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EUV Wavefront Metrology System in EUVA

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Abbreviations

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EEI	EUV Experimental Interferometer
EWMS	EUV Wavefront Measurement System
PO	Projection Optics
PDI	Point Diffraction Interferometer
LDI	Line Diffraction Interferometer
LSI	Lateral Shearing Interferomete
CGLSI	Cross-Grating LSI
FFT	Fast Fourier Transform method

Outline

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1. Target of EUV Metrology Laboratory in EUVA
2. Reproducibility of PDI
3. Applicability of PDI to a six-mirror system
4. Improvement of CGLSI
5. Outline of EWMS
6. Summary

Target of EUV Metrology Laboratory in EUVA

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Target

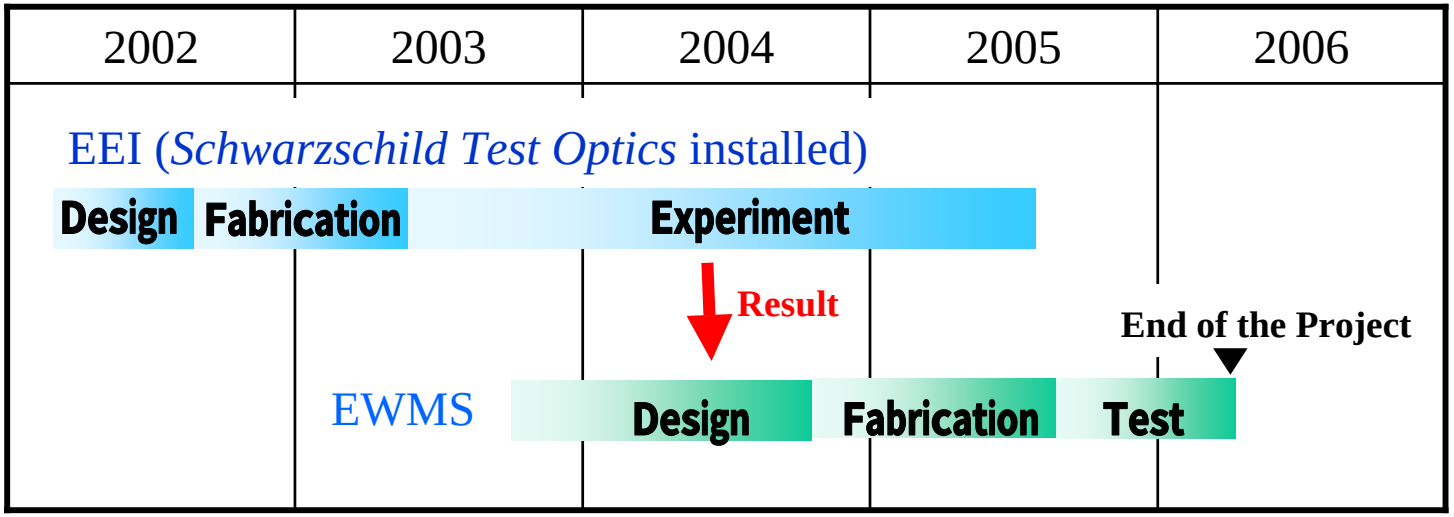
EWMS (EUV Wavefront Metrology System)

An interferometer for **six-mirror Projection Optics** with **0.1nm** accuracy

Approach

EEI (EUV Experimental Interferometer)

