3D METROLOGY CONFERENCE

Aachen November 2022

Super Cat Eye Reflector – Development and Technology

Presentation
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CONFEMA
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Super Cat Eye Reflector – Development and Technology

Existing n=2 reflectors are not successful on the market available

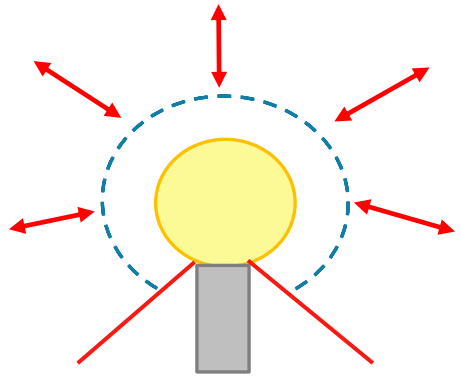
- NPL
- Etalon

Goal: beam reflection in itself

measurement from all visible directions

Basic: specific glass material refraction index n=2

dependency from light wave

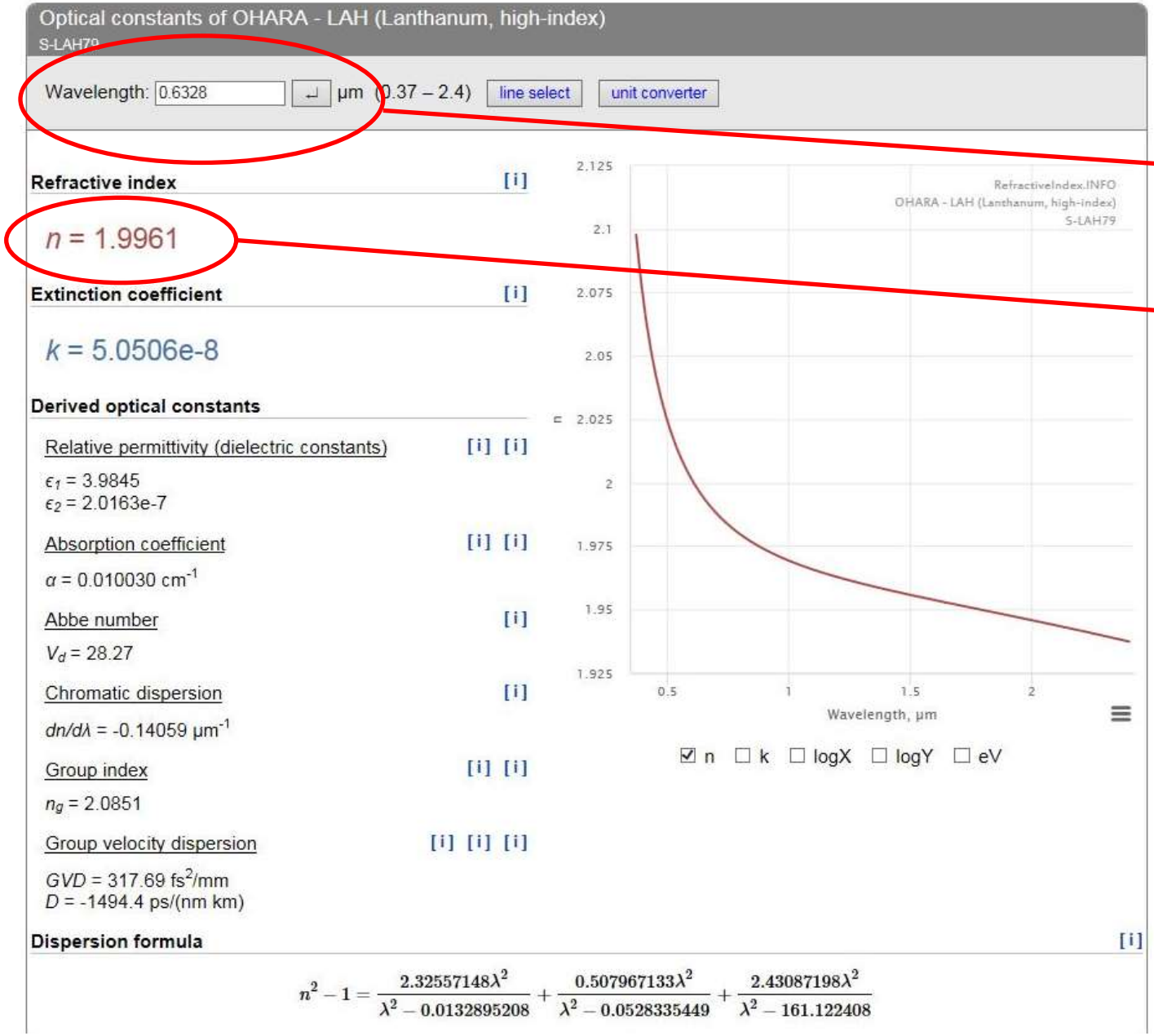


Reflector Sphere
n=2 material

Technical Data from OHARA Material S-LAH 79

Information: John Palmateer (Boeing) 2015
about glass material S-LAH 79
from Japanese supplier OHARA

HEXAGON Special Project Department started a feasibility study
technical data about S-LAH 79
material are available in small plates only
210 mm x 160 mm x 19 mm
one material plate costs around 25’000 US$



IFM – HeNe beam
wave length ʎ=632.8nm

for HeNe interferometer beam phase refraction index is relevant n=1.9961

$$n^2 - 1 = \frac{2.32557148\lambda^2}{\lambda^2 - 0.0132895208} + \frac{0.507967133\lambda^2}{\lambda^2 - 0.0528335449} + \frac{2.43087198\lambda^2}{\lambda^2 - 161.122408}$$

ADM – beam
wave length λ=795nm

for ADM beam
group refraction index
is relevant n=2.0361

Production of first Reflector Spheres

First results:

- maximum diameter around 17.5 mm
- spheres showing light yellow color
- very sensitive sphere surface
- first test measurements did show very poor reflection signal
- signal quality is by far not suitable for measurements

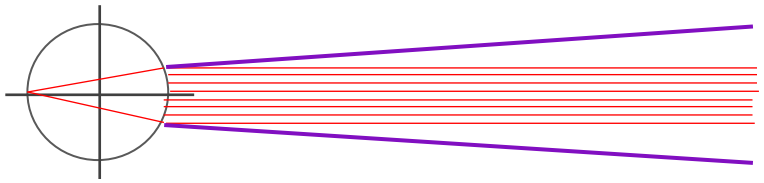
Next step → larger sphere diameter possible and helpful?

