



中国科学院西安光学精密机械研究所  
XI'AN INSTITUTE OF OPTICS AND PRECISION MECHANICS OF CAS

# TMT大尺寸大气色散校正棱镜结构系统 集成设计与分析

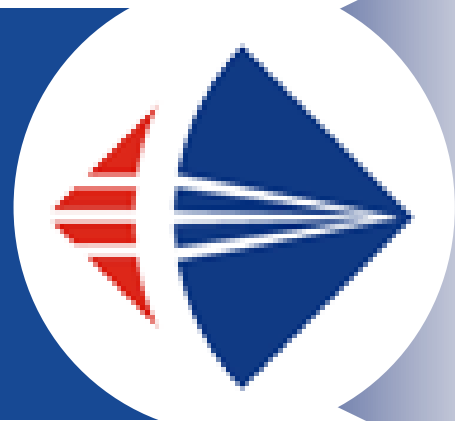
阮萍 吕涛 温婉莎

2023 Advanced Telescope and Instrument Technology Conference

2023年11月

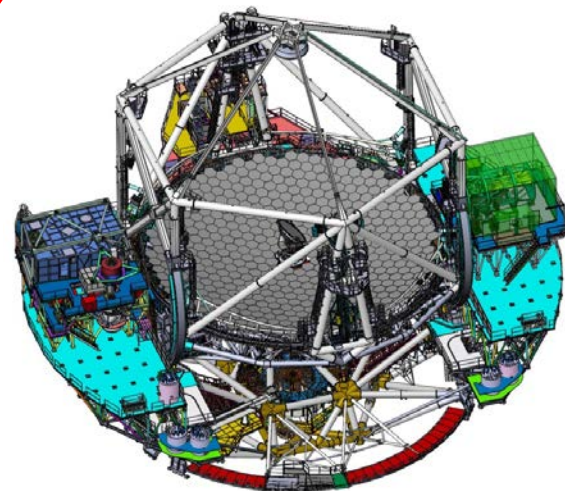
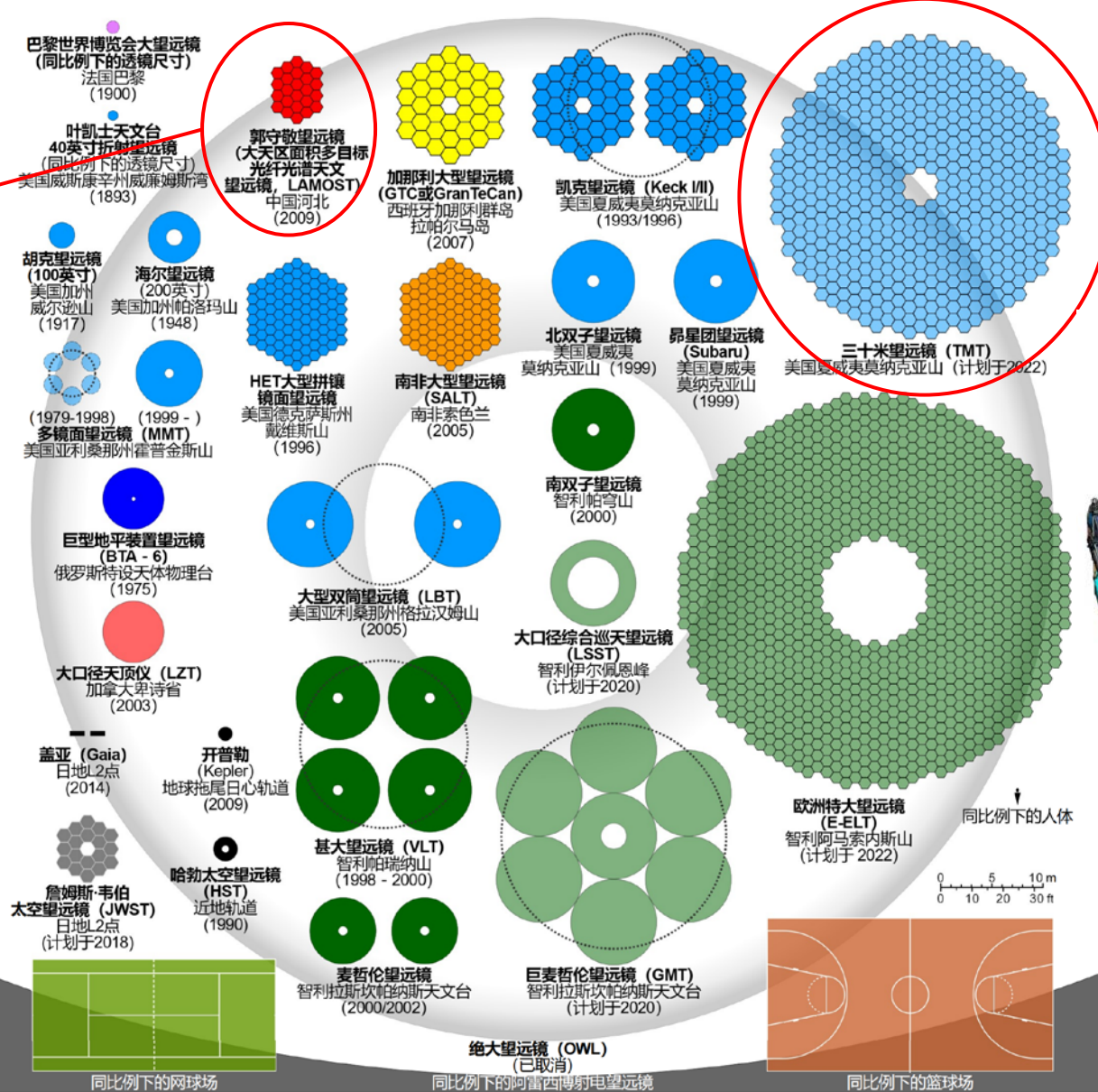
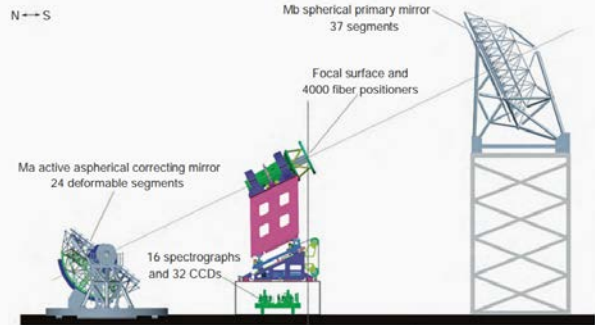
# 目录