A prototype interferometer to determine measurement methods for EWMS



Review of EEI

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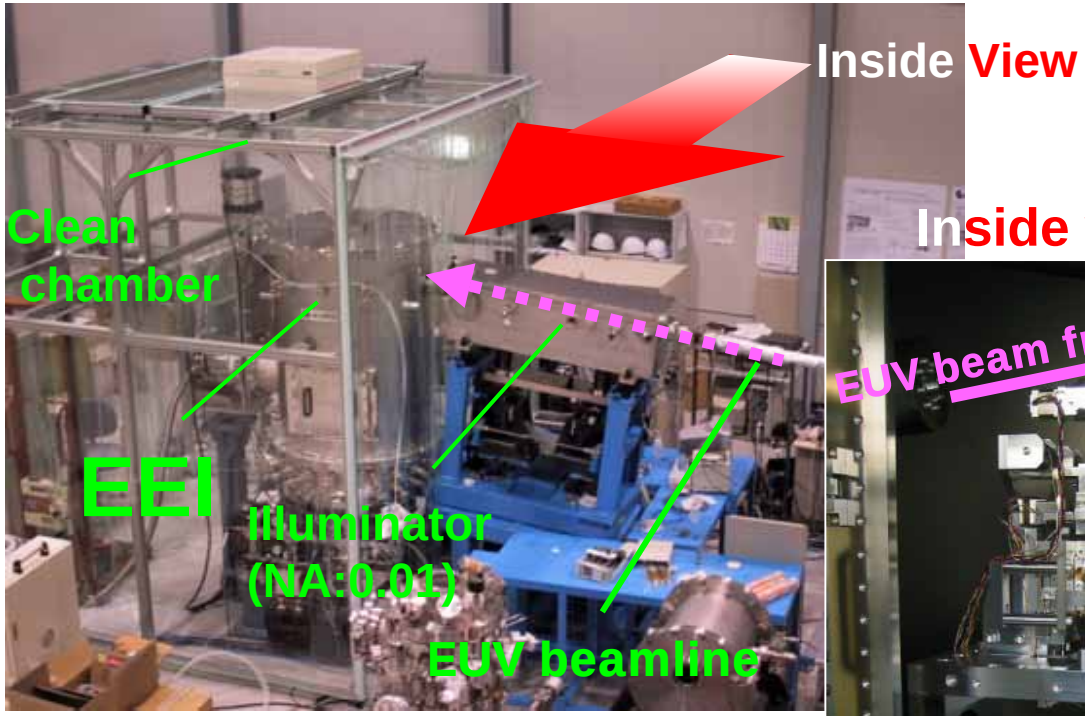
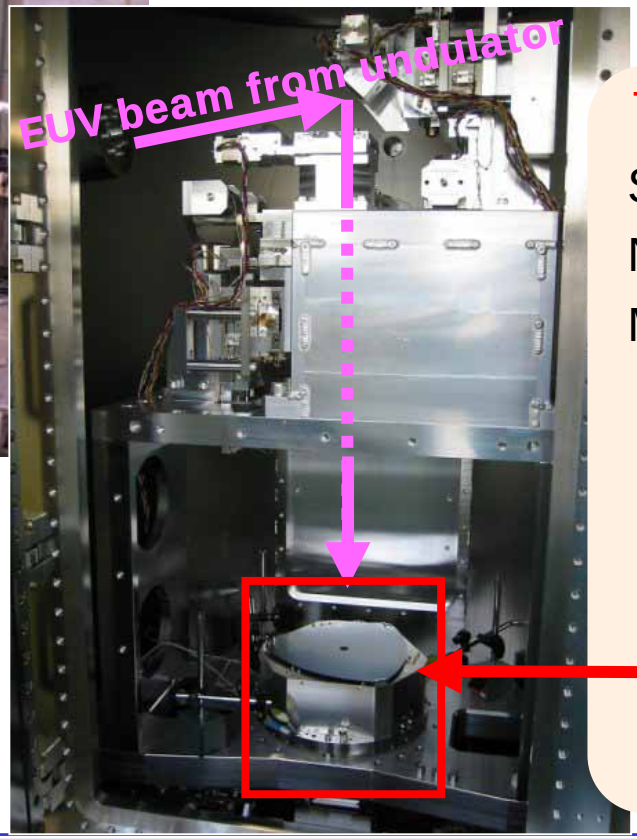
Overall view of EEI



Installed at NewSUBARU of Univ. of Hyogo

Inside view of EEI

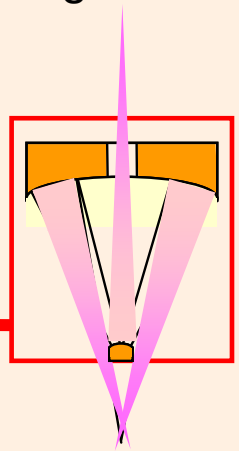


Test Optics

Schwarzschild

NA 0.2

Mag. 1/20



Results of evaluation

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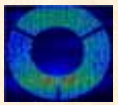
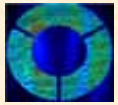
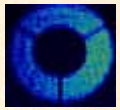
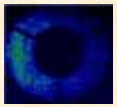
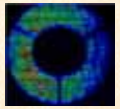
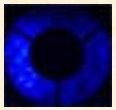
Available Methods			Interferogram	Features
Diffraction type Interferometer		**PDI** (Point)		***High accuracy*** Narrow cover range of aberration Large loss of the light Intensity
		LDI (Line)	 X  Y	Higher contrast than PDI Two interferograms necessary
Lateral Shearing Interferometer	One dimensional grating	**LSI**	X  Y	Two interferograms necessary Difficult to determine astigmatism
		SLSI (Slit type)	 X  Y	Two interferograms necessary Difficult to determine astigmatism
		DLSI (Double Grating)	 X Y	Two interferograms necessary Difficult to determine astigmatism
		CGLSI (Cross Grating)	 4-Window	***Easy alignment***

