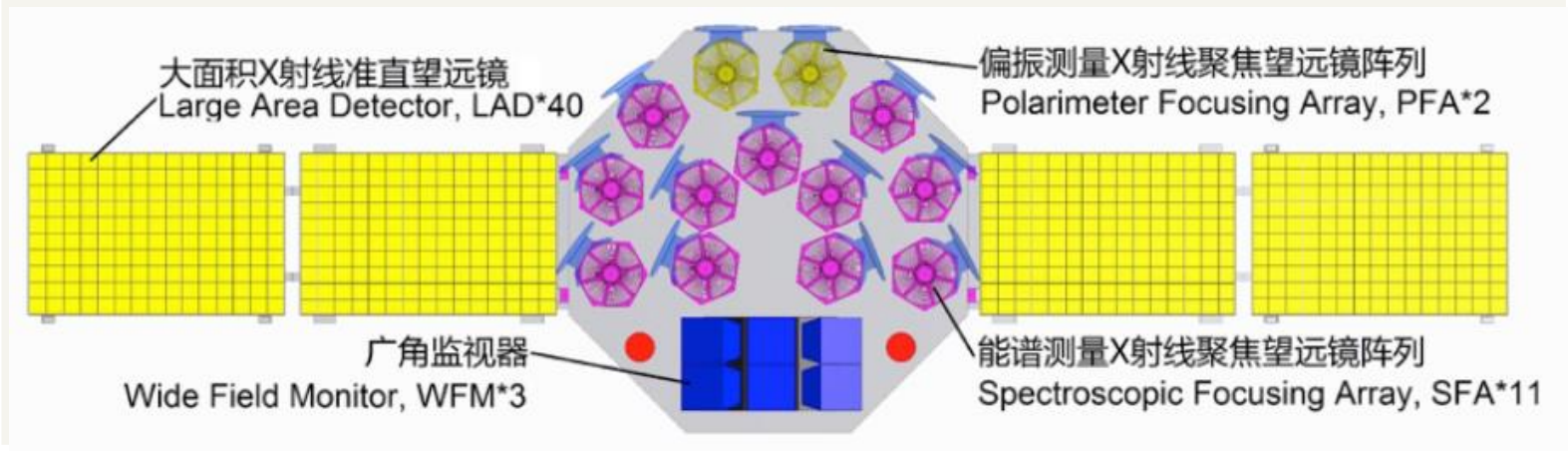
Development of SFA optics and focusing system

Qiushi Huang, Zhenxiang Shen, Bin Ma, ZhongZhang, Kun Wang, Hongfei Jiao, Xiaoqiang Wang, Zhanshan Wang

Key Laboratory of Advanced Micro-Structured Materials MOE
Institute of Precision Optics and Engineering (IPOE)
Tongji University