- 1 三十米望远镜
- 2 大气色散校正器
- 3 研制进度
- 4 总结

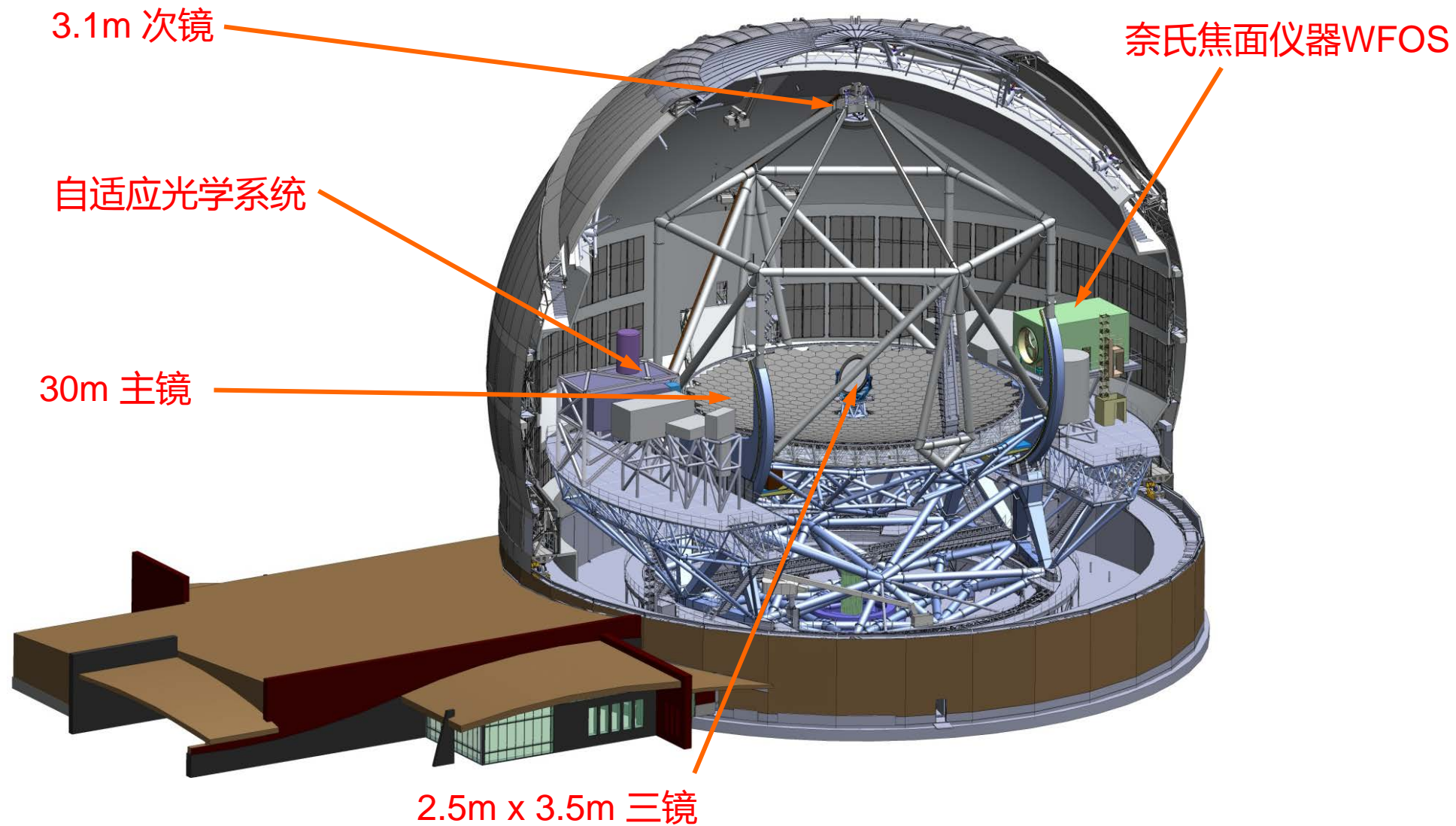


# 三十米望远镜

# 1-1 TMT

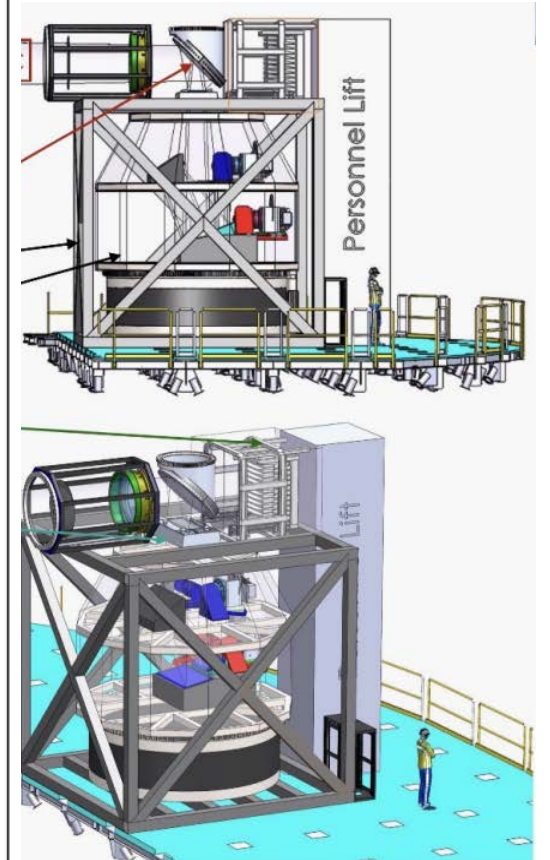
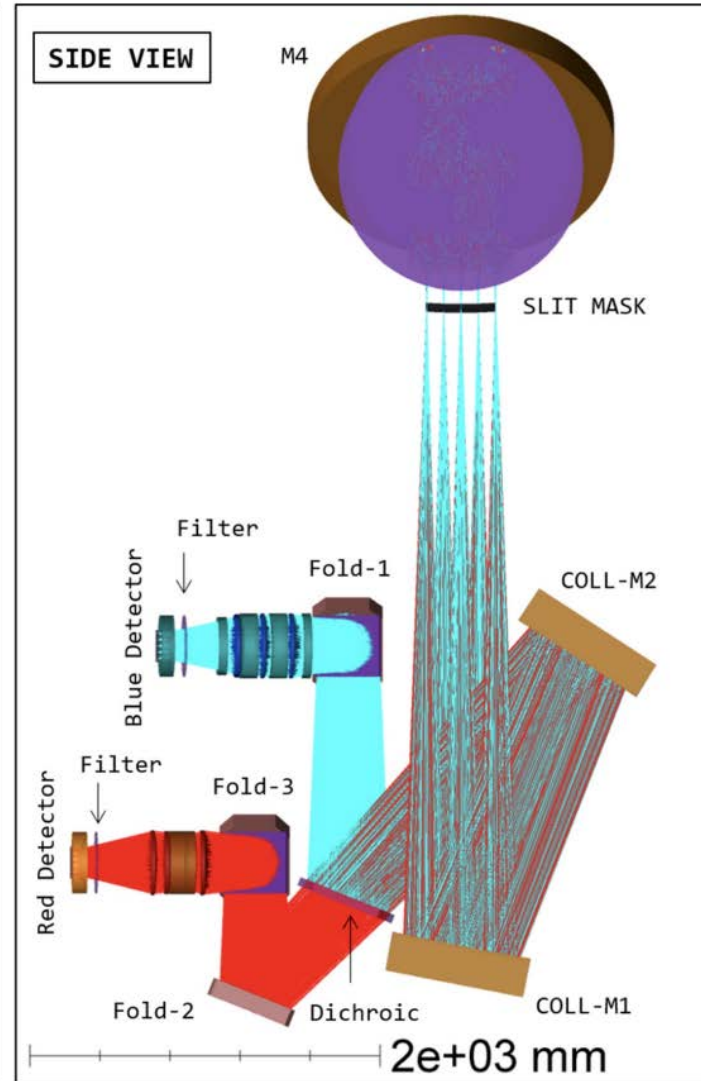
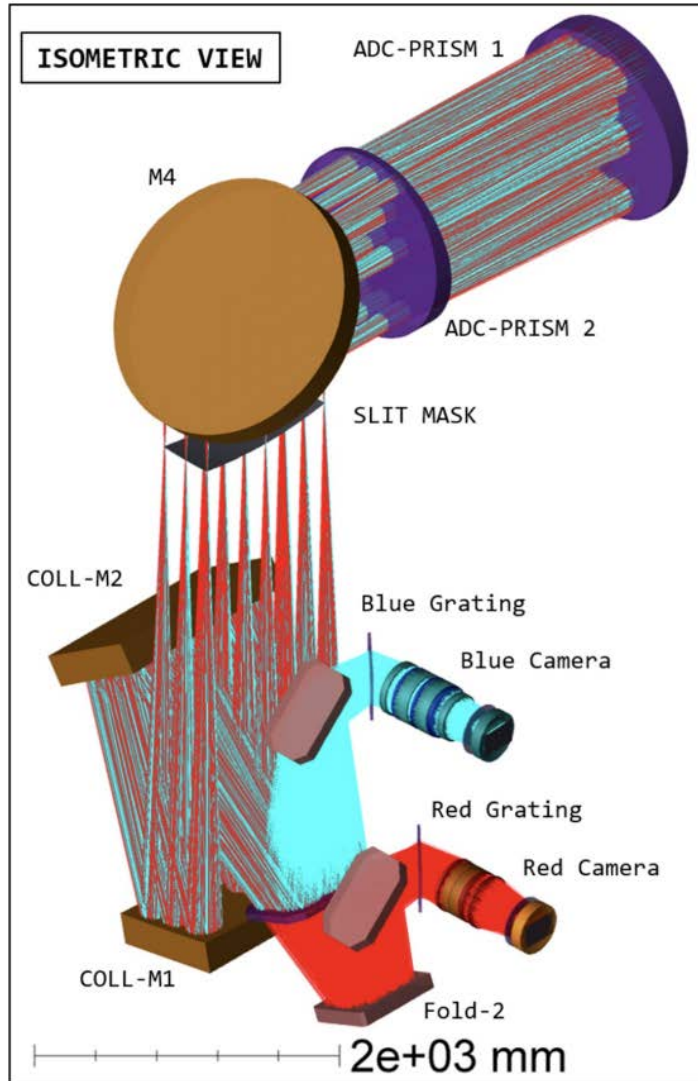
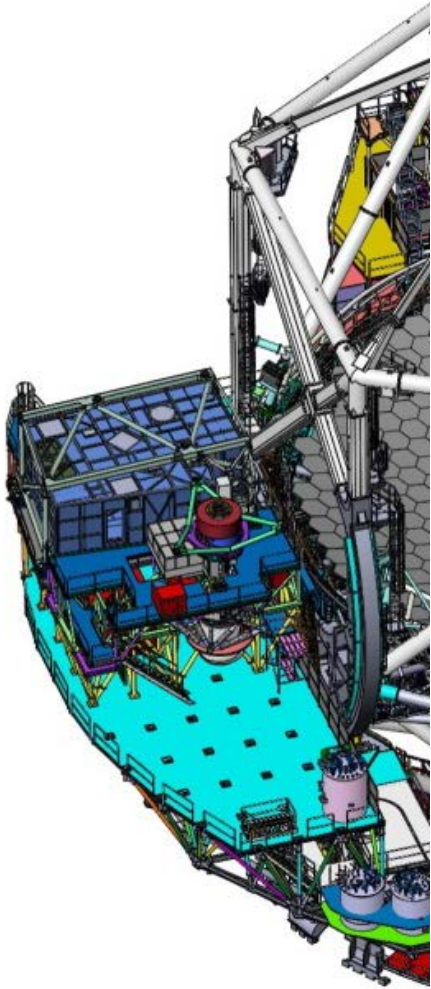


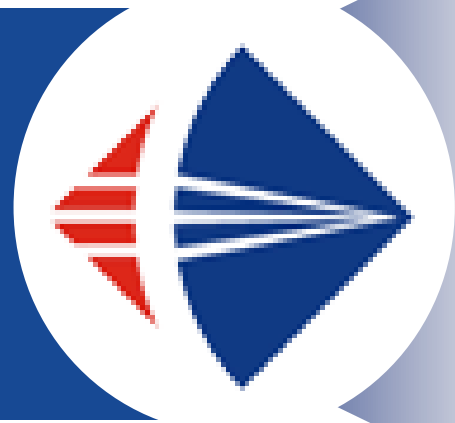
# 1-1 TMT



# 1-2 WFOS

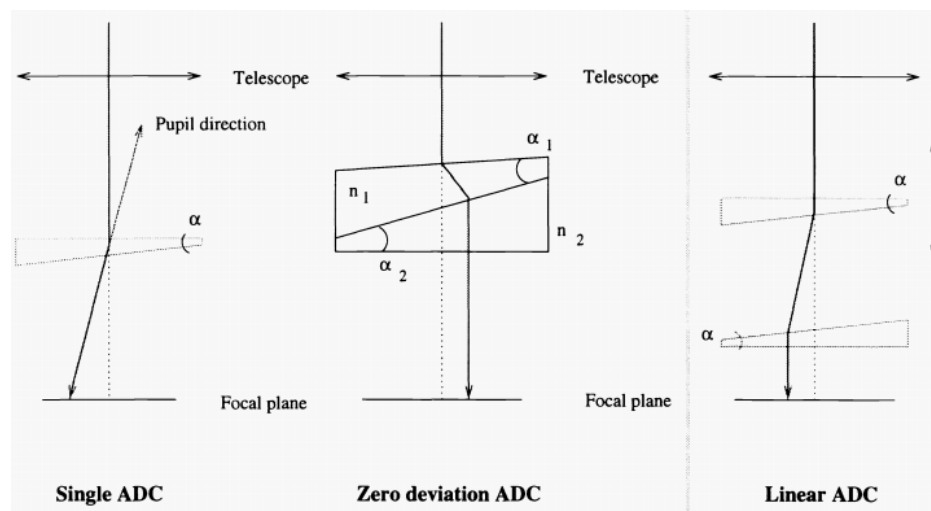
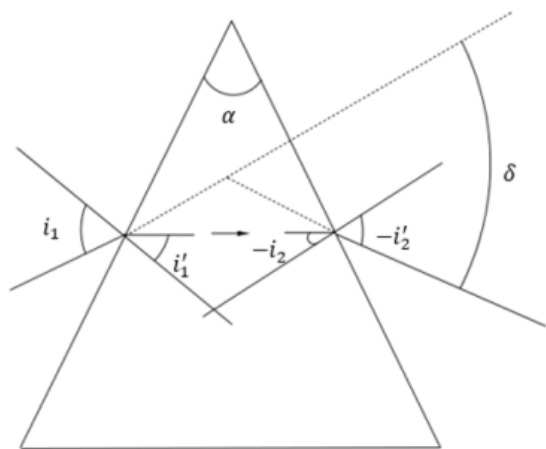
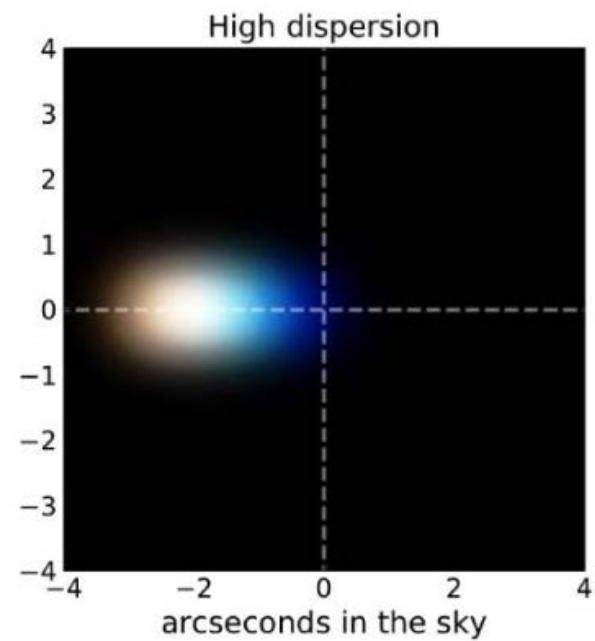
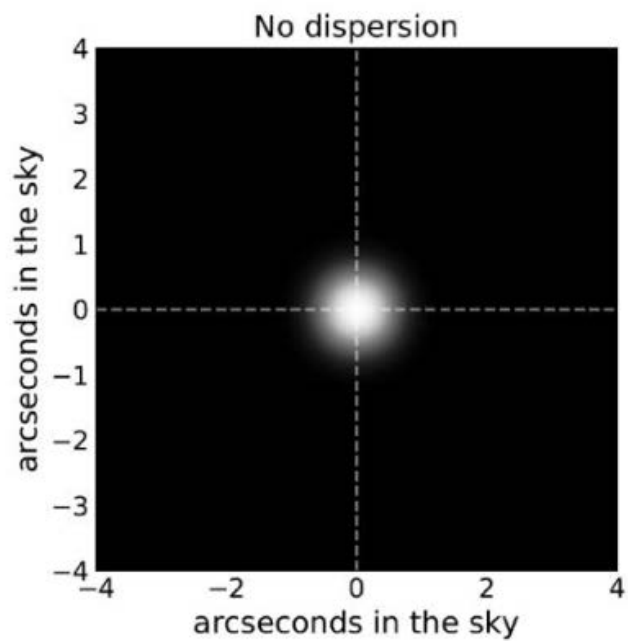
## Spectrometer Layout



