# The Experimental EUV Interferometer with Several Measurement Methods

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# Outline

Review of EUV Experimental Interferometer (EEI)

Analysis of the data measured by the EEI

- Comparison with Visible PDI
- Effect of Center Obscuration
- Effect of 2nd Pinhole Size

Conclusion

# Review of EEI (EUV Experimental Interferometer)

**Purpose**

Early study of the EWMS for 6 mirror P.O.

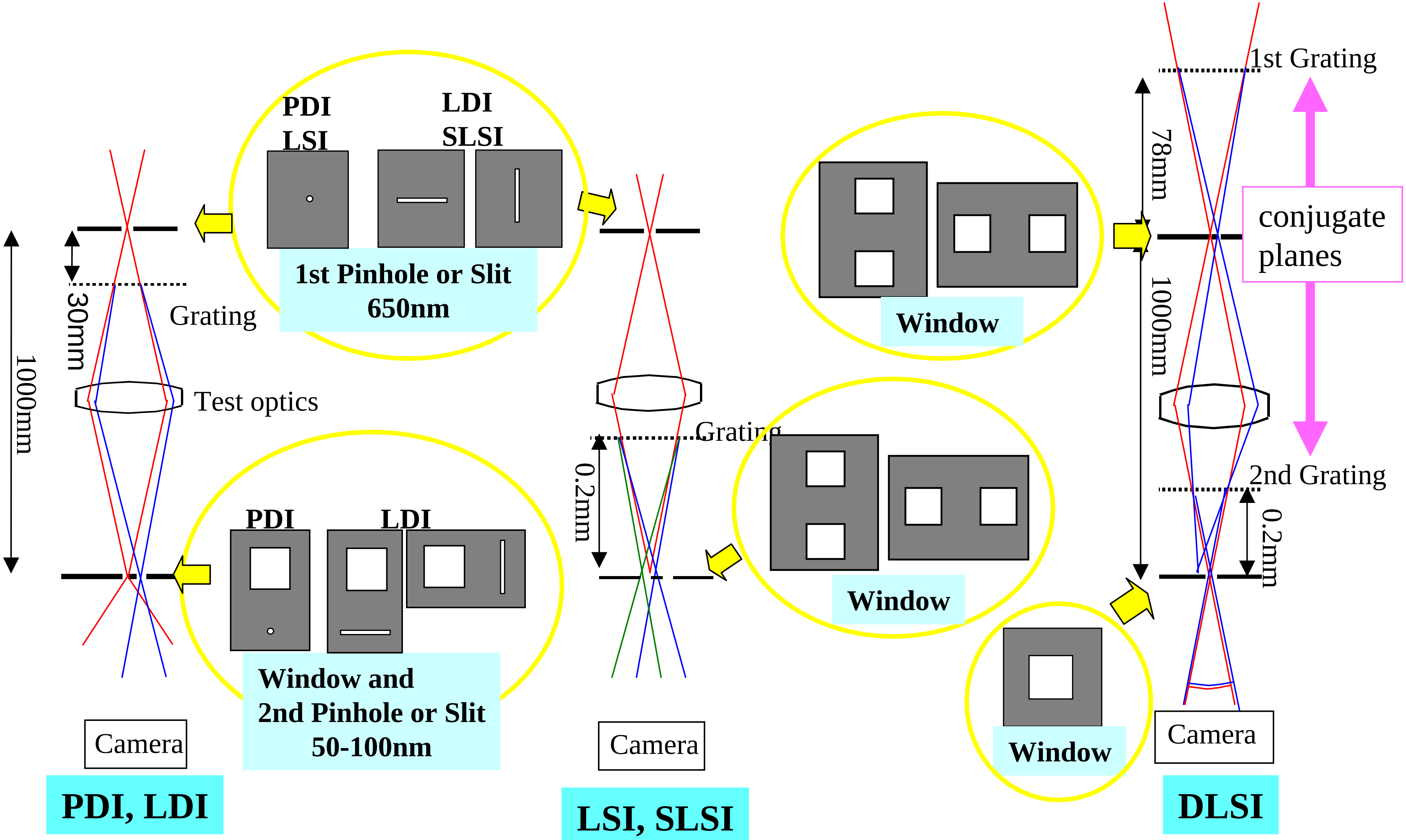
Comparison of the 5measurement methods

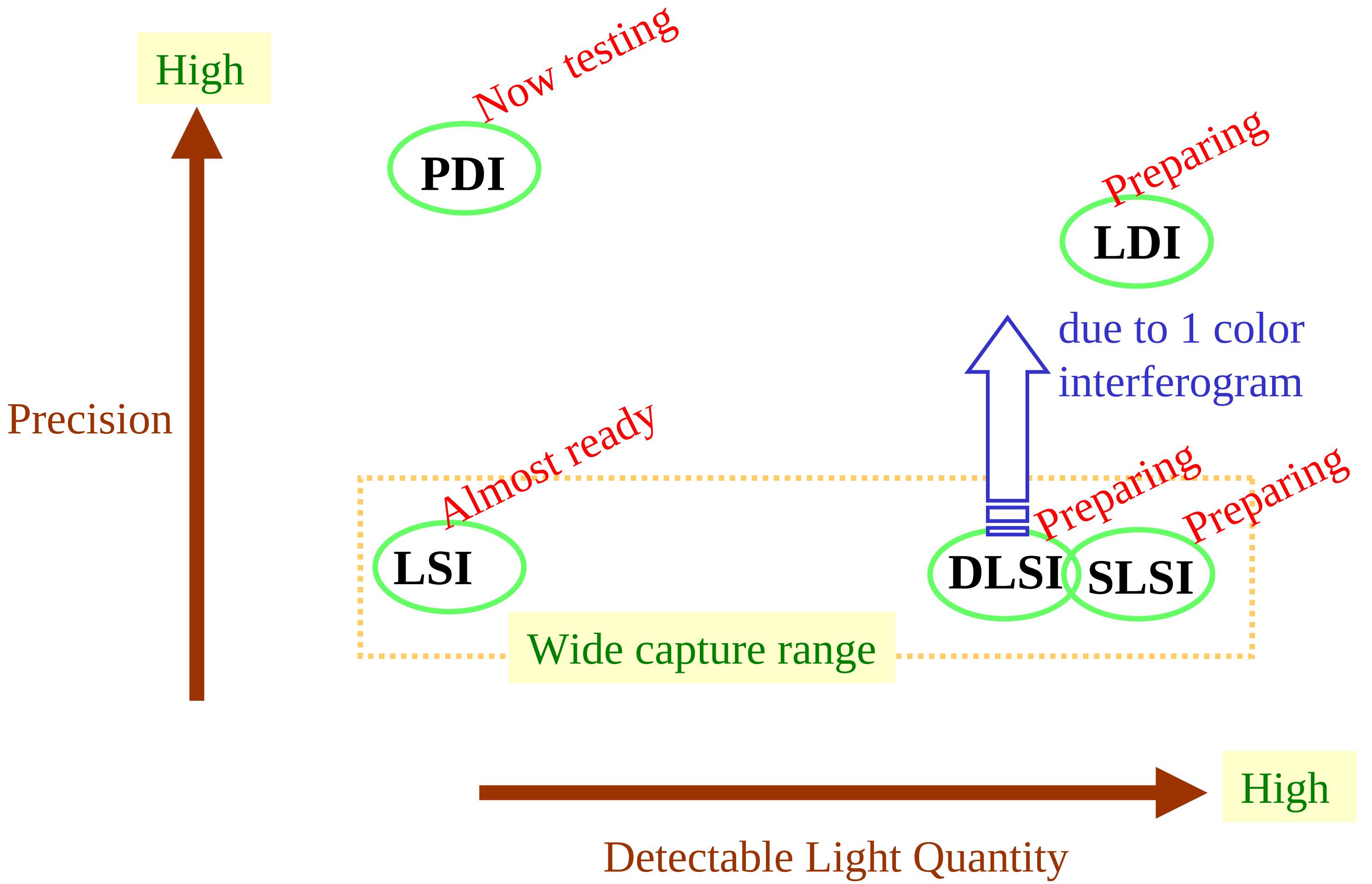
**EWMS** (EUV Wavefront Metrology System) is
the interferometer for the 6-mirror projection system,
and
is scheduled to be completed by March 2006.

