



# Optical Characterization of 300 mm SiC mirrors due to thermal variations


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Korea Basic Science Institute (KBSI)



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# 1. INTRODUCTION

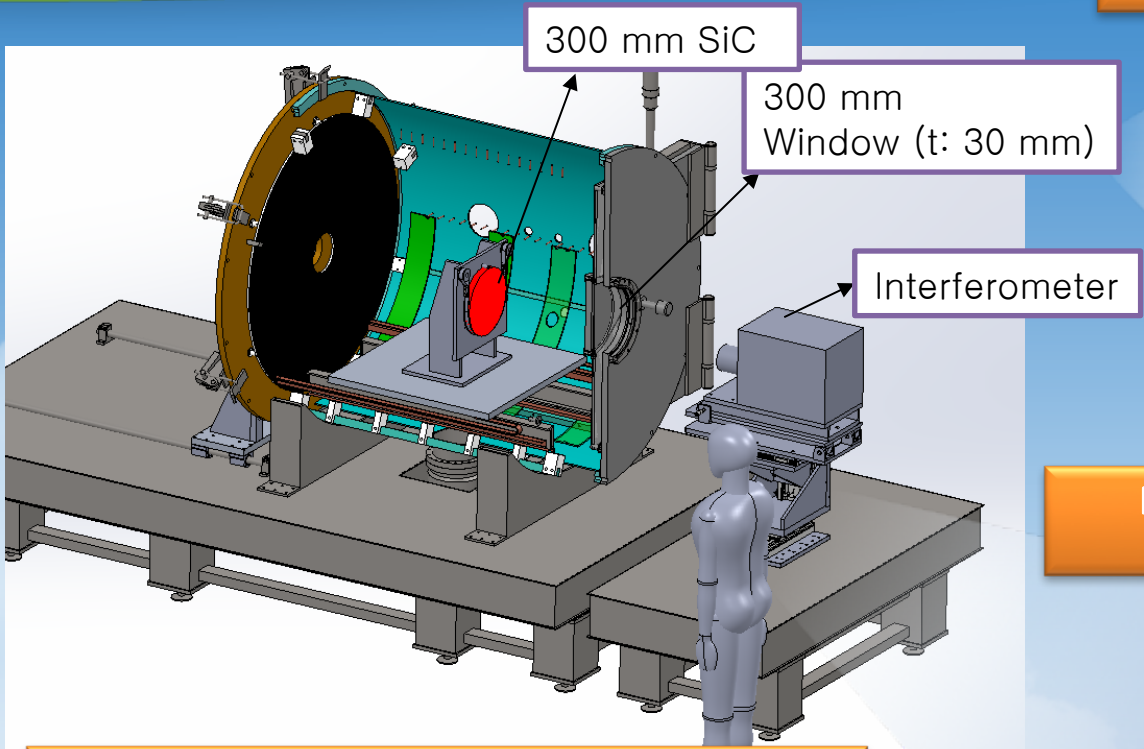
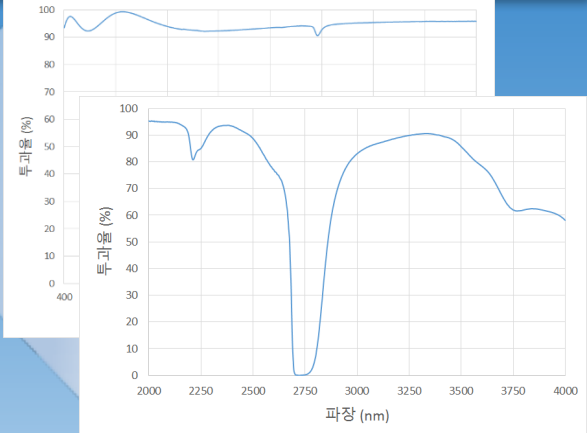
# 1. Collaboration plan overview

- Collaboration partners: KASI, NOAO, GO
- Objectives
  - Develop polishing and testing procedures for SiC lightweight blanks
    - For 300 mm flat blanks
    - Polishable surfaces (Si CVD, or SiC CVD over-coated)
  - Test of optical and mechanical characteristics
    - Optical surface WFE maps
    - Environmental tests (Thermal variations)
  - Optical surface characterizations
    - Surface figuring
    - Structure function
    - Surface micro-roughness
- Deliverables
  - Three SiC polished mirrors
  - Final report of SiC mirror polishing and tests

## 2. THERMAL TEST SETUP AND SIMULATION

# 2. Preparation of environmental testing chamber

Transmission curve on Chamber window



Preliminary design for environmental testing (-40, -10, +20 degree Celsius)

Mechanical mounting specifications for interferometer movement

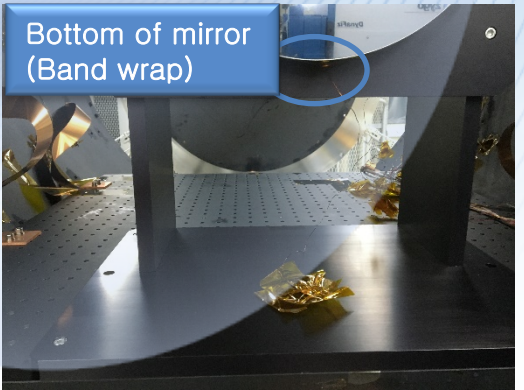
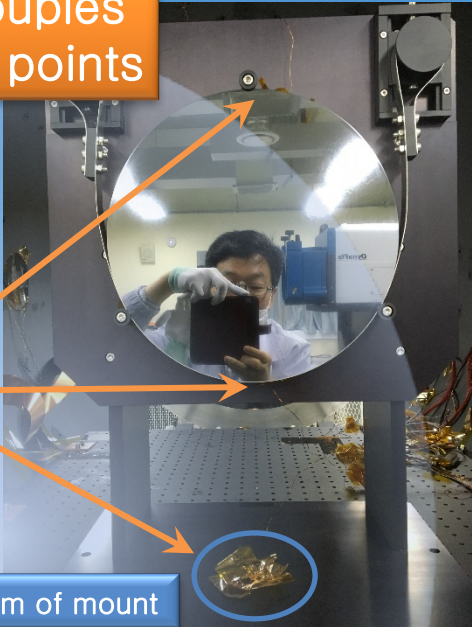
Parameters	Specifications
X Stroke	±90mm
Y Stroke (manual)	±5mm
Z Stroke	±90mm
Tilt (manual)	±3 (±5mm)
Load	100kgf
Accuracy	10µm
Repeatability	5µm
Speed	0.05~20mm/sec
Linearity	±0.07mm/190mm