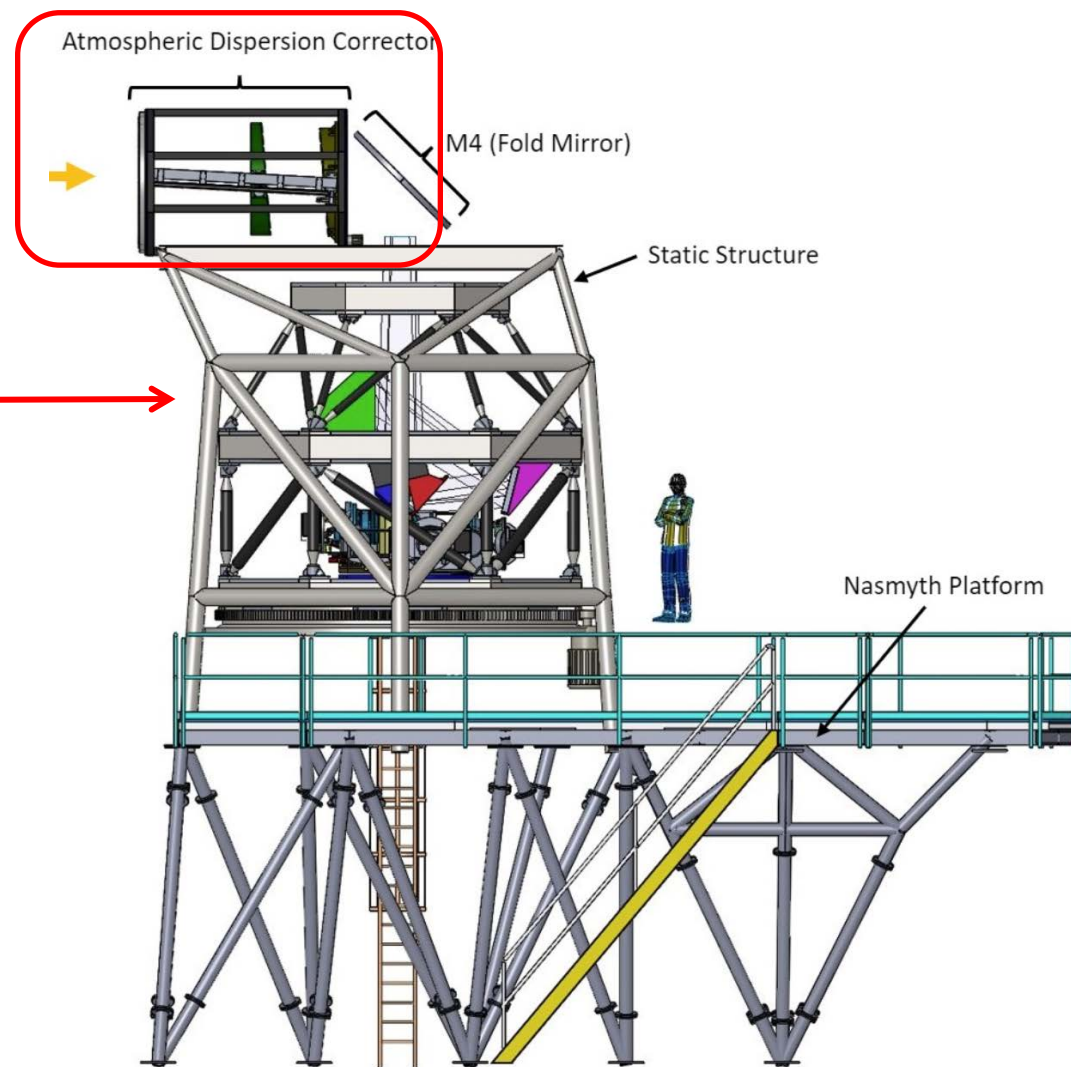
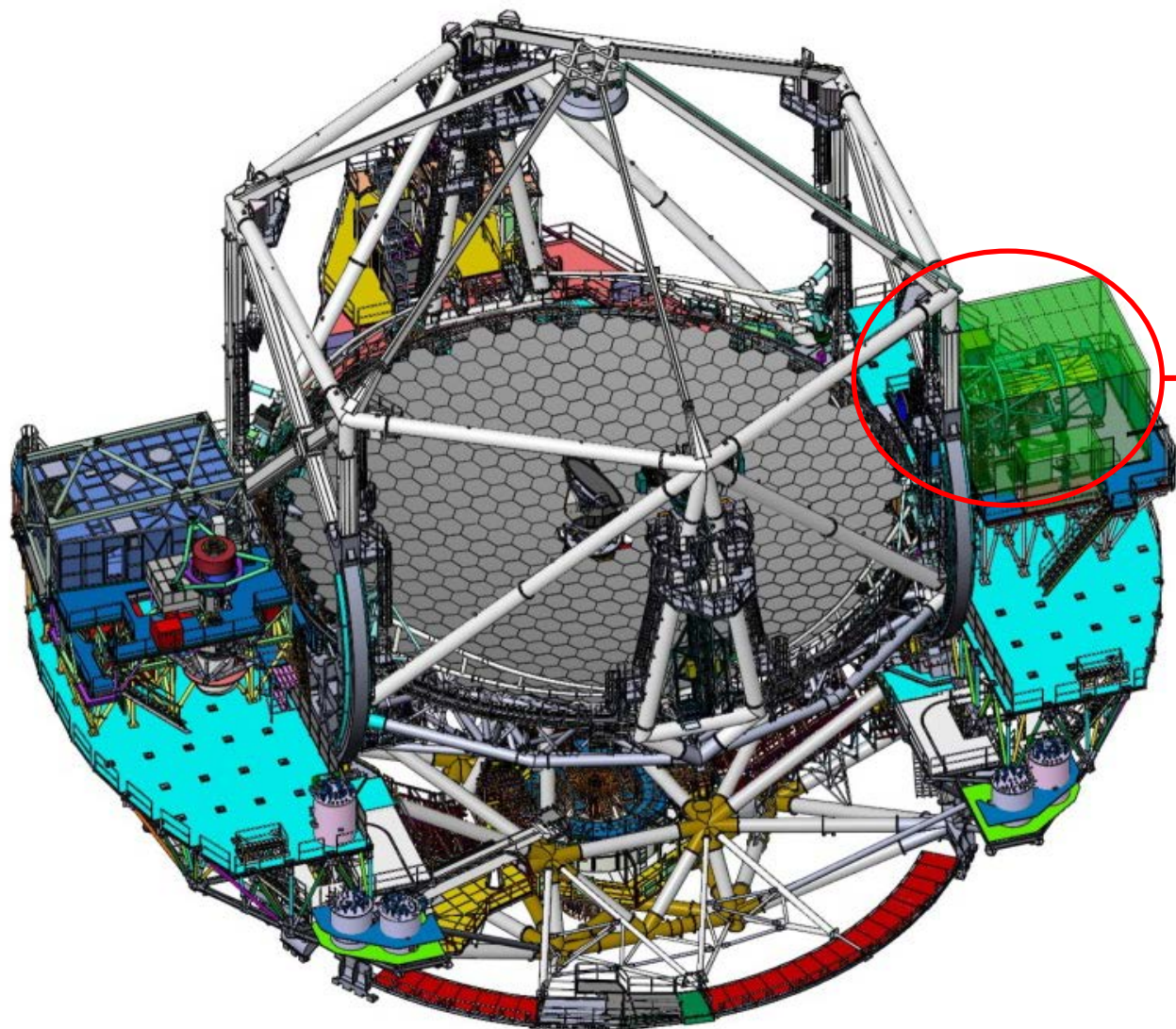


# 色散校正器

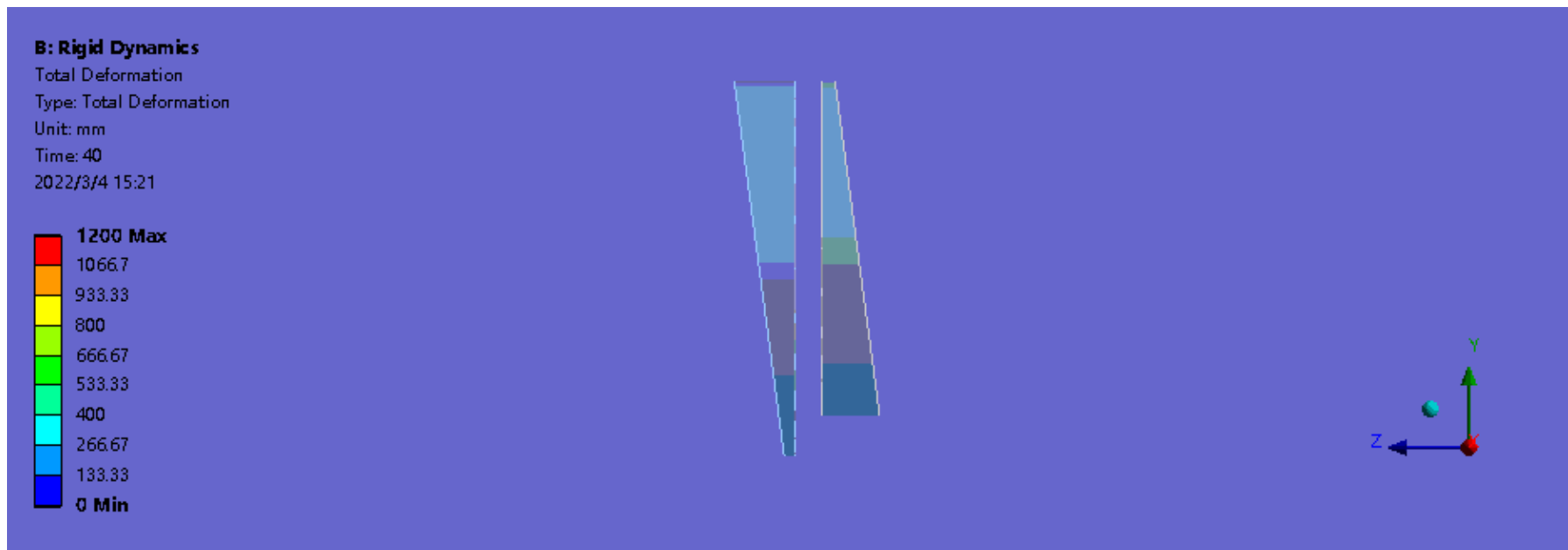
# 2 大气色散校正器



# 2 大气色散校正器



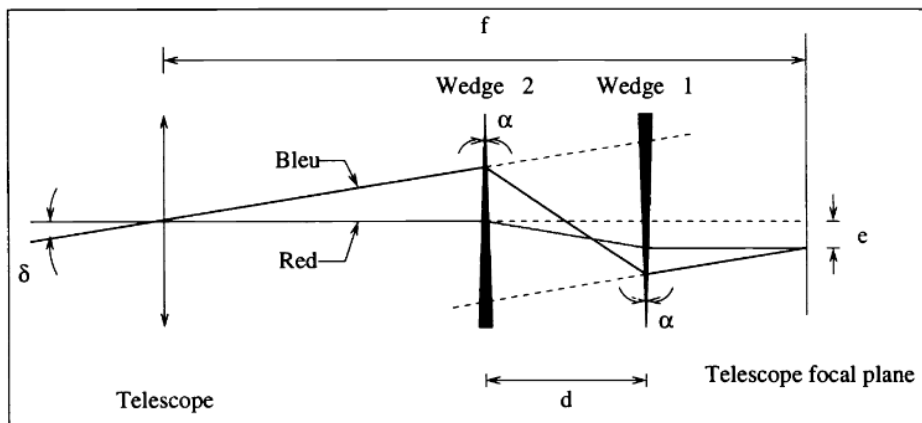
## 2 大气色散校正器



2000 mm范围内的平移运动

360°的旋转运动

# 2 大气色散校正器



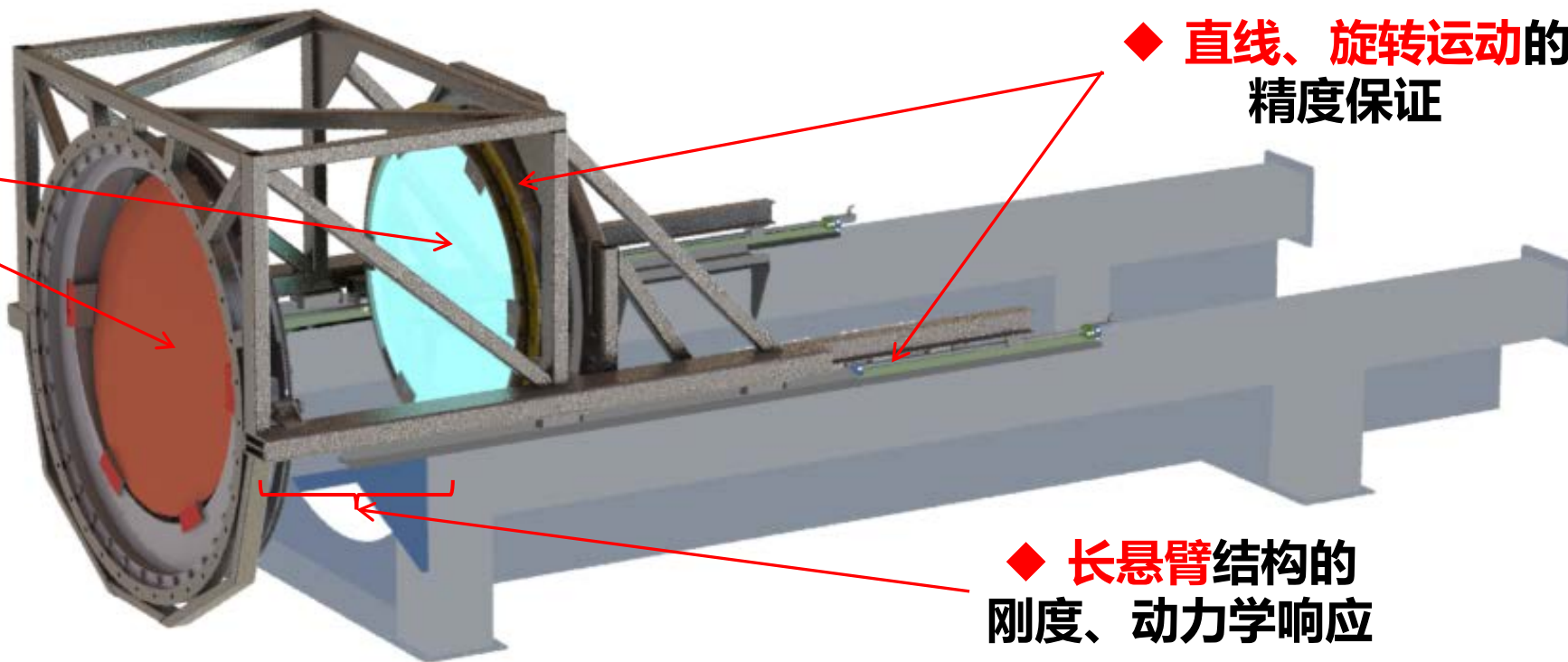
Material	silica (Herasil)
Diameter	590 mm
Prism angle	2.34°
Prism thickness	22.5 mm (centre)
Anti-reflection coating	MgF <sub>2</sub> @ 420 nm
Prism 2 motion range	20 - 1100 mm = f(z)
Prism 1 (fixed)	600 mm before Cassegrain focus