**5 Measurement methods of the EEI**

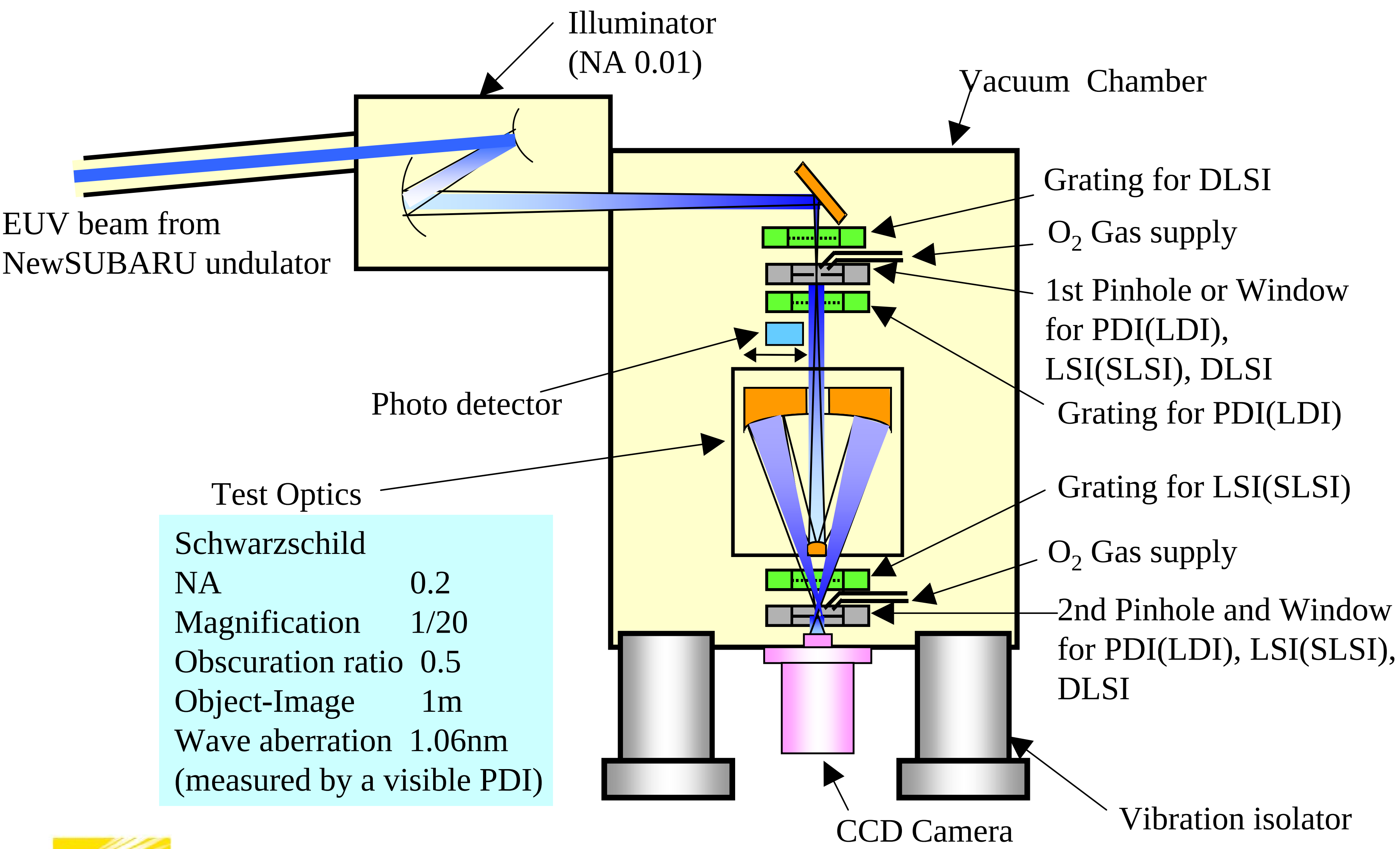
PDI : Point Interferometer
LDI : Line Diffraction Interferometer
LSI : Lateral Shearing Interferometer
SLSI : Slit-type Lateral Shearing Interferometer
DLSI : Double-grating Lateral Shearing Interferometer

# Configuration of EEI



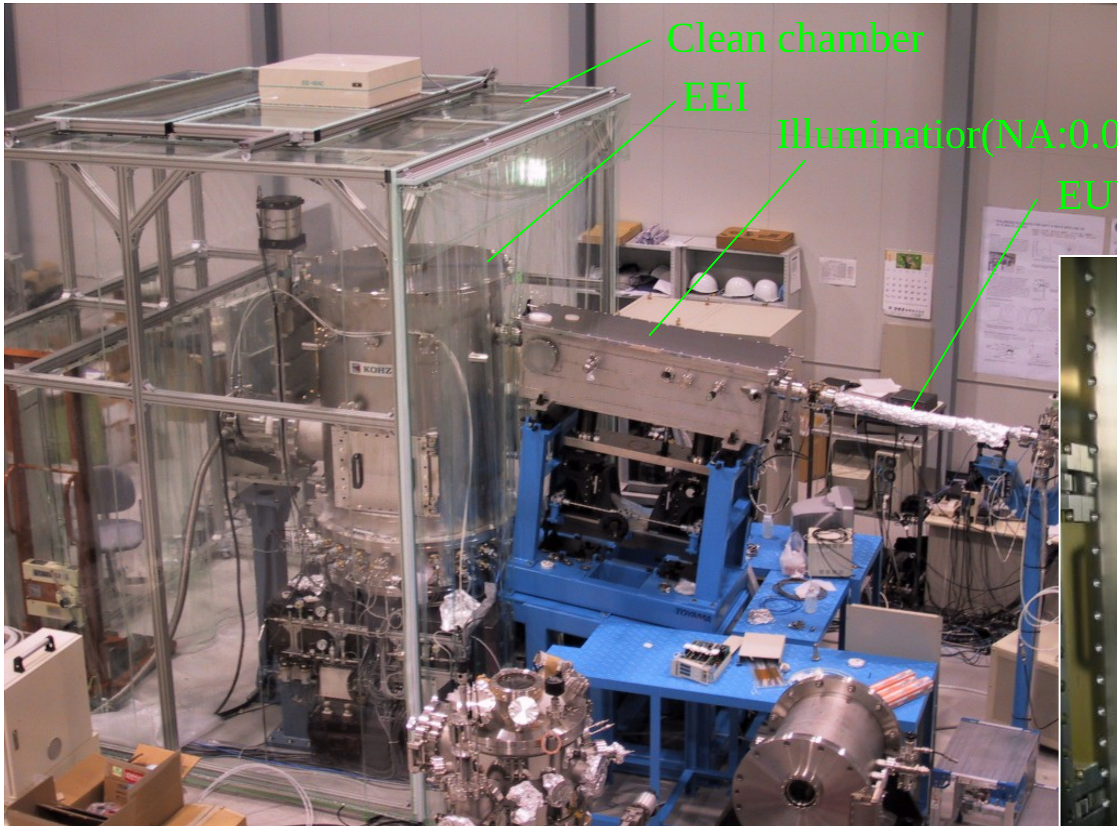

High
Now testing
PDI
Preparing
LDI
due to 1 color
interferogram
Precision
Almost ready
Preparing
Preparing
LSI
DLSI
SLSI
Wide capture range
High
Detectable Light Quantity