# 2. Preparation for thermal test setup (1/2)



Setting Thermocouples in 3 different points

Location of 3 Thermocouples

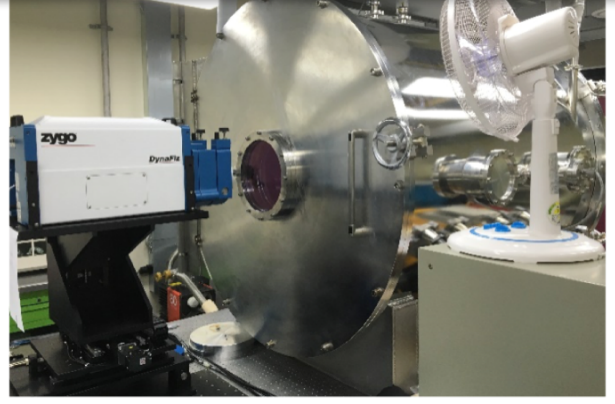


# 2. Preparation for thermal test setup (2/2)

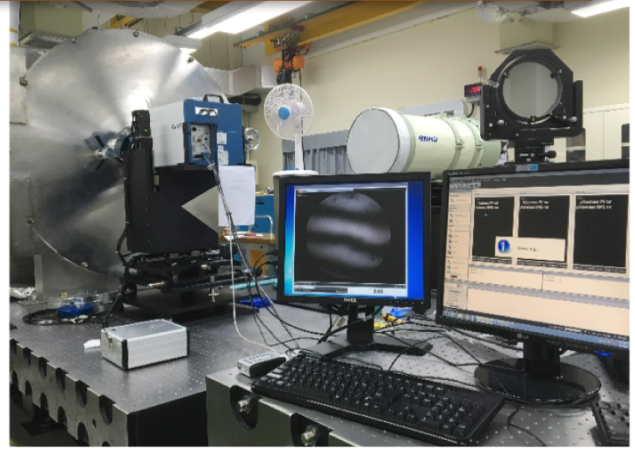
SiC setup in Chamber



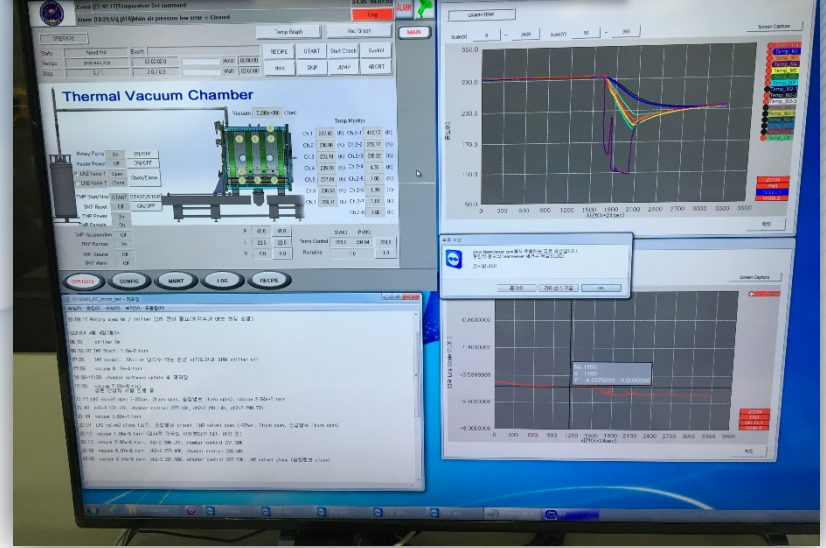
Chamber closed and measurement setup



WFE measurement while changing temperatures (+20C, -10C and -40C)



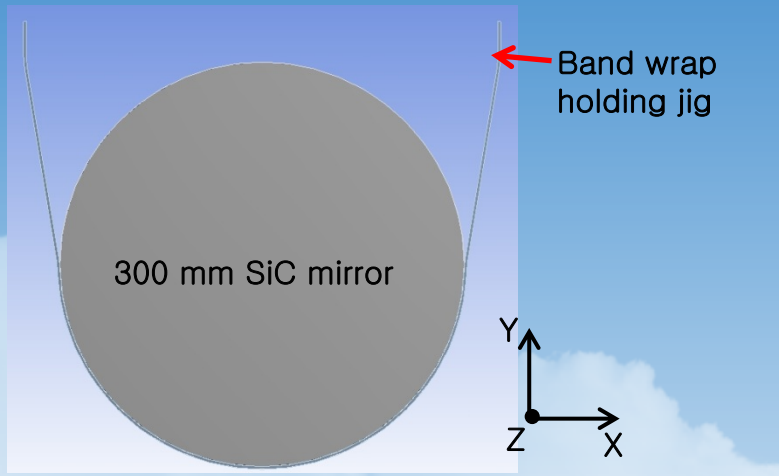
Control panel of Chamber





# 2. Initial simulation for environmental testing

## 3D modeling and Mirror properties

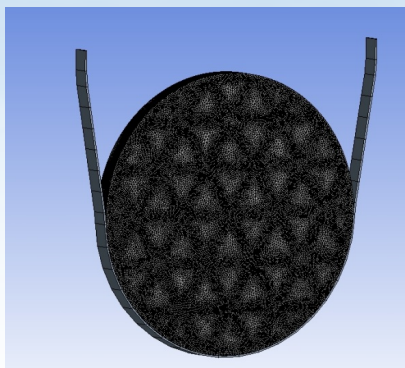


Ref. : Rohm and Hass, 2008 catalog

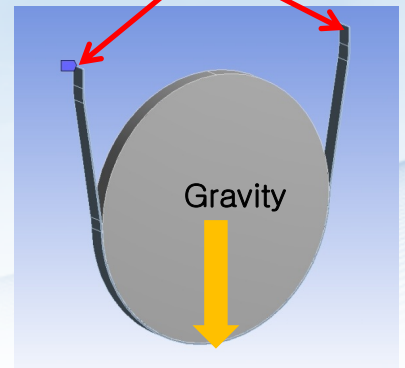
Material Typical properties		
Material	SiC	S.Steel (Band wrap)
Elastic Modulus(Gpa)	466	193
Coefficient of Thermal Expansion(m/m/K)	$2.2 \times 10^{-6}$	$17.2 \times 10^{-6}$
Heat Capacity(Jkg <sup>-1</sup> K <sup>-1</sup> )	640	0.5
Thermal Conductivity(K m <sup>-1</sup> K <sup>-1</sup> )	300	16.2
Poisson's Ratio	0.21	0.25

