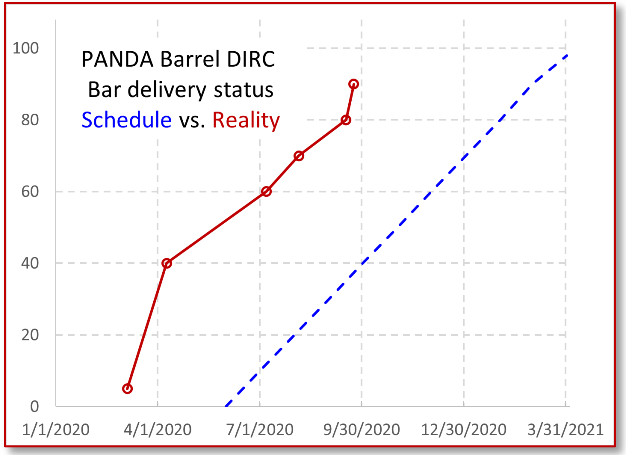
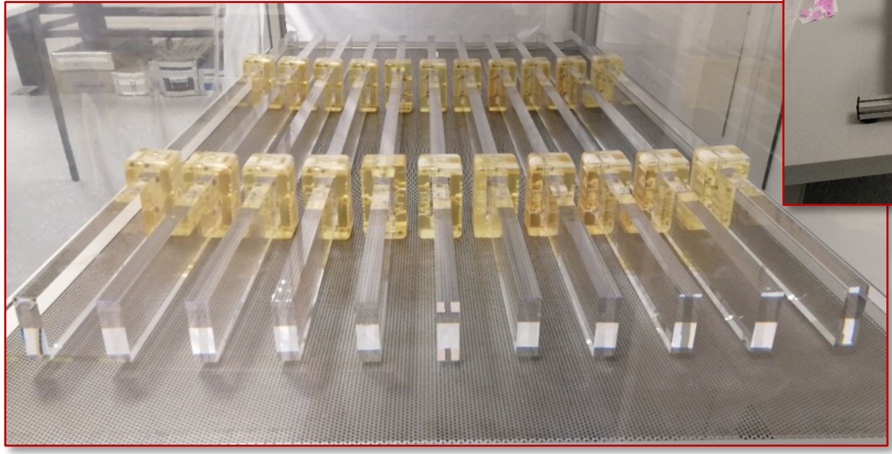
Nikon Bar Production Status of Delivery and Acceptance

G. Schepers, PANDA Collaboration Meeting,
GSI Darmstadt, 27.10.2020

PANDA Barrel DIRC radiator fabrication progress

- Fabrication of DIRC bars at Nikon Corp, Japan progressing well
  - Received 90 of 98 ordered bars, ~5 months ahead of schedule
- All bars meet fabrication specs, performing detailed QA in GSI DIRC lab
- Procurement of 8-14 additional bars in preparation

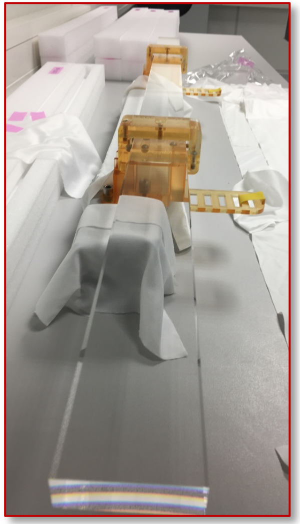




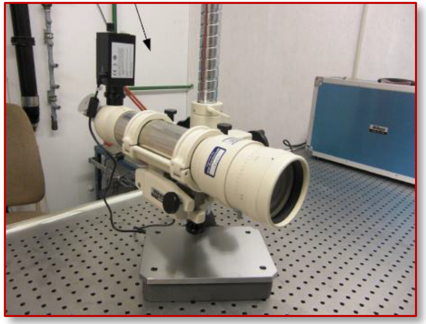
New bars in GSI DIRC lab

Detailed Delivery

- Q3 2019 Call for tenders for Fused silica bars successful
- Sep 5, 2019 Placed order for 98 bars with option for up to 8 more bars (need 96) with Nikon Corp, Japan.
- Sep 2019 Production started
- March 20 Delivery started
  - March 20 5 bars
  - April 35 bars
  - July 20 20 bars
  - August 20 10 bars
  - September20 10 bars
  - ➢ October20 10 bars
  - ➢ **90 of 98 Bars at GSI**
  - 8 bars to come in 2020
  - ➢ Order of additional bars in preparation

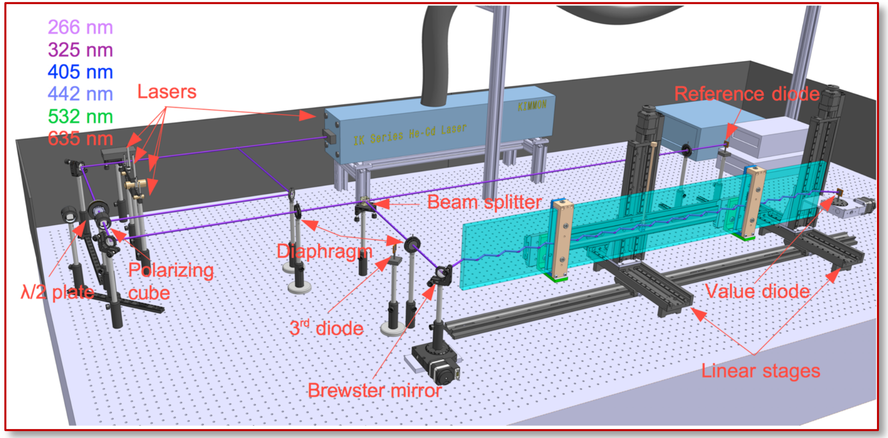


- **Visible inspection**
  - Clean surfaces, no residue from cleaning nor packing, sharp corners?



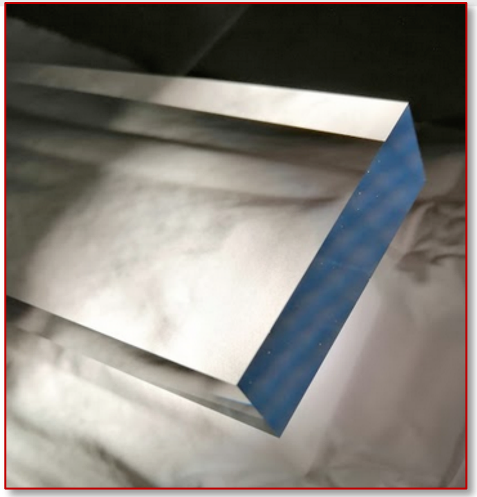
- **Autocollimator**
  - Shape, parallelism, squareness

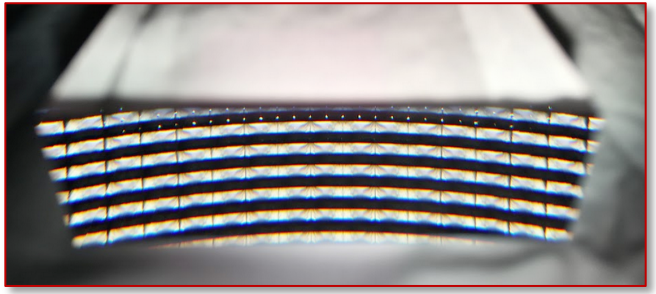
- **Laser setup**
  - Internal reflection for:
    - Bulk absorption
    - Reflection coefficient
    - ➢ Subsurface damage
  - **External reflection**
    - Shape



Visible Inspection with Ring Light

- Clean surface
- Sharp edges
- Clear view through the bar

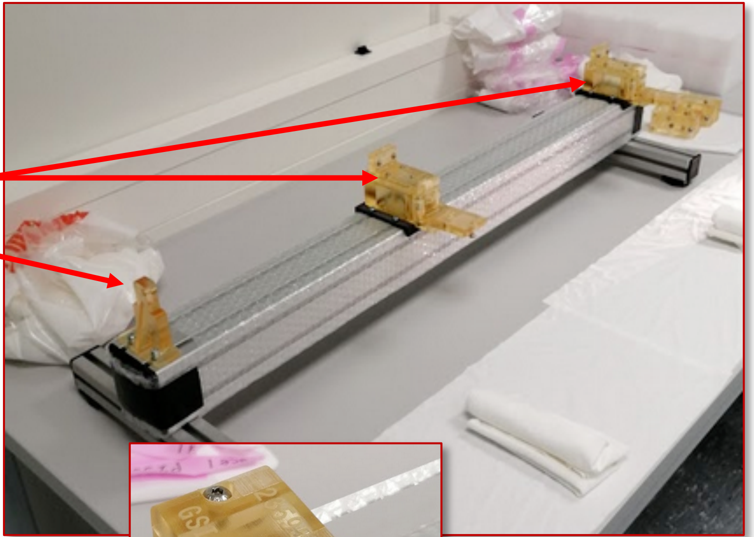


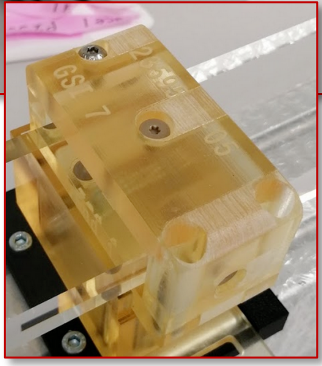


Unpacking in “Cleanroom”: Horseshoes

Preparation

Stand with labeled horseshoes
and end stop



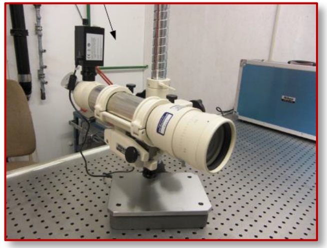


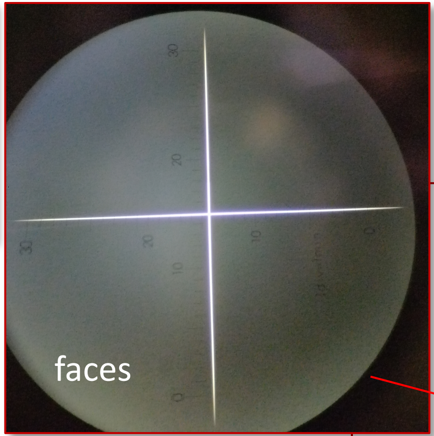
Bar stays in horseshoe (holder) for all tests until it is placed in barbox