# Diagram of EEI

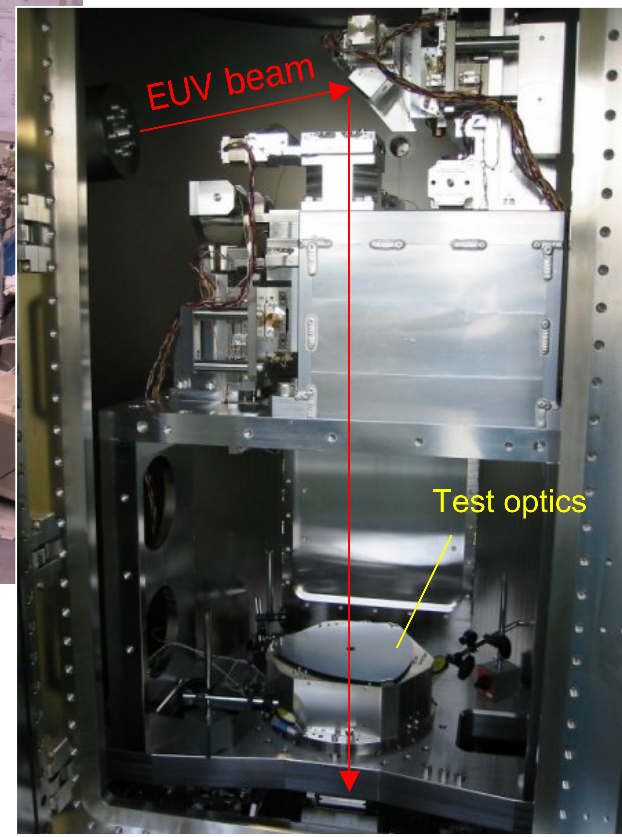



| | |
|---|---|
| Schwarzschild | |
| NA | 0.2 |
| Magnification | 1/20 |
| Obscuration ratio | 0.5 |
| Object-Image | 1m |
| Wave aberration | 1.06nm |
| (measured by a visible PDI) | |

# EEI at NewSUBARU




Entire view of EEI




Inside of EEI

# PDI Data - (1)Interferogram and Wavefront

**2nd Pinhole**

**Diameter 100nm**
**Thickness 200nm**
**Material Ta**

**Exposure**

**1sec/frame**

Algorithm

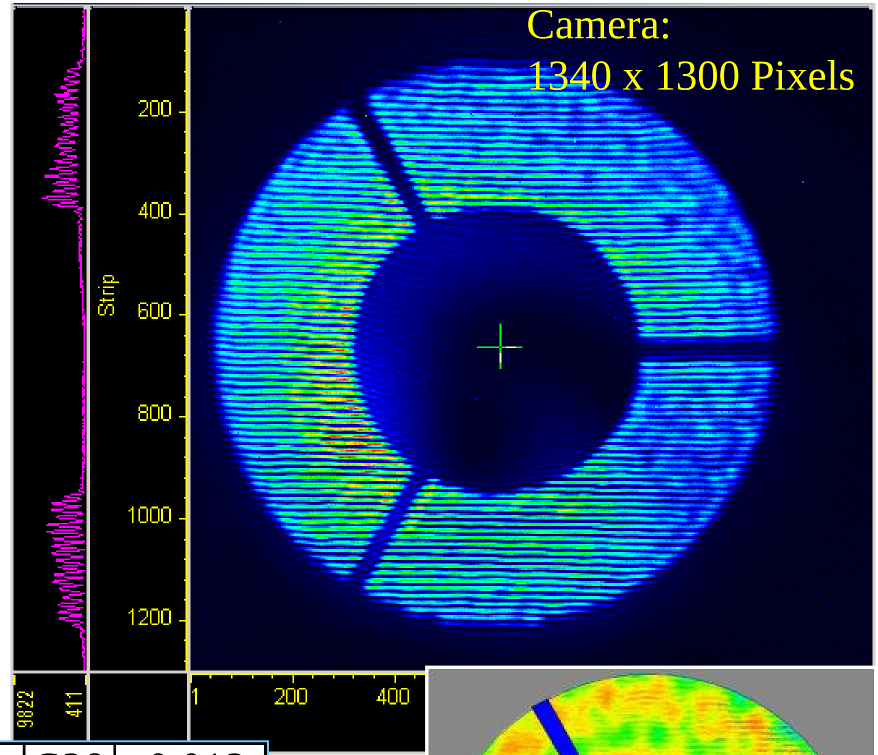
**9 Buckets (90deg)**

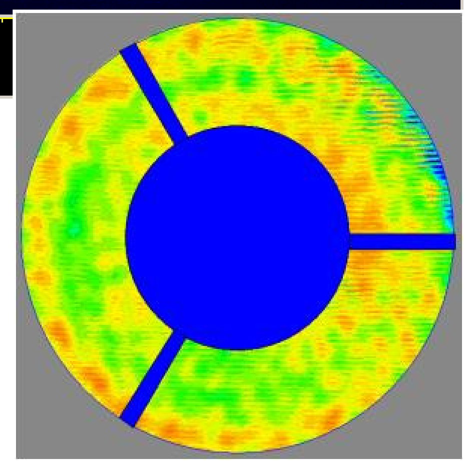
Result

RMS 1.21nm (0.089λ)