## Boundary condition

Fixed support

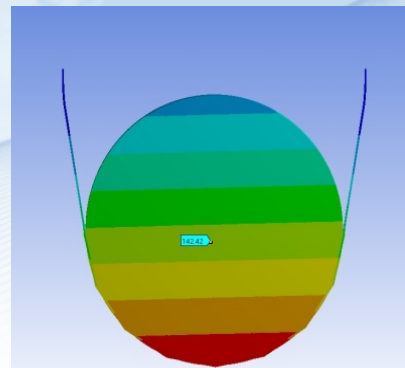


Nodes : 1553372  
Mesh elements : 8114945

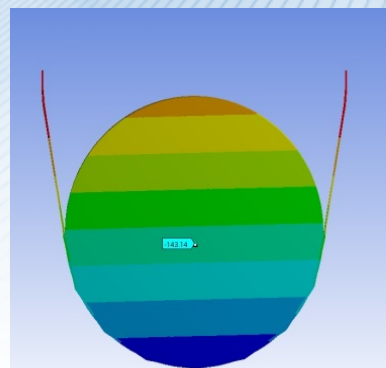


Thermal constant : -40 °C

## Initial result



Total Deformation



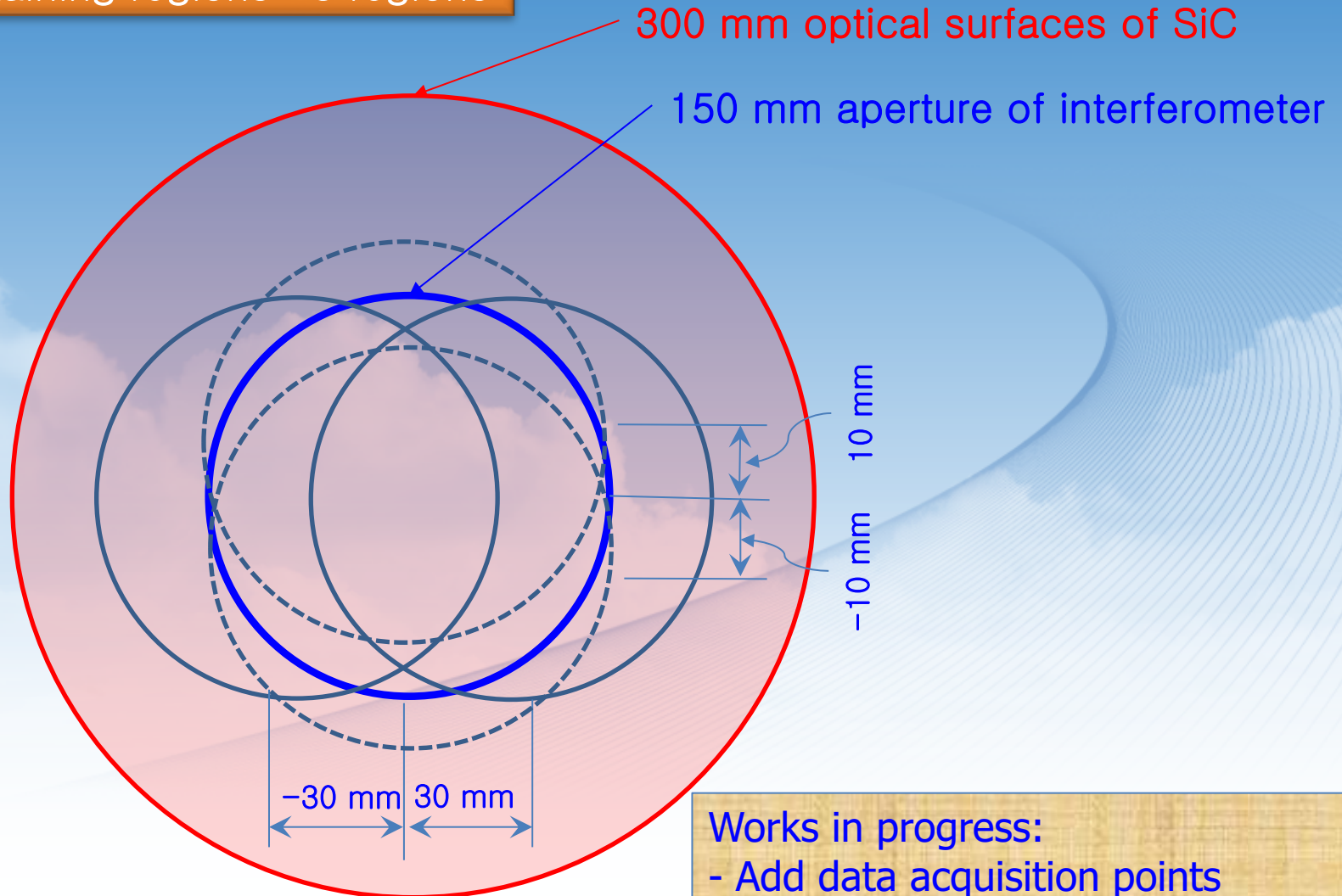
Z축 Deformation

Works in progress:  
- To be considered for Bimetallic effects and removed piston, tip-tilt