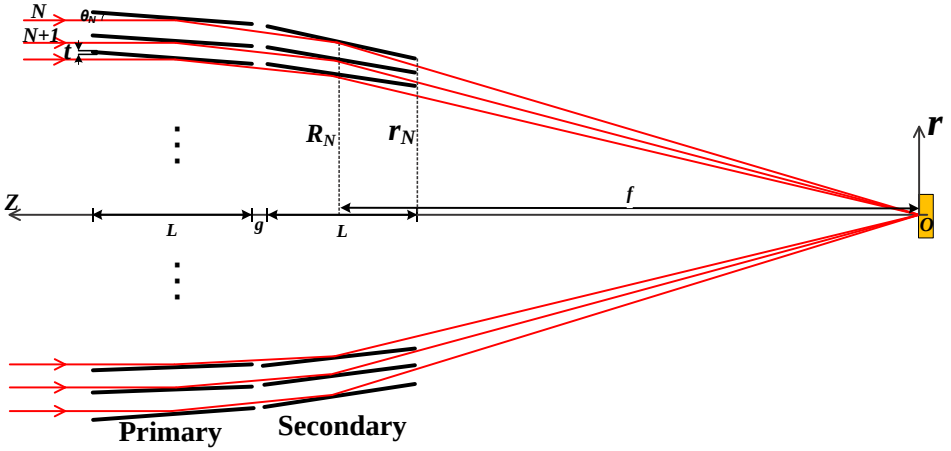
SFA modules for eXTP



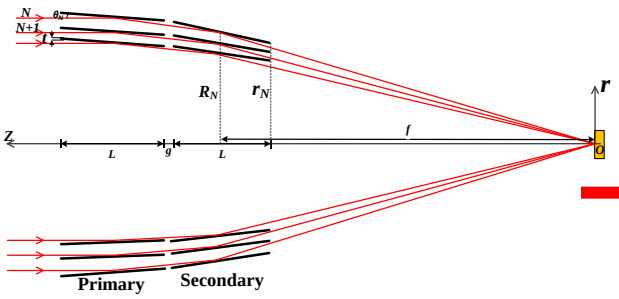
E= 0.5-10keV

- f=4.5m, ϕ=100-450mm
- N=176

Angular reso. =1 arcmin



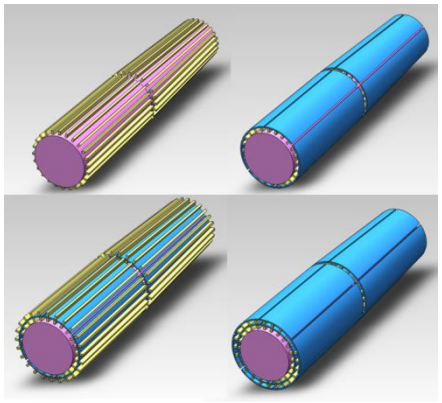
Development process for X-ray telescope



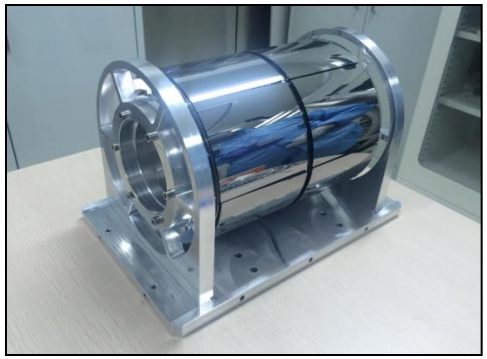
Optical design

Hot Slumping glass

Coating

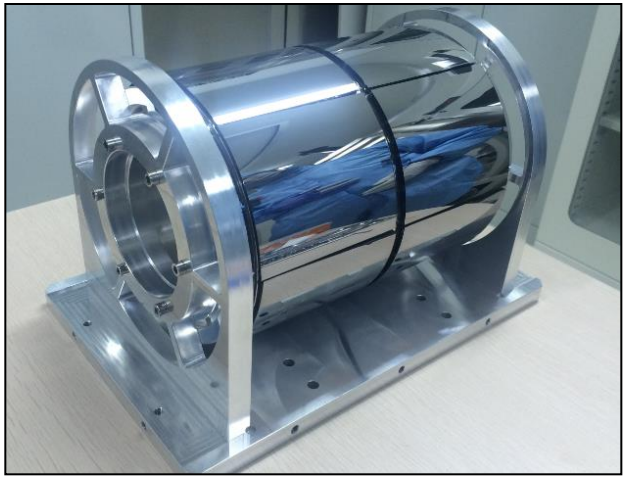


Assembly



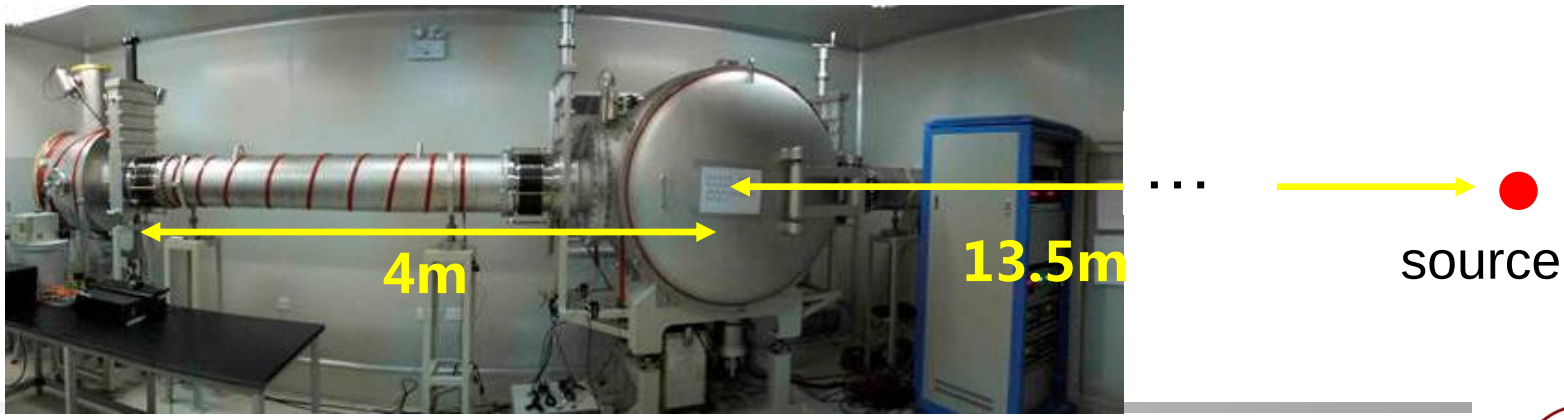
Prototype measurement

1st prototype in March, 2016

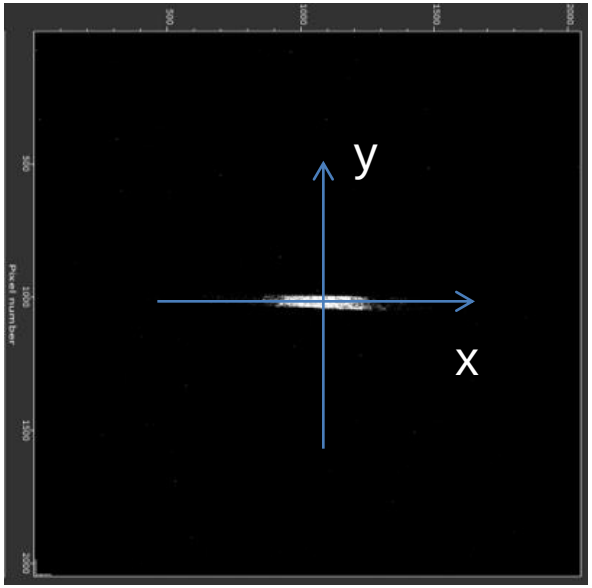


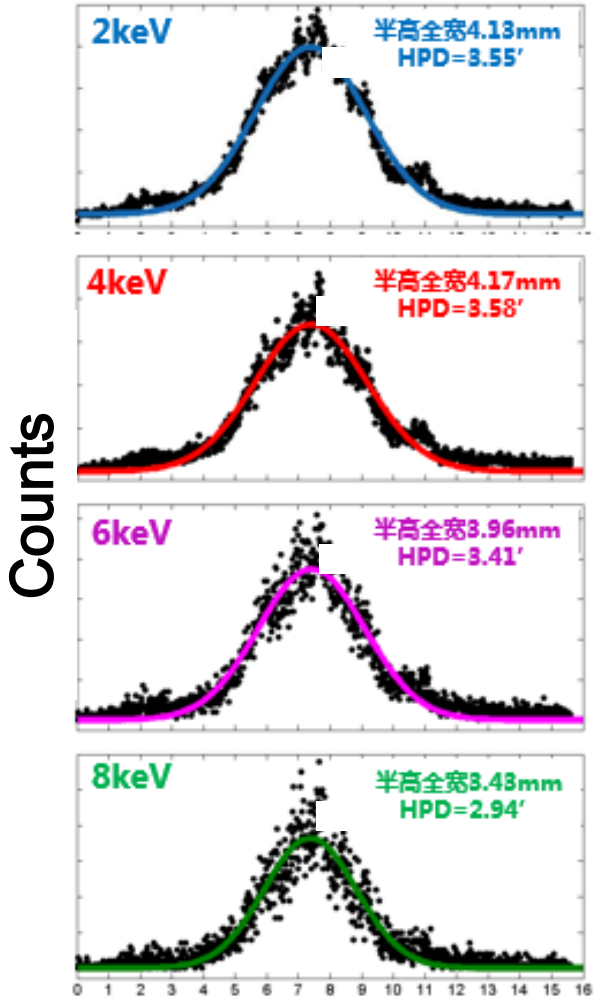
F=4m
Ø=170mm
5 shells
60 mirrors primary+secondary
Pt coating
0.3 mm thickness

National Astronomical Observatory of China



1st prototype in March, 2016





Pencil beam measurement
HPD =~ 3’