Physicist with whole body protection

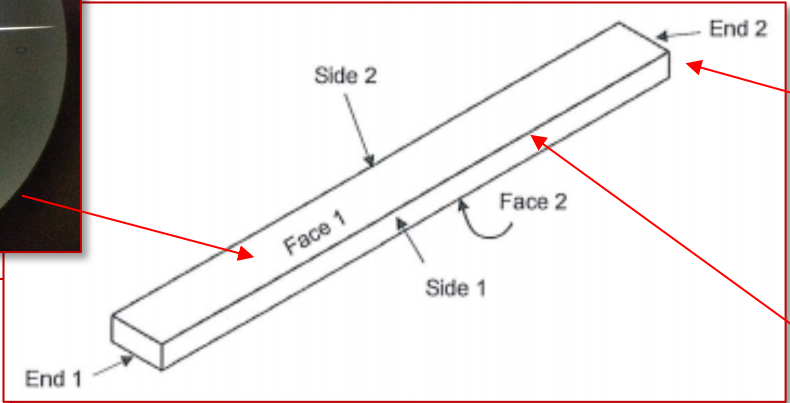
Unpacking about 30min per bar

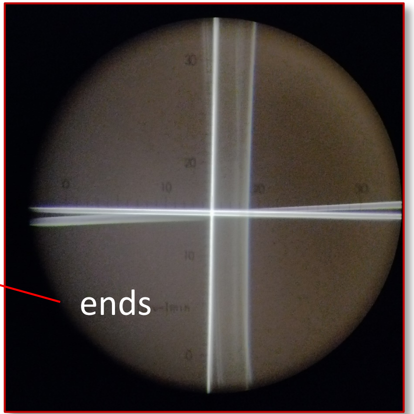
Autocollimator: Parallelism and Squareness

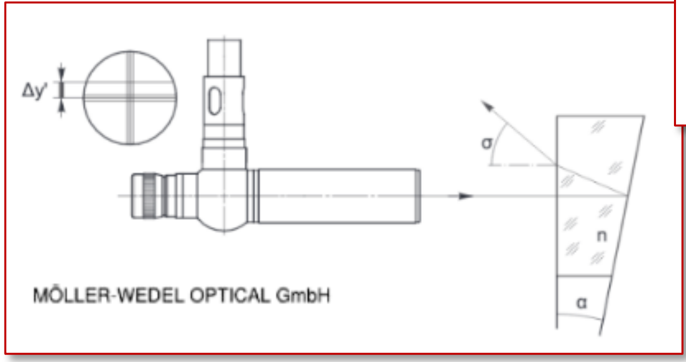




Faces show “perfect” parallelism

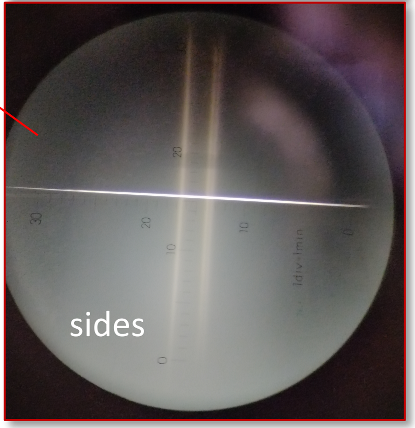






Ends and sides show “fuzzy” image

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

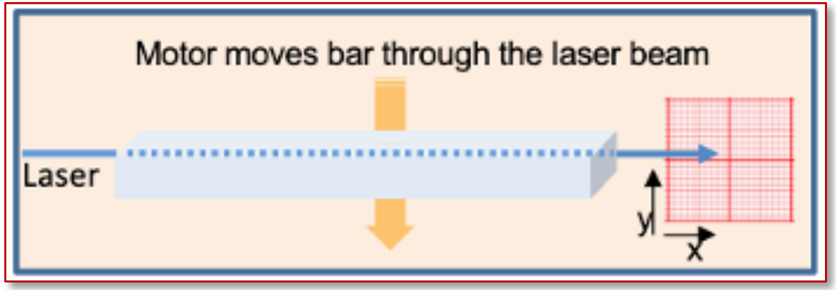


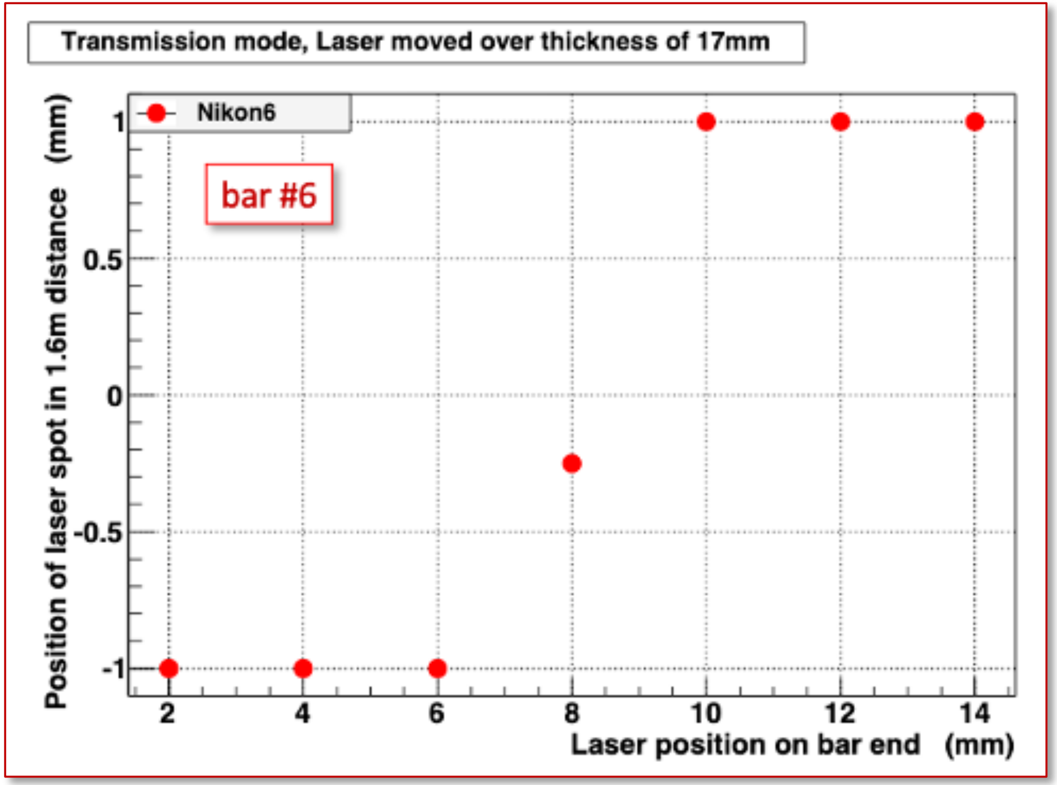
Observed Steering of Laser Beam by the Bulk Material

When the laser beam passes straight though 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