Ideas and Solutions to Improve Return Signal

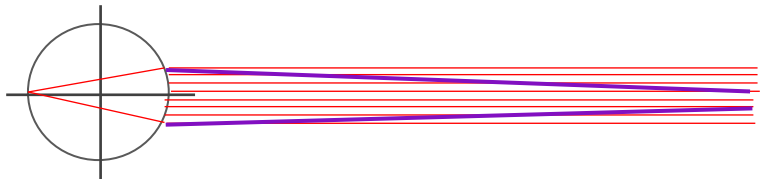
Optical ray and beam calculations based

- on optical material characteristics (S-LAH 79)
- relevant n=1.9961 for IFM (λ=632.8nm) wave length and
- relevant n=2.0361 for ADM beam (λ=795nm) wave length

→ optimum sphere diameter Ø≈19mm for both wave lengths



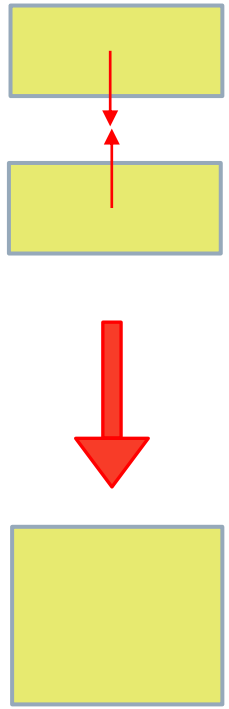
n=1.9961 for IFM beam (λ=632.8nm)



n=2.0361 for ADM beam (λ=795nm)

Ideas and Solutions to Improve Return Signal

Increasing sphere to optimum diameter of 19 mm

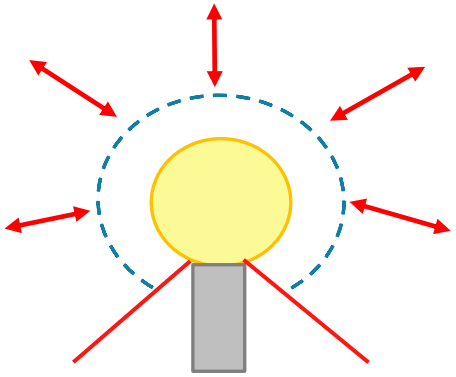


- would need *adhesive* or *anodic* bonding to connect 2 plates together
- relatively new technology unknown production risk
- much higher production costs (additional process and double material costs)
- would get approximately 12 % higher signal
- finally still much too low return signal especially ADM-signal

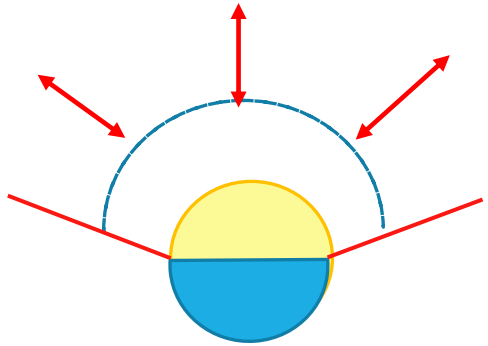
→ **RESULT:** this idea doesn't solve the problem

Ideas and Solutions to Improve Return Signal

Reduction of beam reflection angle that expensive material can be used



Solution



Maximum reflection angle

- total reflection within the sphere
- too low return signal

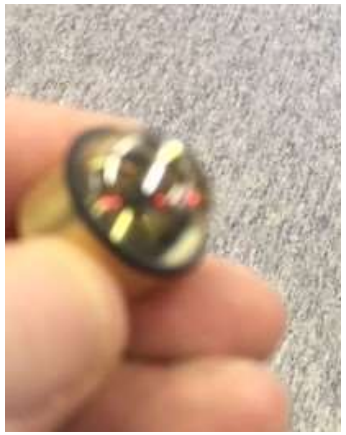
Reduced reflection angle

- half sphere mirror coating from backside
- Sufficient return signal

Sphere n=2 – Back-Side Mirror Coating

First spheres with back-side mirror coating

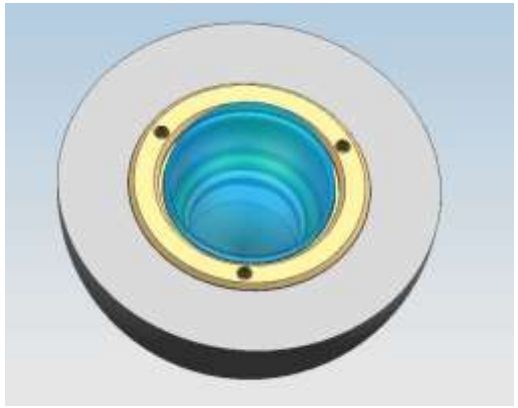
- get sufficient return signal
- measurements in all orientations possible

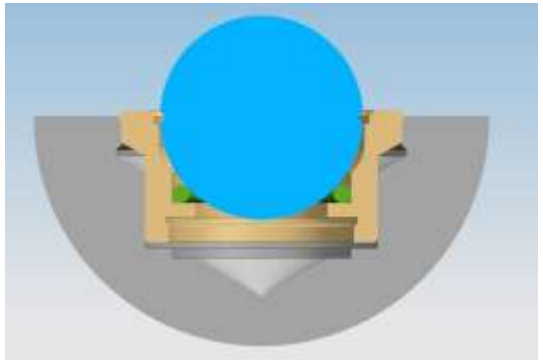


Sphere n=2 – Super Cat Eye Reflector (1.5″ SCE)

Integration of back-side coated sphere into 1.5″housing

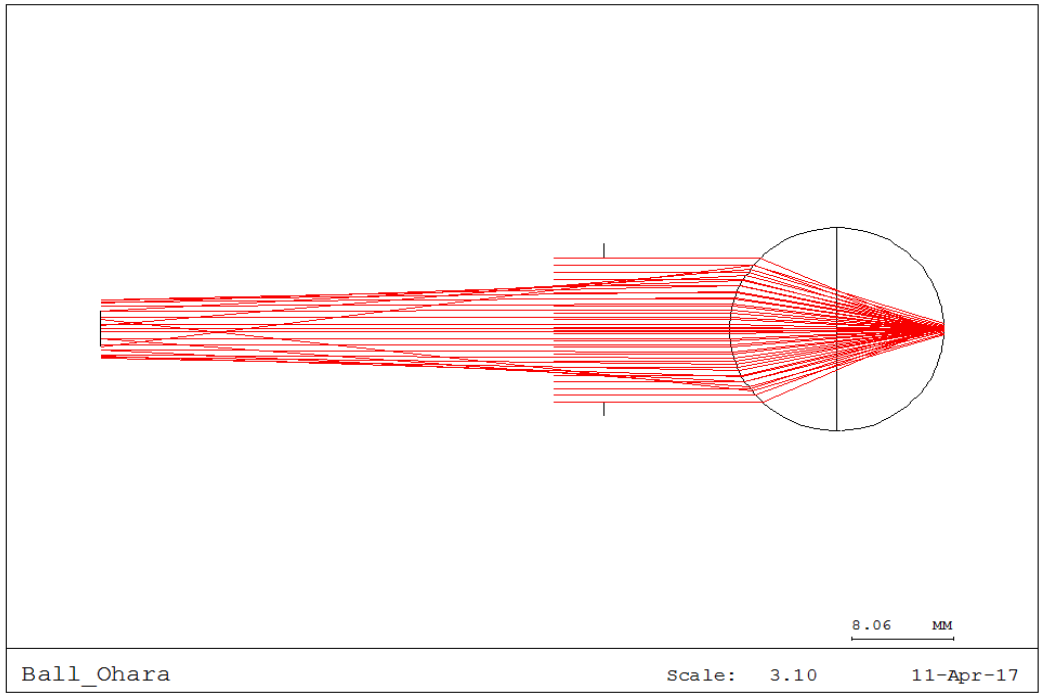
- glass body adjustment into depth
- influence of sphere diameter tolerance
- measurements in all orientations possible
- comparable with 1.5 ″CCR