1. Optical design
2. Slumping glass
3. Coatings
4. Assembly

Coating design for 1-10keV

Pt, C layers

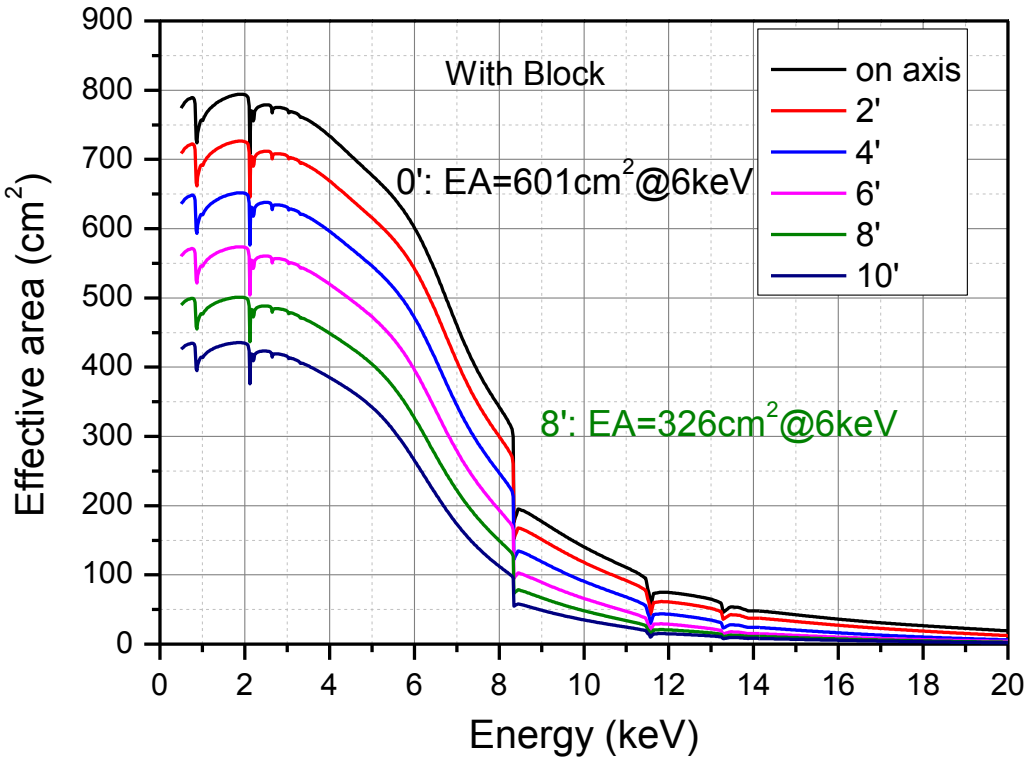
θ = 0.16~0.71deg

N=176

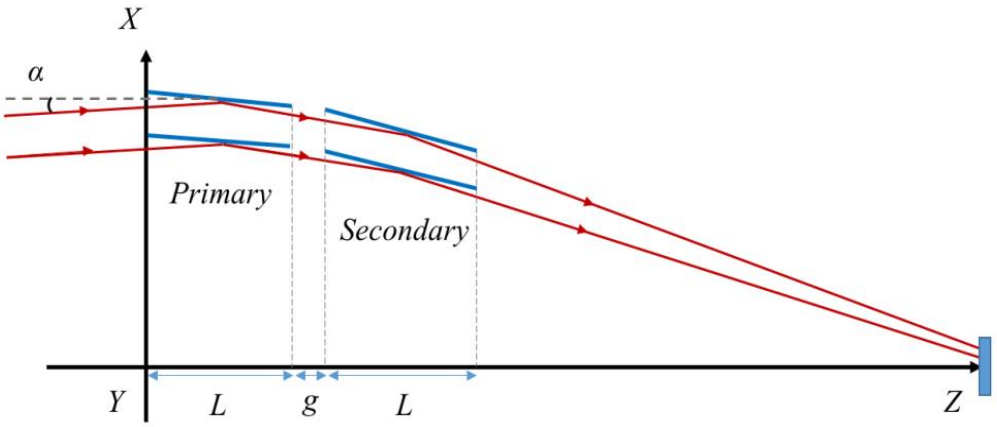
Ø=100mm~450mm

f=4.5m

Mirror length= 100mm

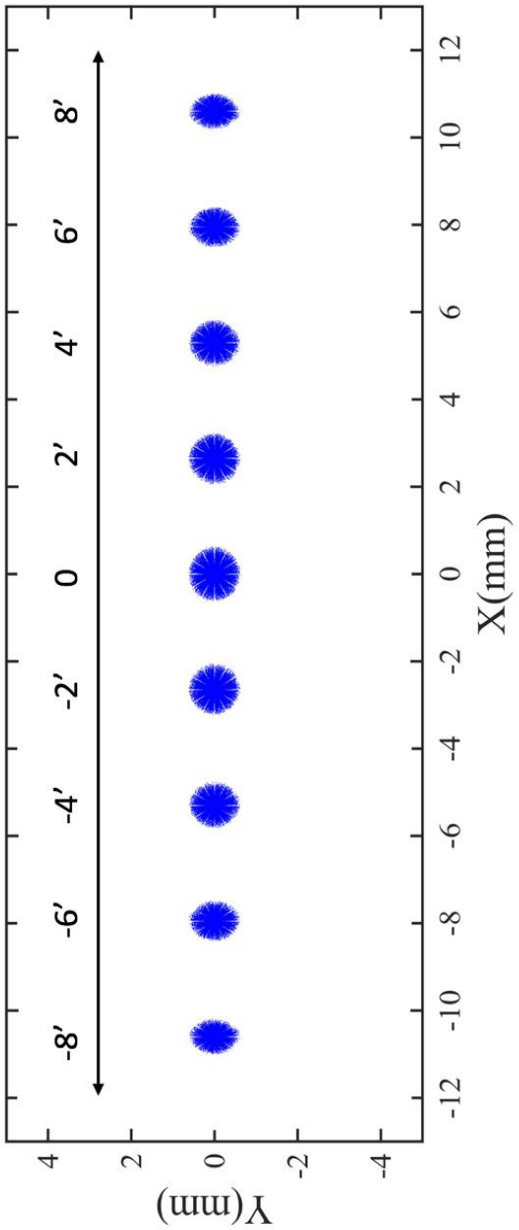


Focal spot off axis



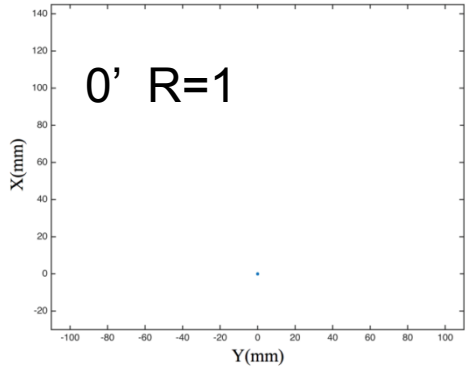
Focal spot position shift with off-axis incidence

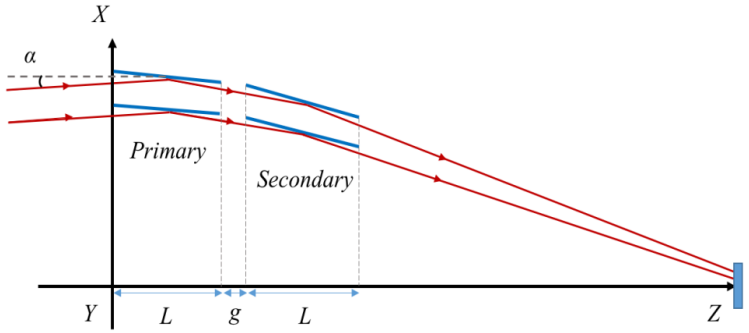
Off axis	Spot deviation (mm)	HPD（6keV）
		With block
0’	0	17.68’’
4’	5.2993	14.45”
8’	10.6017	11.98”
10’	13.2529	11.64”

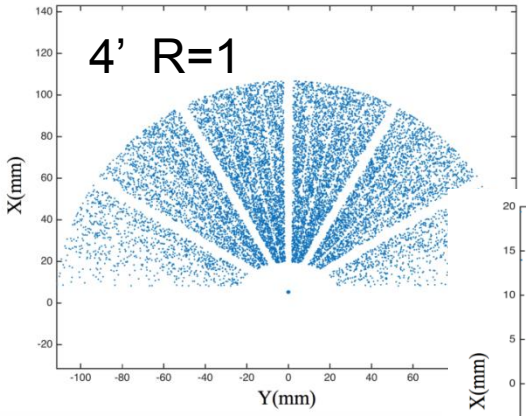


Stray light

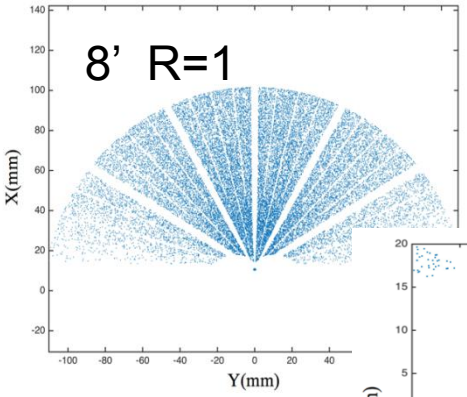
Incident beam reflected by only primary or secondary mirror:

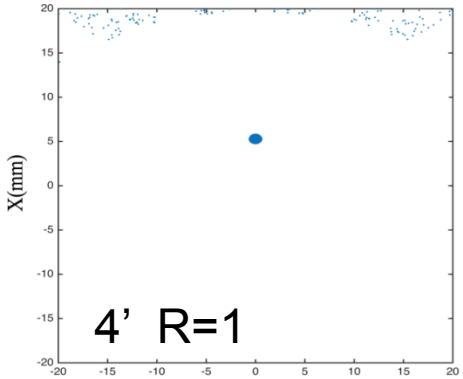


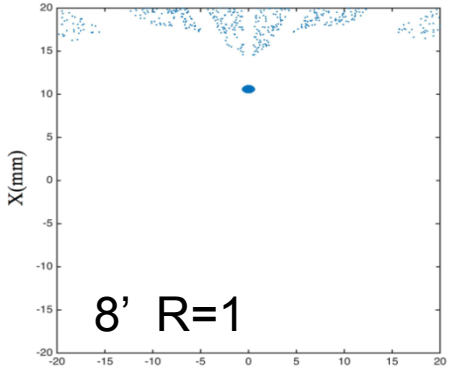




40x40mm
Detector size

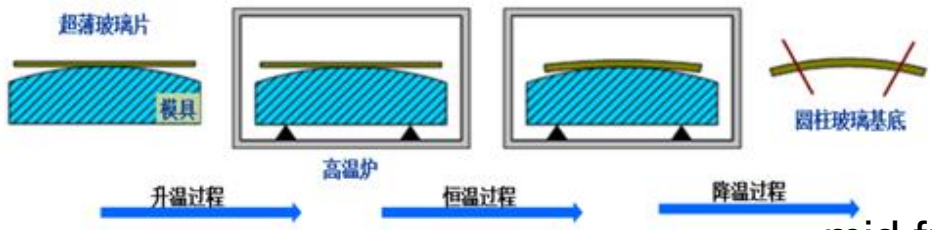




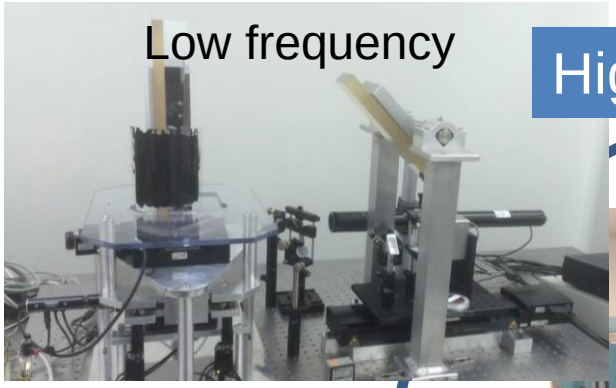


1. Optical design
2. Slumping glass
3. Coatings
4. Assembly

Slumping glass optics (SGO)