# 3. EXPERIMENTAL RESULTS

### 3. Data obtaining regions

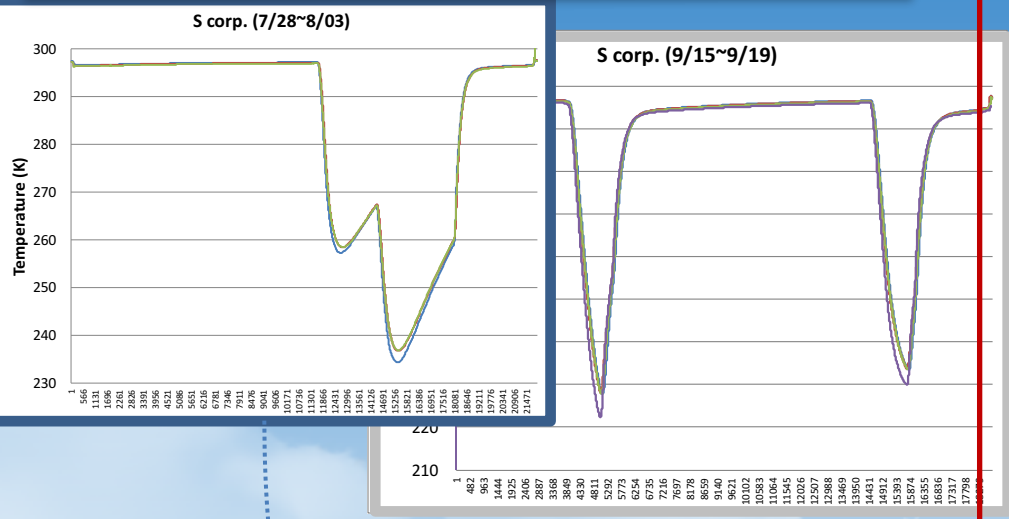
Data obtaining regions : 5 regions



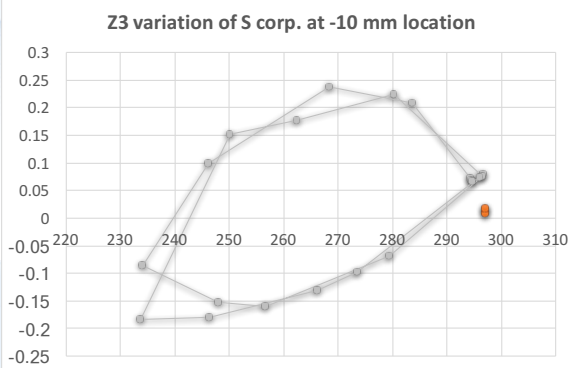
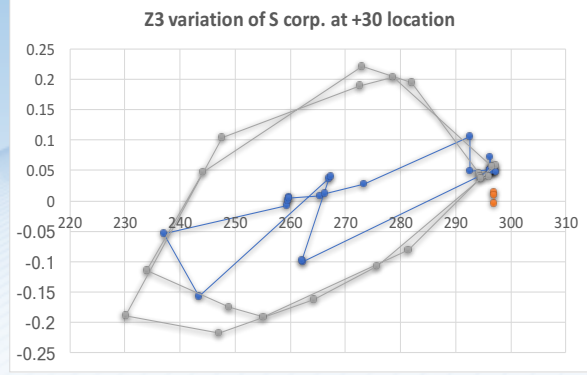
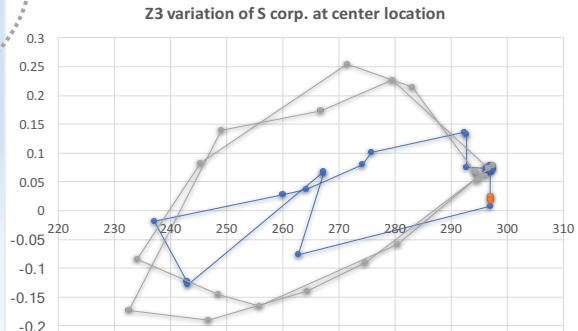
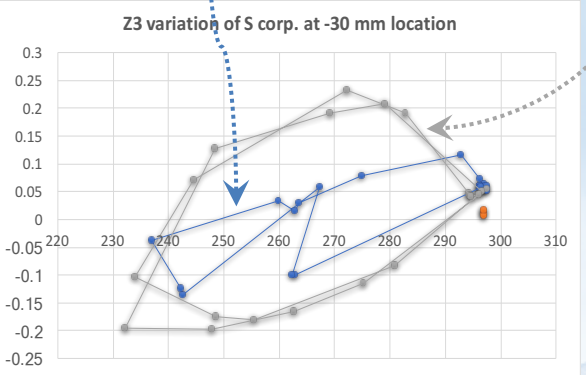
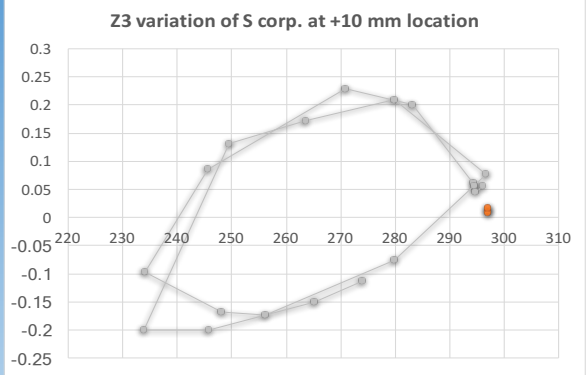
Works in progress:  
- Add data acquisition points

# 3. Defocus variations with different SiC

## Temperature profiles

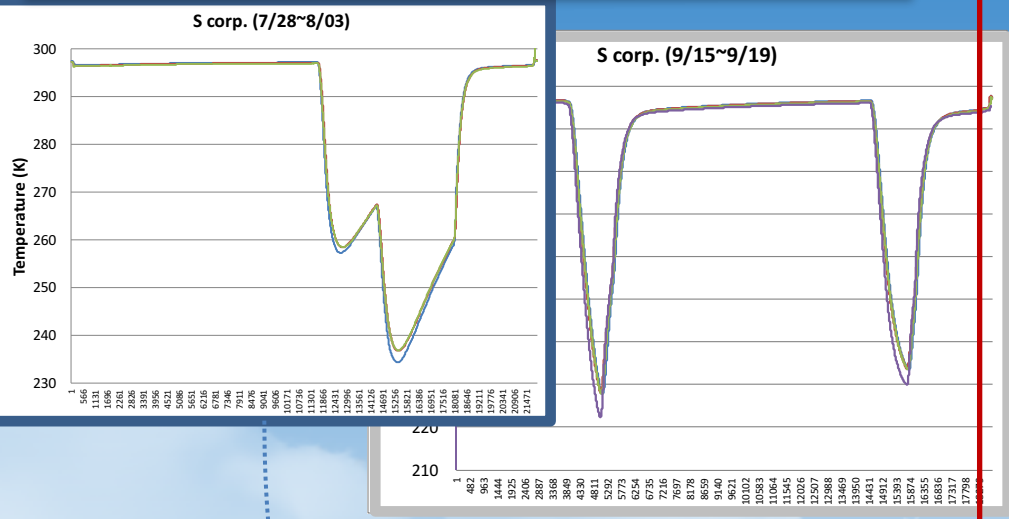


SiC from S corp.  
 X-axis: Temperature  
 Y-axis: Defocus (Z3 (Zygo), um)

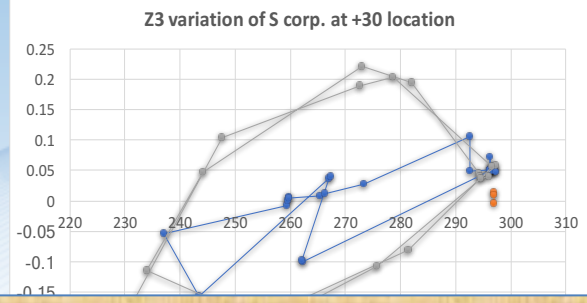
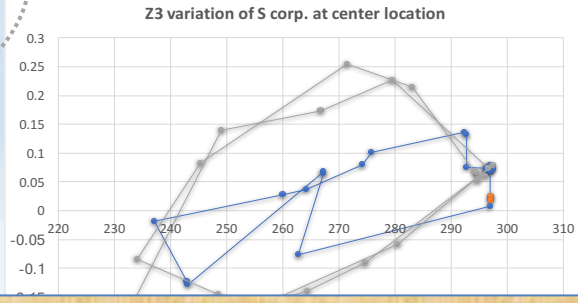
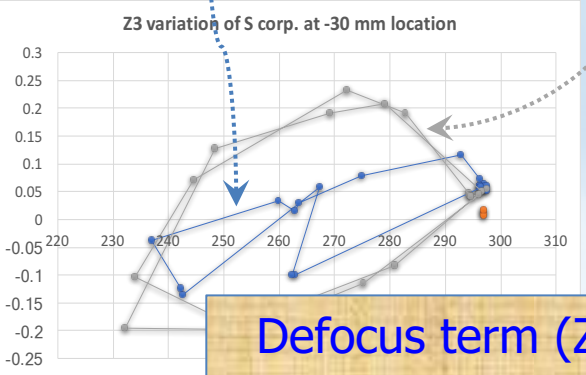
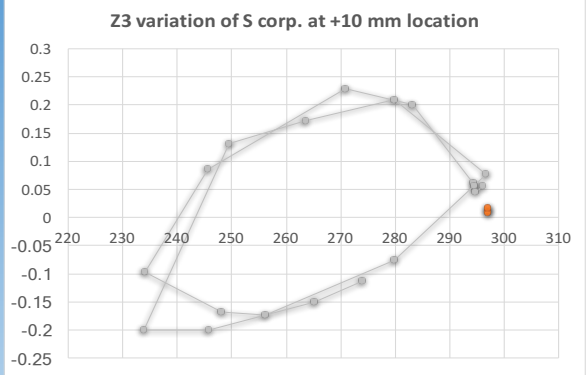