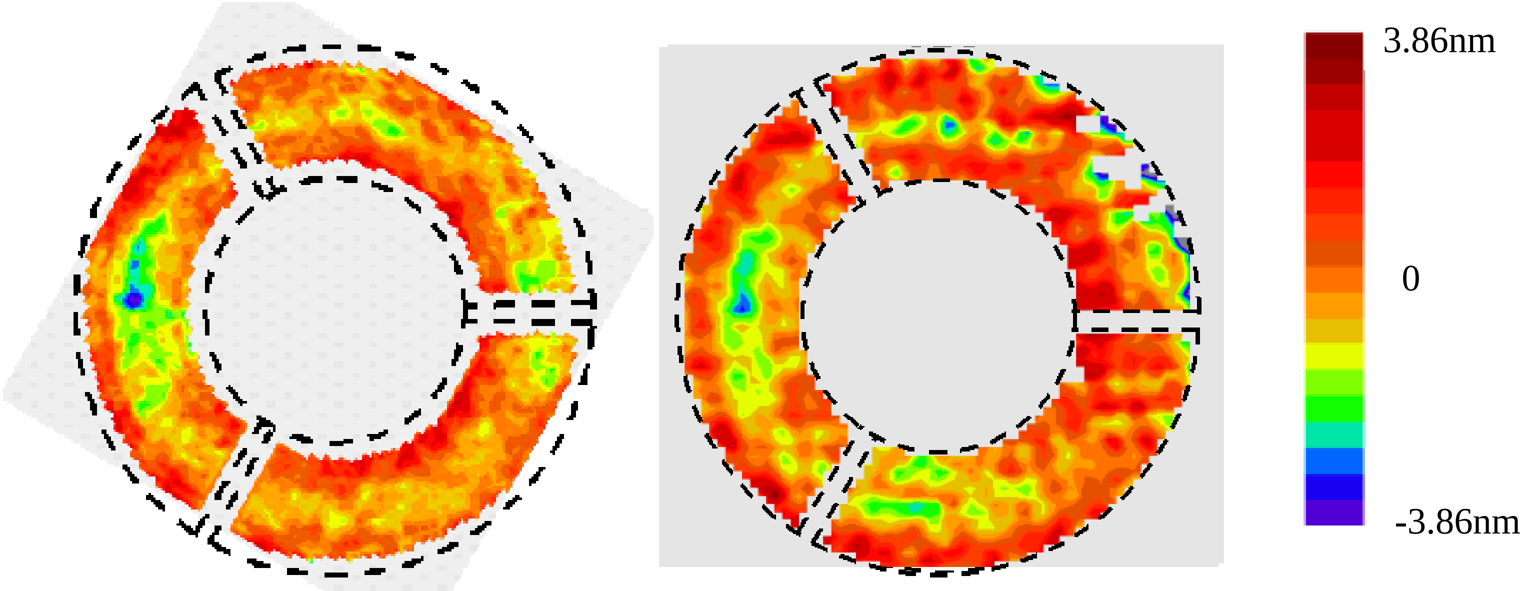
Zernike coefficients

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C1 | 5.480 | C10 | 0.010 | C19 | -0.022 | C28 | 0.012 |
| C2 | 0.014 | C11 | 0.027 | C20 | -0.010 | C29 | 0.003 |
| C3 | -0.035 | C12 | -0.072 | C21 | 0.030 | C30 | 0.014 |
| C4 | 0.694 | C13 | 0.028 | C22 | -0.015 | C31 | 0.013 |
| C5 | -0.015 | C14 | 0.013 | C23 | -0.035 | C32 | -0.012 |
| C6 | 0.021 | C15 | -0.117 | C24 | 0.167 | C33 | 0.010 |
| C7 | -0.129 | C16 | 0.748 | C25 | -0.518 | C34 | 0.053 |
| C8 | 0.164 | C17 | -0.029 | C26 | 0.010 | C35 | -0.062 |
| C9 | -0.850 | C18 | 0.027 | C27 | 0.012 | C36 | 0.120 |





Wavefront map

# Data PDI - (2)Comparison with Visible PDI




Wavefront of the visible PDI(*)
RMS 1.06nm
(The data close to the edge were removed because of diffraction noise)

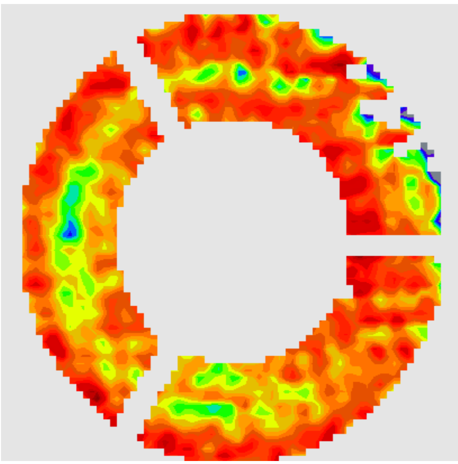
Wavefront of EEI
RMS 1.21nm

These maps resemble each other.