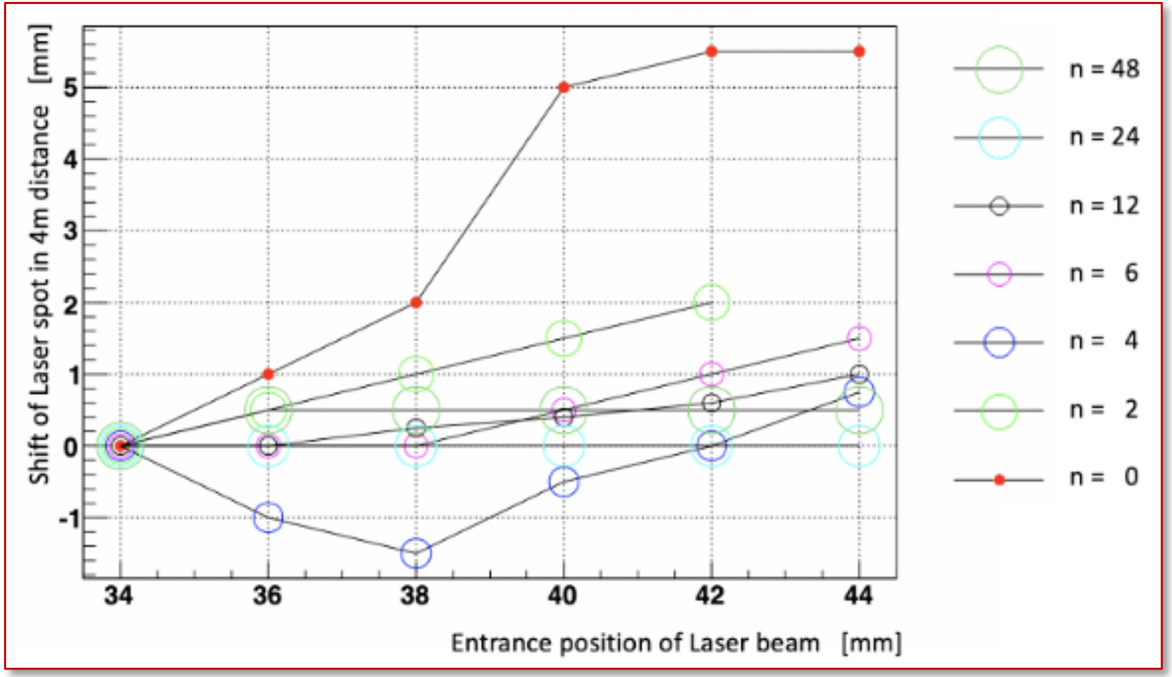




Observed position shift during thickness (17mm) scan

Effect after Internal Reflections

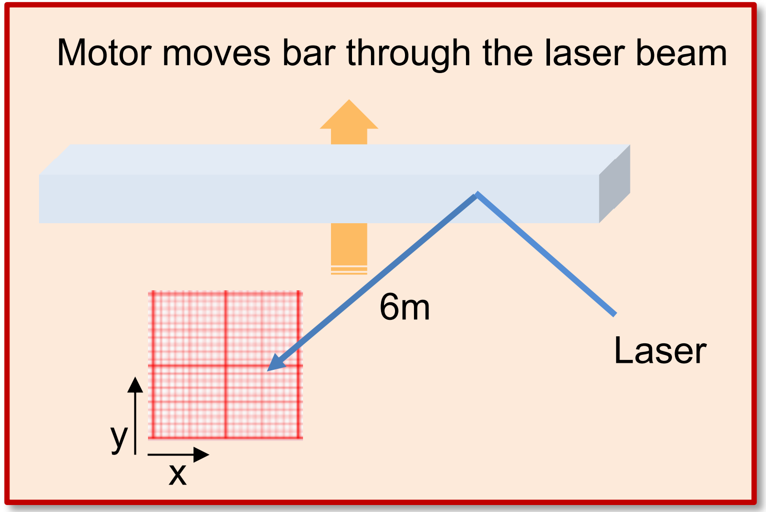
Primary photon propagation in a DIRC is along the length of the bar -
Check if the effect is larger or similar for photons bouncing many times

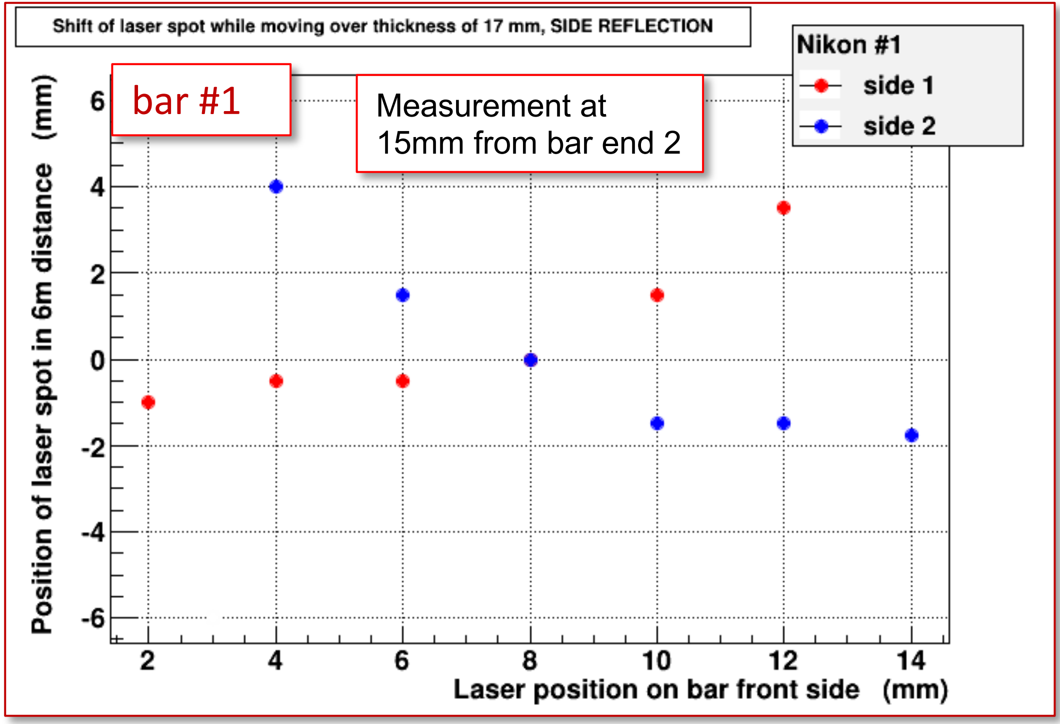


- n: number of internal reflections
- The bar was scanned over its thickness from face2 to face 1
- The shift is shown relative to the spot position of each first laser entrance

Impact of effect is smaller for larger photon angles

Study of Side Shape Deviation





A flat surface would result in a constant beam spot position across the bar side.

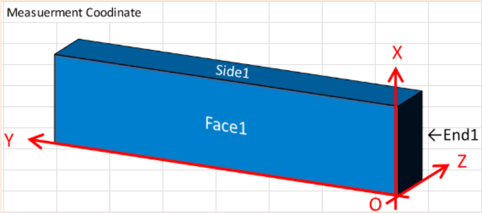
A slope is caused by a convex or concave surface.

The reflection measurements from all bars (see following pages) show a slope consistent with different non-flat (convex/concave/sloped line) shapes

Study of Side Shape Deviation

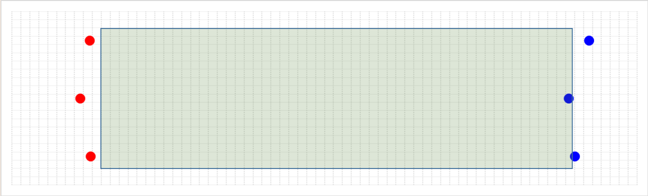
Side1		1197
Z mm	15.5	1.3
	8.5	2.4
	1.5	1.2
Side2		1197
Z mm	1.5	0.0
	8.5	-0.7
	15.5	1.6

CMM values Nikon
at 3mm from End2



convex

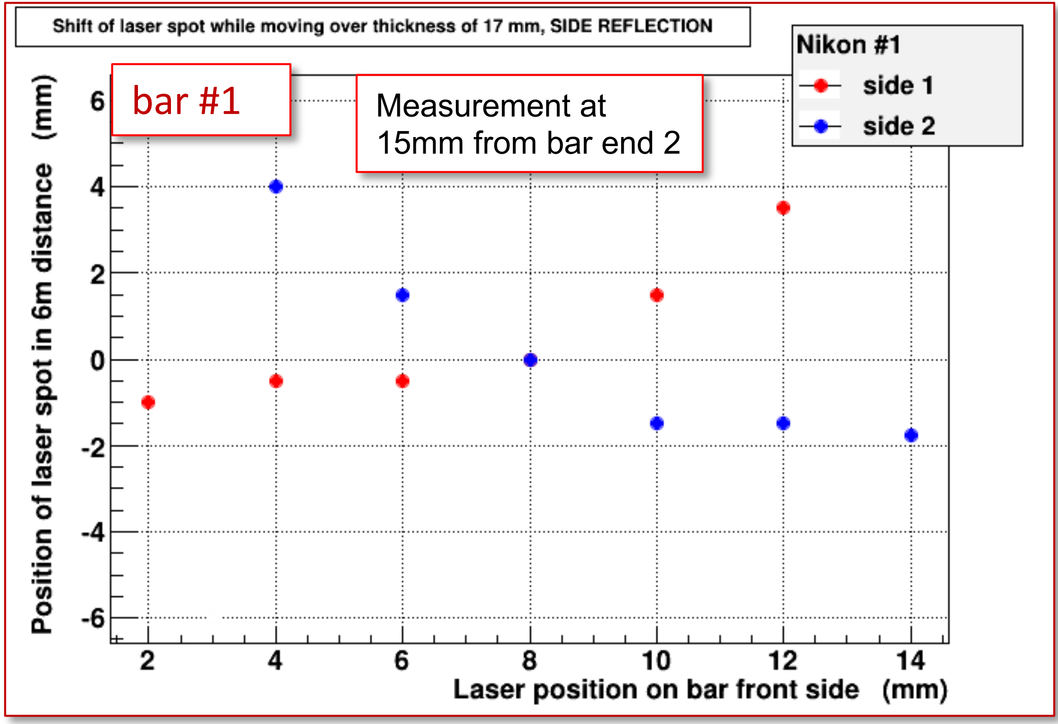
concave



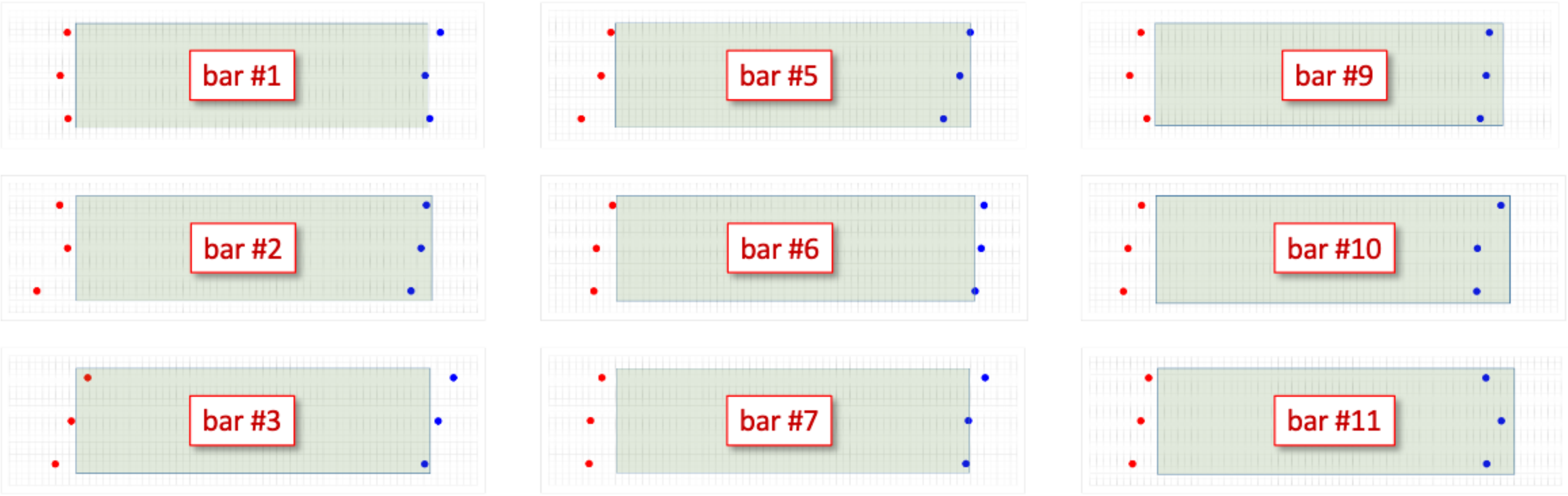
side 1

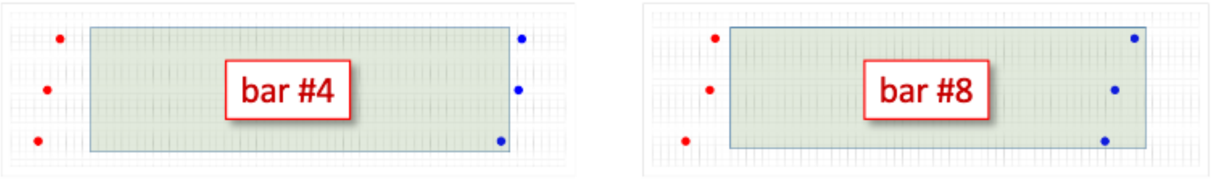
side 2

(positions calculated from CMM data, deviation from reference scaled by factor 1000)