# 3. Defocus variations with different SiC

## Temperature profiles

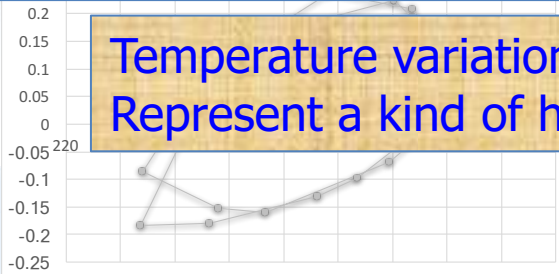


SiC from S corp.  
 X-axis: Temperature  
 Y-axis: Defocus (Z3 (Zygo), um)



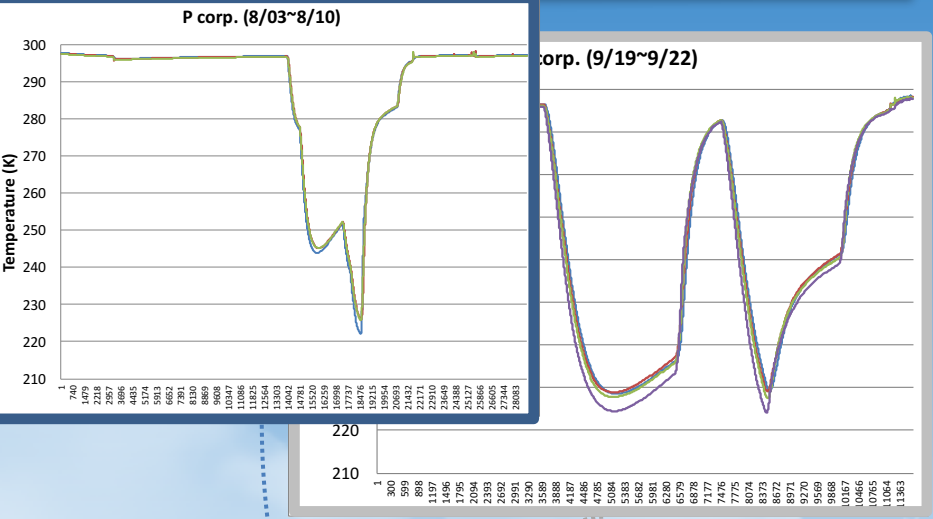
Defocus term (Z3) was a major contributor with varying temperatures in Zernike polynomials at Zygo interferometer.

Temperature variation affects defocus gradients. Represent a kind of hysteresis loop

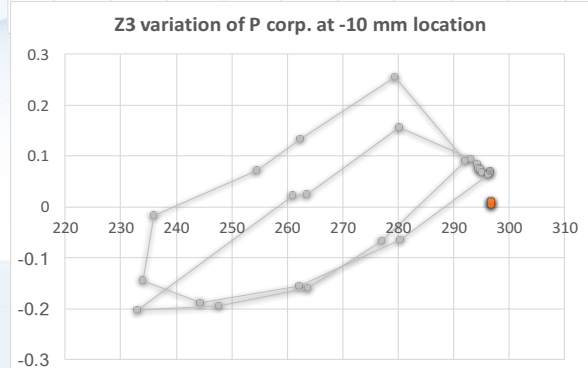
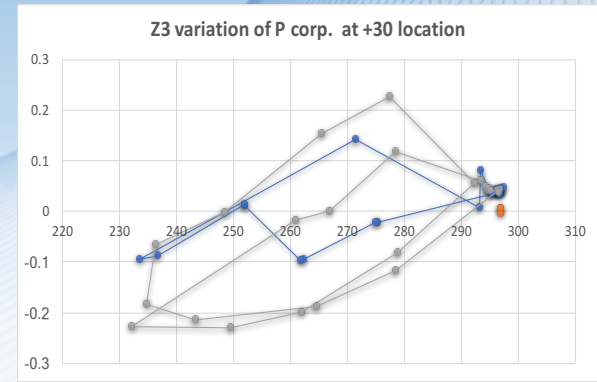
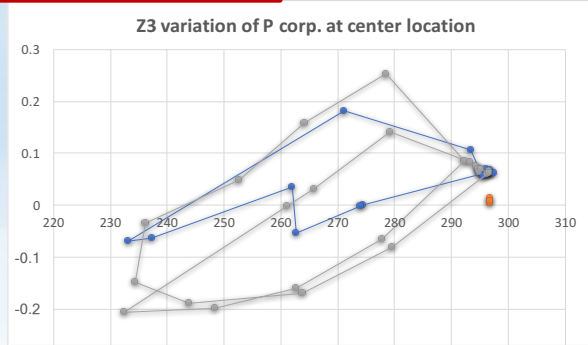
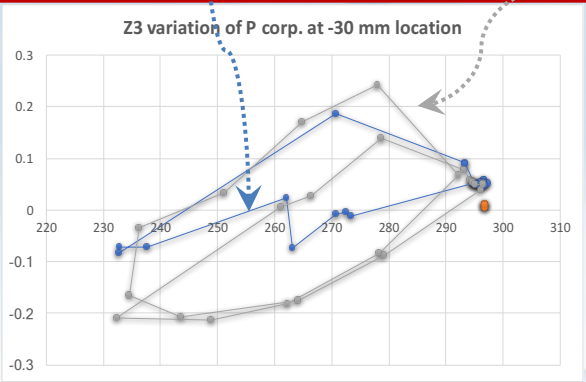
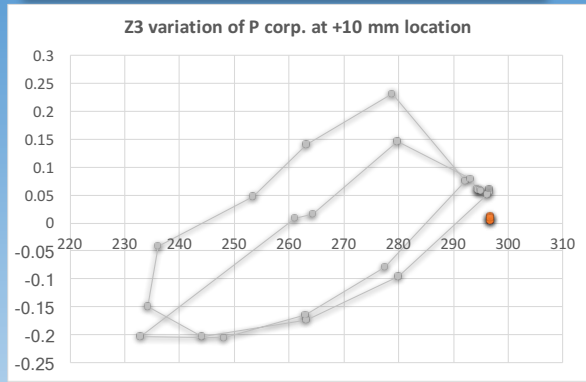