Super Cat Eye Reflector (1.5" SCE)

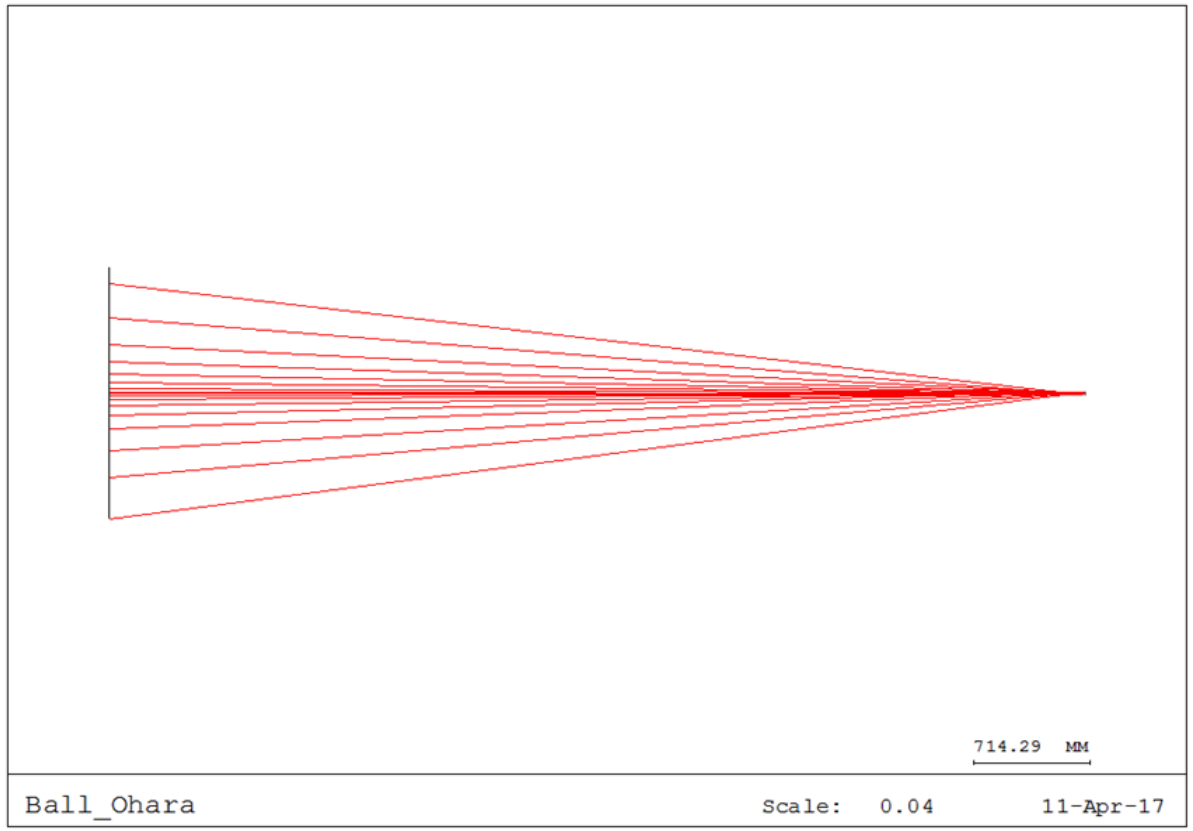
Result: → reflector sphere n=2 in 1.5" housing seems working



Optical rays directly at the sphere

- Optics program select pupil automatically, most times around 4 mm
- wave front are good enough and parallel
- Interferences are possible

Super Cat Eye Reflector (1.5″ SCE)



Optical rays in approximately 6 m distance

- Tracker optics aperture are sufficient
- most divergent beams cannot reach Tracker optics
- within 0.5 mm beam stays locked
- Tracker control-loop is working properly (chitter around center)

1.5” SCE – Super Cat Eye Reflector

Measurement Performance 1.5” SCE is dependent from:

AT930, AT960

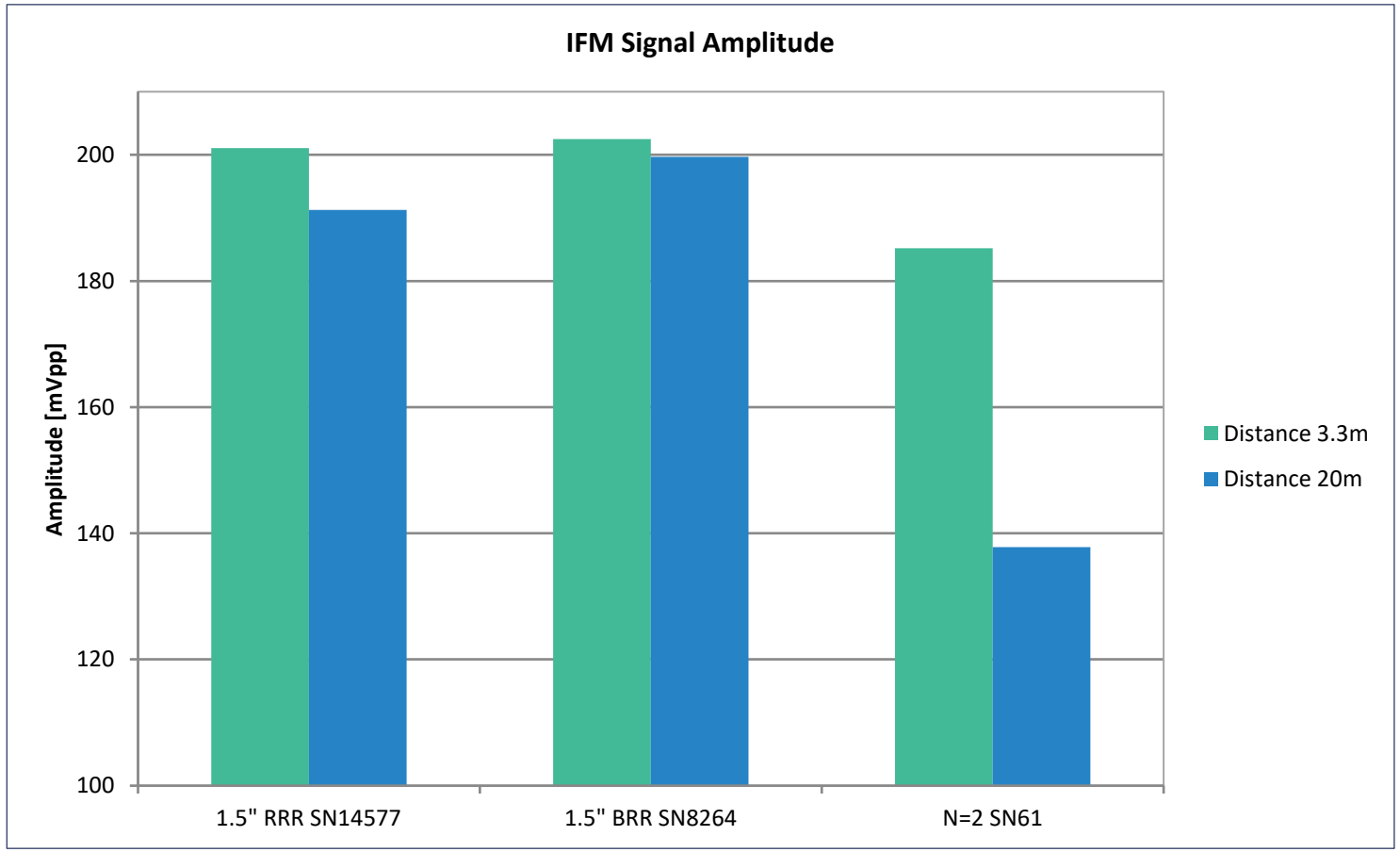
1. Instrument Type
   - AT930, AT960
   - AT402, AT403
   - AT500
2. Instrument Technology
   - ADM/IFM
   - ADM/ATR
3. SCE Manufacturing Quality

AT402, AT403

AT500

1.5″ SCE Reflector – AT930/AT960 IFM Signal Amplitude

IFM = InterFeroMeter (Distance Measurement)



AT930 / AT960

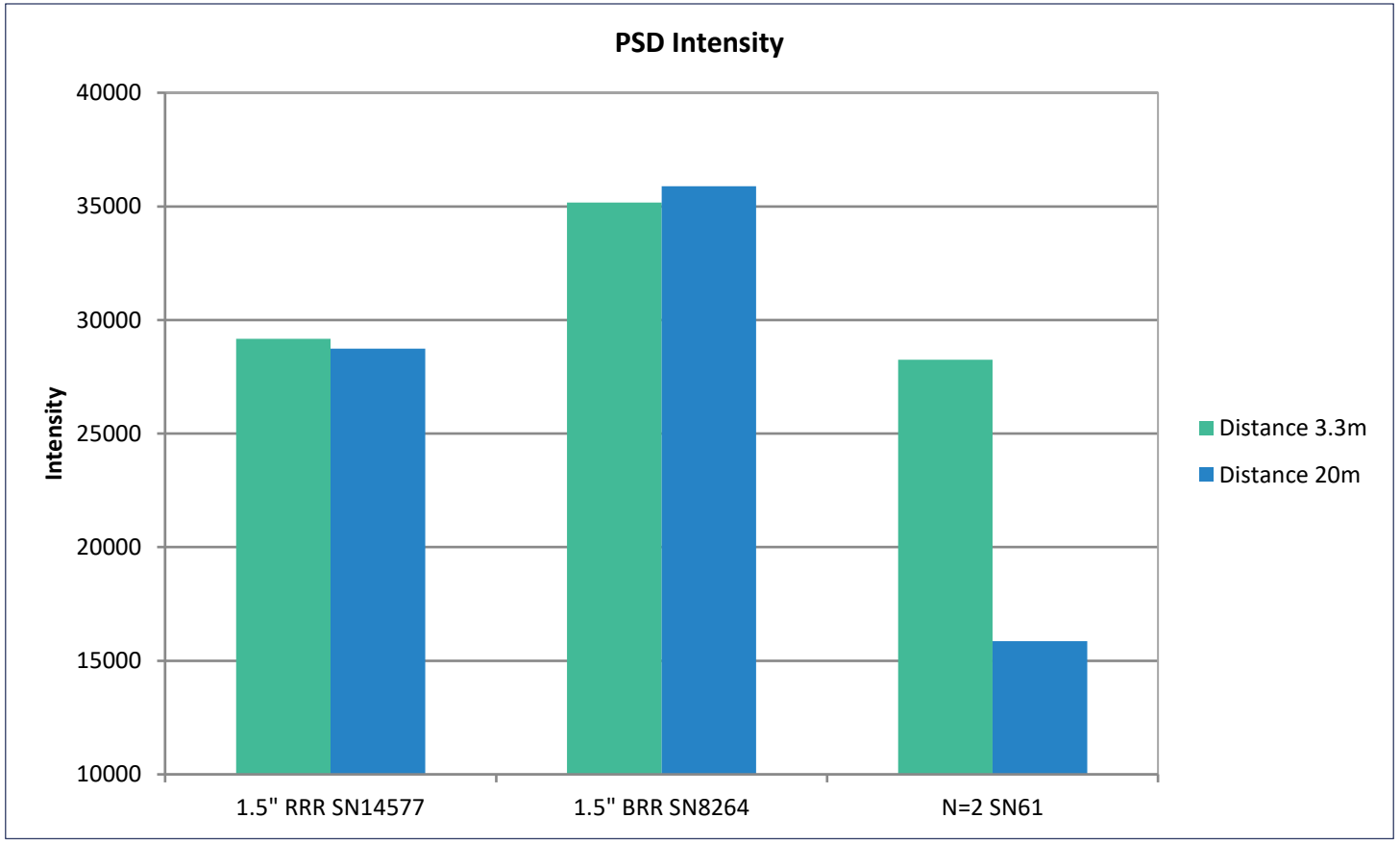
IFM – Signal Amplitude comparison at 3m and at 20m

RESULT:

- Signal strength is okay
- decreases over distances
- critical 20m – 25m

1.5″ SCE Reflector – AT930/AT960 PSD Intensity

PSD = Position Sensitive Diode (Angle Measurements)