➢ **PDI and CGLSI are potential candidates for EWMS**

Optical Configurations of PDI and CGLSI

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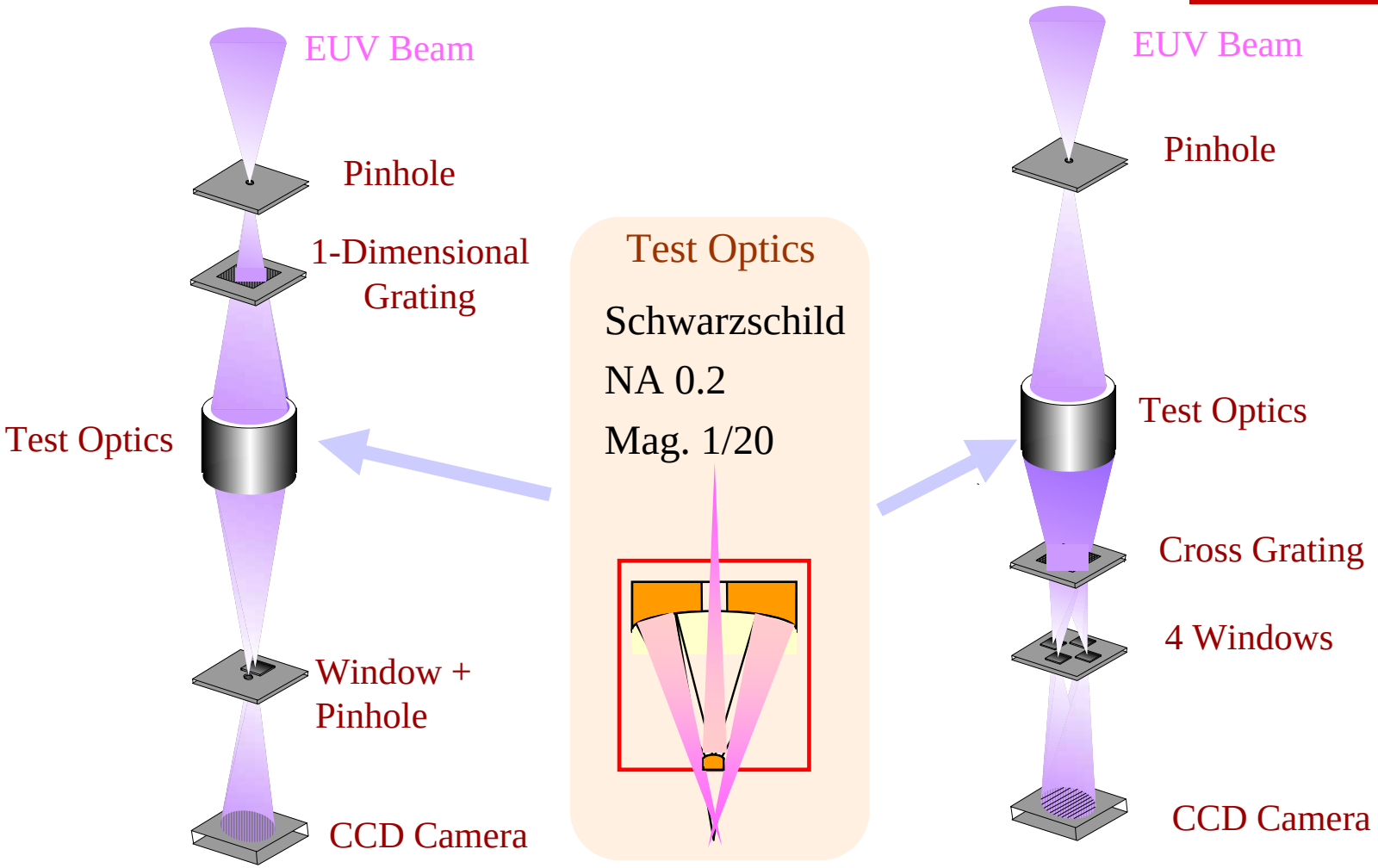

PDI

(**P**oint **D**iffraction **I**nterferometer)

CGLSI

(**C**ross **G**rating **LSI**)

Reproducibility of PDI

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✧**Alignment error of the pinhole and the focus point causes error in the measurement.**

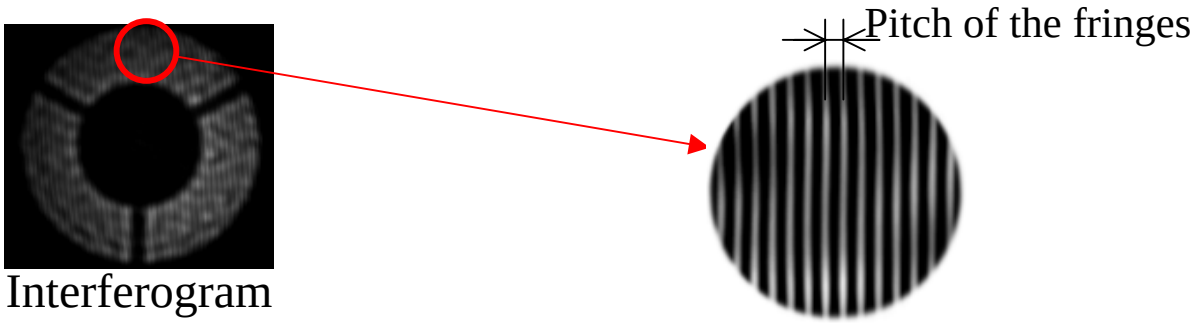
Measurement number	Alignment error ΔX nm	Alignment error ΔY nm	Wavefront aberration nm RMS
1	58.20	6.72	1.352
2	14.88	8.6	1.305
3	21.92	48.3	1.261