# 3. Defocus variations with different SiC

## Temperature profiles

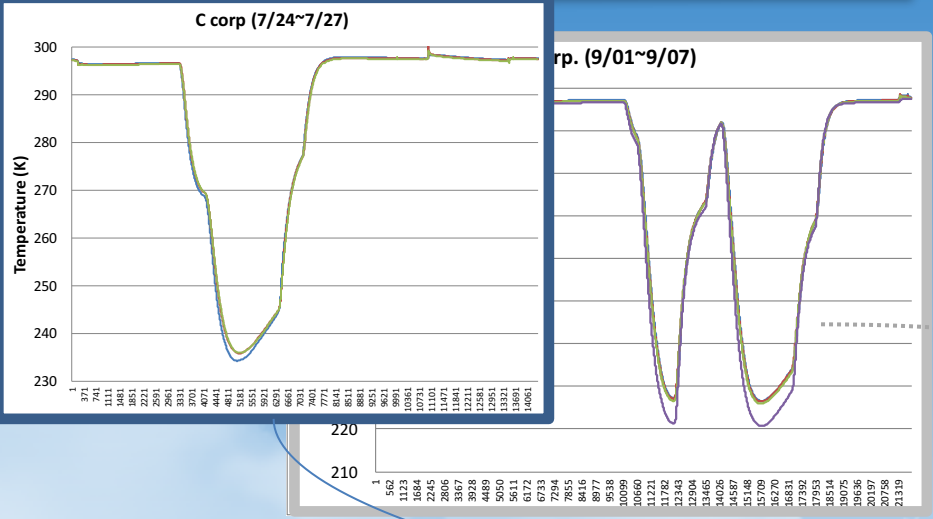


**SiC from P corp.**  
 X-axis: Temperature  
 Y-axis: Defocus (Z3 (Zygo), um)

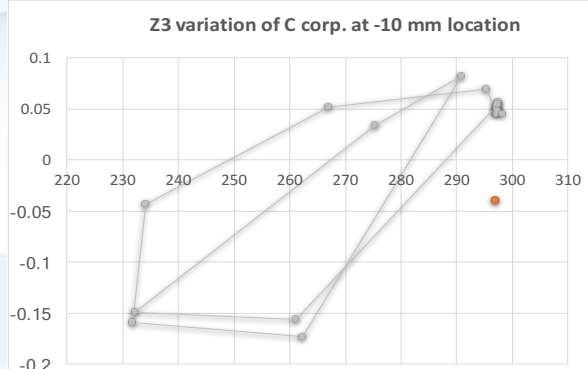
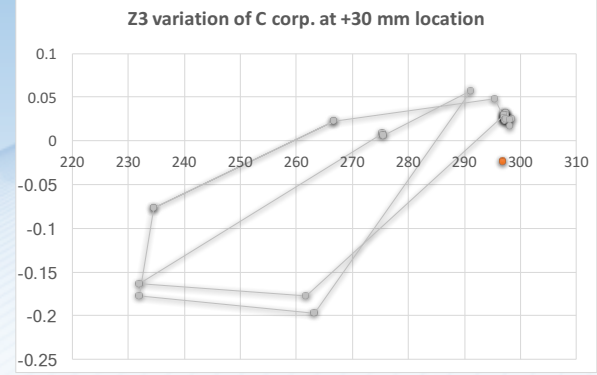
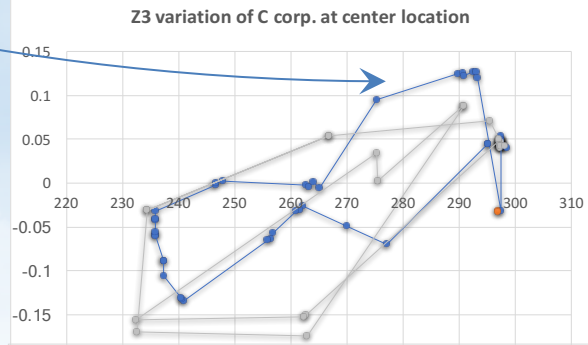
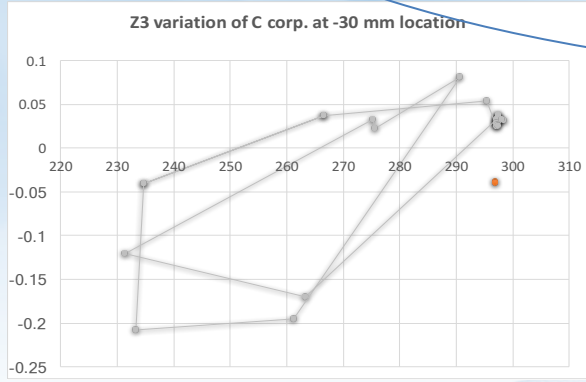
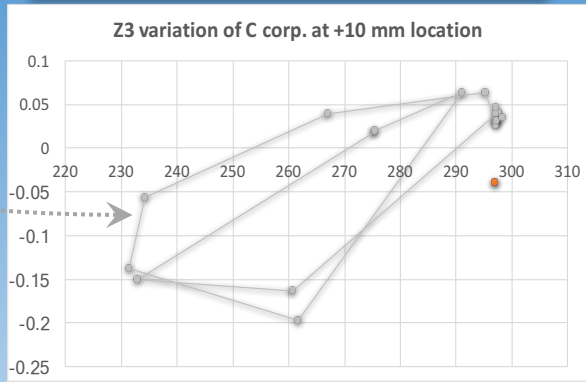