Bar Shape Examples from CMM (Nikon) "consistent" with Laser Measurements





Deviations from ideal bar shape shown
for narrow sides, position 3mm from End 2

(Nikon CMM data, deviation scaled by factor 1000.)

More detailed and precise Data from Nikon for Simulations

Face1		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
X mm	50	-14.1	-3.4	4.4	3.2	8.3	9.2	7.7	2.4	-6.3	-15.0	
	26.5	-13.4	-3.4	4.5	3.3	9.2	10.6	9.9	3.1	-4.1	-14.7	PV
	3	-13.4	-5.9	3.4	3.4	7.7	9.1	8.4	3.9	-4.1	-13.9	25.6

Face2		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
X mm	3	9.6	6.3	-0.9	-5.0	-7.9	-11.3	-8.3	-4.1	1.3	17.8	
	26.5	9.8	8.0	0.7	-4.0	-9.5	-8.4	-7.4	-4.8	1.3	17.7	PV
	50	9.4	7.6	-0.3	-4.7	-9.4	-10.2	-8.3	-4.2	1.3	18.1	29.4

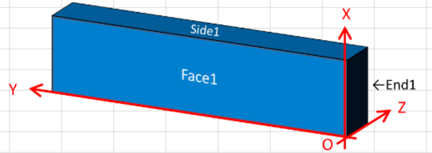
Side1		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
Z mm	15.5	0.4	0.8	0.1	-0.7	-0.8	-0.8	-2.5	-1.1	2.2	1.2	
	8.5	1.4	1.8	-1.1	-1.6	-0.8	0.3	-0.2	0.2	2.5	0.0	PV
	1.5	2.7	1.9	-2.8	-2.9	-1.7	-0.4	0.9	1.2	1.4	-1.5	5.6

Side2		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
Z mm	1.5	-2.0	1.2	-0.3	1.8	0.7	2.0	-3.4	0.3	2.0	-1.1	
	8.5	-0.4	-0.2	-0.7	-1.4	2.3	-3.4	-0.2	-0.9	1.8	0.5	PV
	15.5	1.2	-0.4	-0.5	0.5	0.5	-0.8	3.2	0.7	-1.2	-1.8	6.6

End1		Z mm			
		1.5	8.5	15.5	
X mm	50	0.1	0.5	-0.6	
	26.5	0.1	-0.4	0.5	PV
	3	0.0	-0.5	0.4	1.1

End2		Z mm			
		15.5	8.5	1.5	
X	50	-0.1	0.4	0.2	
	26.5	0.1	-1.0	-0.2	PV
	3	0.1	0.2	0.2	1.4

Measuerment Coodinate



From 3 points over the width…

…to 5 points with higher accuracy

Face1		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
X mm	50	6.1	-0.3	0.8	-1.7	-3.8	-4.8	-4.2	-0.5	2.1	4.0	
	38.25	6.0	0.0	1.0	-1.7	-3.5	-4.6	-3.7	-0.1	2.7	4.3	
	26.5	5.8	0.1	1.3	-1.3	-3.2	-4.3	-3.3	0.2	3.2	4.5	
	14.75	5.0	-0.3	1.1	-1.6	-3.2	-4.2	-3.2	0.3	3.3	4.6	PV
	3	4.2	-0.9	0.9	-2.1	-3.7	-4.7	-3.8	0.1	3.1	4.1	10.9

Face2		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
X mm	3	-3.0	-0.7	-0.8	0.9	4.0	4.3	1.9	-2.3	-3.7	0.2	
	14.75	-3.0	-1.0	-1.0	0.8	4.1	4.3	1.6	-2.1	-4.3	-0.4	
	26.5	-3.3	-1.1	-1.2	0.8	4.2	4.6	1.8	-2.1	-4.3	-0.8	
	38.25	-3.1	-1.1	-1.2	0.9	4.8	4.8	2.1	-1.8	-4.2	-0.7	PV
	50	-3.2	-1.2	-1.1	1.1	5.0	5.2	2.3	-1.8	-4.6	-0.8	9.8

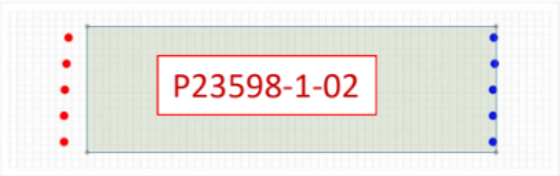
Side1		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
Z mm	15.5	0.6	0.2	-1.0	-1.0	0.8	0.4	-0.6	-1.4	0.4	0.1	
	12	0.8	0.1	-0.9	-0.7	1.0	0.9	-0.3	-1.0	0.6	0.3	
	8.5	0.9	0.2	-1.0	-0.8	1.0	1.0	-0.1	-0.6	0.8	0.1	
	5	0.8	0.2	-1.0	-0.9	0.8	1.0	-0.1	-0.6	0.8	0.1	PV
	1.5	0.8	0.0	-1.5	-1.4	0.5	0.6	-0.5	-0.7	0.6	-0.3	2.5

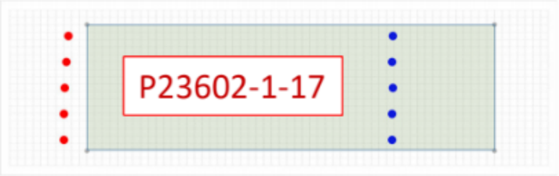
Side2		Y mm										
		1197	1064.3	931.7	799	666.3	533.7	401	268.3	135.7	3	
Z mm	1.5	0.6	0.1	-0.6	-0.8	0.0	0.1	-0.9	-1.1	0.2	0.2	
	5	1.0	0.2	-0.5	-0.5	0.4	0.6	-0.5	-0.5	0.6	0.4	
	8.5	1.3	0.1	-0.6	-0.5	0.3	1.1	-0.1	-0.3	0.7	0.2	
	12	1.3	0.0	-1.2	-1.0	0.0	1.0	-0.2	-0.3	0.7	0.2	PV
	15.5	1.3	-0.2	-1.7	-1.6	-0.4	0.6	-0.4	-0.3	0.8	0.2	3.0

End1		Z mm					
		1.5	5	8.5	12	15.5	
X mm	50	-0.5	-0.6	-0.7	-0.8	-0.7	
	38.25	0.3	0.3	0.4	0.2	0.3	
	26.5	0.7	0.7	1.1	0.8	0.8	
	14.75	0.1	0.0	0.3	-0.2	0.2	PV
	3	-0.6	-0.8	-0.3	-0.6	-0.5	1.9

End2		Z mm					
		15.5	12	8.5	5	1.5	
X	50	-0.5	-0.7	-0.9	-0.8	-0.8	
	38.25	0.7	0.5	0.5	0.6	0.4	
	26.5	0.9	0.3	0.6	0.4	0.8	
	14.75	0.3	-0.1	0.0	0.2	0.2	PV
	3	-0.7	-0.7	-0.6	-0.6	0.0	1.8

Bar Shape Examples from CMM (Nikon)
Shape improved

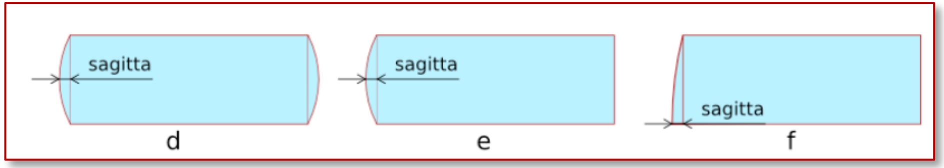




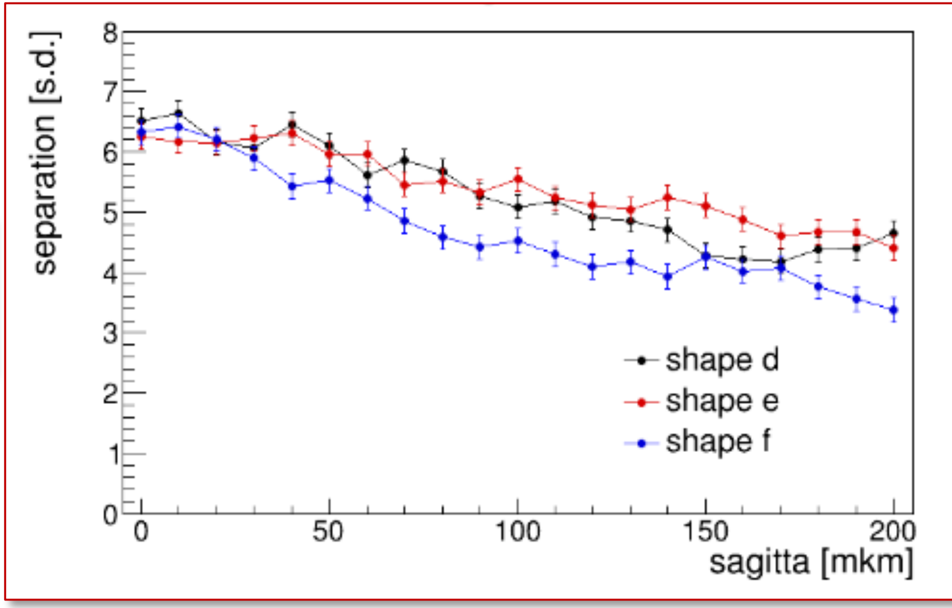
Deviations from ideal bar shape shown
for narrow sides, position 3mm from End 2

(Nikon CMM data: 200717_surface shape data, deviation scaled by factor 1000.)