(*)Equipment of Nikon sagamihara plant

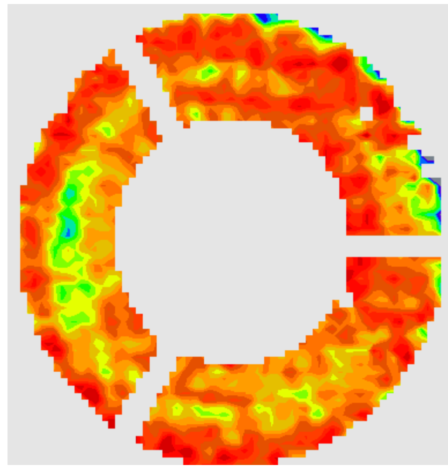
# PDI Data - (3) Reproducibility

1 st data



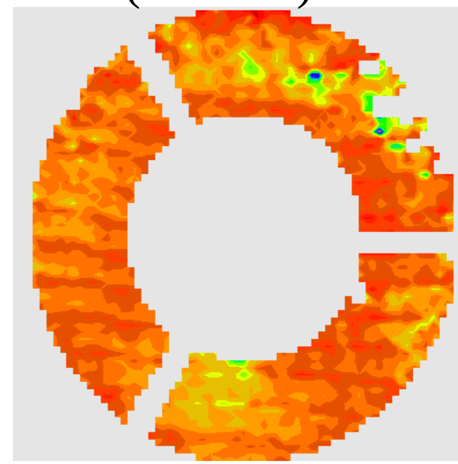
RMS 1.21nm
(Tilt & Power removed)

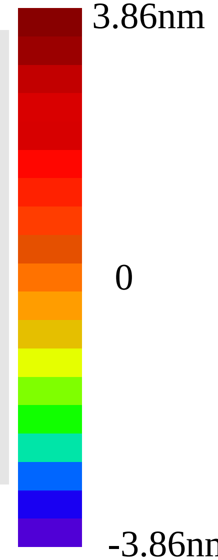
2nd data
(10min. later)



RMS 1.10nm
(Tilt & Power removed)

Difference
(1st- 2nd)






RMS 0.64nm

# Zernike Analysis

Differences between 1st and 2$^{nd}$ measurements

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C1 | -0.282 | C10 | 0.002 | C19 | 0.005 | C28 | 0.015 |
| C2 | 0.007 | C11 | 0.019 | C20 | -0.003 | C29 | 0.011 |
| C3 | -0.014 | C12 | -0.029 | C21 | -0.005 | C30 | -0.003 |
| C4 | 0.295 | C13 | -0.018 | C22 | -0.007 | C31 | -0.005 |
| C5 | 0.002 | C14 | 0.028 | C23 | 0.002 | C32 | 0.023 |
| C6 | 0.006 | C15 | -0.077 | C24 | 0.040 | C33 | -0.012 |
| C7 | -0.024 | C16 | 0.334 | C25 | -0.193 | C34 | 0.024 |
| C8 | 0.038 | C17 | -0.005 | C26 | 0.022 | C35 | -0.016 |
| C9 | -0.352 | C18 | -0.015 | C27 | -0.019 | C36 | 0.068 |

Axial symmetrical terms (C4,C9,C16,...) varied considerably. ← Center obscuration

Low order astigmatism terms(C5,C6) was reproduced remarkably. ← Large 2nd pinhole