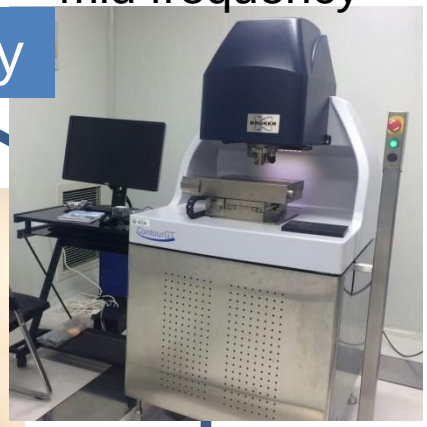


Low frequency

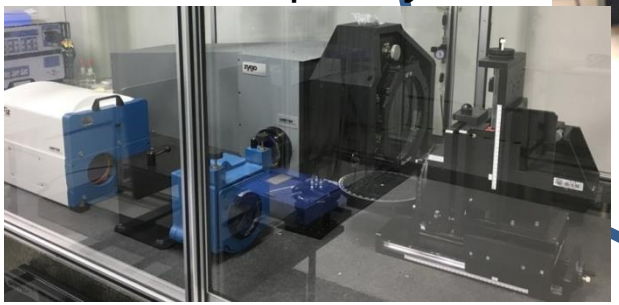


High accuracy metrology

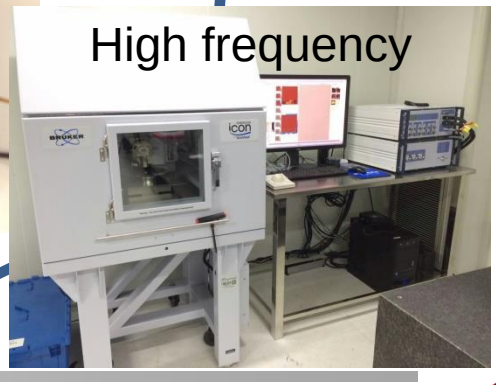
mid frequency



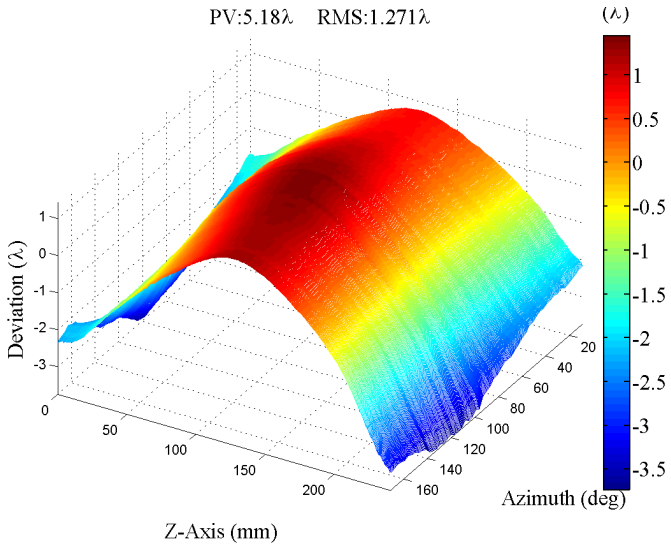
Low frequency

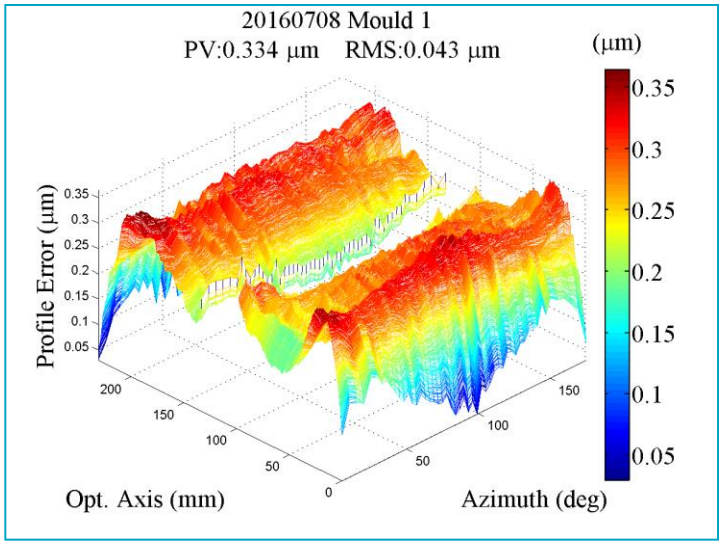


High frequency



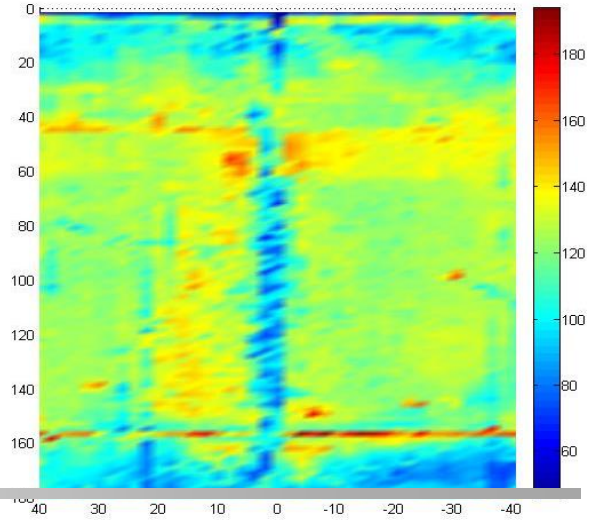
Improved mandrel



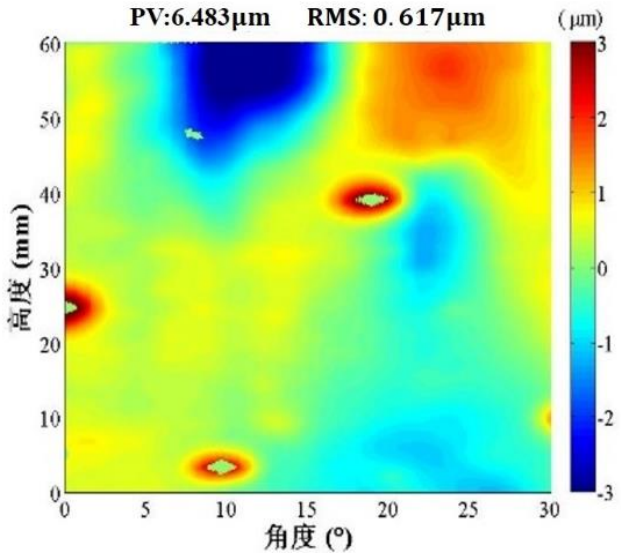


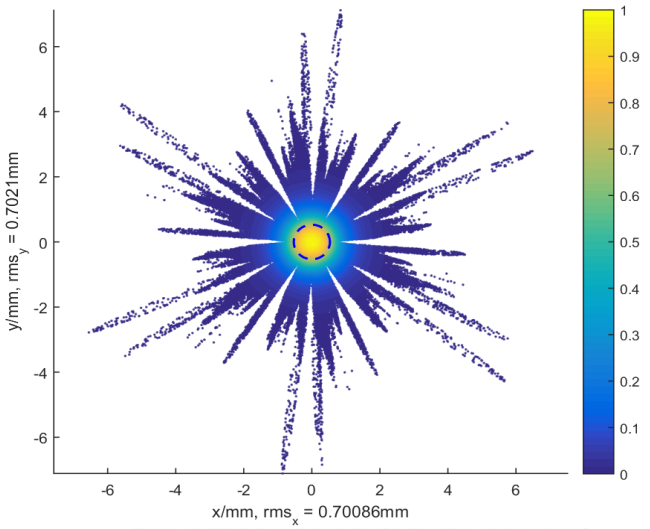
Improved slumping process

Measure and reduce surface contamination

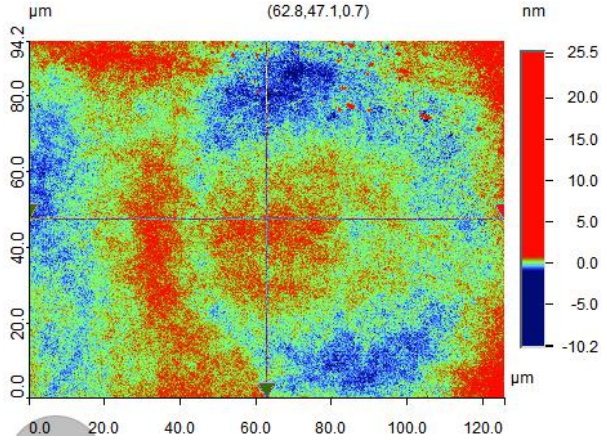


New slumping results

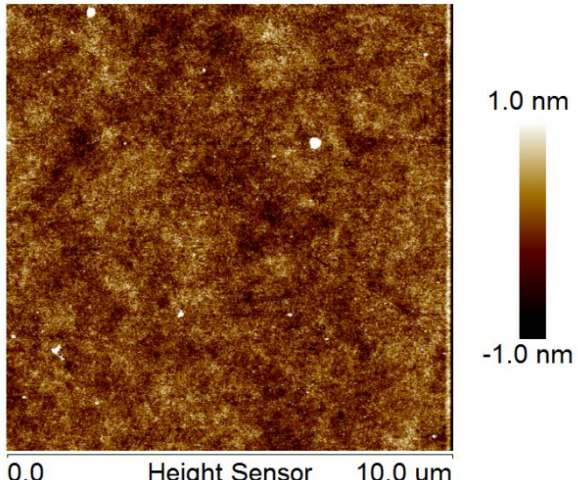




Best mirror
HPD=49”