Simulations of Influence on DIRC Performance
Shape of the Sides



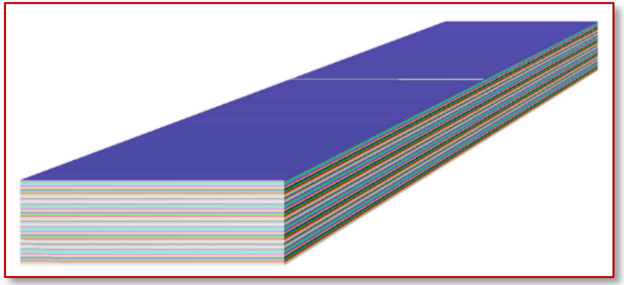
simulated bar shapes

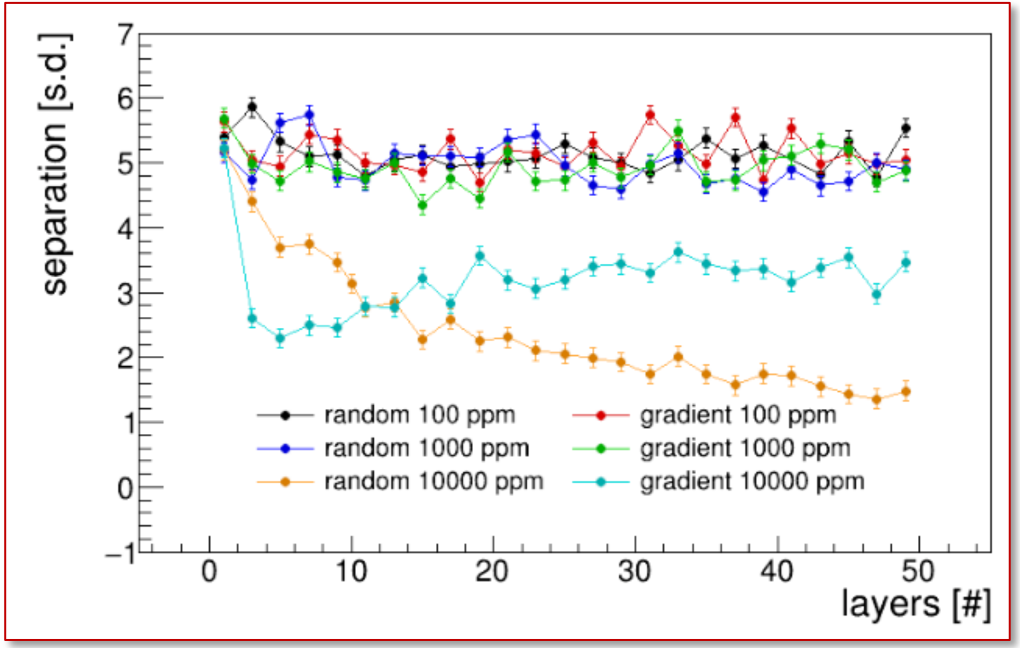


Maximal Sagitta around 10µm (Nikon)

➢ minor influence

Simulations of Influence on DIRC performance
Striae





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

➢ minor influence

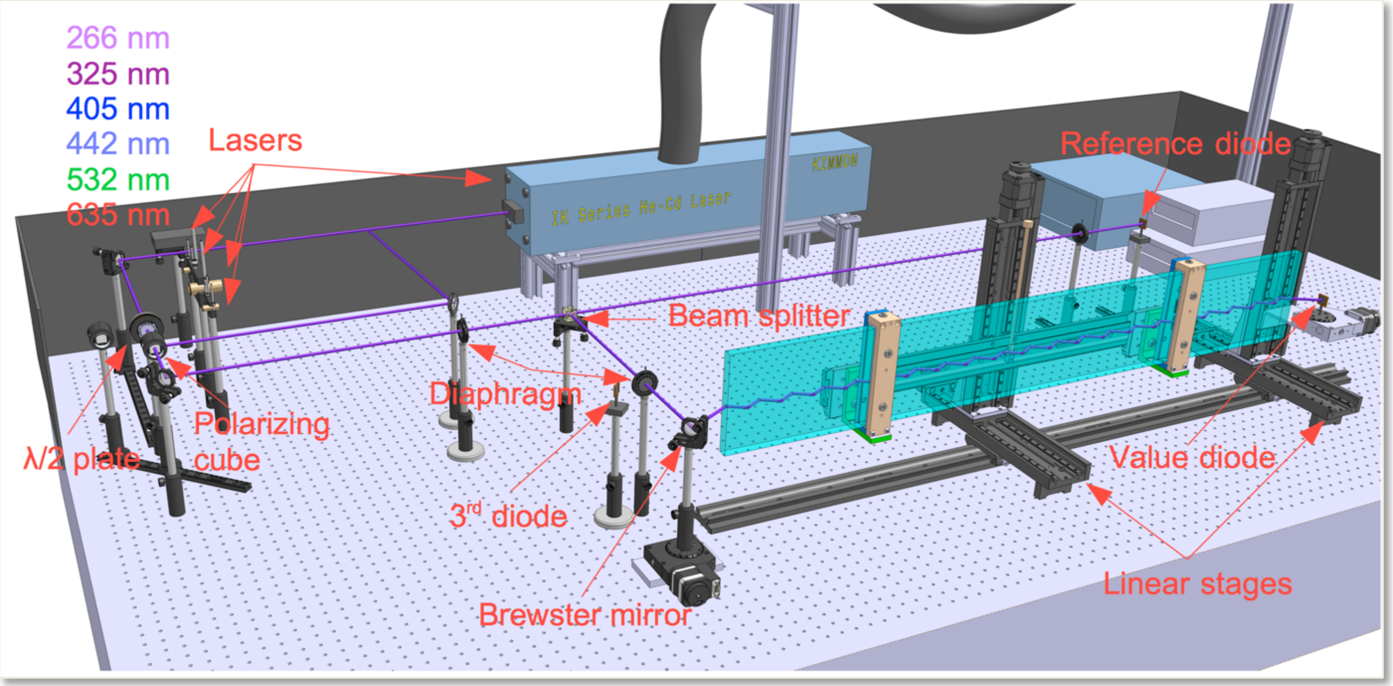
Conclusions on the observed shape and striae of the Nikon bars

Influence on performance (displacement of photon within one MCP PMT pixel) is minor and no reason not to accept the bars

Internal Reflection Measurement: Surface Roughness

Producer is not able to measure internal reflection

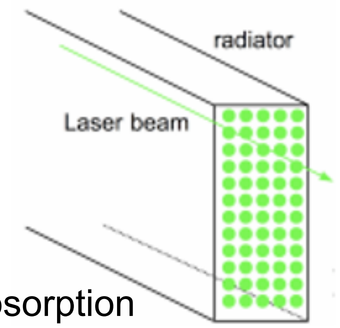
Measurement of the wavelength dependent reflection coefficient gives access (via SST) to the surface roughness and thus to possible subsurface damage by the production method