# 3. Defocus variations with different SiC

## Temperature profiles

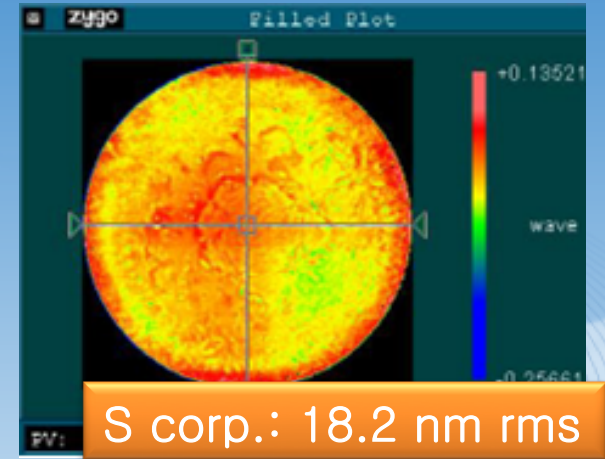
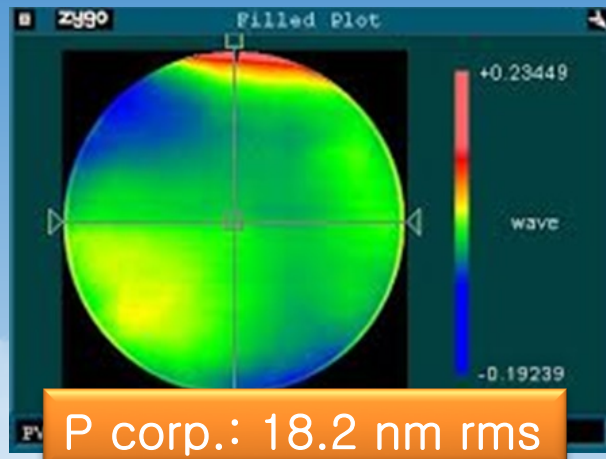
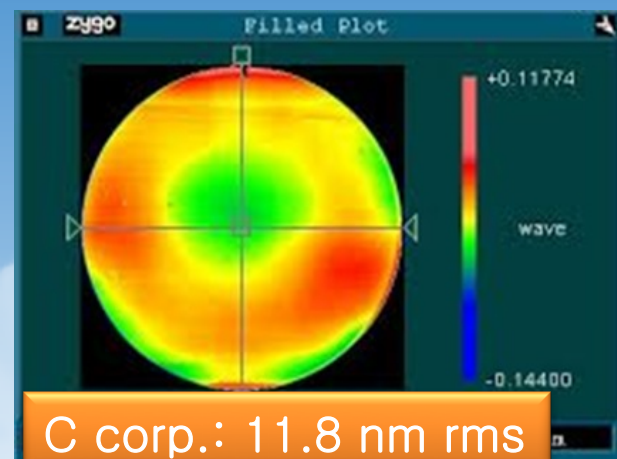


SiC from C corp.  
 X-axis: Temperature  
 Y-axis: Defocus (Z3 (Zygo), um)

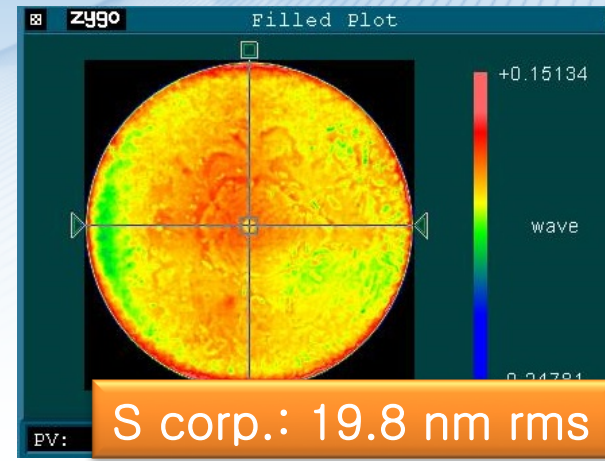
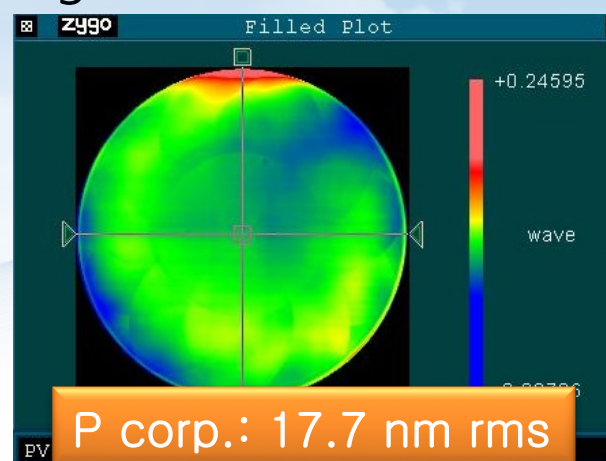
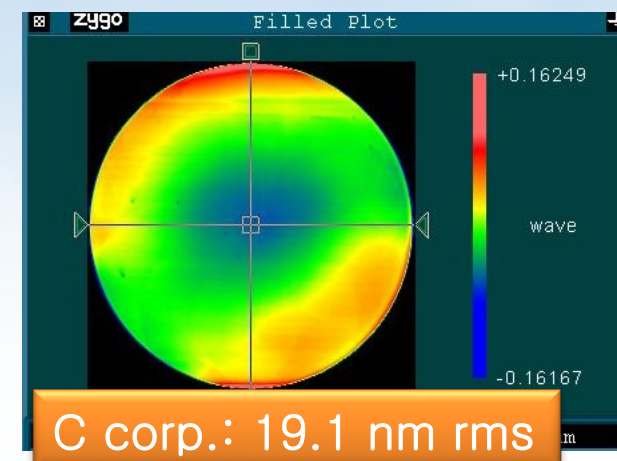


### 3. Surface figures before and after environmental testing

- Polished optical surfaces
  - C, P, and S corp. (requirement:  $< 20$  nm rms)