AT930 / AT960

PSD – Intensity comparison at 3m and at 20m

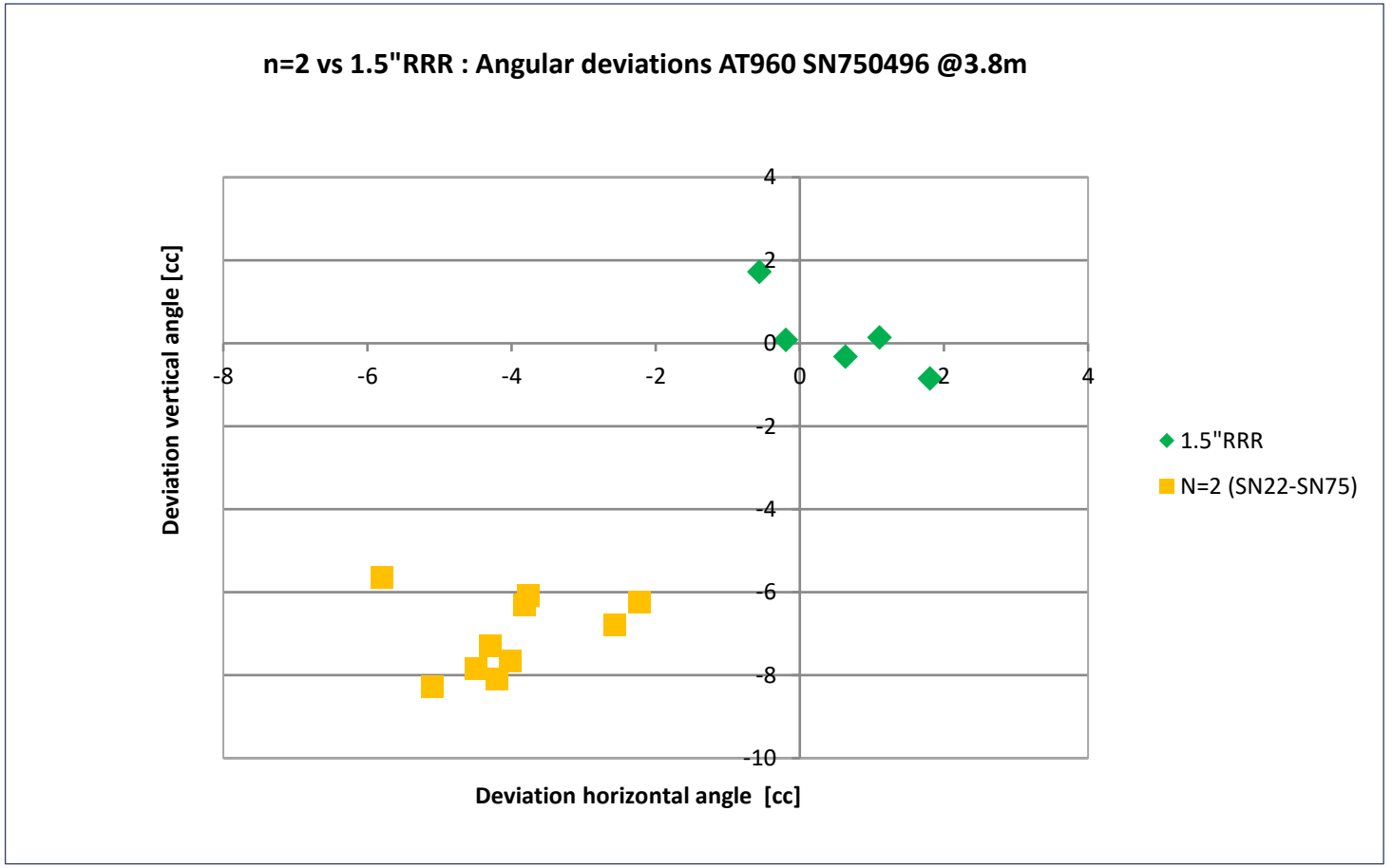
RESULT:

- PSD – Intensity is okay
- decreases over distances
- some noise during tracking

1.5” SCE Reflector – AT930/AT960 Position Repeatability

AT930 / AT960

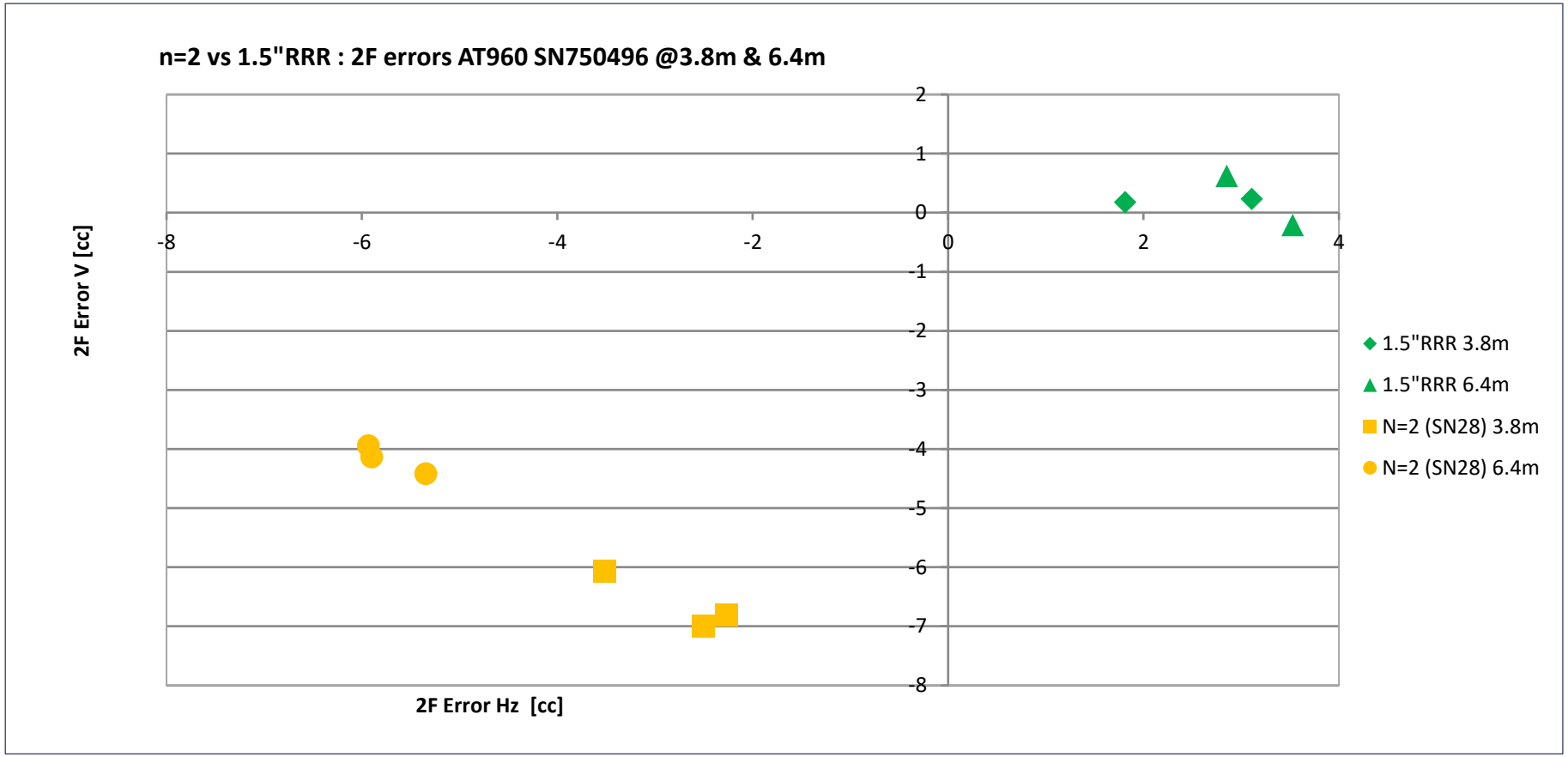
- Systematic angle deviation 1.5”RRR to 1.5”SCE
- Repeatable between SCE samples
- changes over distance
- specific for different sensors