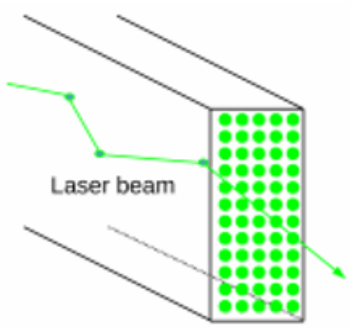
Motor-controlled laser scanning system

SST: scalar scattering theory

Envisaged Method



Bulk absorption



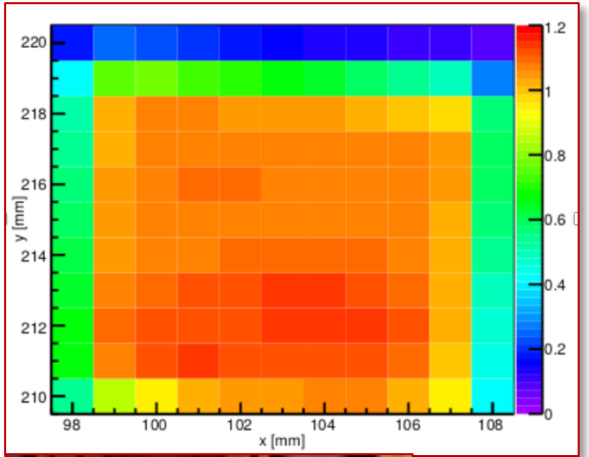
Reflection Coeficient

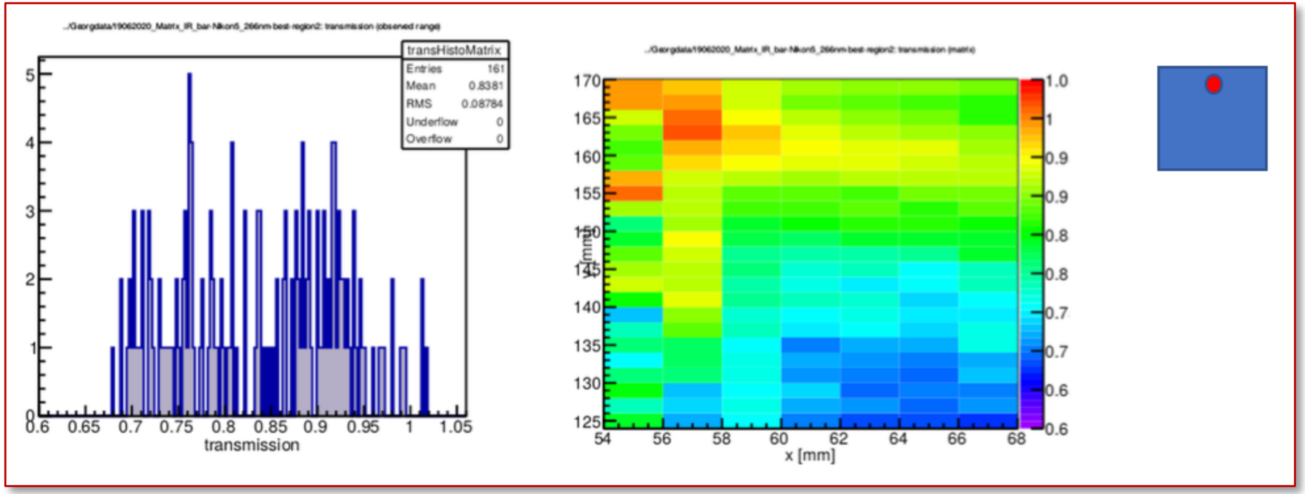
Scanning of a matrix of positions on the bar to cover the highest portion of the material/surface

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

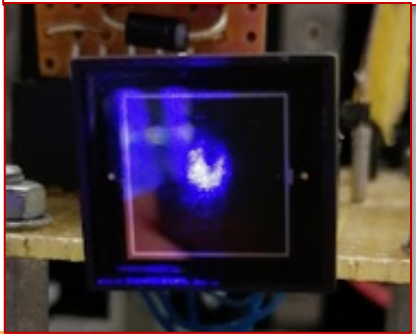
Inhomogeneity of the UV-photodiodes: HAMAMATSU 1227-1010-BQ series

Photodiode 10x10mm





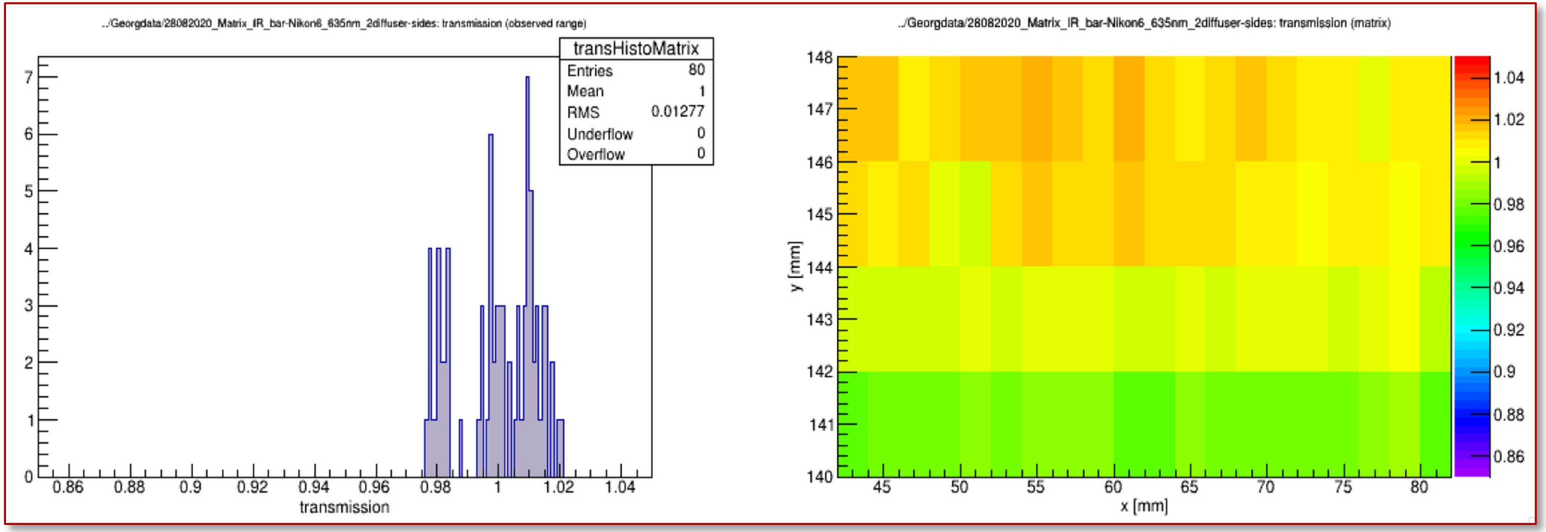
Measurement of Transmission with Nikon bar #5 extremely broad



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

Dependence on the Position on Si-Photodiode

Example:
Internal Reflection from the sides at 635nm

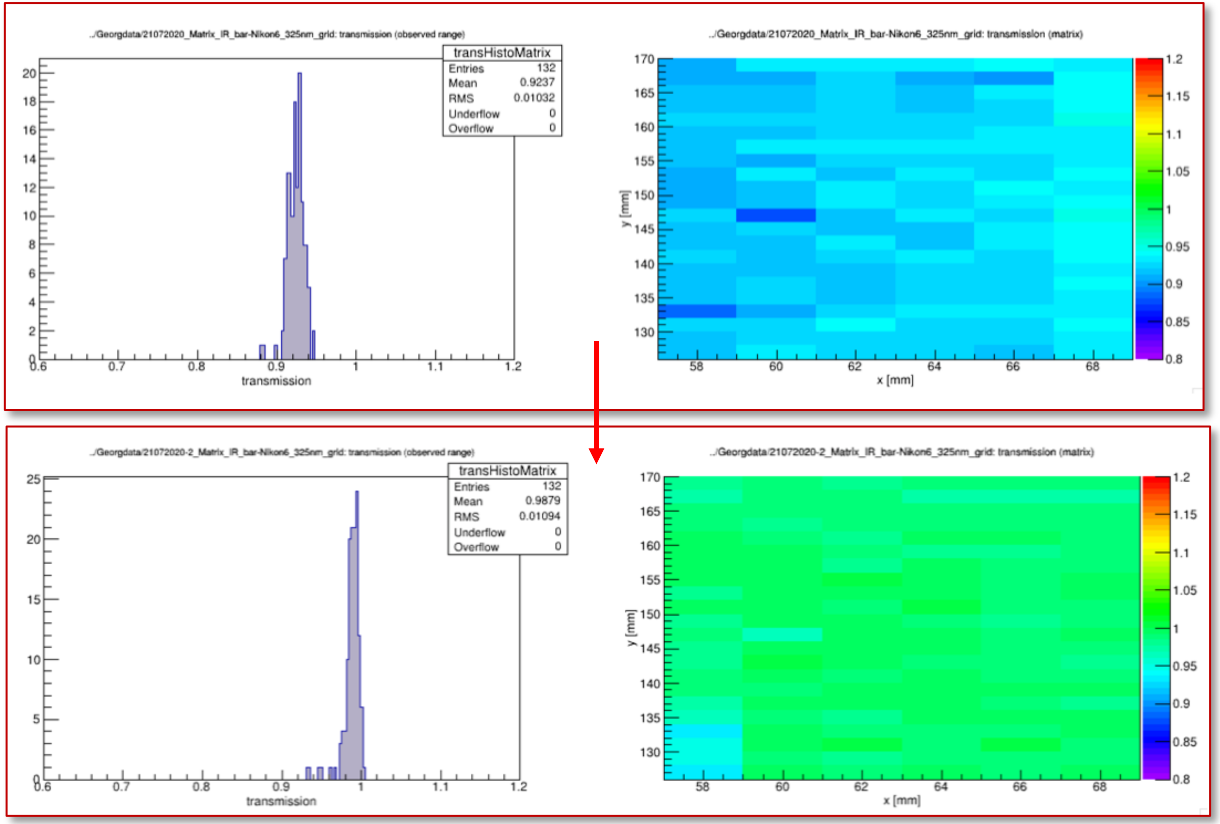


Example:
Bulk absorption at 325nm

Laser spot was put to the
“Best region of the Photodiode”

Still no reproducible results:

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



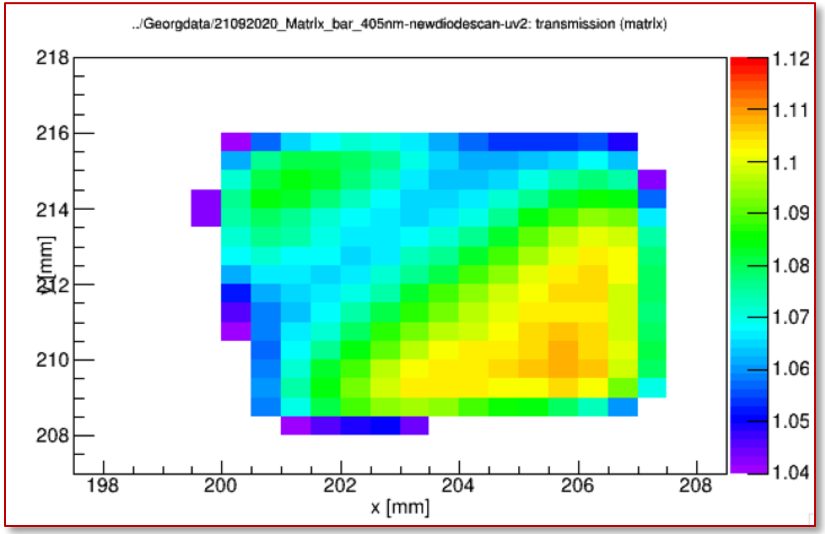
Dependence on the Position on Si-Photodiode