## 2 大气色散校正器

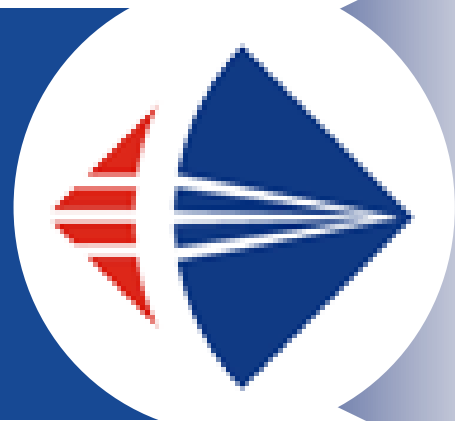
望远镜 \ 参数	补偿形式	棱镜尺寸	运动特性
VLT	LADC	590 mm	1100 mm
Keck	LADC	1000 mm	1700 mm
TMT	LADC	1460 mm	2000 mm & 360°

◆ 重力、温度、变姿态  
表面面型精度保证



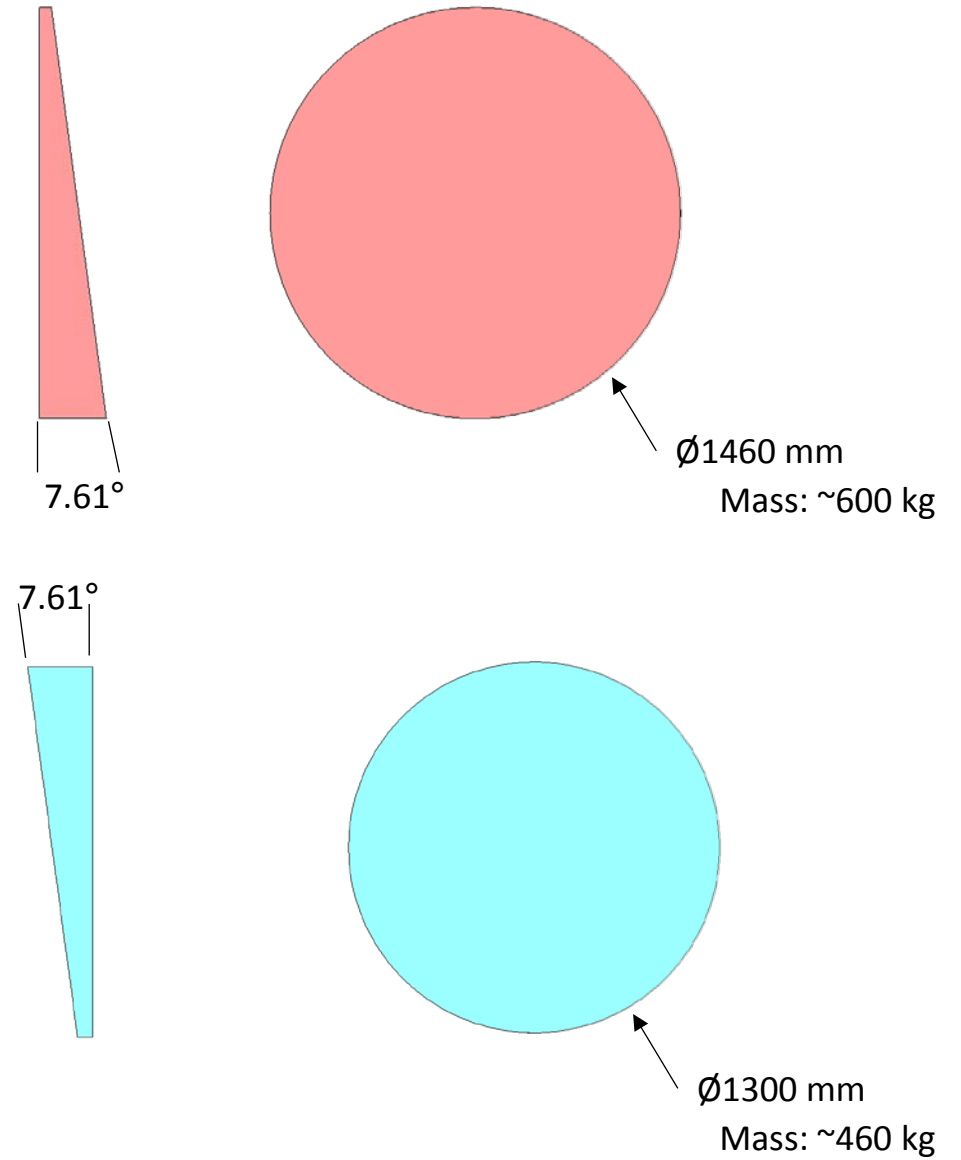
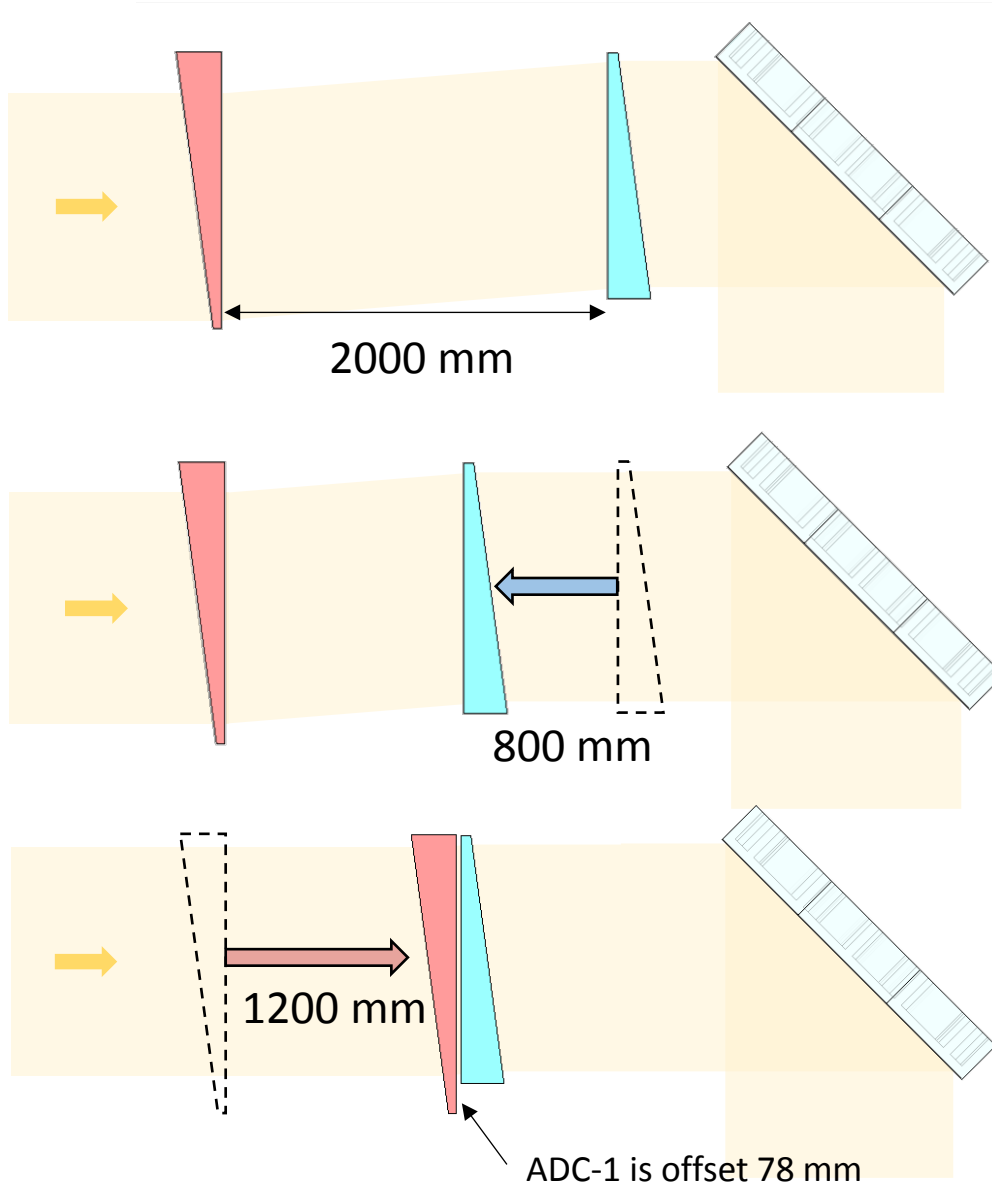
◆ 直线、旋转运动的  
精度保证

