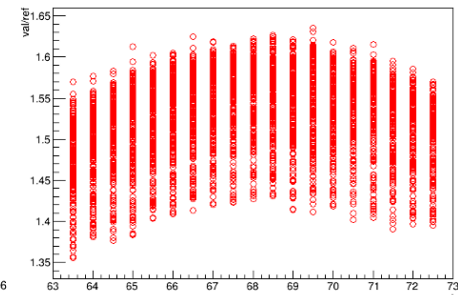




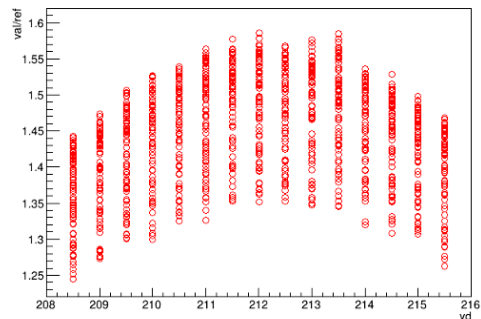
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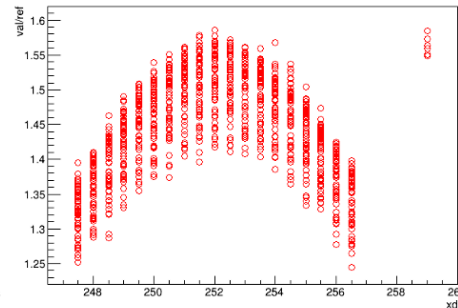
val/ref:xd {val/ref>1.24&&filter>0}



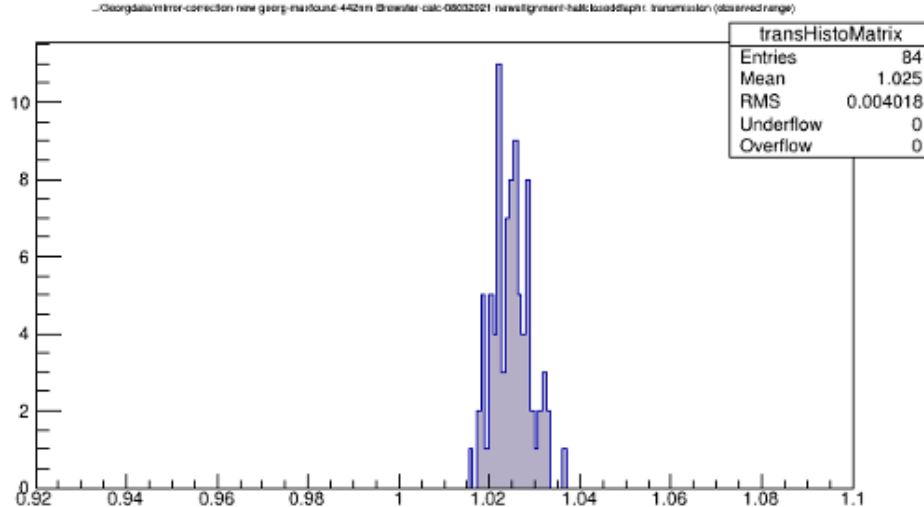
val/ref:yd {val/ref>1.24&&filter<1}



val/ref:xd {val/ref>1.24&&filter<1}

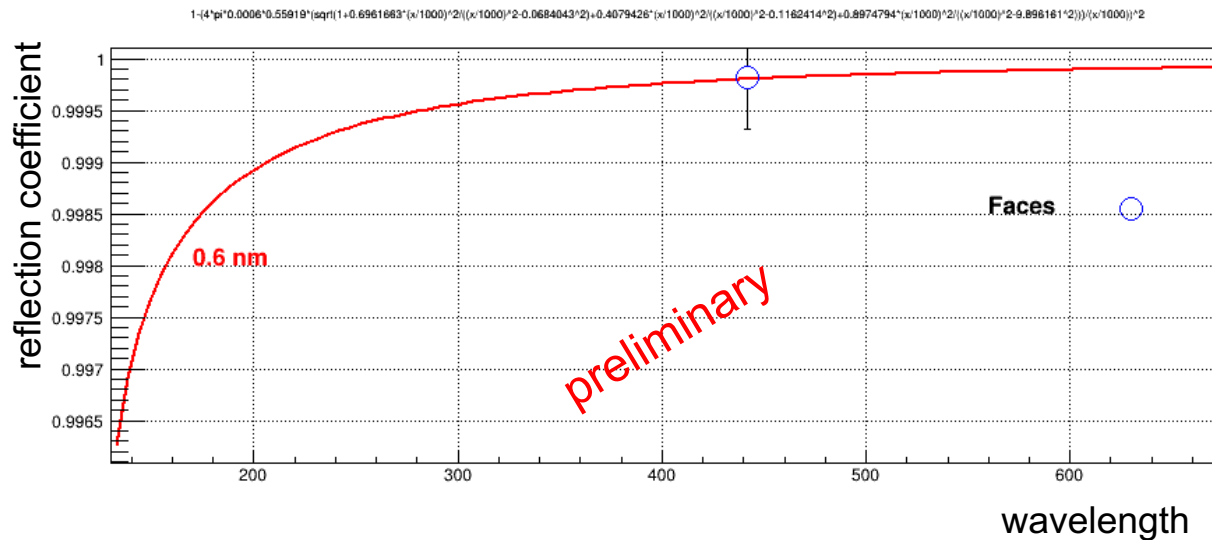
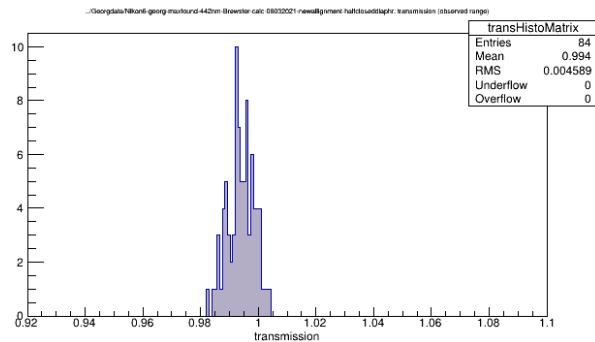


Projections



Ratio between Brewster-reflected and direct light

442nm diaphragms do not cut into core of the beam
Mirror correction 0.97579 (old value 0.98173)



442 nm - Faces
with new Maximum Intensity Method and new Mirror Correction Factor

- Nikon
 - Delivered the 98 bars about 5 month ahead schedule and further 14 bars
 - Very good and complete spread sheets: All bars fulfil our specifications
- QA@GSI
 - Shape and material deviations identified (very good (online-) communication)
 - Measurements and simulations: no relevant influence on performance of the DIRC
 - No reason not to accept the bars
 - Measurement of reflection coefficient/sub-surface damage delayed by the unprecedented behavior of the bars from Nikon
 - New method found to be independent on the displacement of the laser spot
 - Maximum Intensity-Method
 - Preliminary results are promising, has to be established

Outlook

- Method for determination of subsurface damage still to be improved
- 5 Nikon bars to be measured for the use in the pollution setup
 - Results on material tests in 2021/22