50X, Rms= 0.468nm

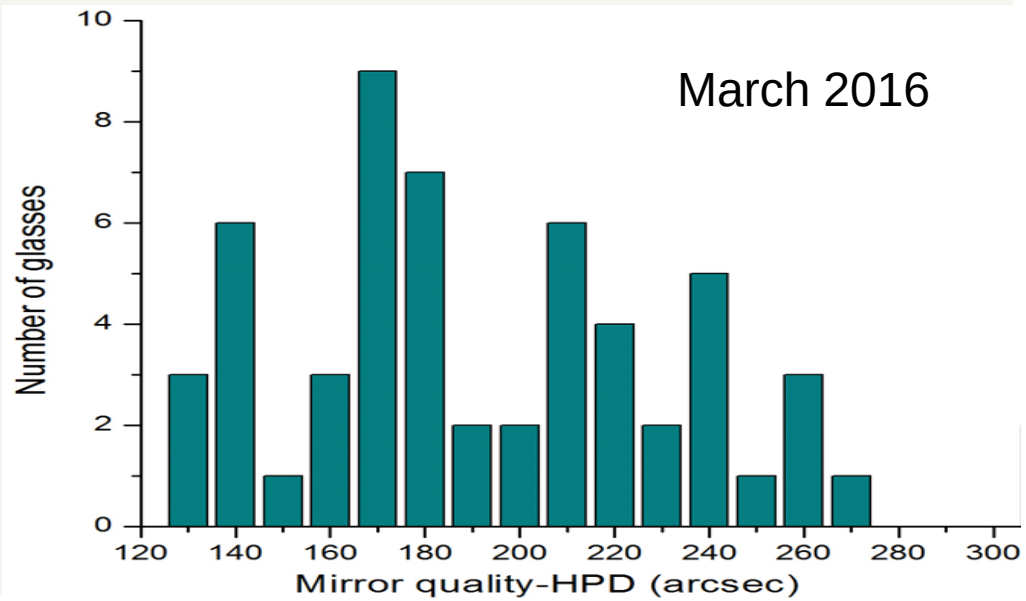


Rms=0.31-0.38 nm

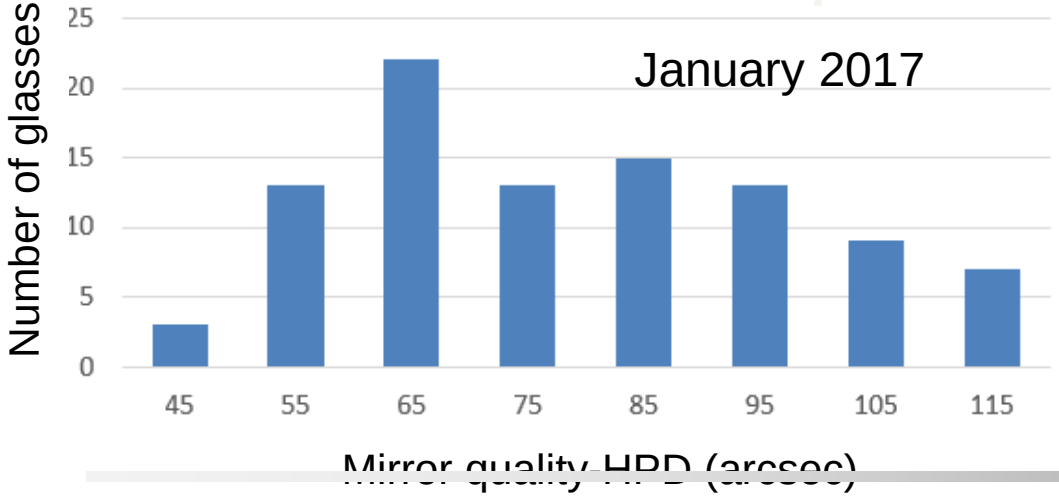
New slumping results

Improvement of Free-standing mirrors !

130”-240”



60”-110”

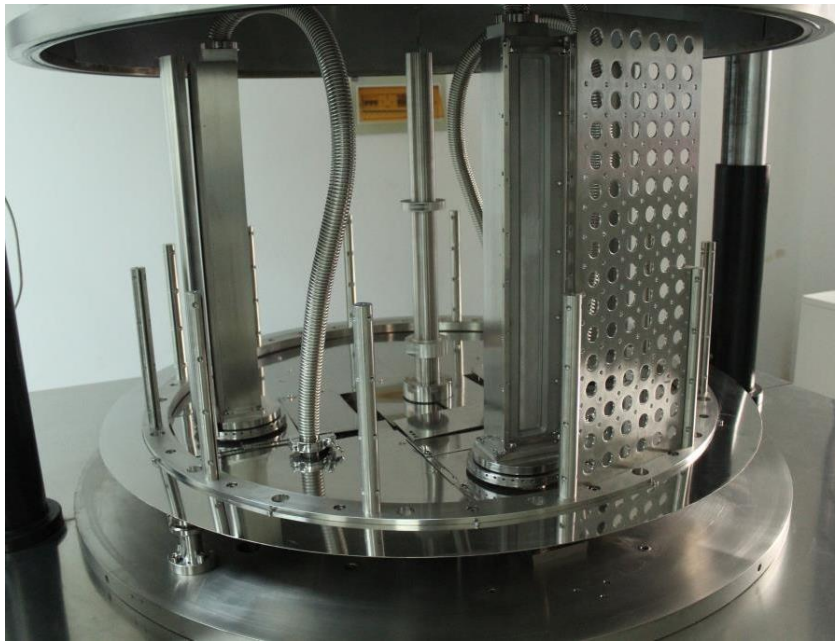


1. Optical design
2. Slumping glass
3. **Coatings**
4. Assembly

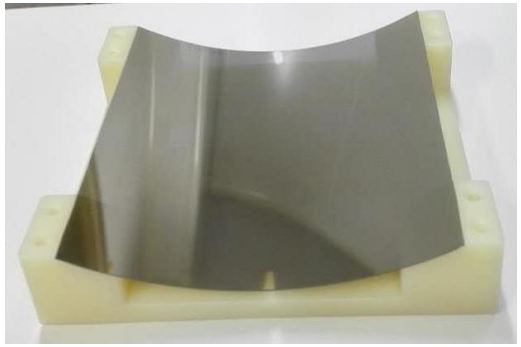
Coating facility

Cylindrical Magnetron Sputtering Coater for eXTP

Deposition on slumping glass,
or deposition on cylindrical glass mandrel



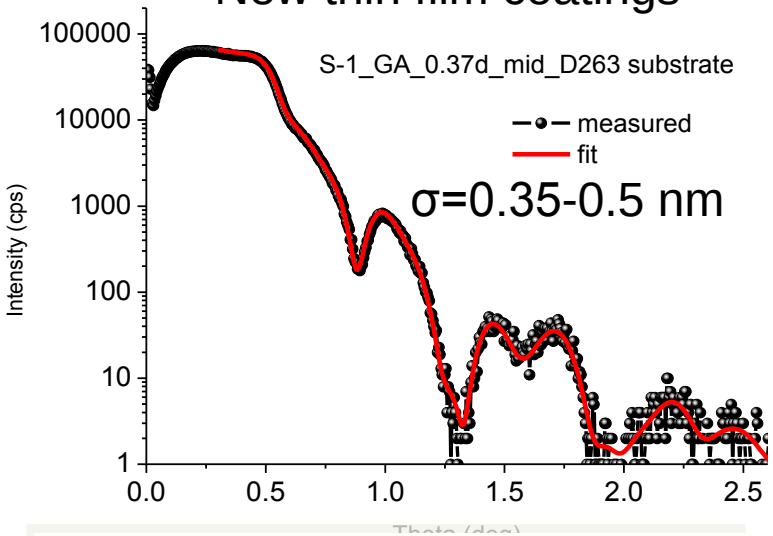
Grazing incidence X-ray measurement

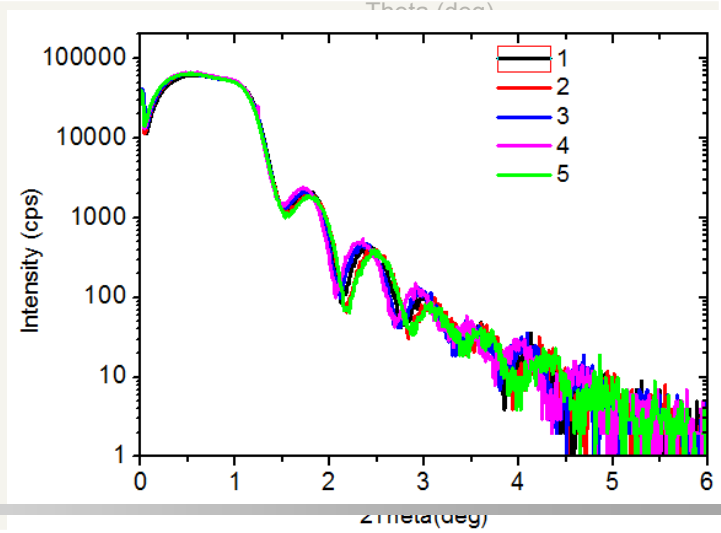


(unoptimized)