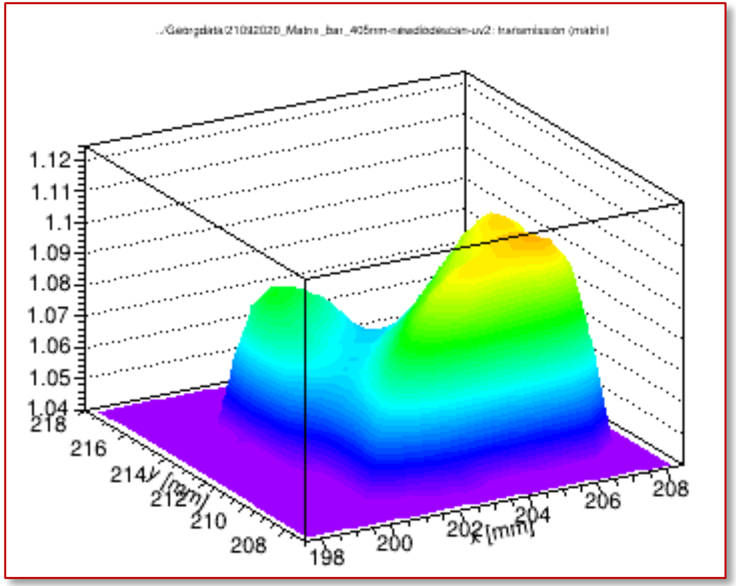
Need to become independent of the laser spot position on the photosensor

- New photosensors and/or diffuser

New UV-photodiodes ordered:
HAMAMATSU 1227-1010-BQ series

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



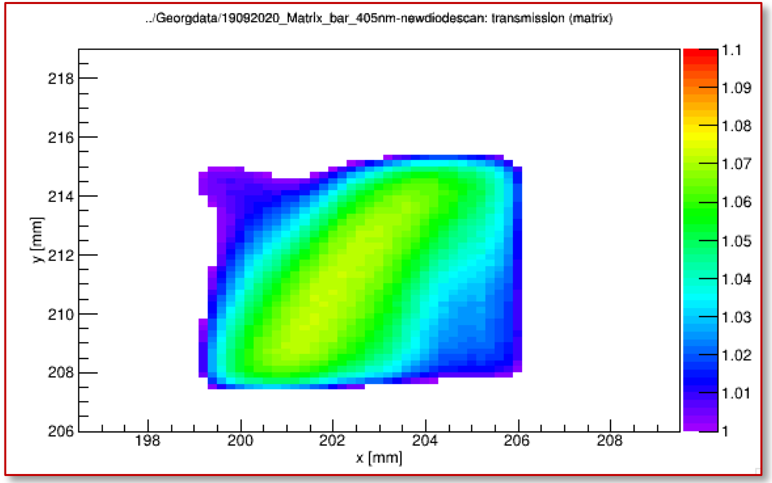


New Diode 2

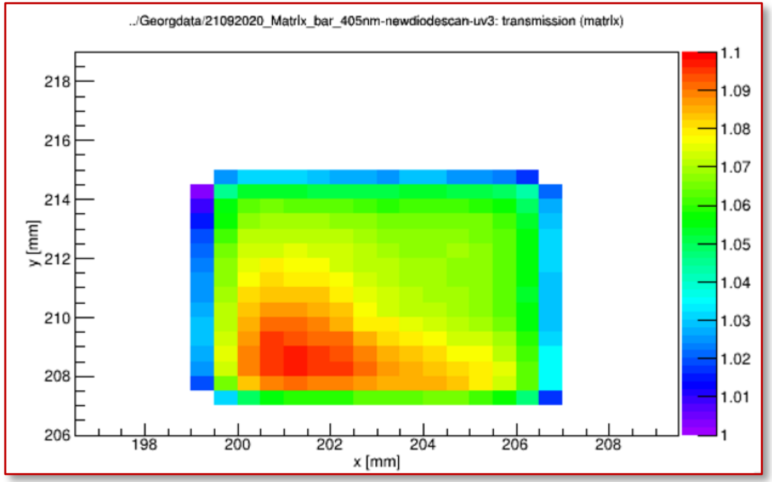
Not a better performance than the "old" sensors