1.5″ SCE Reflector – AT930/AT960 Angles 2 Face Errors

AT930 / AT960

- 2 Face Check 0ut of tolerance (200 – 300 %)
- 2 Face Error changes over distance

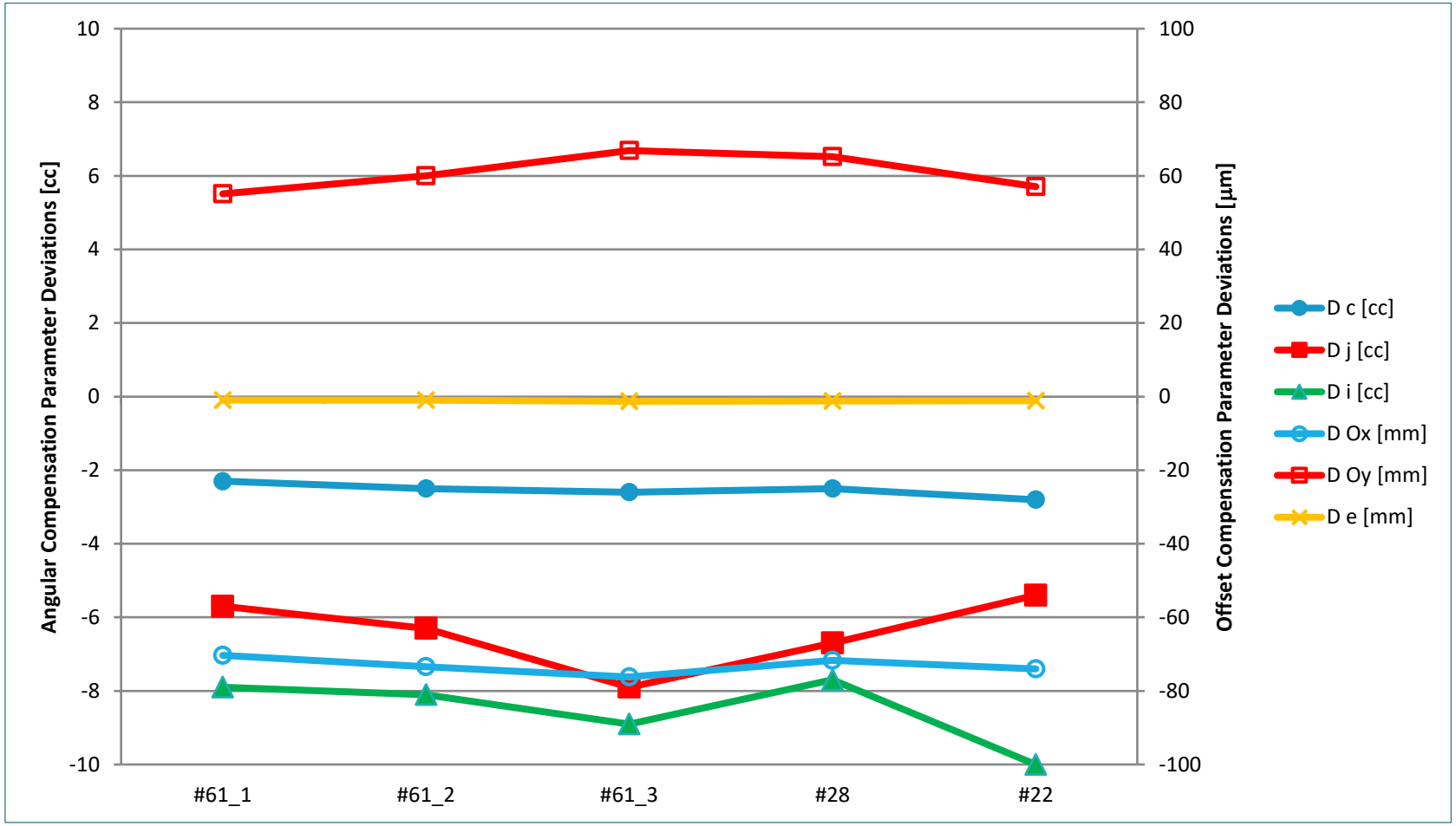


1.5″ SCE Reflector – AT930/AT960 Axes Compensation

AT930 / AT960

Axes Compensations

- out of tolerance
- 105 – 120 % used
- Axes compensation model does not fit
- repeatability of compensation parameters is good



1.5” SCE Reflector – AT930/AT960 Measurement Performance

AT930 /AT960 Instrument

- did show systematical differences
- calculation of different compensation parameters
- tests with distance related collimation model (similar like AT402 has to be implemented)

AT930, AT960

RESULT: 1.5” SCE Reflector type needs an initial Introduction measurement for AT930/AT960 sensors

1.5″ SCE Reflector – AT402/AT403 Performance

AT402, AT403

AT402/AT403 uses different system setup

- Absolut Distance Meter (ADM) with specific frequency change
- Active Target Recognition (ATR – CCD Camera) for angle measurement instead of PSD
- different spot quality at ATR image for SCE reflector

ATR image 1.5”RRR

ATR image 1.5”SCE

1.5″ SCE Reflector – AT402/AT403 Performance

AT402/AT403 uses

- frequency sweep for initial fast coarse measurement
- different technologies for large frequency shift are implemented
  a) frequency bandwidth increasing by a mechanical flap
  b) new digital solution for frequency bandwidth increasing (flapless)