thickness uniformity < 8%

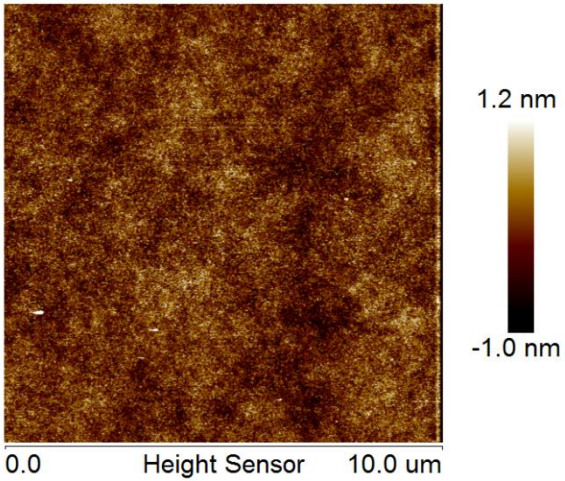
New thin film coatings



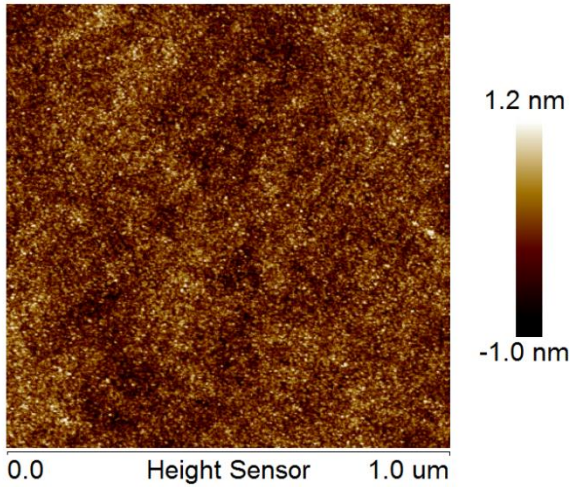


Roughness & stress measurement

Roughness

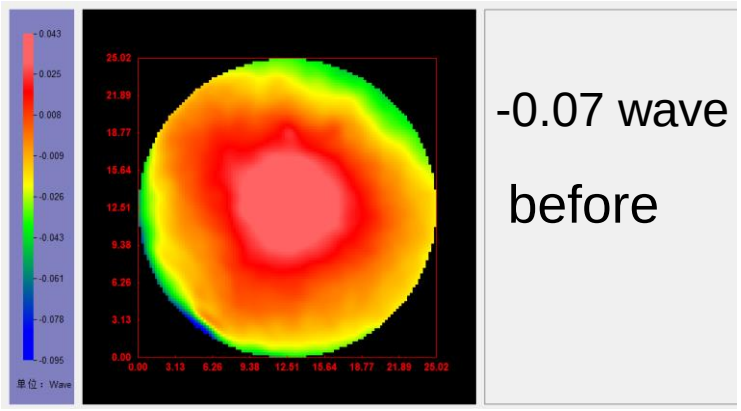


RMS=0.37 nm



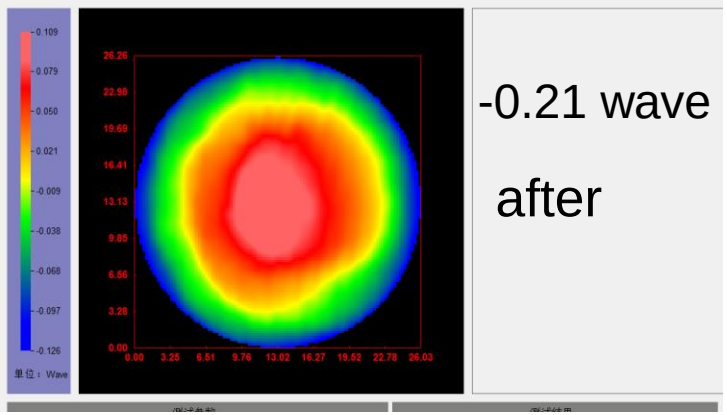
RMS=0.32 nm

Stress



-0.07 wave

before



-0.21 wave

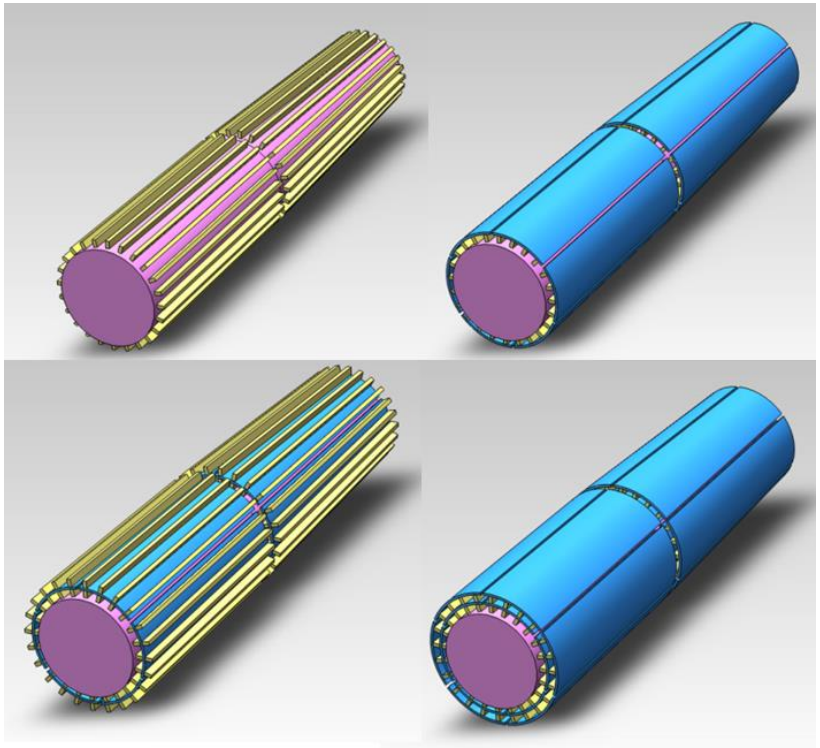
after

$$\sigma_f = \frac{1}{6}\left(\frac{1}{R_{post}} - \frac{1}{R_{pre}}\right)\left(\frac{E_s}{1-V_s}\right)\frac{{t_s}^2}{t_f}$$