Reproducibility was 0.103 nm RMS

➢**Precise pinhole alignment is necessary to improve the reproducibility.**

✧Fringe pitch changes with respect to the position of the pinhole.

✧The alignment was improved using the fringe pitch.



Reproducibility of PDI

Supported by NEDO

✧**Measurement results after the improvement in alignment.**

Measurement number i	Wavefront aberration Wi nm RMS	Difference from mean wavefront Wi-Wm nm RMS	Alignment error ΔX	Alignment error ΔY
1	1.36	0.043	0.7nm	-8.0nm
2	1.32	0.037	-6.0nm	-18.7nm
3	1.32	0.050	-17.7nm	-5.5nm
4	1.33	0.032	0.9nm	-0.5nm
5	1.29	0.043	-1.4nm	-0.7nm
6	1.31	0.040	-0.7nm	-0.3nm
7	1.28	0.070	-10.0nm	-0.3nm
Average	Mean wavefront Wm 1.31	Average ***0.045***		

➢**Alignment error has been improved to better than 20 nm.**

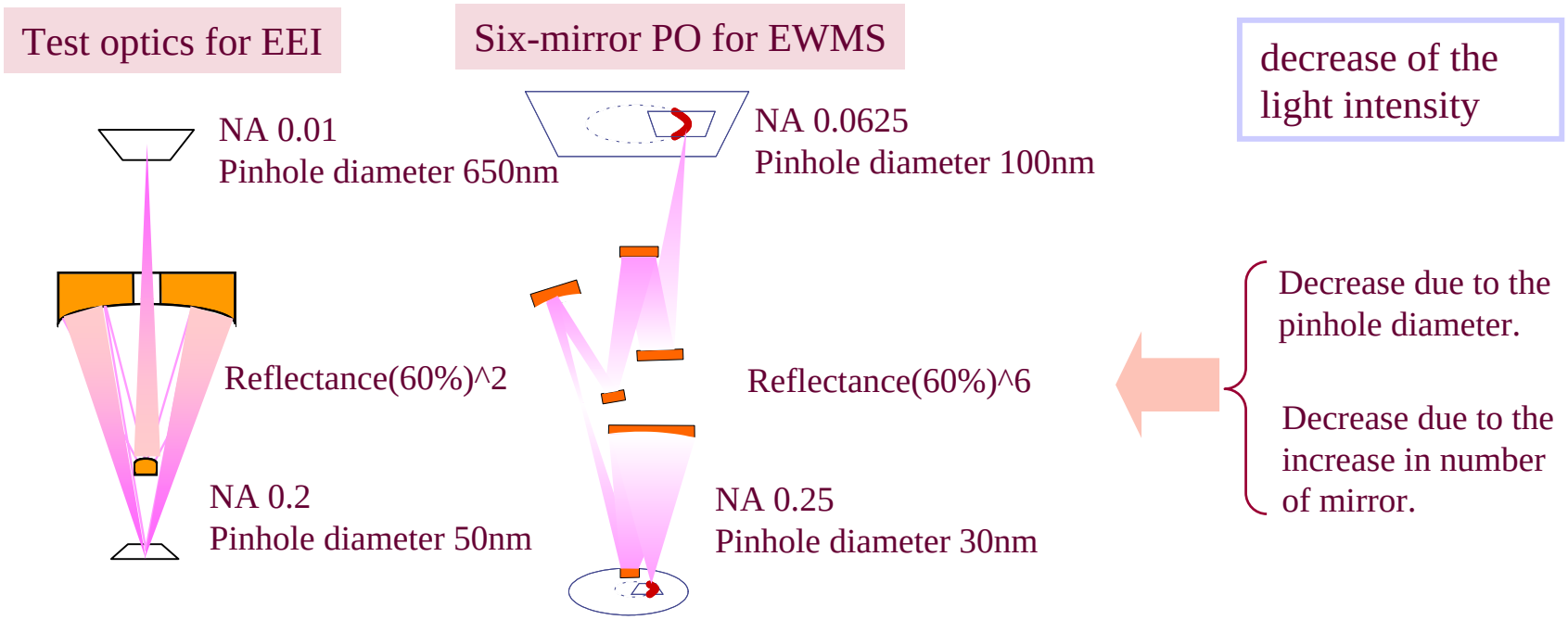
➢**Reproducibility of PDI has been improved to 0.045 nm RMS.**

Applicability of PDI to a six-mirror system

Supported by NEDO

✧Can PDI be applicable to six-mirror system with the reduced light intensity?