◆ 长悬臂结构的  
刚度、动力学响应

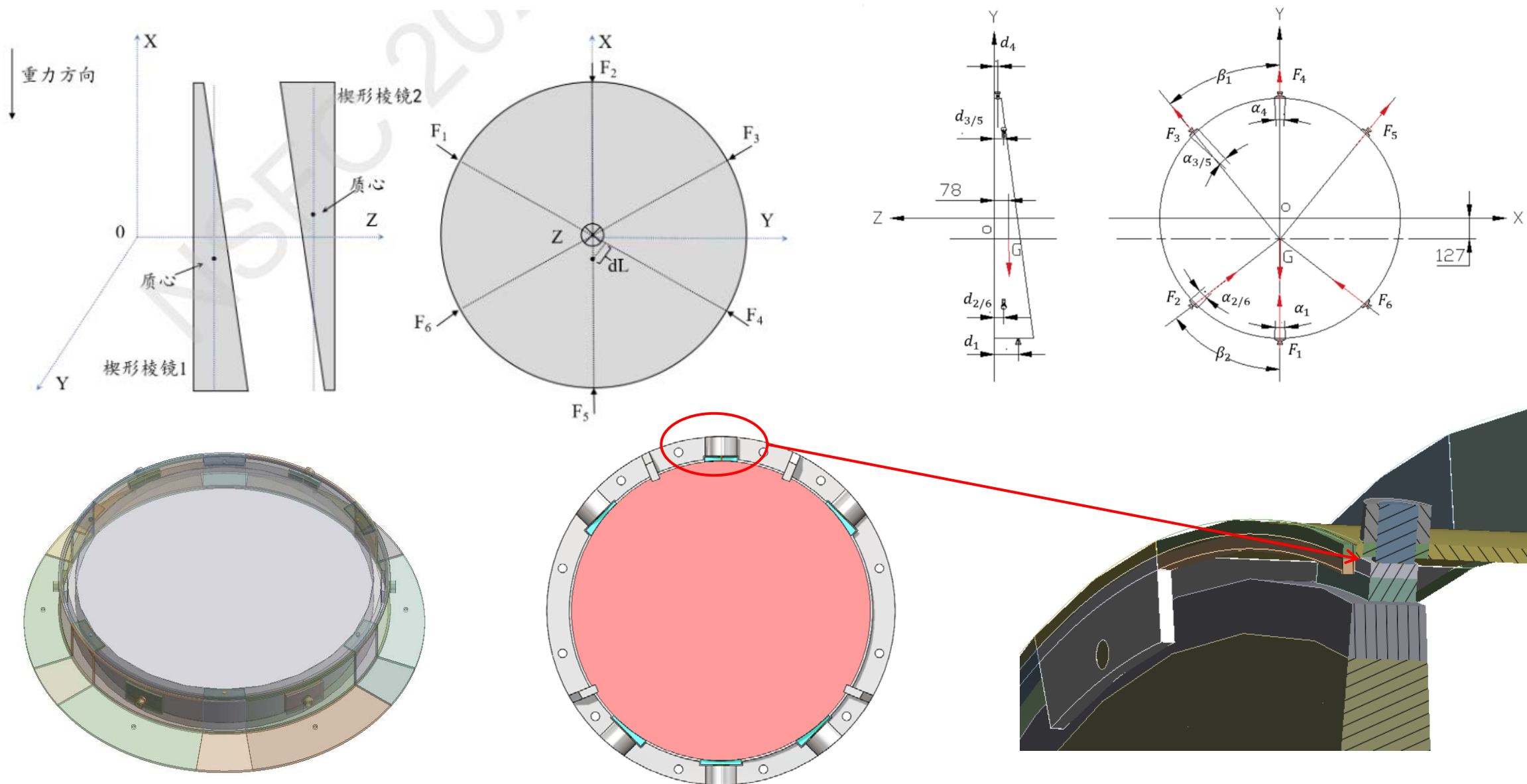


# 研制进展

# 3-1 LADC

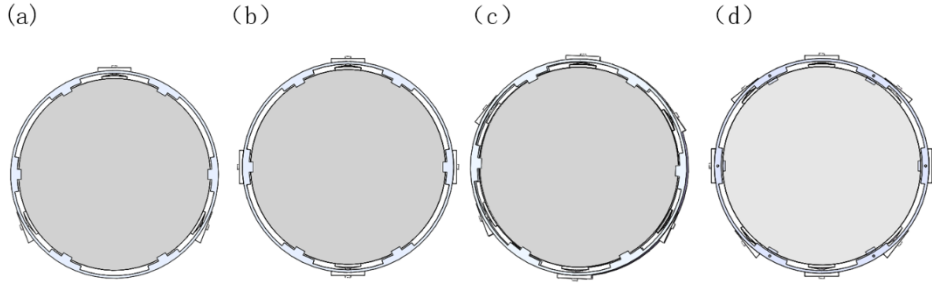


# 3-1 LADC支撑方案

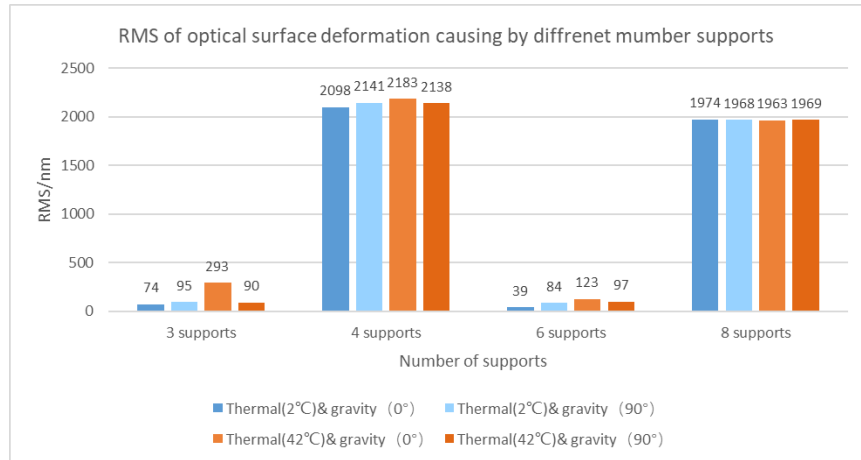


# 3-1 LADC结构参数化

支撑点个数分析对比

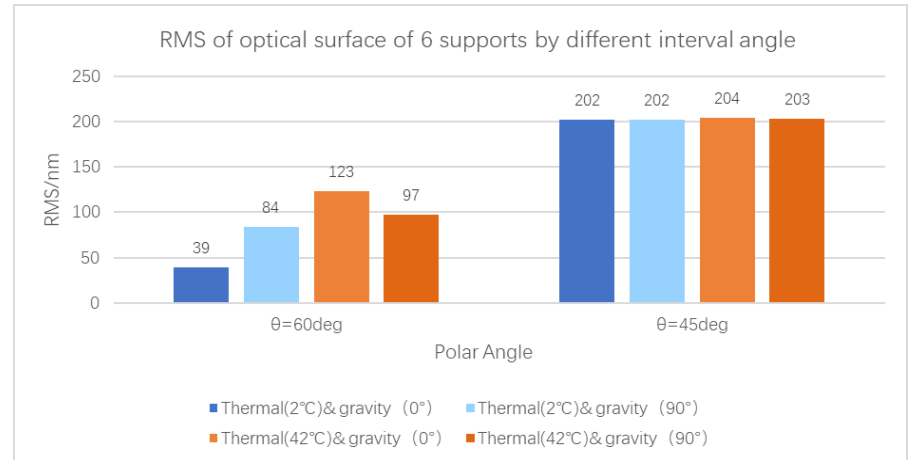
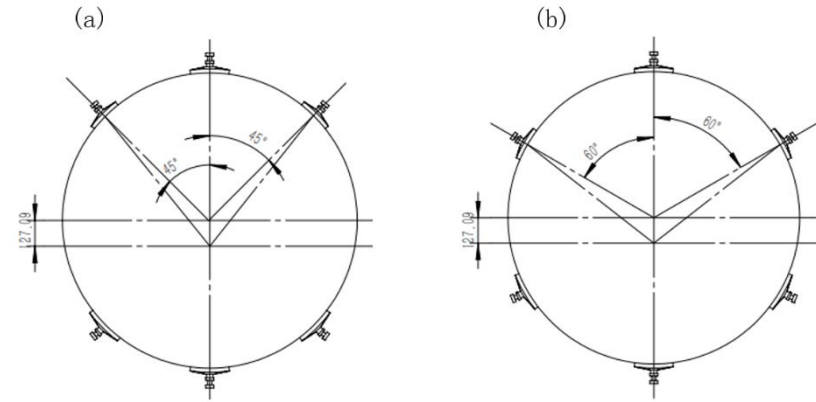


3点, 4点, 6点, 8点支撑方案



3点, 4点, 6点, 8点支撑方案在不同工况下的光学表面RMS值

六点支撑点位置分析对比

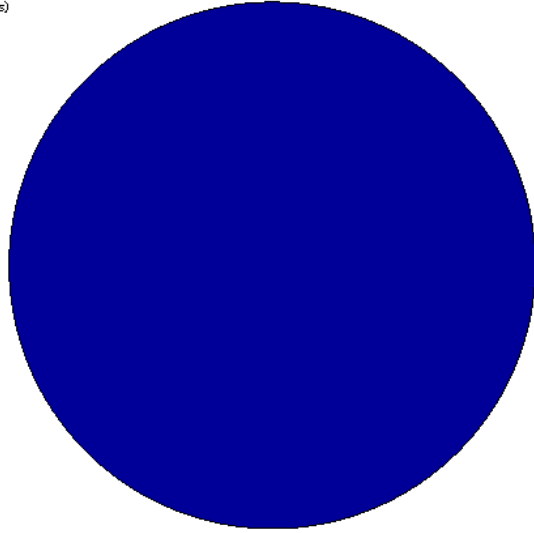
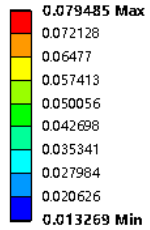


45°布局及60°布局在不同工况下的表面RMS值

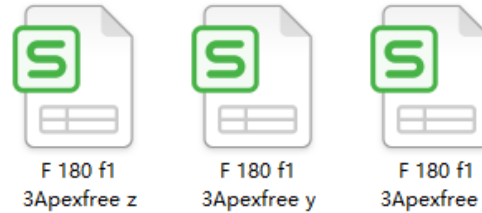
# 3-1 LADC集成分析

## B: Static Structural

Directional Deformation  
 Type: Directional Deformation(Z Axis)  
 Unit: mm  
 Global Coordinate System  
 Time: 1 s  
 2023/11/18 10:48



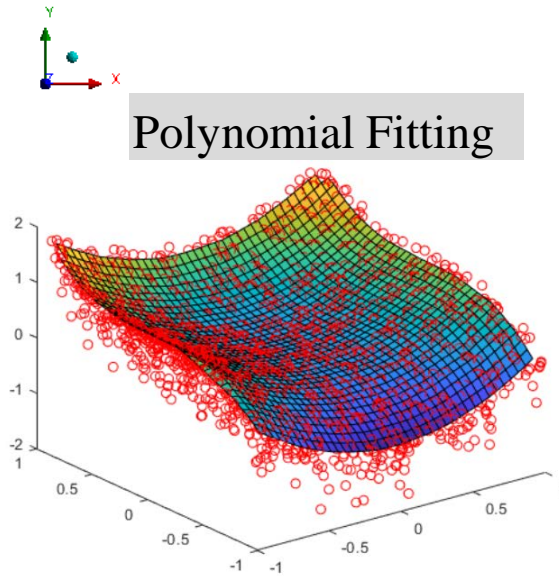
Export displacement data from FEA



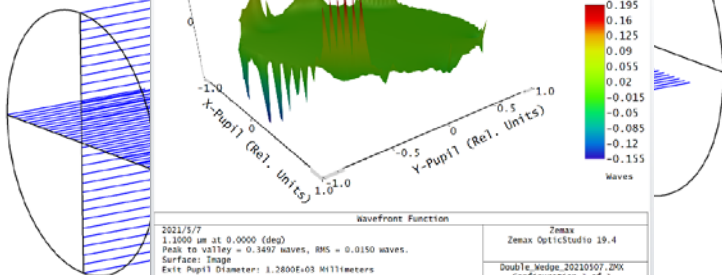
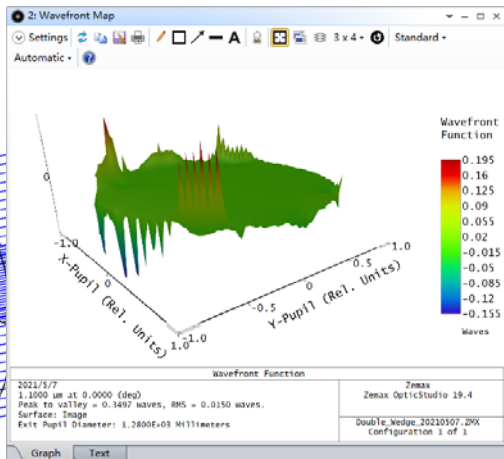
Surface nodes information

A	B	C	D	E	F	G
Node Number	X Location (mm)	Y Location (mm)	Z Location (mm)	Directional Deformation (mm)		
35703	-1.3693	207.1	0	-2.67E-06		
35715	598.65	177.25	0	-6.84E-06		
35730	56.844	159.47	0	-2.50E-06		
35731	104.29	145.98	0	-2.65E-06		
35759	576.04	148.79	0	-8.39E-06		
35760	613.27	146.05	0	-8.10E-06		
35774	-57.608	0.29757	0	-2.11E-06		
35779	-126.67	-312.33	0	-8.92E-06		
35785	581.38	346.08	0	7.48E-06		
35793	23.357	114.43	0	-2.54E-06		
35794	-51.928	66.608	0	-2.14E-06		
35805	246.45	-198.49	0	4.59E-06		
35810	-77.207	203.06	0	-3.21E-06		
35829	-619.43	-2.2193	0	6.54E-06		
35847	207.56	599.07	0	1.86E-05		
35849	187.63	510.68	0	1.43E-05		
35851	-629.72	34.999	0	6.35E-06		
35852	-661.68	-2.8228	0	6.92E-06		

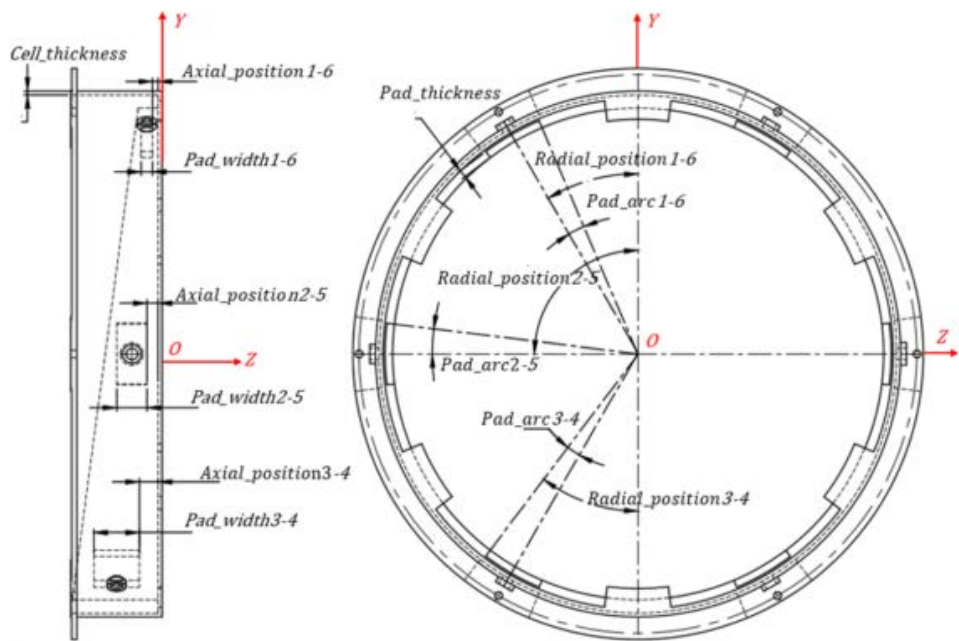
Polynomial Fitting



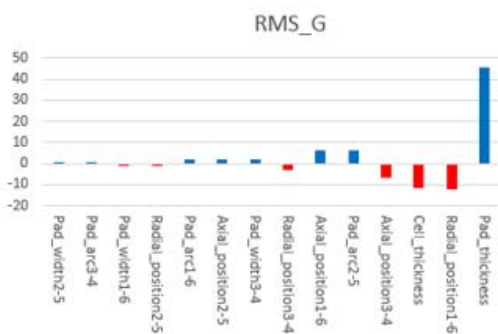
```
Zernike_Main.m x +
70 - InitialResidual=result_displacement_ures-zMatrix*ZernikeCoefficient;
71 - Weight=EvaluateWeight([X, Y], 1);
72 - WeightedZernikeCoefficient=lscov(zMatrix, result_displacement_ures, Weight);
73 - WeightedResidual=result_displacement_ures-zMatrix*WeightedZernikeCoefficient;
74 - MRSE=result_displacement_ures-ZernikeCoefficient(1)*zMatrix(:, 1)-ZernikeCoefficient(1)*zMatrix(:, 1);
75 - MRSE1=result_displacement_ures-WeightedZernikeCoefficient(1)*zMatrix(:, 1)-WeightedZernikeCoefficient(1)*zMatrix(:, 1);
76 - MRSE2=result_displacement_ures-ZernikeCoefficient(1)*zMatrix(:, 1)-ZernikeCoefficient(1)*zMatrix(:, 1);
77 - % WeightedZernikeCoefficient1=lscov(zMatrix, result_displacement_ures, Weight);
78 - % WeightedResidual1=result_displacement_ures-zMatrix*WeightedZernikeCoefficient1;
79 - % MRSE2=result_displacement_ures-WeightedZernikeCoefficient1(1)*zMatrix(:, 1)-WeightedZernikeCoefficient1(1)*zMatrix(:, 1);
80 -
81 - [m n]=size(MRSE);
82 - pv=max(MRSE)-min(MRSE);
83 - rms=sqrt(sum((MRSE-mean(MRSE)).^2)/(m));
```