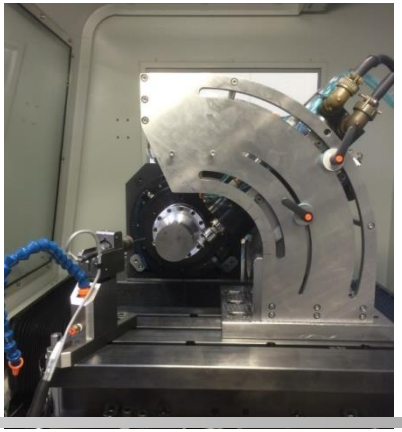
-530~-560MPa

1. Optical design
2. Slumping glass
3. Coatings
4. Assembly

Assembly and Integration of telescope

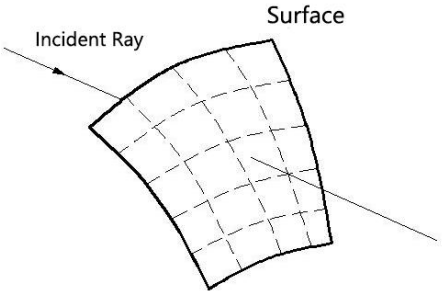


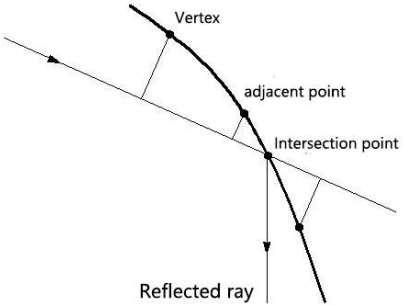
Integration method

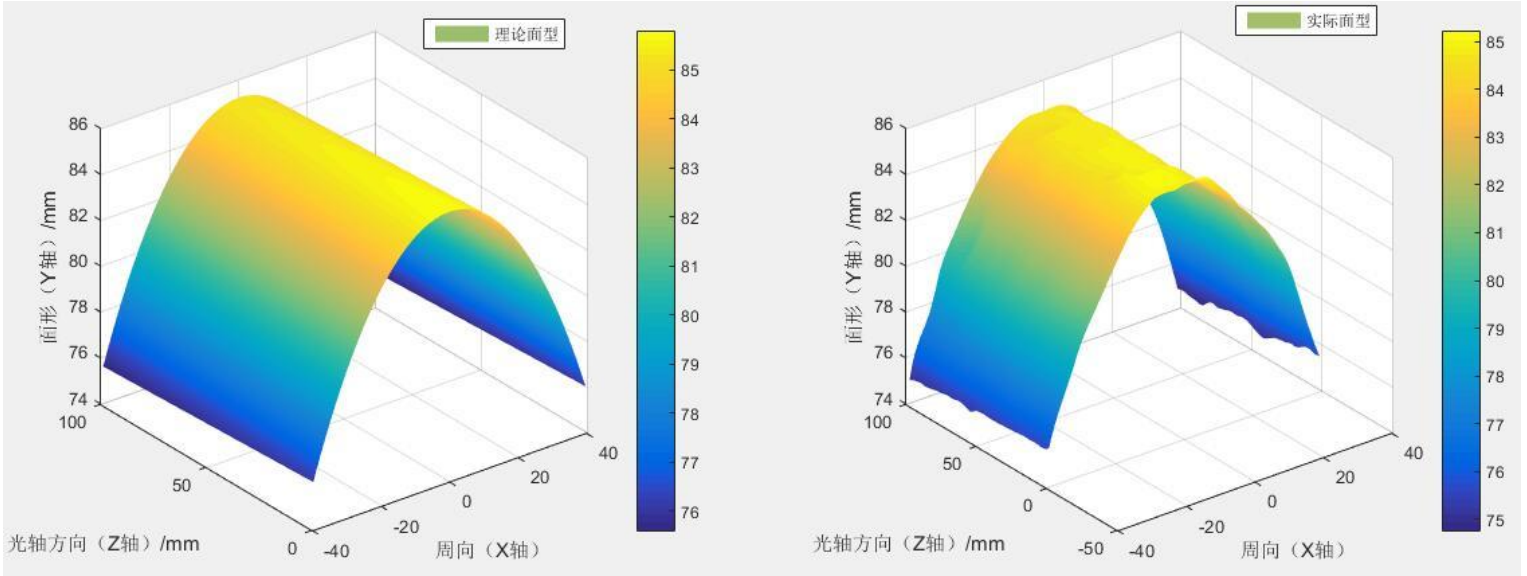


The tilt spindle combined with dish wheel to grind the conic surface

Development of ray-tracing program



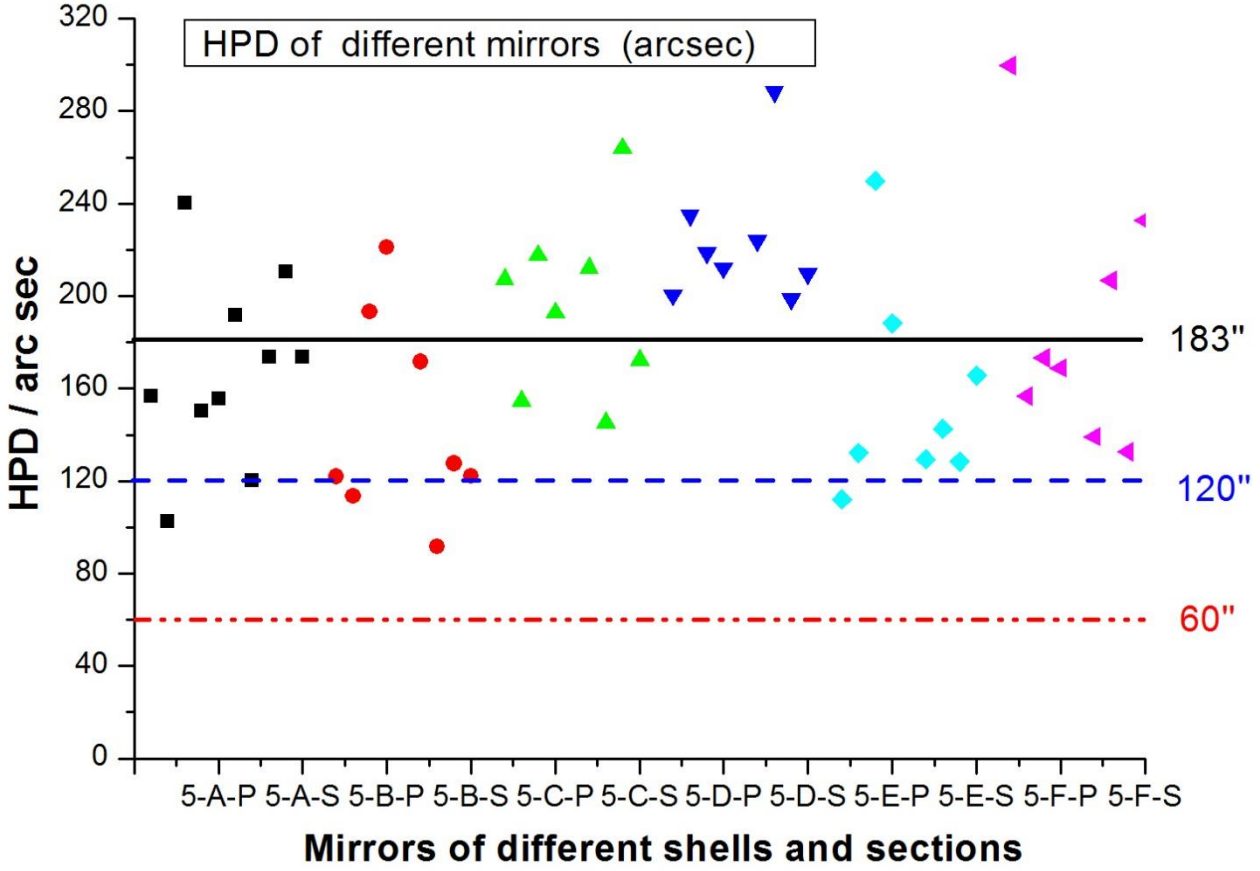




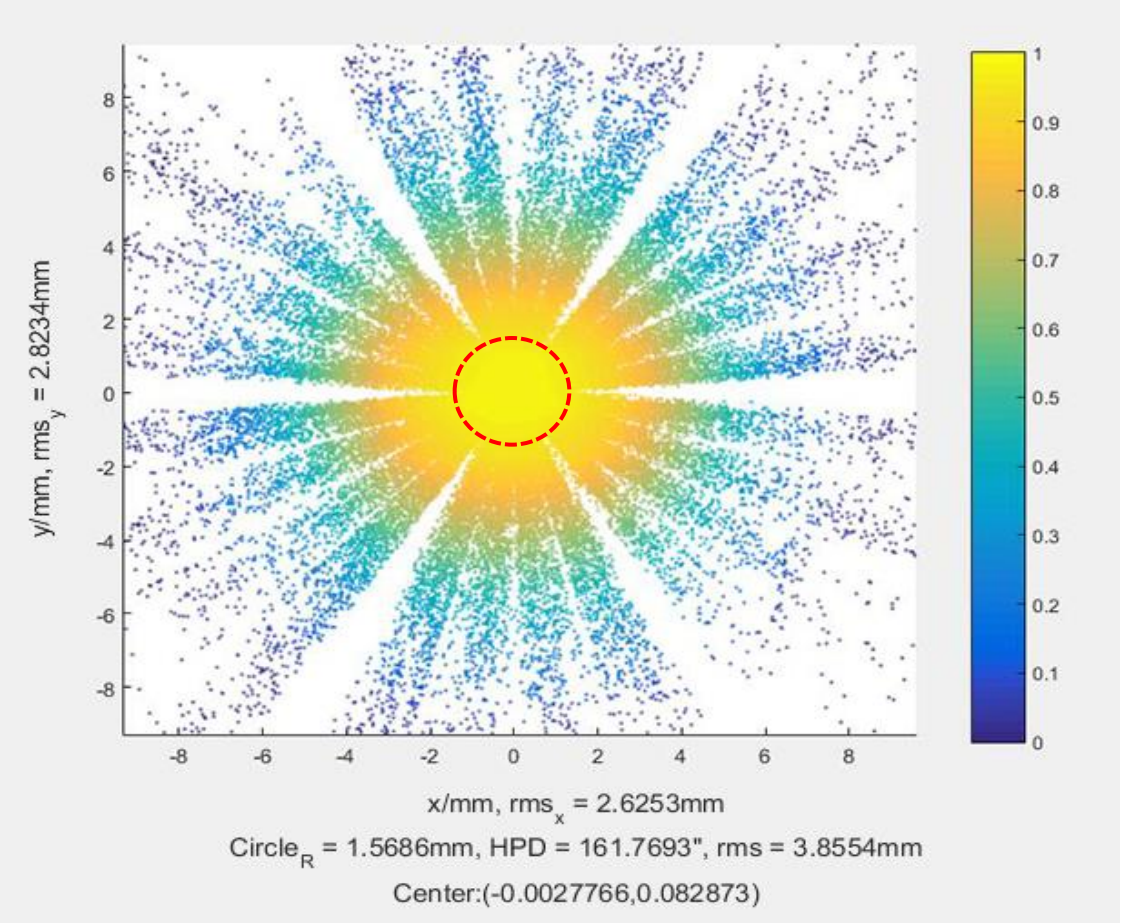
- **The ideal surface figure**
- **Reconstruction of surface figure of the telescope prototype**

Evaluation of the optics performance with metrology data

The calculated HPD performance of each mirror using the ray-tracing program with the measurement data.