We evaluate PDI at 1/20 of the standard light intensity in EEI.



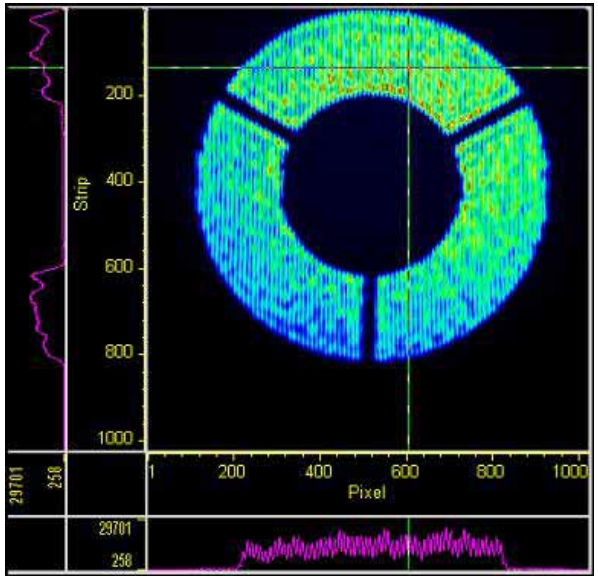
Applicability of PDI to a six mirror system

Supported by NEDO

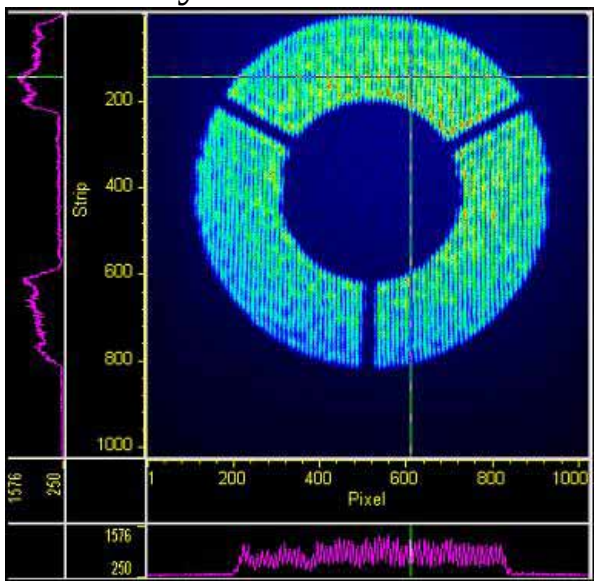
✧Obtained interferograms

These interferograms were obtained under the same alignment of the pinhole and the focus point using ND Filter in the beam line.

Standard light intensity in EEI



1/20 of the standard light intensity in EEI

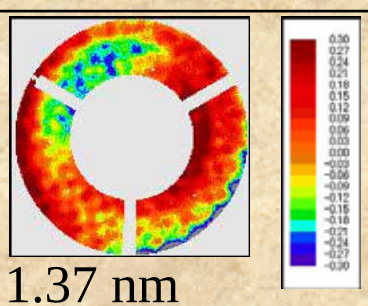
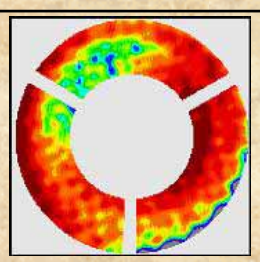
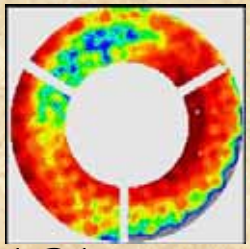
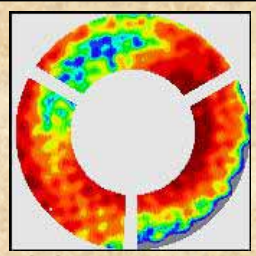


➢High contrast interferograms were obtained even at 1/20 of the standard light intensity in EEI.