“Silent” ADM Improvement related to AT402/AT403 Production number

1.5″ SCE Reflector – AT402/AT403 Performance

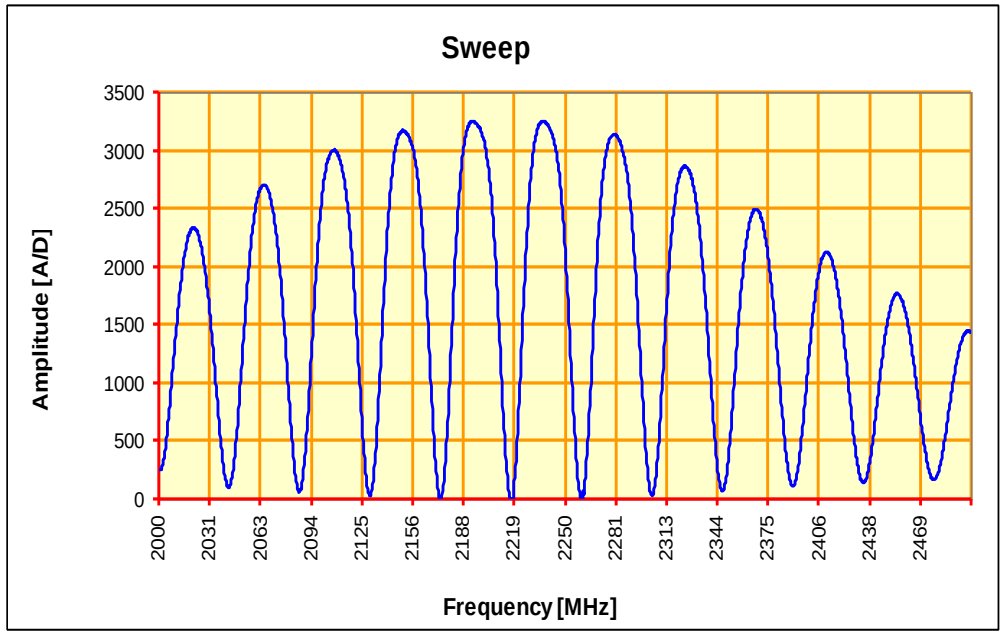
“Silent” AT402/AT403 ADM Improvement

- doesn’t show an impact using RRR,
- both variants deliver proper measurement signals
- “older” mechanical version has 8 times lower signal with SCE would be okay!
- “newer” digital solution has worse signal level which cannot be used with SCE

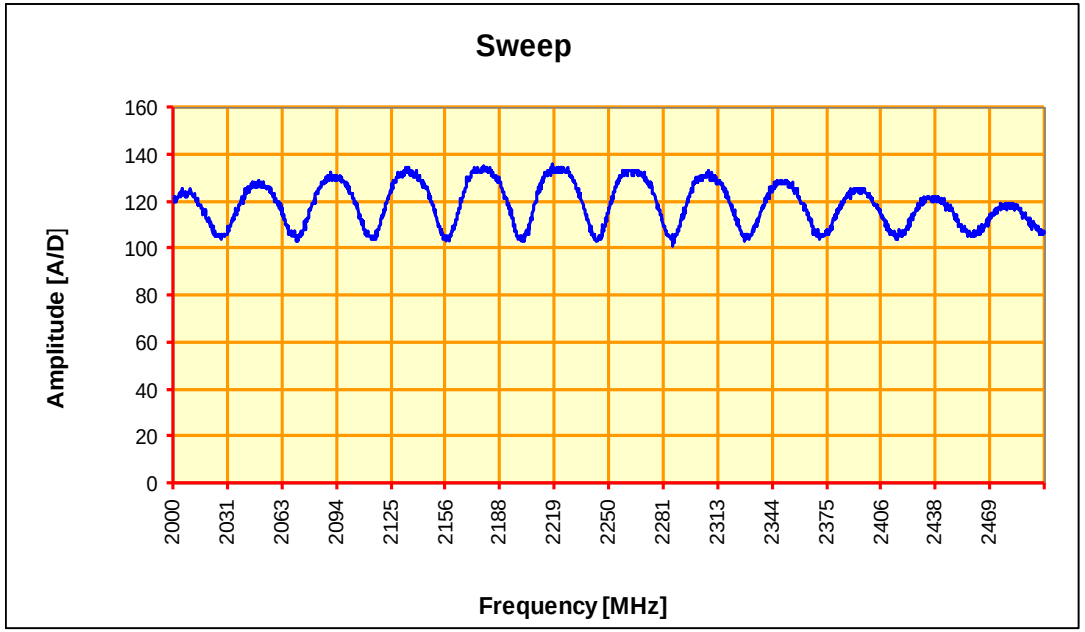
RESULT: further investigations would be necessry

1.5” SCE Reflector – AT402/AT403 Performance

AT402/AT403 using new technology ADM frequency shift



ADM frequency sweep using 1.5”RRR



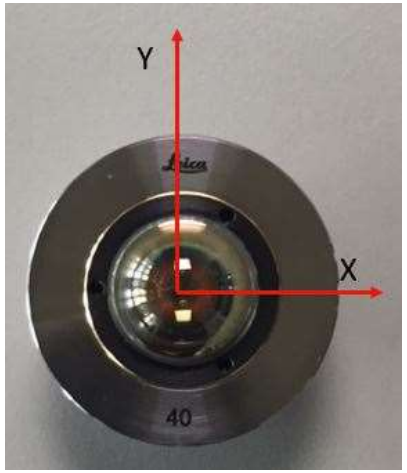
ADM frequency sweep using 1.5”SCE

→ No measurement possible

Super Cat Eye Reflector (1.5″ SCE)

General 1.5″ SCE test measurement

- Measurement repeatability
- Sphere centering
- Sphere diameter tolerance
- Rotation influence
- Maximum tilt angle
- Tilt influence



Super Cat Eye Reflector (1.5″ SCE)

Repeatability – Different SCE Samples

Test Measurements using N2 Reflector-Spheres

26.04.2016

Reflektor	Distance [mm]	StdDev [µm]	Reflektor	Offset [mm]
Referenz	2'716.057	0.32		
Nr.- 2	2'742.179	2.9	Nr.- 2	-26.122
Nr.- 13	2'742.181	2.6	Nr.- 13	-26.124
Nr.- 16	2'742.177	2.2	Nr.- 16	-26.120
Nr.- 17	2'742.181	2.6	Nr.- 17	-26.124
Nr.- 18	2'742.174	2.4	Nr.- 18	-26.117
Referenz	2'716.056	0.36		