# Effect of Center Obscuration on Zernike Coefficients

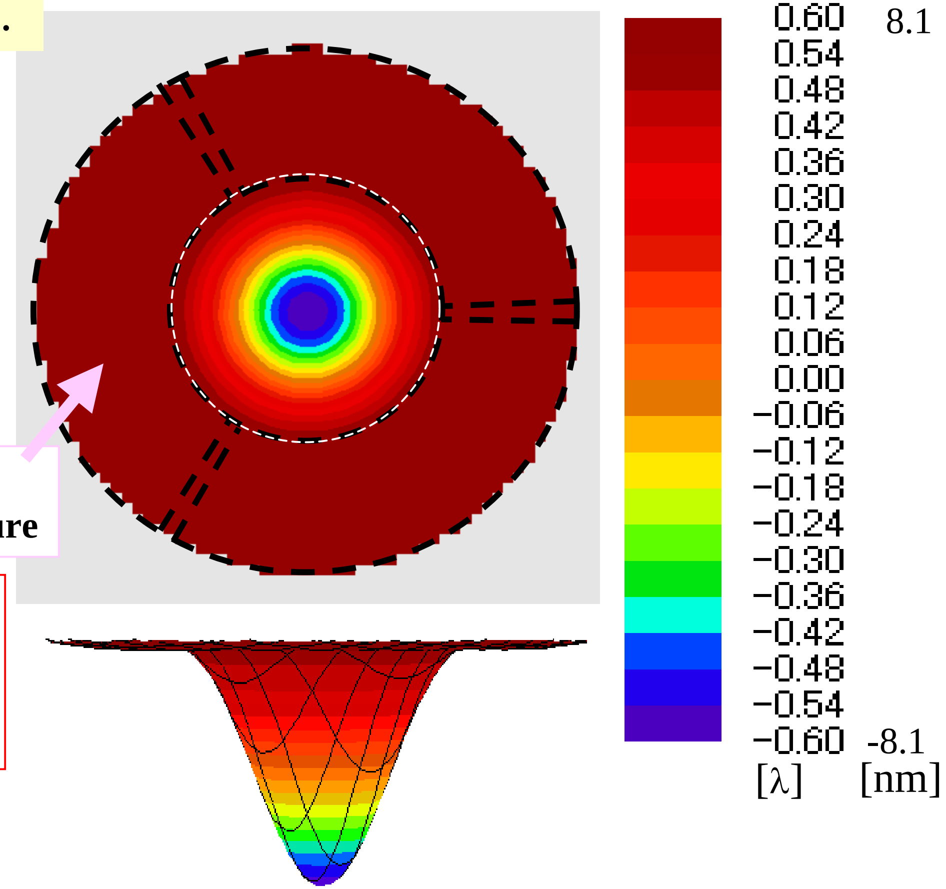
JVA

The center obscuration data are ineffective.

The reproducibility of symmetrical aberrations (C4, C9, C16, C25 and C36) are very sensitive, because of the obscuration.

Evaluation of spherical aberration terms in combinations of Zernike coefficients is indispensable.

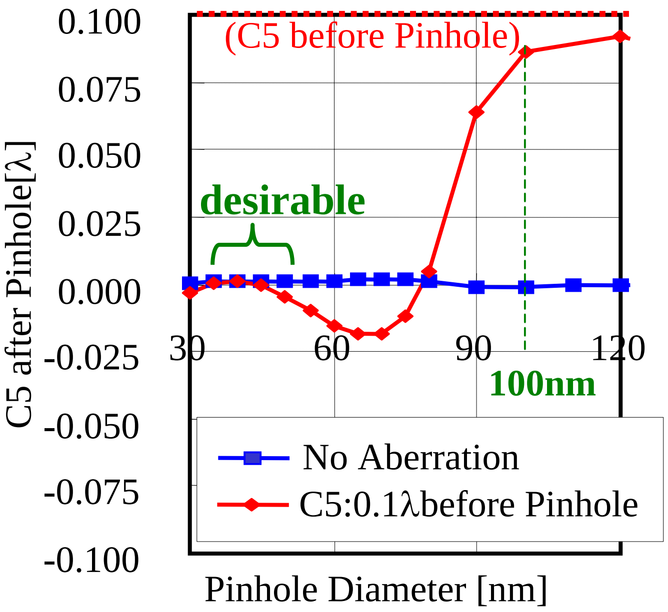
***As the 6 mirror projection system has no obscuration, this phenomenon doesn't exist at the EWMS.***