Applicability of PDI to a six mirror system

Supported by NEDO

✧Results

	1/20 intensity	Standard intensity	Difference
1st trial	 1.37 nm	 1.35nm	***0.043*** nm
2nd trial	 1.31nm	 1.32nm	***0.041*** nm

nm RMS (Z5-36)

- **PDI at 1/20 of the standard light intensity in EEI was in well agreement with PDI at a standard light intensity.**
- **PDI is applicable to the measurement of a six-mirror PO.**

Improvement of CGLSI

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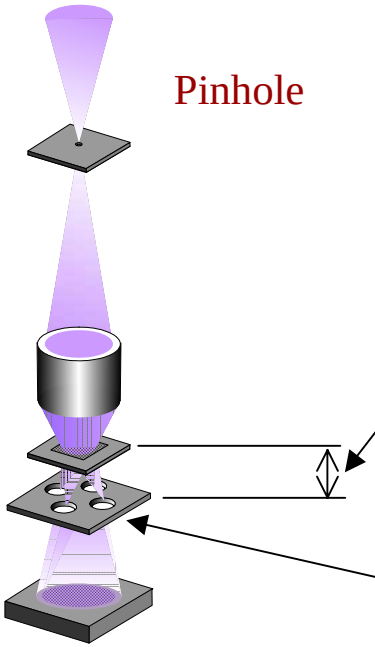
✧Difference between CGLSI and PDI was 0.28 nm RMS.(*1)

✧To improve CGLSI we optimized the measurement condition and the data analysis method.

✧Optimization of optical elements and alignment.



Distance between the grating and the window was set to the design value precisely.

Fringe pitch changes with respect to the distance between the grating and the window. We set the grating using this fact.

Optimization of the window size.

(*1)Ref. Hasegawa et. al, EIPBN 2, June 2005

Improvement of CGLSI

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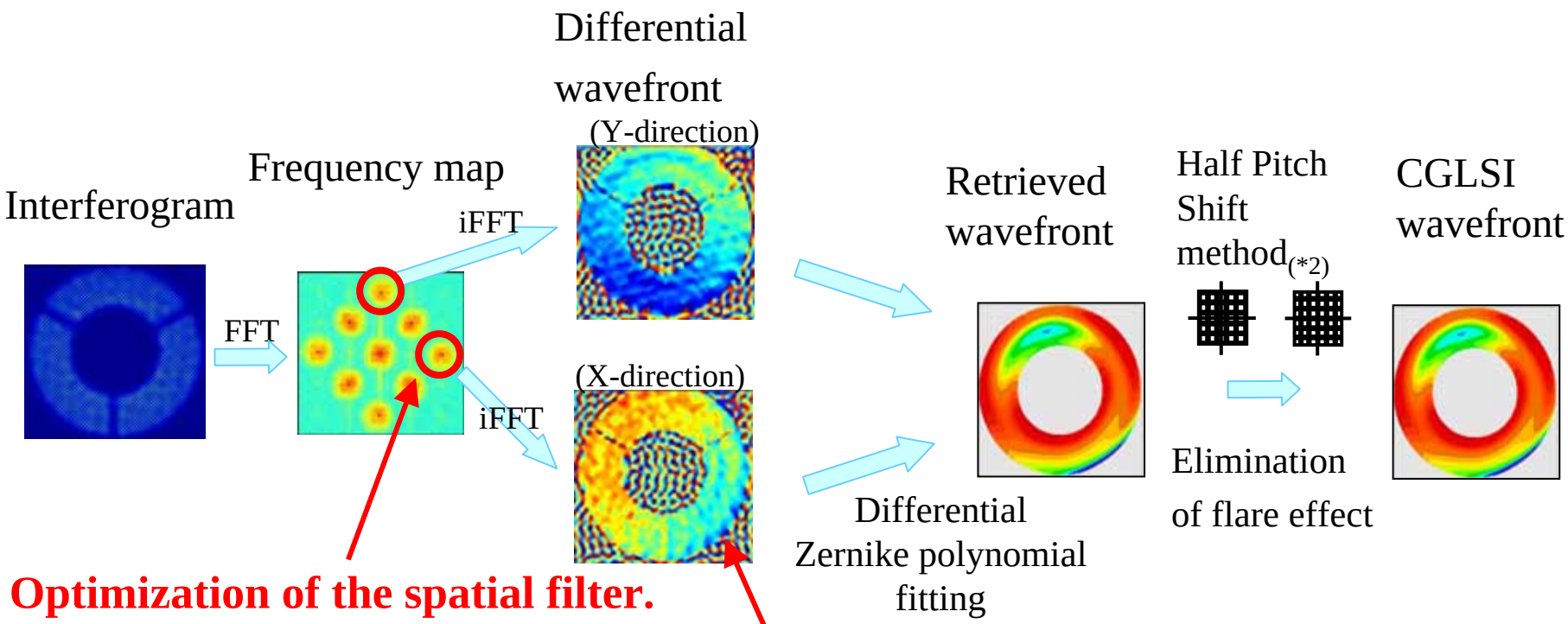
✧Optimization of the data analysis method



Optimization of the spatial filter.

Distance between two focus points calculated from the experiment was used for evaluating CCD tilt.