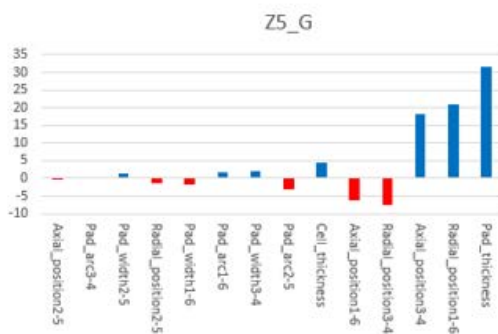
# 3-1 LADC集成分析



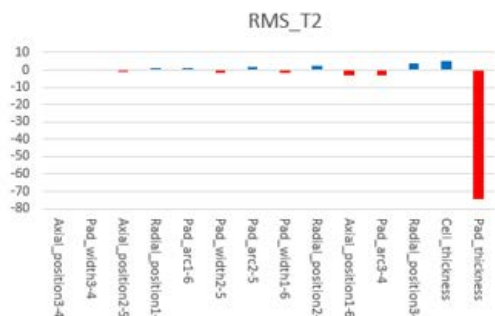
Variable name	<i>Axial_position1 – 6</i>	<i>Axial_position2 – 5</i>	<i>Axial_position3 – 4</i>
Value range	15mm – 50mm	40mm – 100mm	55mm – 160mm
<i>Radial_position1 – 6</i>	<i>Radial_position2 – 5</i>	<i>Radial_position3 – 4</i>	<i>Pad_arc1 – 6</i>
15° – 45°	75° – 105°	15° – 45°	1.5° – 7°
<i>Pad_arc2 – 5</i>	<i>Pad_arc3 – 4</i>	<i>Pad_width1 – 6</i>	<i>Pad_width2 – 5</i>
1.5° – 7°	1.5° – 7°	25mm – 35mm	30mm – 84mm
<i>Pad_width3 – 4</i>	<i>Pad_thickness</i>	<i>Cell_thickness</i>	
30mm – 150mm	4mm – 31mm	5mm – 15mm	



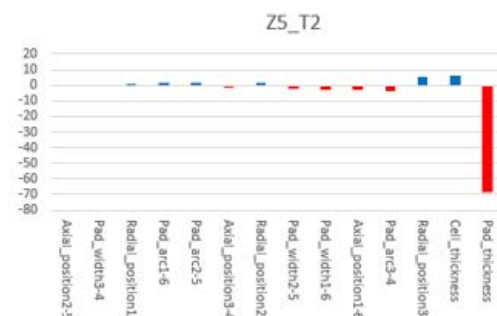
(a)



(b)

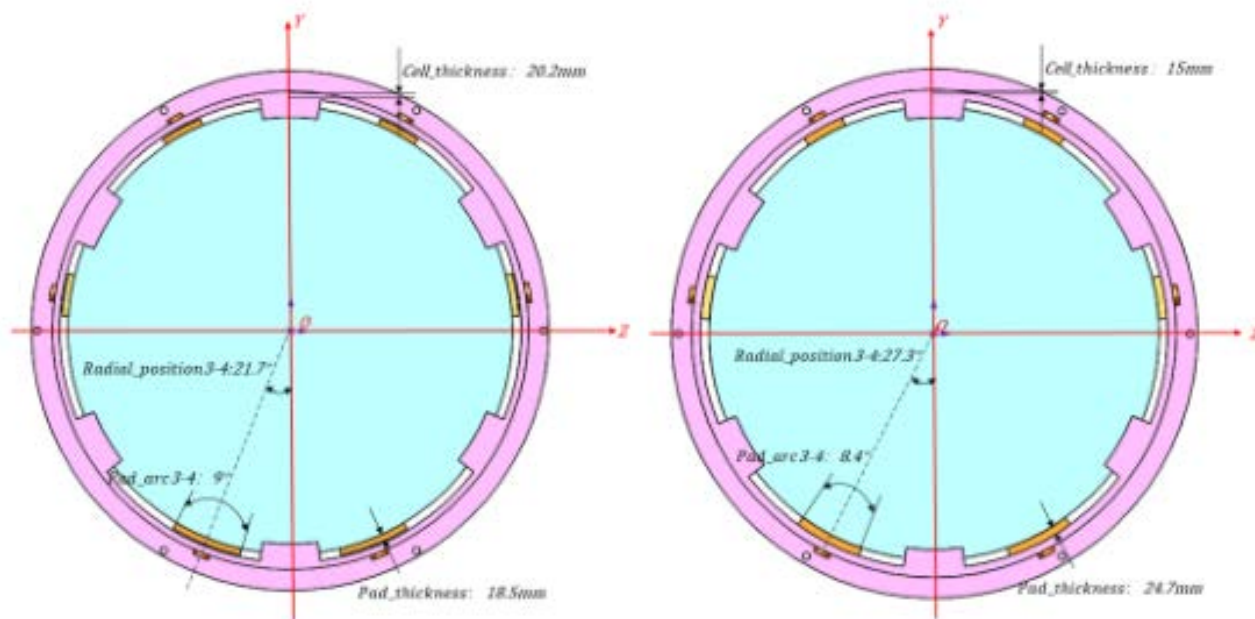


(c)



(d)

# 3-1 LADC集成分析

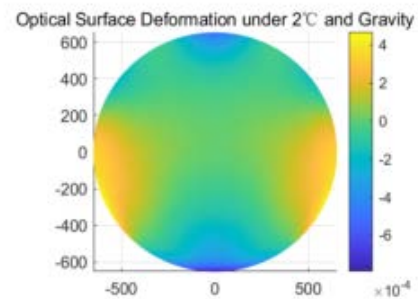


Input parameters

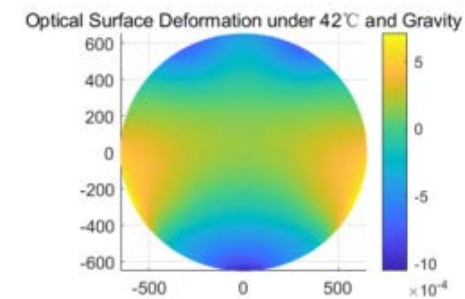
	Pad_thickness	Cell_thickness	Radial_position3-4	Pad_arc3-4
Initial value	20mm	10mm	30°	7°
Optimum value	24.7mm	15mm	27.3°	8.4°

Results

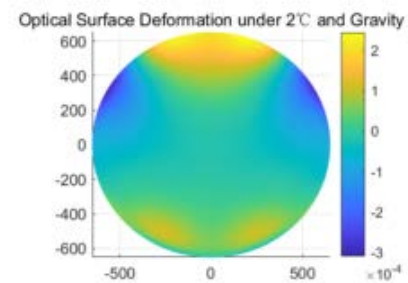
	RMS-G-2°C	RMS-G-42°C
Initial value	154.99nm	289.13nm
Optimum value	78.6nm	108.4nm



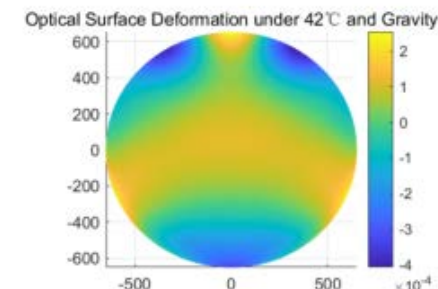
(a)



(b)



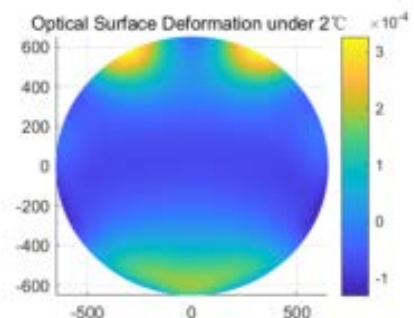
(c)



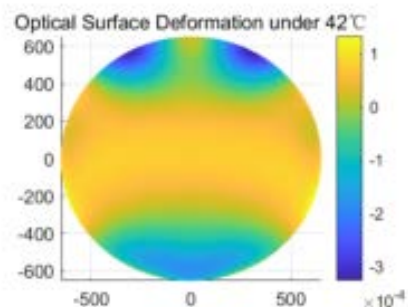
(d)