Test Measurements using N2 Reflector-Spheres

ADM Offset measurements (6-19)

03.05.2016 12:10 Uhr

Reflektor	Distance [mm]	StdDev [µm]	Reflektor	Offset [mm]
Referenz	2'716.014			
14	2'742.135		14	-26.121
5	2'742.138		5	-26.124
6	2'742.132		6	-26.118
19	2'742.128		19	-26.114
12	2'742.136		12	-26.122
Referenz	2'716.014			
1	2'742.138		1	-26.124
15	2'742.134		15	-26.120
20	2'742.132		20	-26.118
8	2'742.135		8	-26.121
11	2'742.134		11	-26.120
Referenz	2'716.014			
10	2'742.137		10	-26.123
7	2'742.134		7	-26.120
3	2'742.132		3	-26.118
4	2'742.134		4	-26.120
Referenz	2'716.014			

Super Cat Eye Reflector (1.5″ SCE)

1.5″ SCE -Reflector
well oriented

1.5″ SCE -Reflector
tilt left side

1.5″ SCE -Reflector
tilt upwards

1.5″ SCE -Reflector
tilt down side

1.5″ SCE -Reflector
tilt right side

Super Cat Eye Reflector (1.5″ SCE)

1.5″ SCE samples

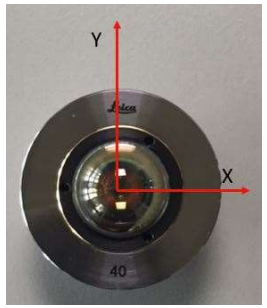
tilt measurements

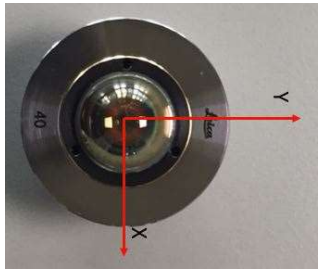
Test Measurements using N2 Reflector-Spheres							
Tilt Measurements							
03.05.2016							
Reflektor	center	upwards	down side	left side	right side	center	
	Dist in [mm]	Dist in [mm]	Dist in [mm]	Dist in [mm]	Dist in [mm]	Dist in [mm]	
Referenz	2'716.013						12:37 Uhr
14	2'742.133	2'742.135	2'742.135	2'742.136	2'742.137	2'742.134	
5	2'742.138	2'742.138	2'742.136	2'742.137	2'742.135	2'742.138	
6	2'742.132	2'742.137	2'742.133	2'742.136	2'742.137	2'742.132	
19	2'742.130	2'742.132	2'742.137	2'742.136	2'742.135	2'742.129	
12	2'742.139	2'742.139	2'742.139	2'742.136	2'742.140	2'742.139	
Referenz	2716..016						
1	2'742.140	2'742.140	2'742.138	2'742.136	2'742.143	2'742.140	
15	2'742.137	2'742.140	2'742.136	2'742.139	2'742.136	2'742.136	
20	2'742.139	2742..139	2'742.141	2'742.142	2'742.136	2'742.138	
8	2'742.140	2'742.139	2'742.141	2'742.142	2'742.138	2'742.138	
11	2'742.000	2'742.135	2'742.142	2'742.141	2'742.141	2'742.138	
Referenz	2'716.020						14:05 Uhr
10	2742..144	2'742.145	2'742.137	2'742.142	2'742.140	2'742.144	
7	2'742.135	2'742.140	2'742.135	2'742.143	2'742.135	2'742.136	
3	2'742.139	2'742.142	2'742.139	2'742.131	2'742.148	2'742.139	
4	2'742.139	2'742.130	2'742.149	2'742.144	2'742.139	2'742.139	
Referenz	2'716.019						14:50 Uhr

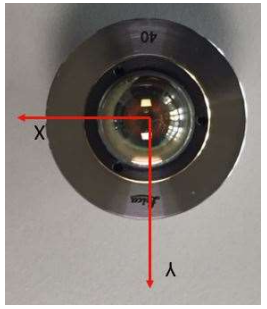
Super Cat Eye Reflector (1.5″ SCE)

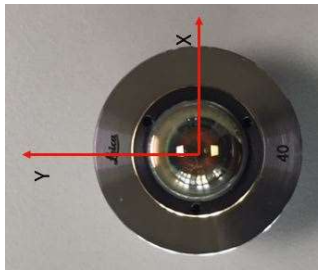
1.5″ SCE samples

Rotation influence









Test Measurements using N2 Reflector-Spheres						
Rotation Dependancy Measurements						
03.05.2016						
Reflektor	0°	90°	180°	270°	360° = 0°	
	Dist in [mm]	Dist in [mm]	Dist in [mm]	Dist in [mm]	Dist in [mm]	
Referenz	2'716.020					15:12 Uhr
14	2'742.140	2'742.141	2'742.141	2'742.140	2'742.139	
5	2'742.143	2'742.142	2'742.144	2'742.143	2'742.143	
6	2'742.138	2'742.139	2'742.138	2'742.138	2'742.138	
19	2'742.135	2'742.137	2'742.135	2'742.136	2'742.136	
12	2'742.143	2'742.145	2'742.143	2'742.143	2'742.143	
Referenz	2'716.020					
1	2'742.147	2'742.146	2'742.146	2'742.147	2'742.147	
15	2'742.148	2'742.143	2'742.142	2'742.142	2'742.144	
20	2'742.144	2'742.145	2'742.144	2'742.145	2'742.145	
8	2'742.146	2'742.147	2'742.147	2'742.146	2'742.147	
11	2'742.146	2'742.148	2'742.147	2'742.147	2'742.147	
Referenz	2'716.024					
10	2'742.150	2'742.152	2'742.151	2'742.150	2'742.151	
7	2'742.147	2'742.146	2'742.147	2'742.146	2'742.146	
3	2'742.147	2'742.147	2'742.147	2'742.148	2'742.147	
4	2'742.146	2'742.147	2'742.146	2'742.147	2'742.146	
Referenz	2'716.026					

Performance Data of 1.5” SCE

AT930/AT960

- Initial reflector type compensation necessary
- reflection angle ± 75°
- measurement range ≤ 20 m
- measurement accuracy ± 3µm

→ working like regular 1.5” reflector ≤ 20 m

AT402/AT403/AT500

open technical questions have to be answered before an market introduction is possible

→ not working properly

Remark to the 75 mm Cat Eye Reflector

75 mm Cat Eye Reflector is a completely different solution

- Perfect calculated reflector (like a high performance objective)
- Combination of glass components to reduce optical errors and effects
- Working with all instruments
- Reflection angle ± 60°
- measurement range > 50 m
- measurement accuracy ± 3µm
- Size and weight are large

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Thank you for your attention

Raimund Loser

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