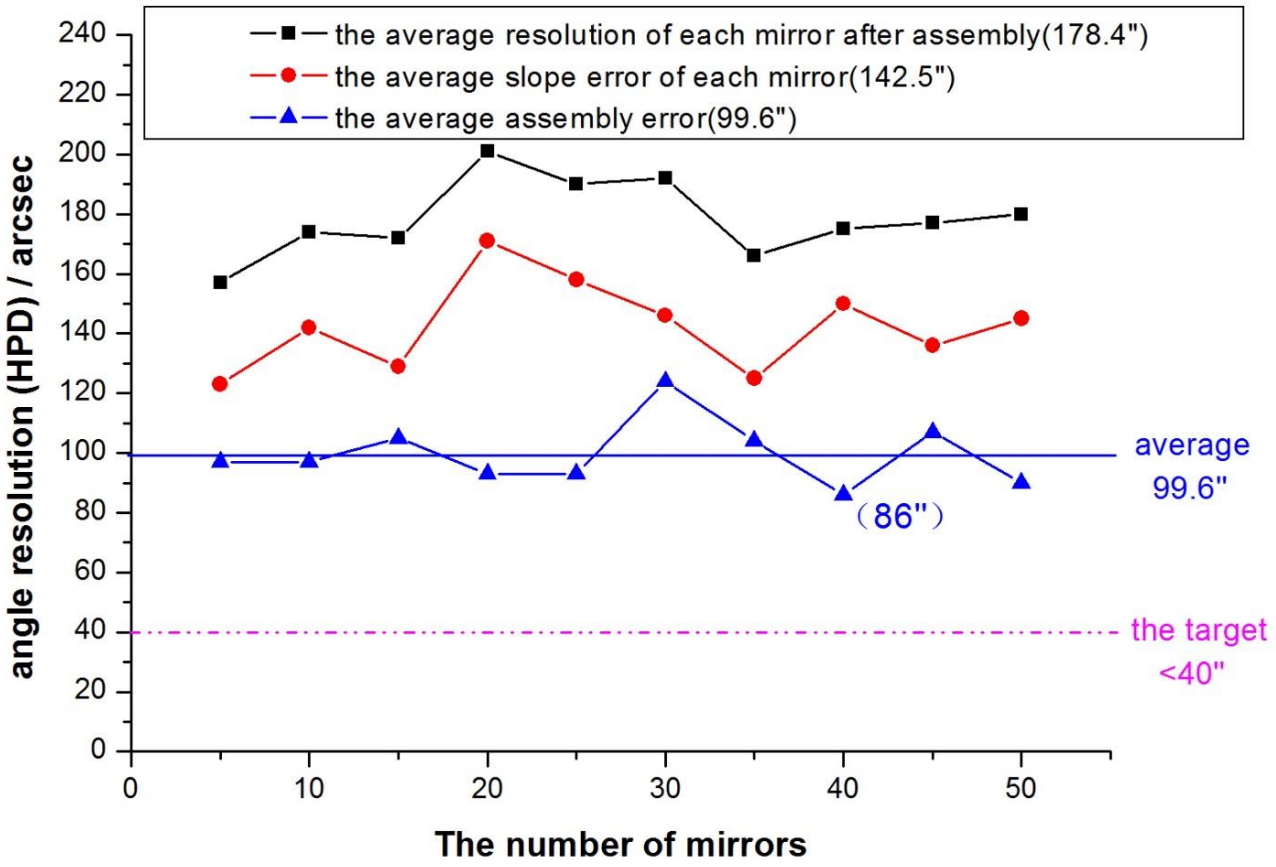


Evaluation of the prototype performance



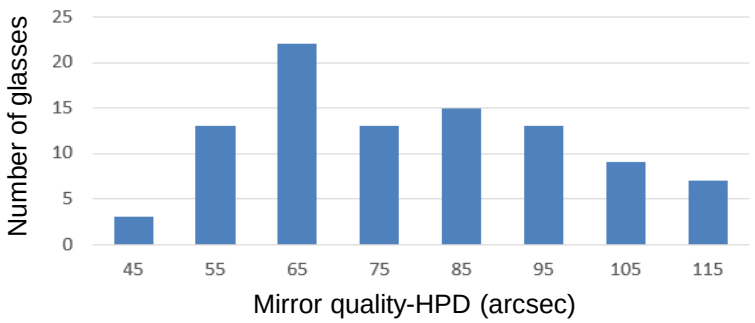
Simulated focusing performance of the prototype is 162 arcsec. Consistent with the measured result.

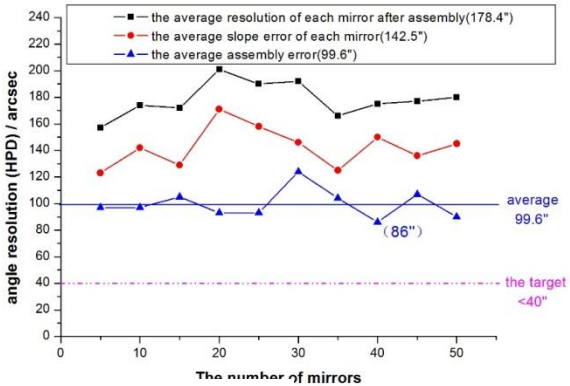
Evaluation of assembly error

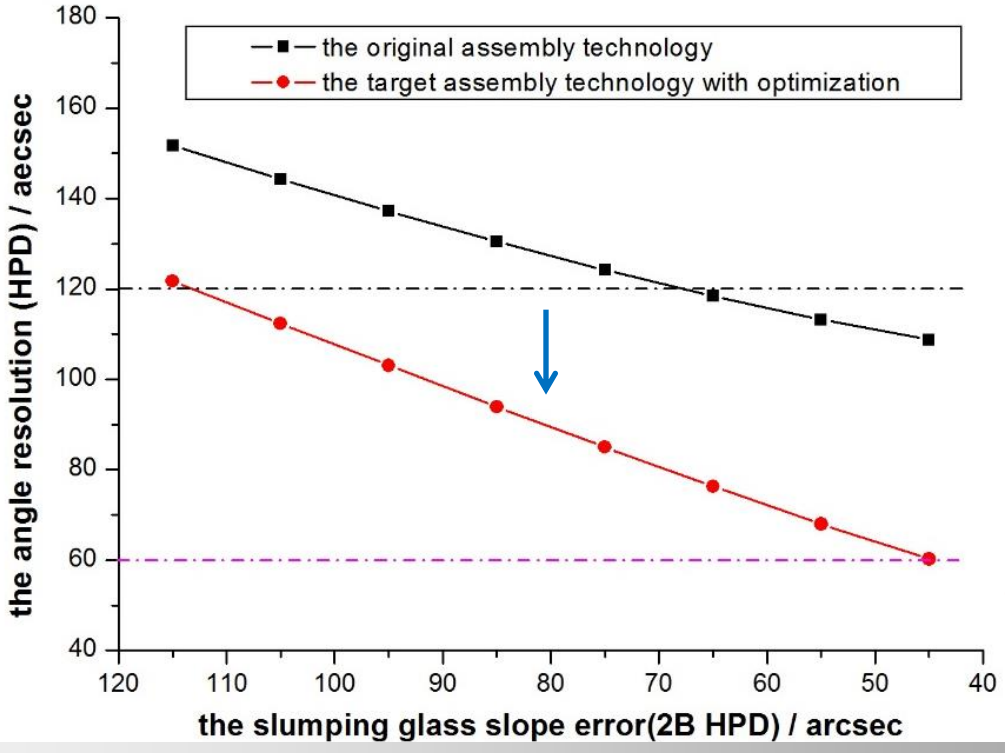


Average assembly error is ~99.6”, need to decrease to 40”.

To achieve 1 arcmin …



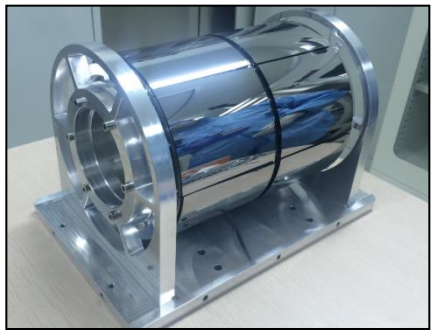




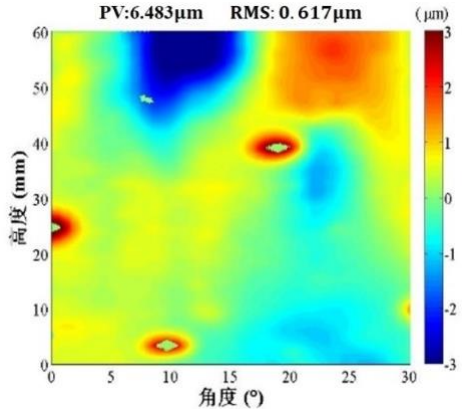
Current assembly (100”)

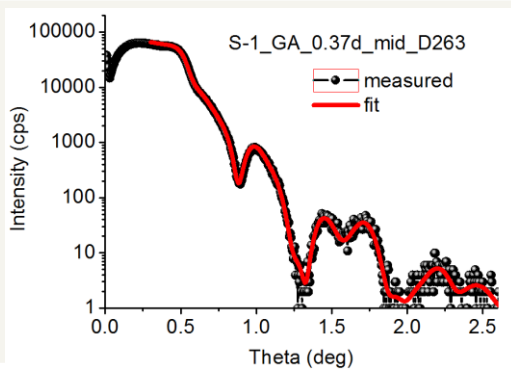
Further optimized assembly … (40”)

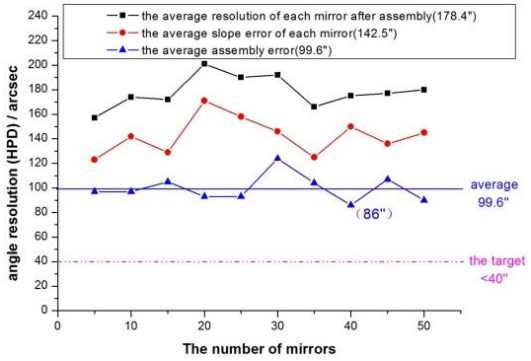
Conclusion



1st prototype HPD=~3’







Current level ~2’

Moving forward to 1 arcmin !

Thank you for your attention !