力热耦合条件下的光学表面变形

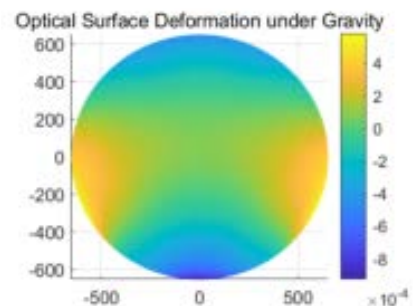
# 3-1 LADC集成分析



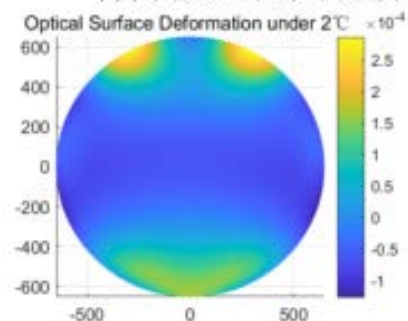
(a) 优化前 2°C 下的光学表面变形



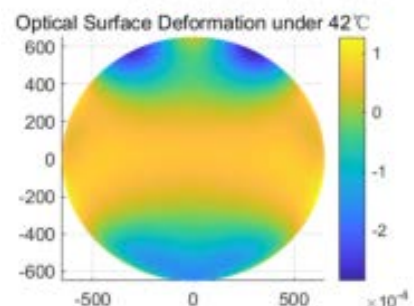
(b) 优化前 42°C 下的光学表面变形



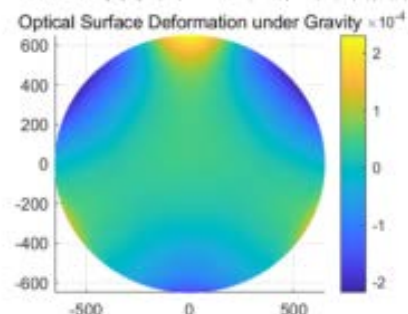
(c) 优化前重力工况下的变形



(d) 优化后 2°C 下的光学表面变形

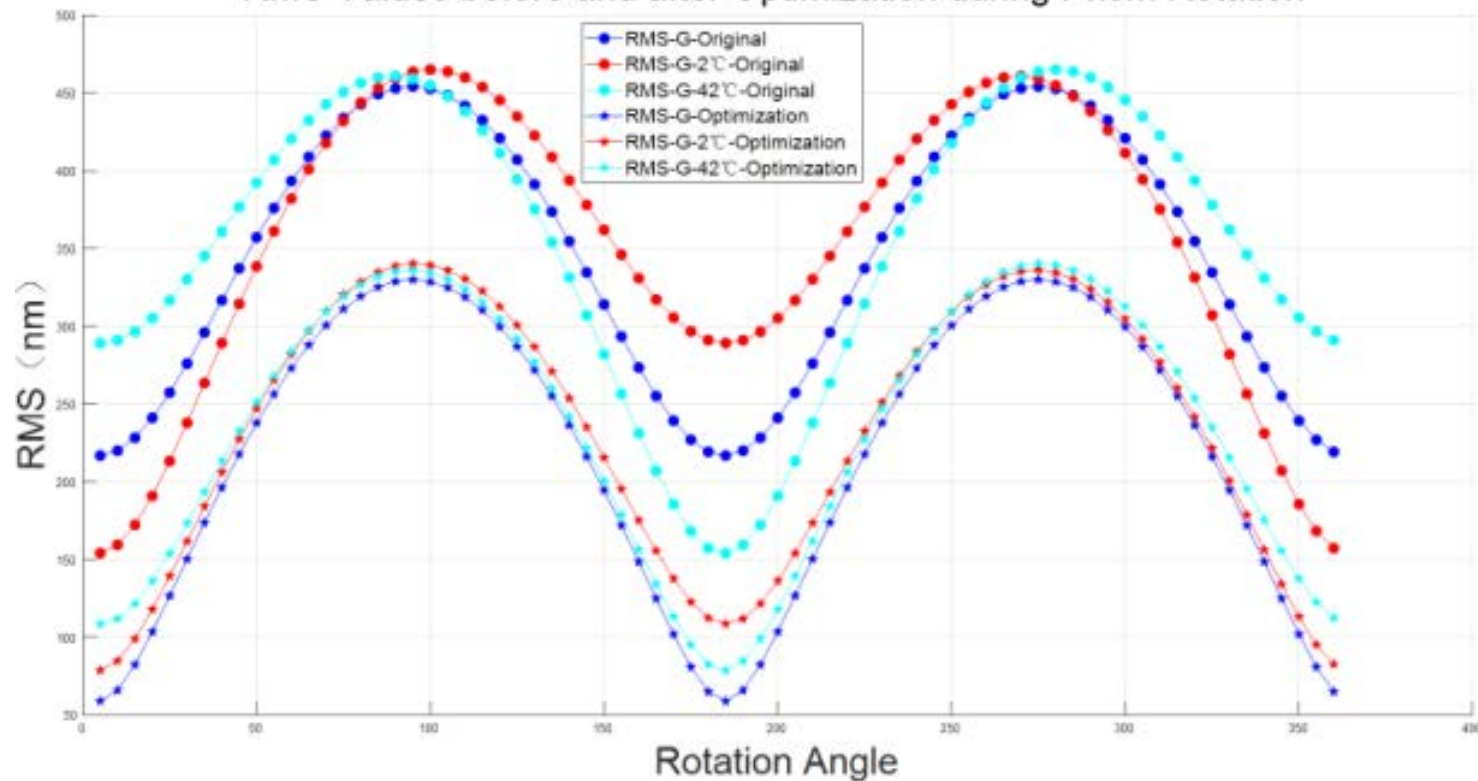


(e) 优化后 42°C 下的光学表面变形

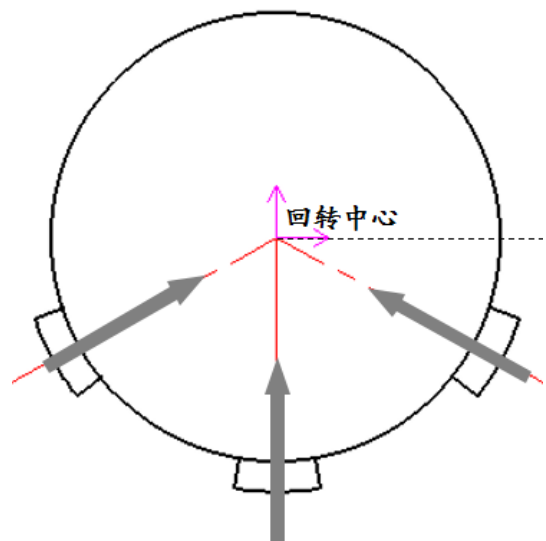


(f) 优化后重力工况下的变形

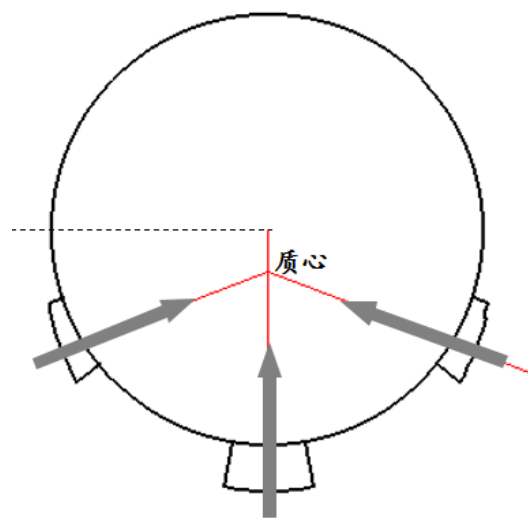
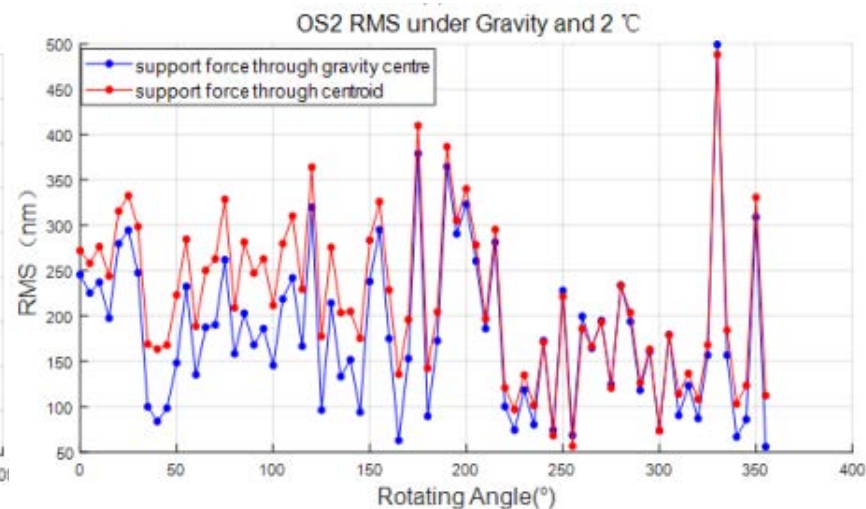
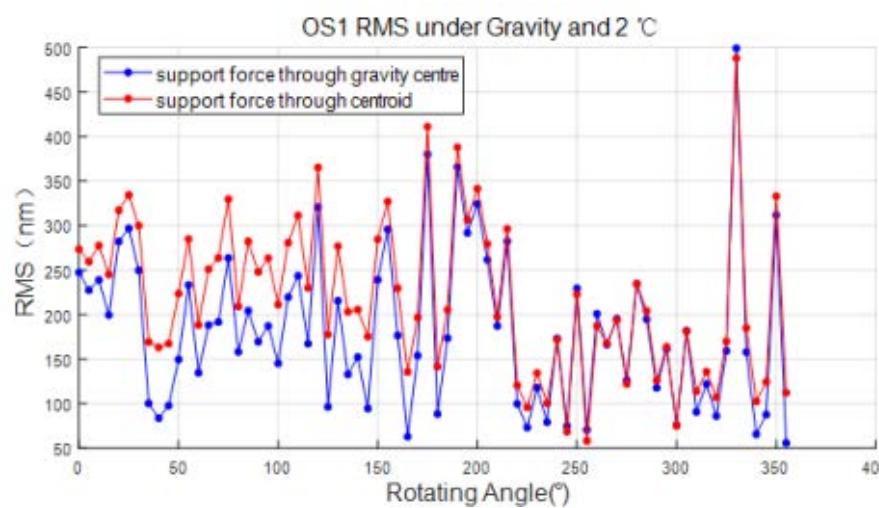
RMS Values before and after Optimization during Prism Rotation



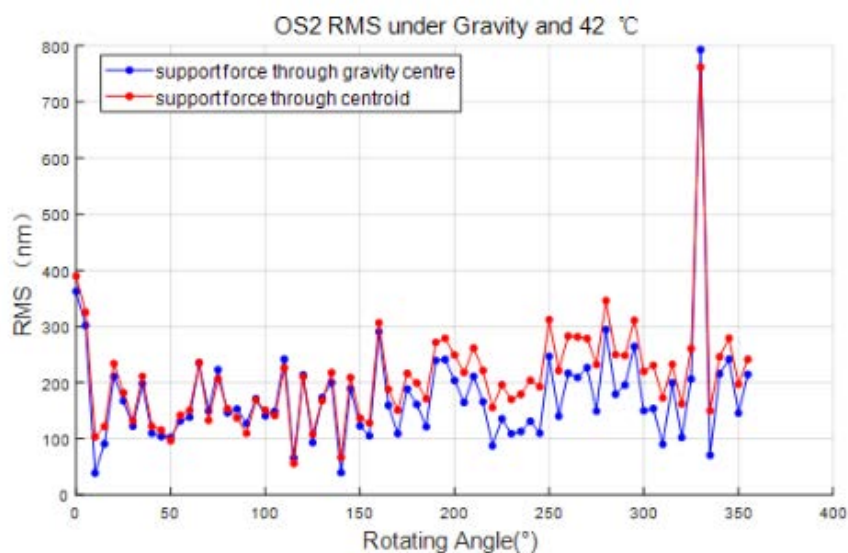
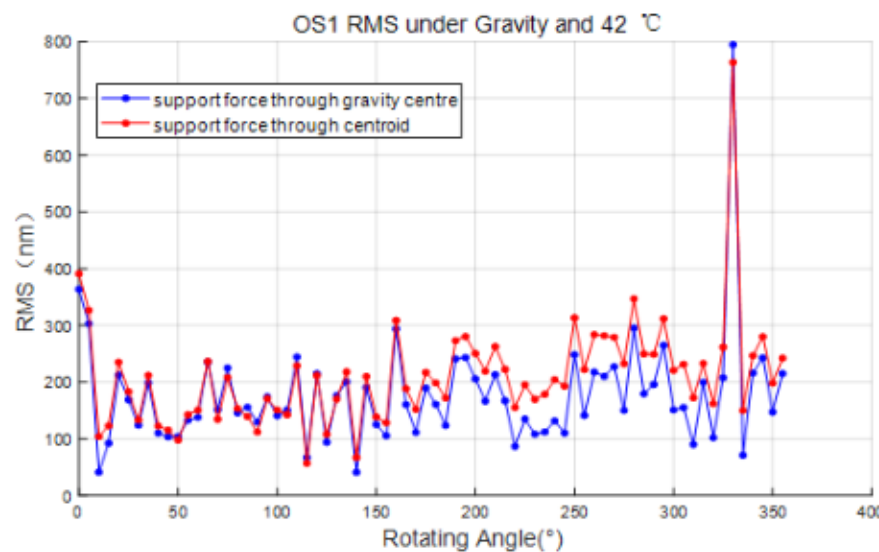
# 3-1 LADC集成分析



(a)

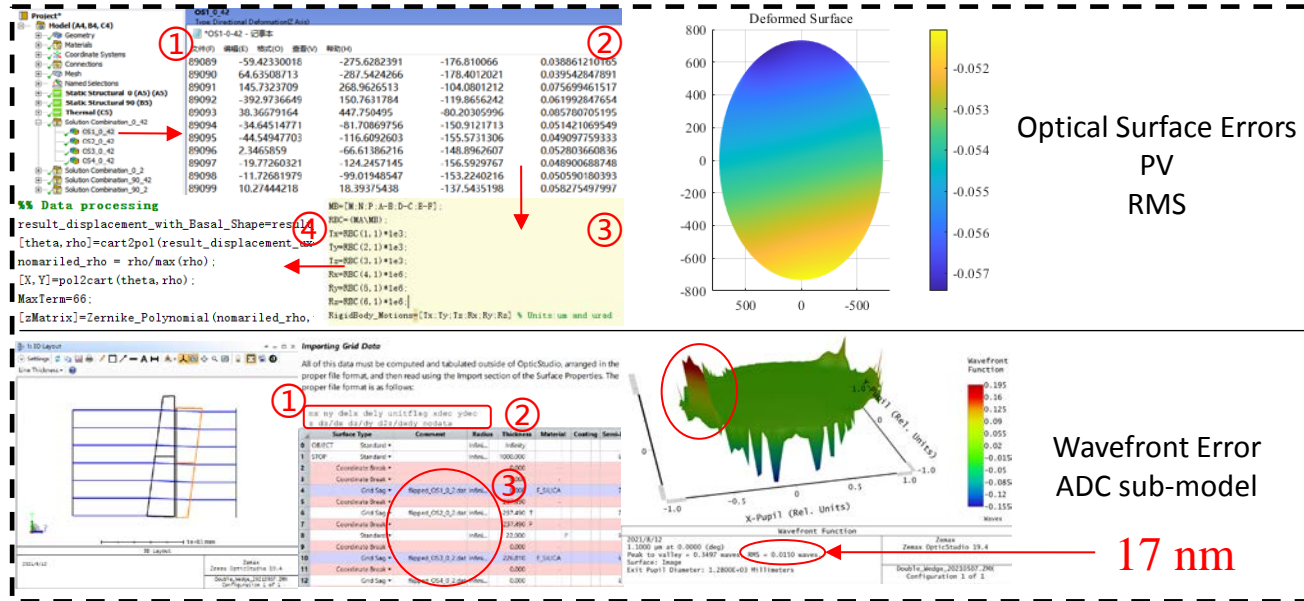


(b)