New UV-photodiodes ordered:
HAMAMATSU 1227-1010-BQ series

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

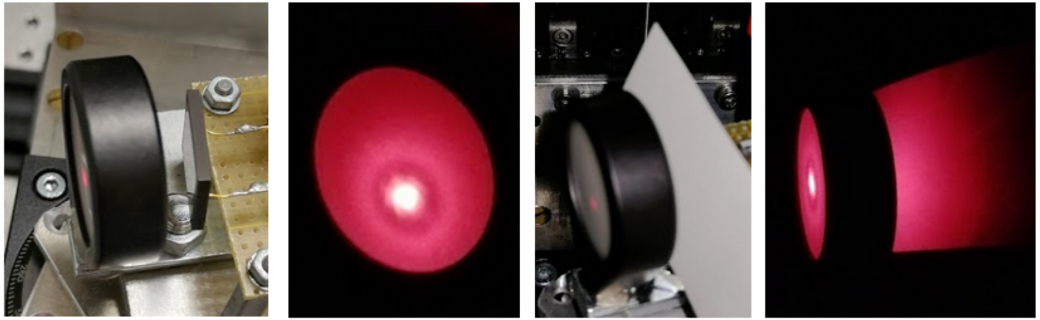


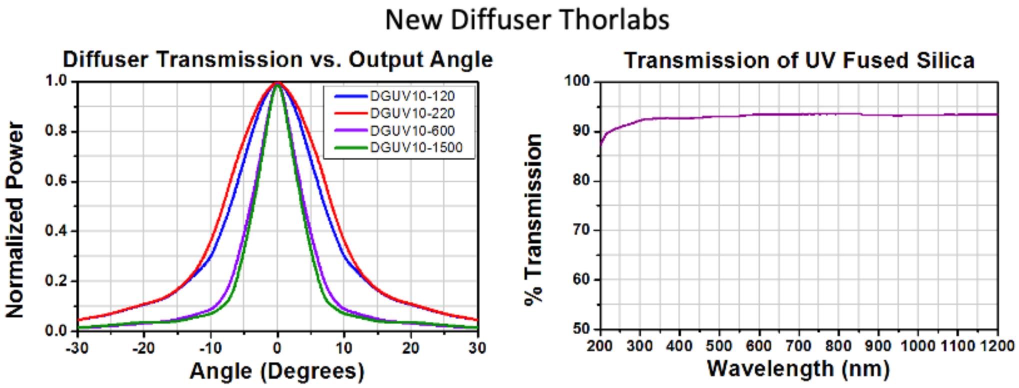
New Diode 1

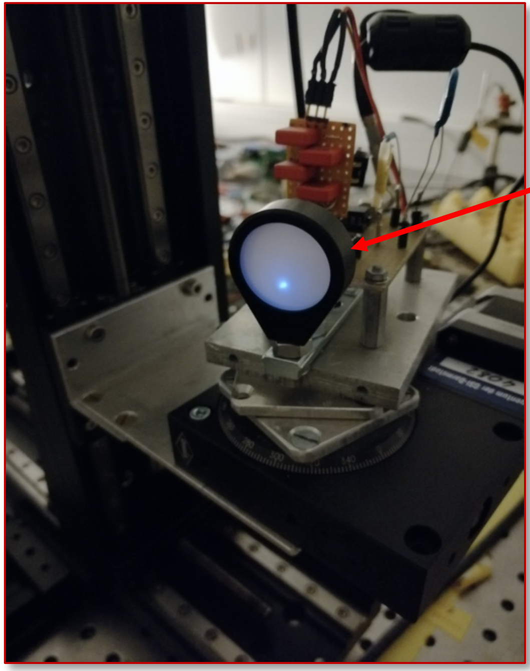


New Diode 3

Diffuser in the Laser Setup

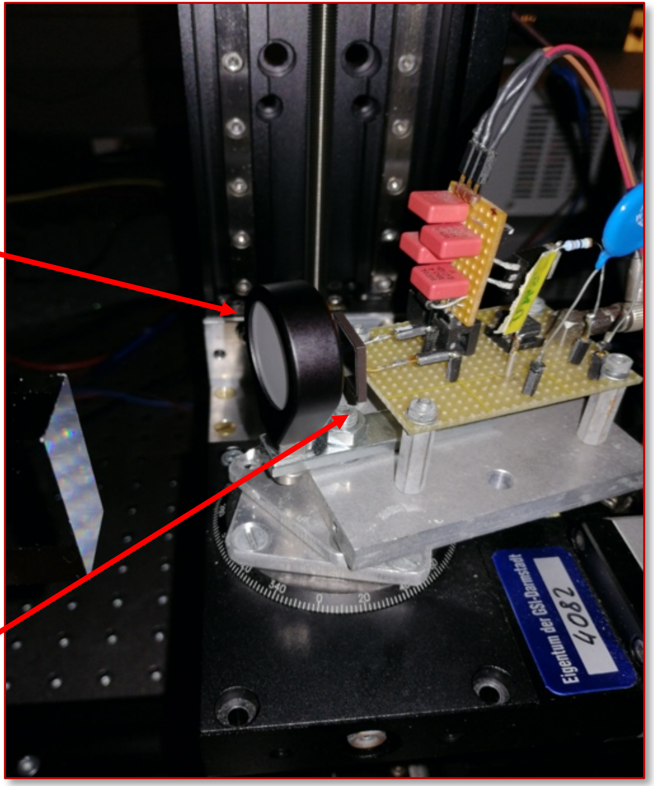




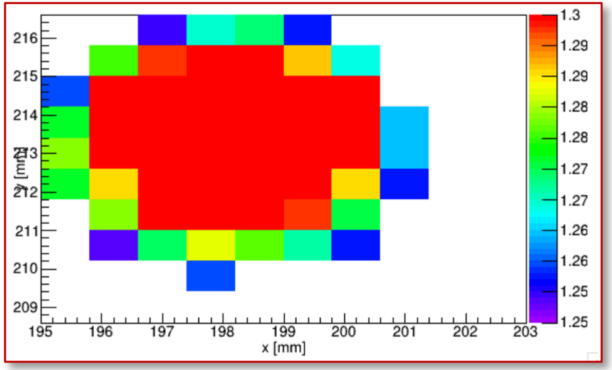


Diffuser

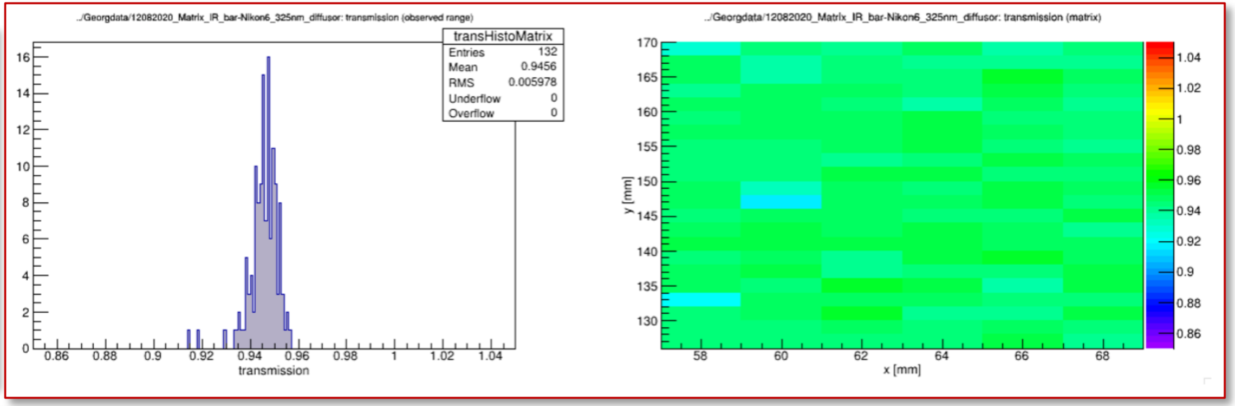
Si photodiode

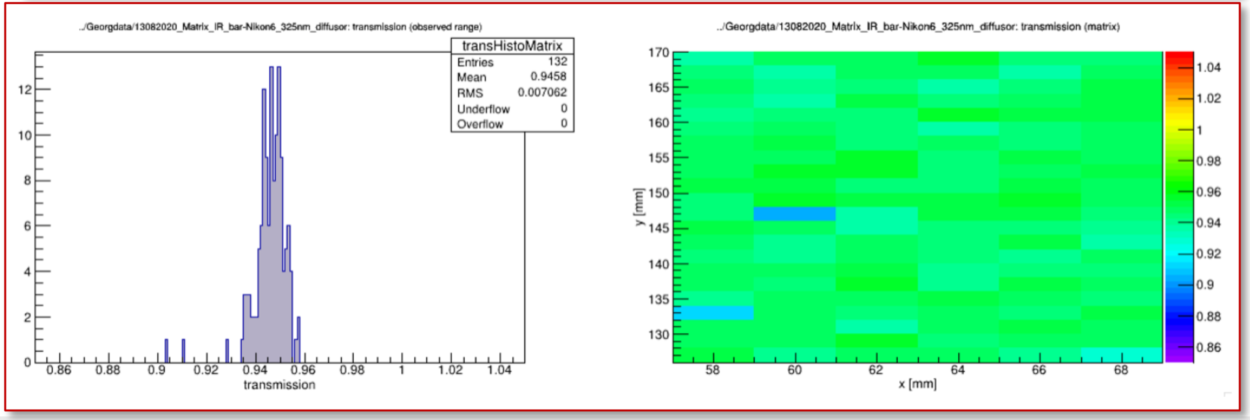


Measurement with Diffuser



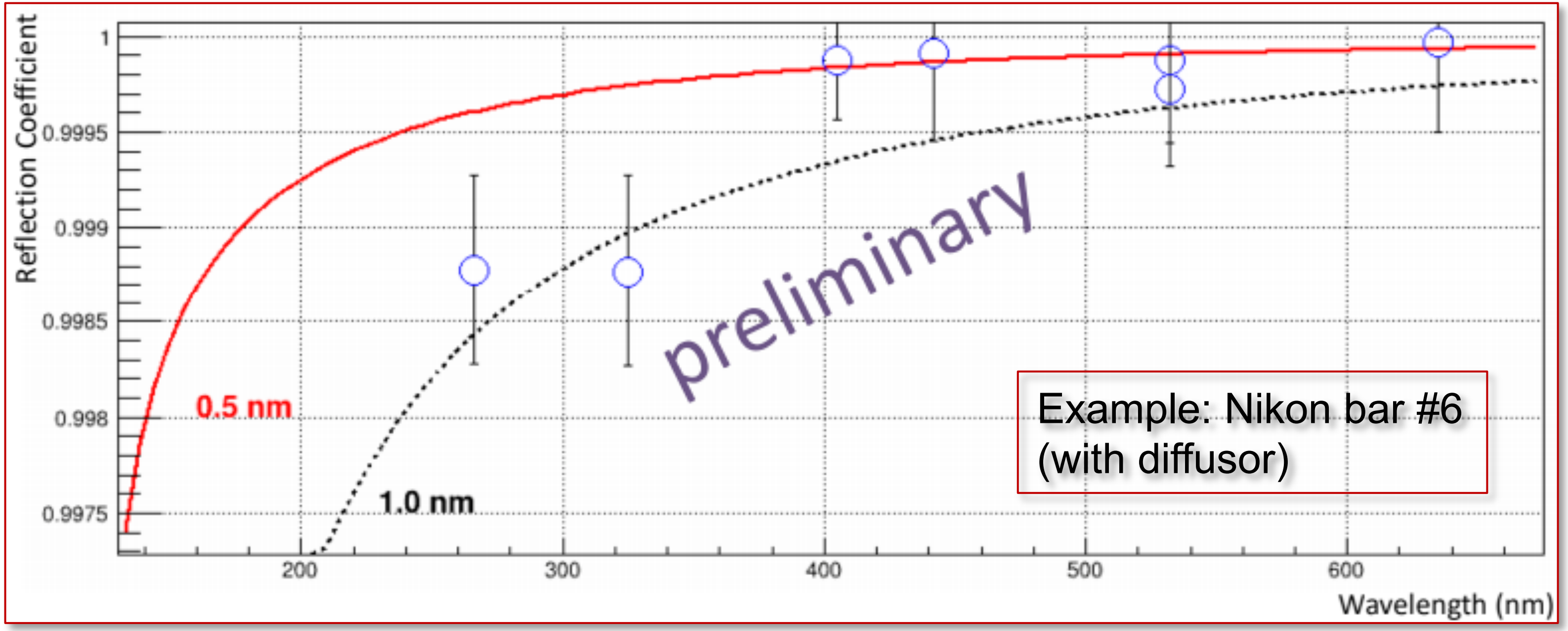
Scan of the UV-photodiode behind the diffuser





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

Wavelength dependent Reflection Coefficient



Results compared to Scalar Scattering Theory

Promising results for Nikon bar #6

- Distribution in compliance with a surface roughness of 5Å as measured by Nikon
- No sub-surface damage visible

Conclusion

- Nikon delivered the bars about the bars 5 month ahead schedule! (90 of 98 bars already at GSI)
- All bars fulfil our specifications (very good documentation)
- Shape and material deviations identified (very good (online-) communication)
  - Measurements and simulations show 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 to be found and to be established
  - Independence on the displacement of the laser spot by means of diffusers
  - ➢ Preliminary results are promising

Outlook

- Method for determination of subsurface damage still to be improved
- Last 8 bars of the first order to come
- Additional bars (8+6) are/will be ordered to be delivered in 2020


Thank You

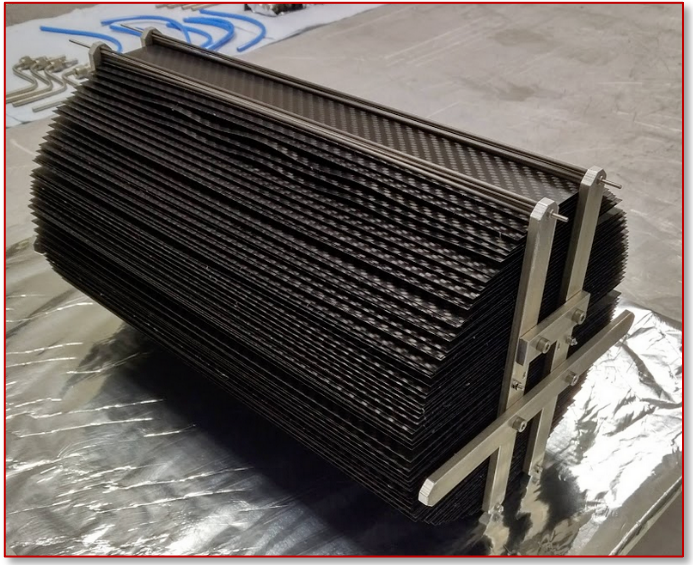
Material Tests: Pollution Setup

Had to move from Laser lab to the mechanical workshop

Four “identical” bar to be studied after determination of their surface roughness

“Reference bar” (no pollution) will go into the Setup in November

Pollutants are
- Carbon fiber material for the bar boxes
- Material for the horseshoes



Laser scanning system

Beam steering made our usual laser scanning measurements more complicated but not impossible.

Determined transmission probability (along long bar axis) and

coefficient of total internal reflection (48 reflections)

Transmission scan examples:

T ≈ 99.6%/120cm at 442nm (bar 1)

T ≈ 98.2%/120cm at 325nm (bar 3)

Reflection coefficient examples:

R ≈ 0.9998 at 442nm (bar 2)

R ≈ 0.9984 at 325nm (bar 3)

Good T/R results so far, meet DIRC requirements