(*2)Ref. Kato et. al, SPIE vol. 5751, 110-117 (2005)

Improvement of CGLSI

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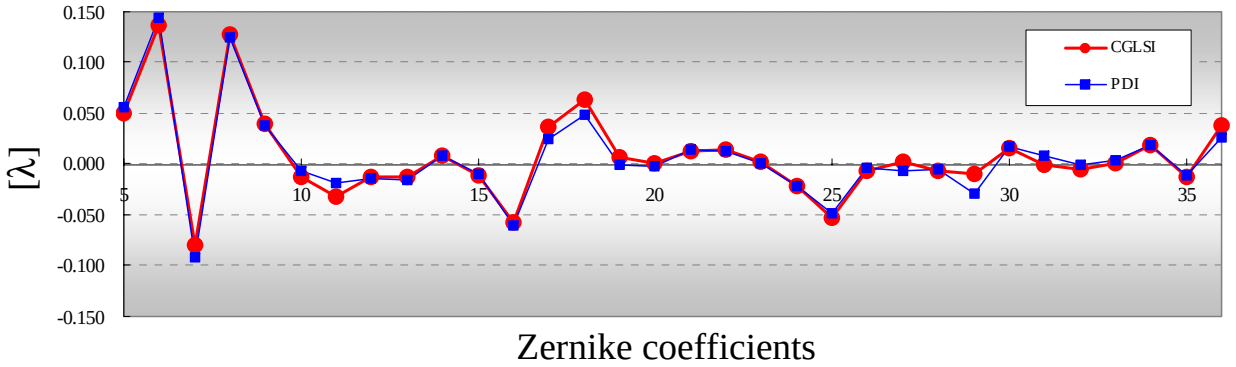
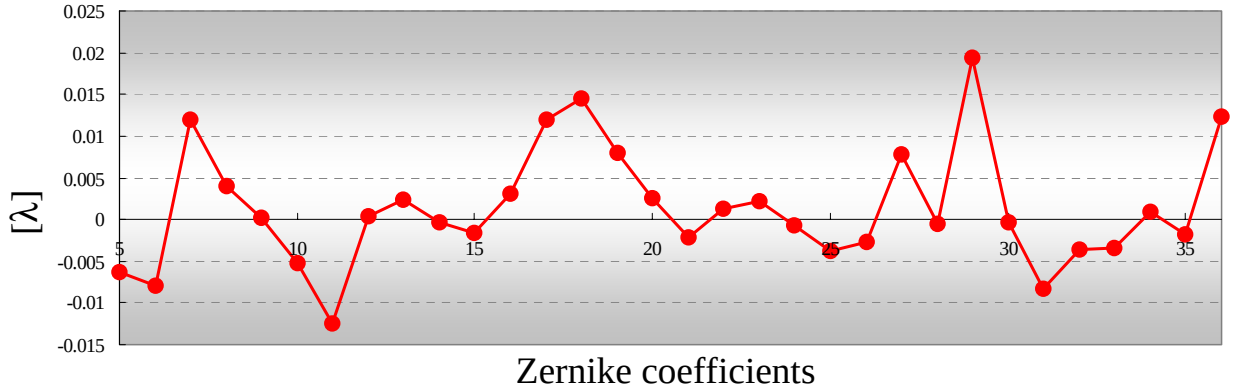
✧Comparison between PDI and CGLSI



Wavefront Aberration nm RMS

CGLSI	PDI
1.24nm	1.26nm



RMS of difference

0.17 nm

- **Difference between CGLSI and PDI is 0.17 nm RMS.**
- **This value is small enough to evaluate a six-mirror PO.**