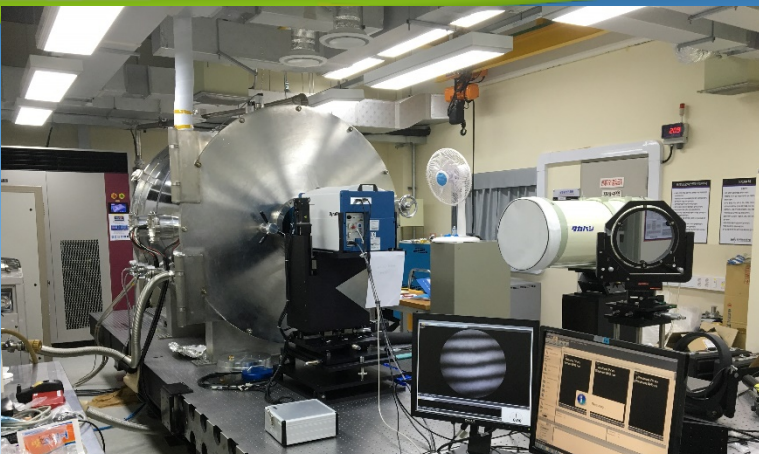
- After environmental testing



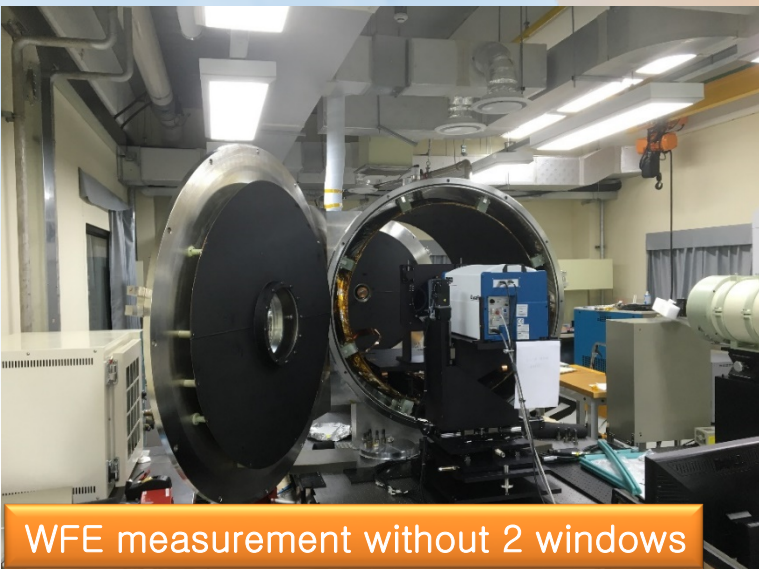
Represent not much differences of form shapes due to temperature experiment except C corp.



# 3. Chamber windows effect

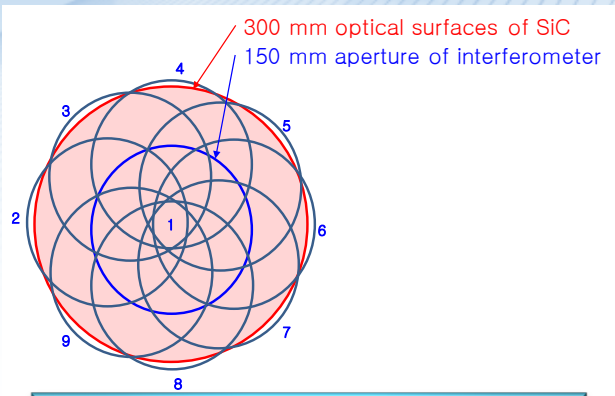
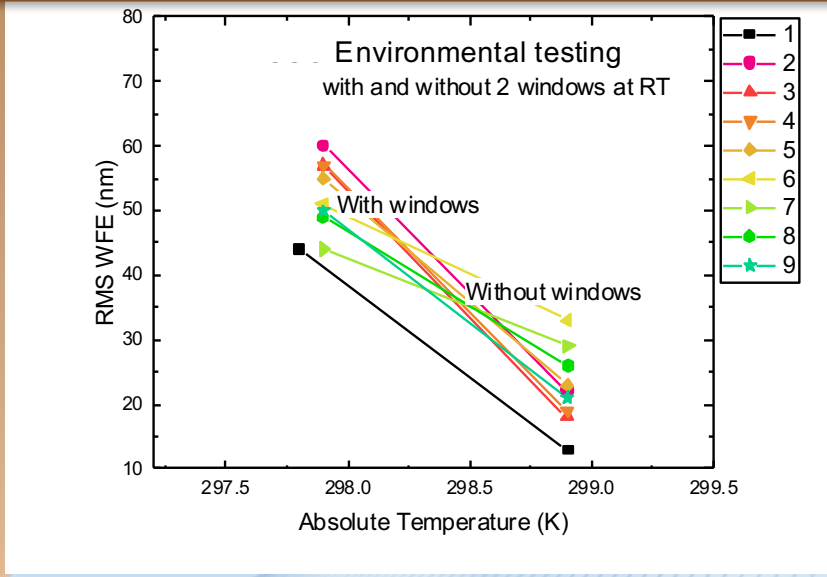


WFE measurement during environmental testing  
 → including 2 windows at vacuum chamber



WFE measurement without 2 windows

Decreased WFE ~ 30 nm rms WFE due to 2 windows using SiC from S corp.



Data obtaining regions : 9 regions

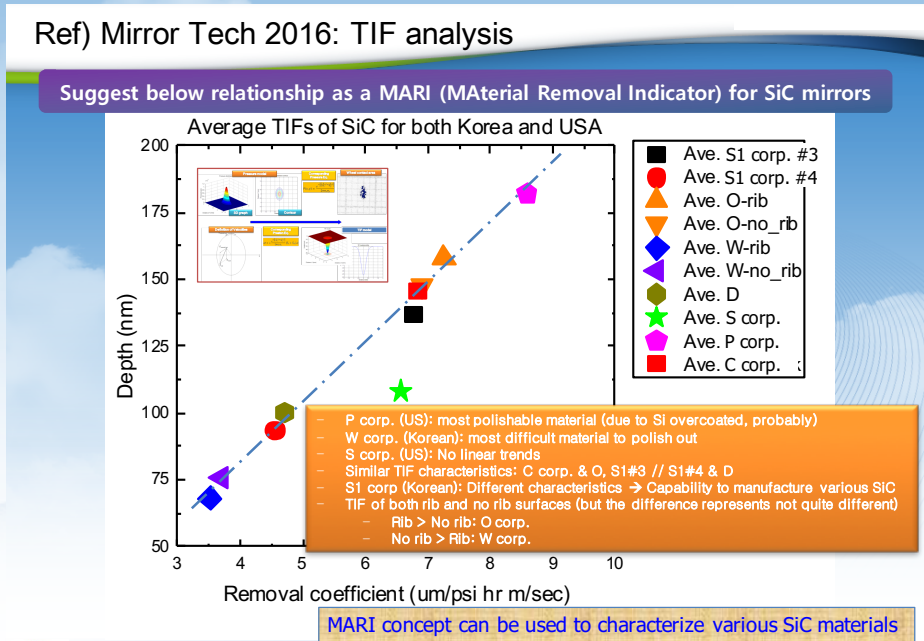
# 4. CONCLUSION AND FUTURE WORKS

## 4. Conclusion

- ❖ Environmental test was performed for 3 different SiC mirrors
  - Defocus term is a major contributor in surface characteristics.
  - Temperature input variations affect defocus gradients.
- ❖ Consistent surface form (defocus) variation is presented for different temperatures at -40, -10, and +20 degree Celsius.
- ❖ Observed a reduction of WFE  $\sim 30$  nm due to 2 windows in Thermal-Vacuum Chamber
- ❖ Future works
  - Revisits WFE data analysis without edges using mask option of interferometer

# 4. Future works

- ❖ KASI, NOAO, and GO plans to fabricate a 500 mm off-axis aspheric mirror and develop metrology systems
  - Period: 2017~2018
  - Scope: Development of off-axis aspheric mirrors testing methodology
- ❖ KASI, NOAO, and GO will extend MAterial Removal Indicator (MARI) concept shown in Mirror Tech Days 2016 for different SiC materials and TIF wheels.





Thank you for your attention