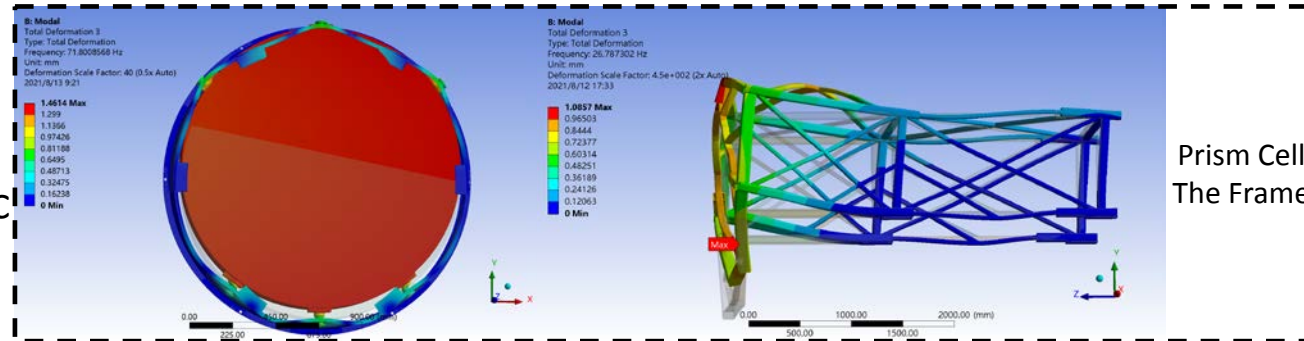


# 3-1 LADC集成分析

01/  
Static



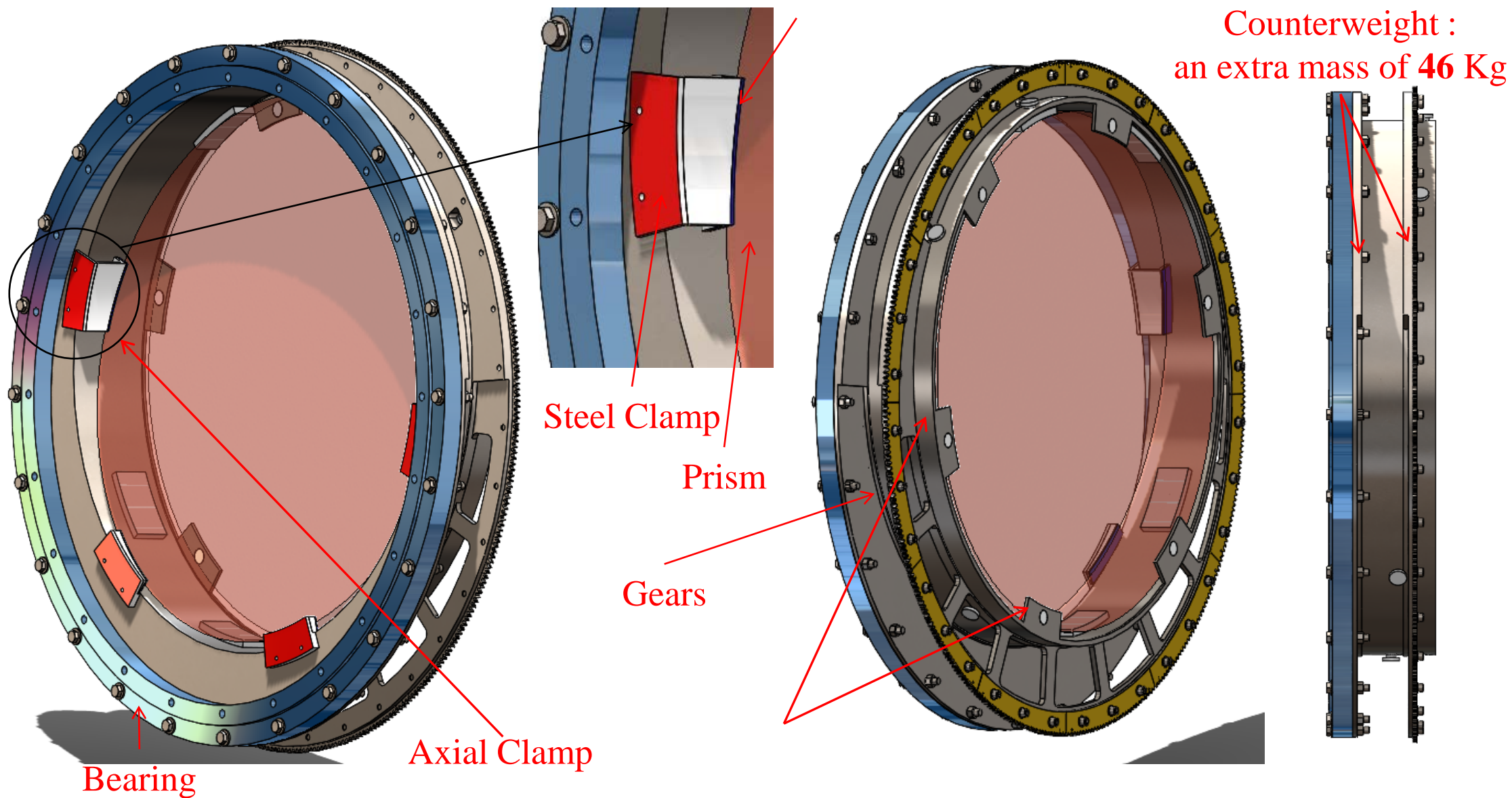
02/  
Dynamic



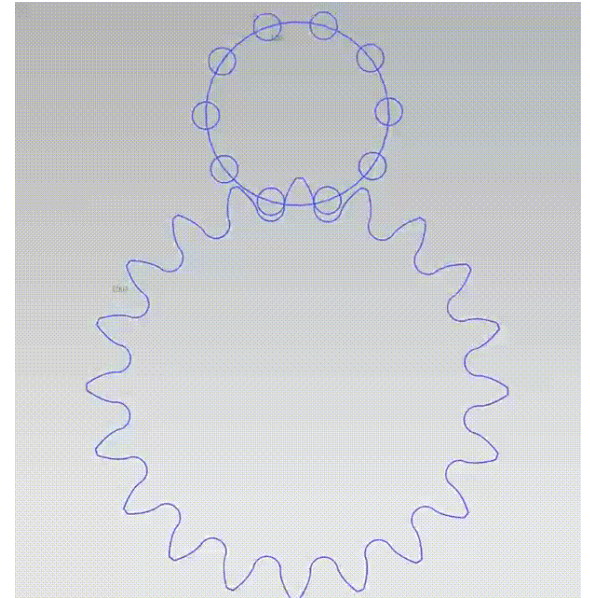
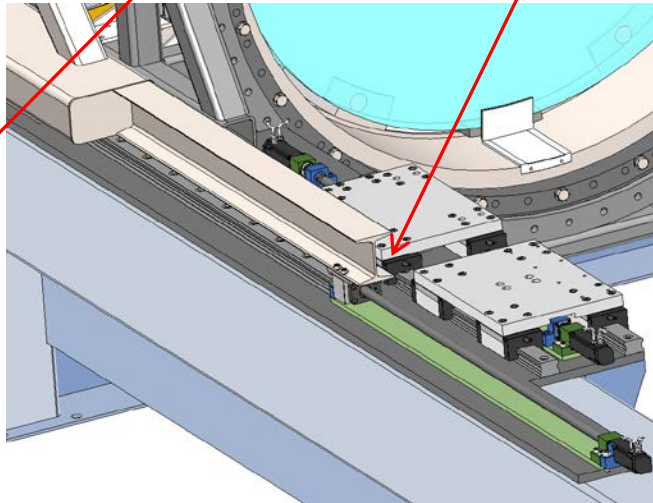
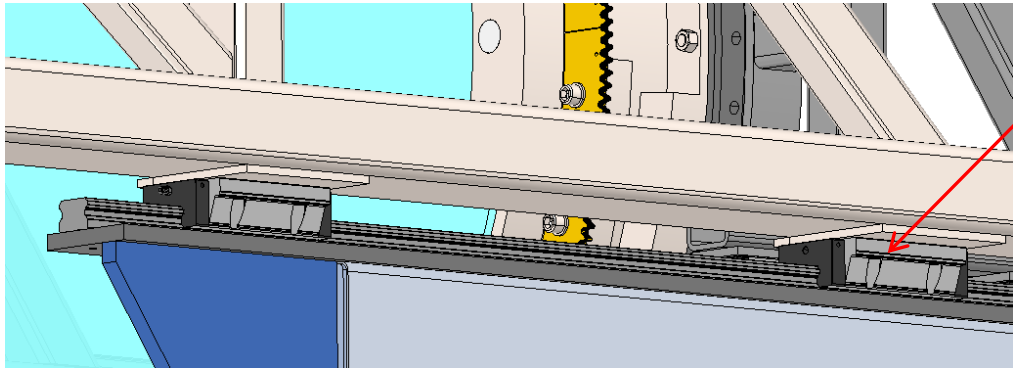
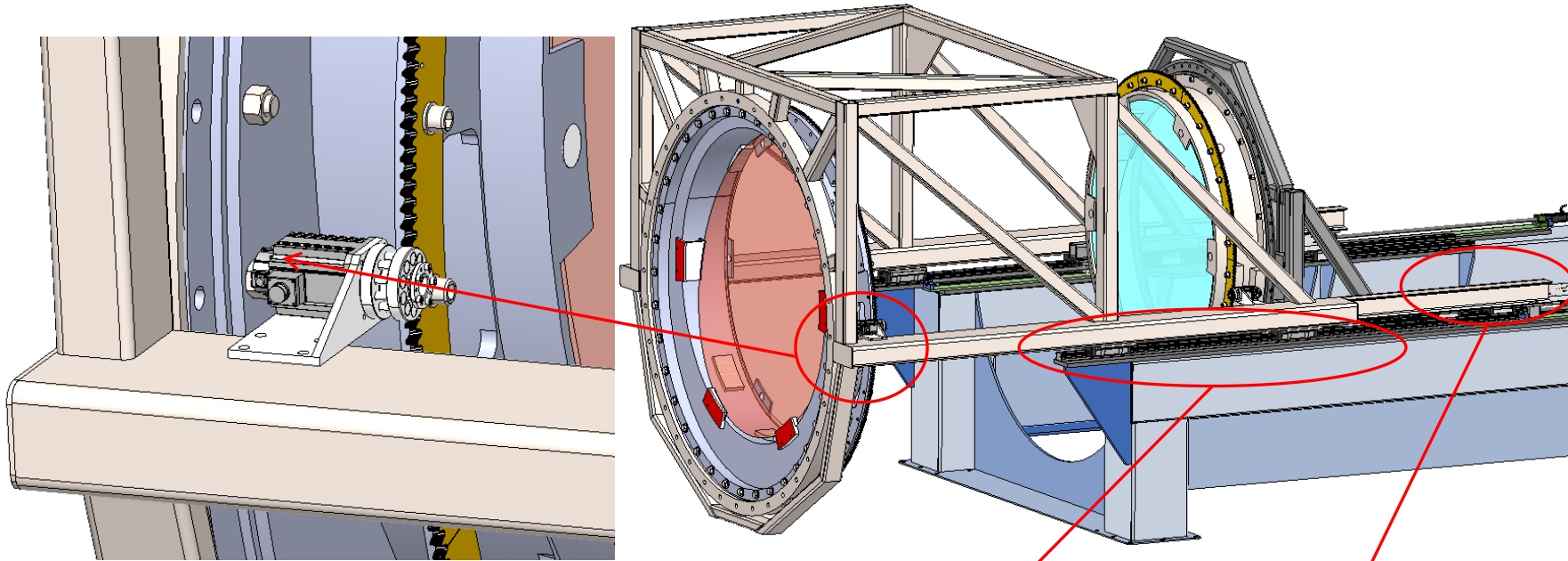
Item		Optical Surface Accuracy/nm		
		PV	RMS	
Thermal and gravity	0 deg	OS1	952.4	87.9
		OS2	873.2	79.3
	90 deg	OS1	1203.5	85.7
		OS2	1355.3	82.3

Item		Modal Information
Prism Cell	1st	60 Hz, translate along Y
	2nd	67 Hz, tilt around Y
Frame	1st	~20 Hz, translate along X

# 3-2 LADC运动机构



# 3-2 LADC运动机构



# 4 总结

项	指标	备注
<b>棱镜光学表面误差RMS</b>	<b>~100 nm</b>	<b>旋转运动360°全范围&amp;20°C温变</b>
线性平移	~2000 mm	
旋转运动	360°	
平移精度	0.5 mm	
旋转定位精度	0.5°	
低阶频响	~22 Hz	