Outline of EWMS

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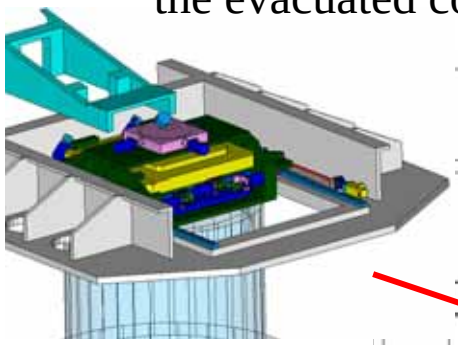
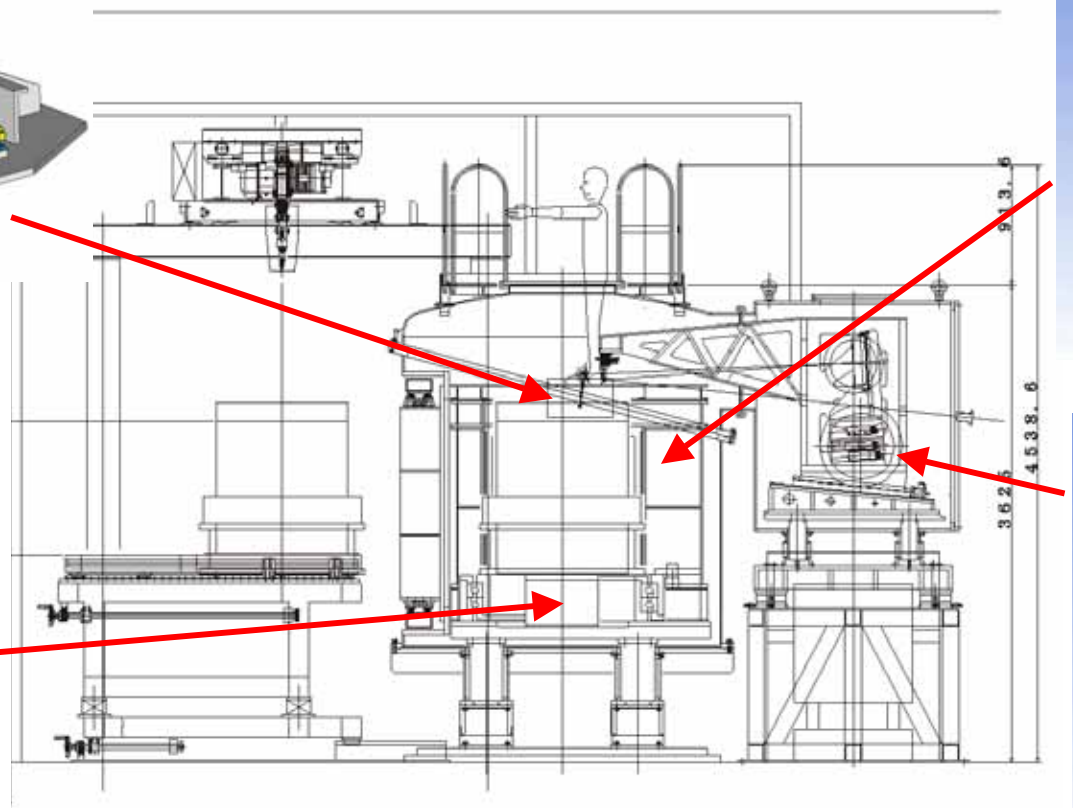
Feature

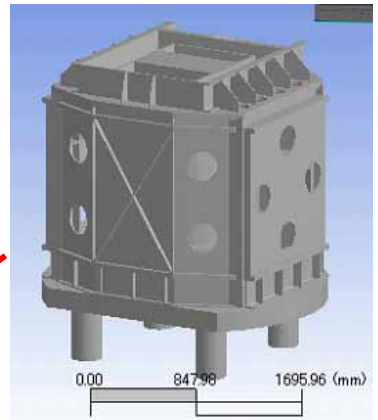
- Six-mirror PO can be evaluated.
- Arbitrary points in the exposure field are measurable.
- Multiple interferometric methods can be operated in succession without breaking the evacuated condition of the chamber.



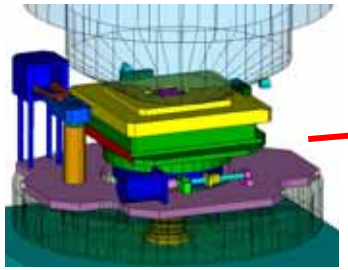
Stages at the object plane



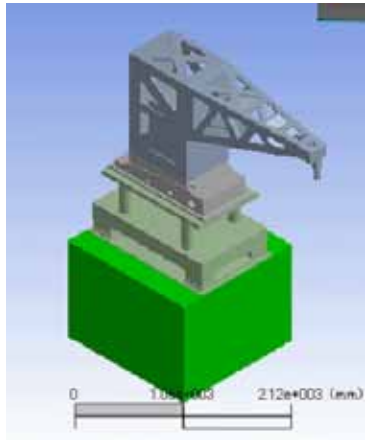
Schematic view of EWMS



Main structure of EWMS



Stages at the image plane



Illumination system

Outline of EWMS

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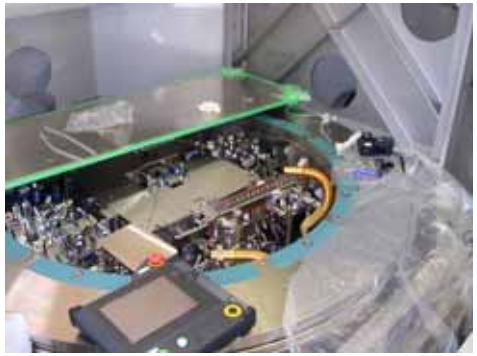
- EWMS has been manufactured.
- EWMS will be transported to NewSUBARU in late November.

Surrogate PO and PO transport

Overall view of EWMS

Stages at the object plane



Stages at the image plane

Summary

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- **Reproducibility of PDI was improved to 0.045 nm RMS.**
- **PDI is applicable to the measurement of a six-mirror PO.**
- **Difference between CGLSI and PDI was improved to 0.17 nm RMS.**
- **The manufacturing of EWMS is going on as scheduled.**

Acknowledgment

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