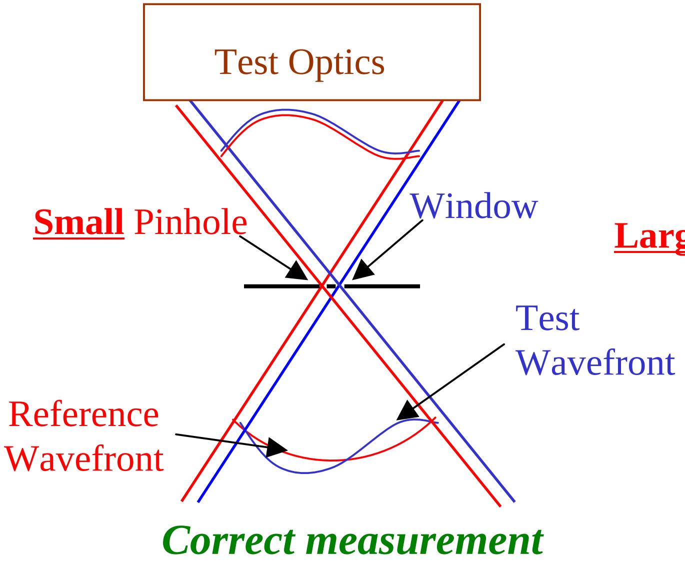


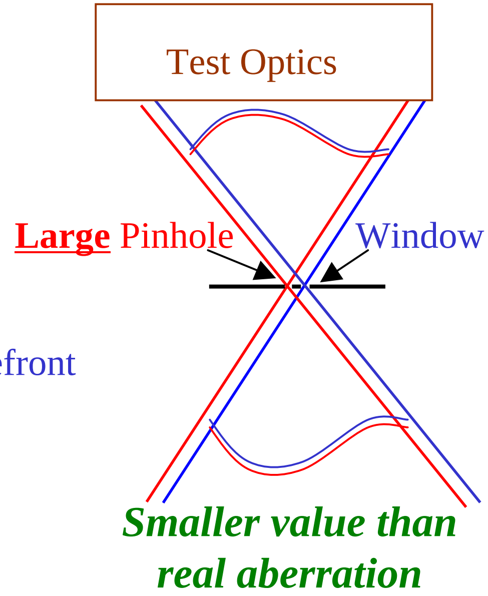

Equivalent wavefront to the changes in C4,C9,C16,C25 and C36

# Effect of 2nd Pinhole Size – (1)Astigmatism

Simulation of Astigmatism after various sizes of 2nd pinholes




**Condition of Simulation**

Pinhole :
- Ta (n=0.9429, k=0.0408)
- Thickness 200nm

Incident beam :
- NA 0.2
- Linear Polarization

Tool : TEMPESTpr™

Most of astigmatism goes through 100nm pinhole.

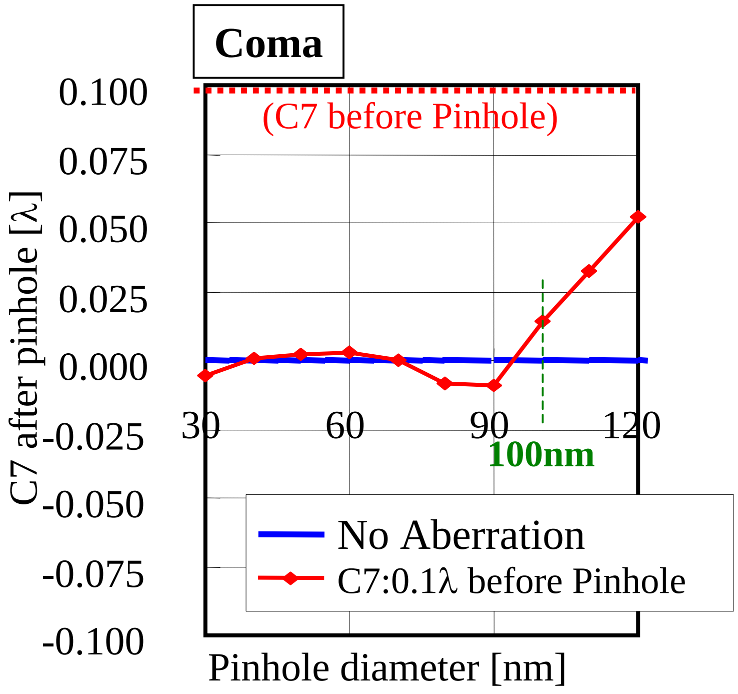
Reference and test wavefront have nearly the same astigmatism.

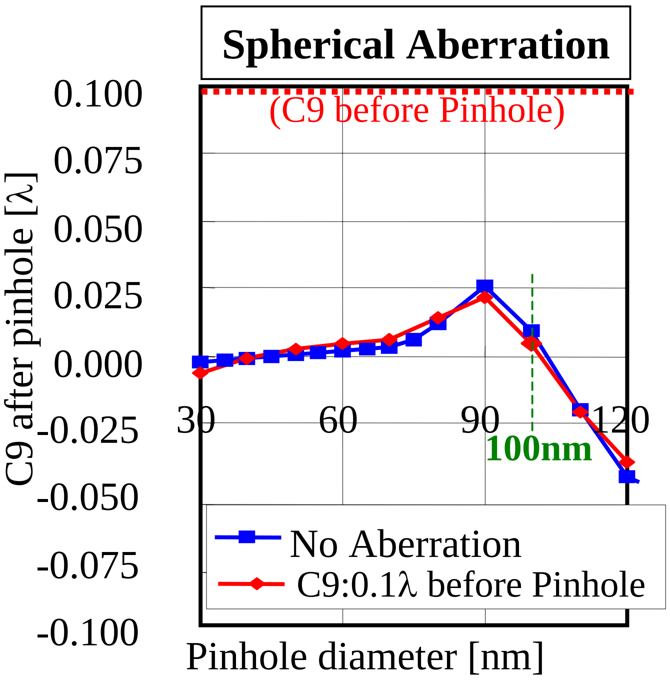
The astigmatism measurement value is always small, whatever astigmatism the test optics have.

A 40-50nm pinhole is desirable for PDI of EEI.

# Effect of 2nd Pinhole Size – (2)Coma, Spherical Aberration

Simulation of Coma and Spherical Aberrations after various sizes of 2nd pinholes




Coma and Spherical aberrations don’t go through 2nd pinhole so much as astigmatism.

# Conclusion

The EUV Experimental Interferometer(EEI) has begun to work, and the wavefront data of NA 0.2 Optics were obtained.

The PDI data by the EEI show the similar results to those by the visible wavelength PDI.

Evaluation of spherical aberration needs the combined analysis of Zernike terms due to the center obscuration.

For the EEI, the desirable size of a 2nd pinhole is proved to be 40-50nm in order to measure astigmatism with high precision.

# Acknowledgment

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