Development Status of Canon's EUVL Exposure Tool

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Canon Inc.

Outline

- EUVL Exposure tool Roadmap
- Optics Evaluation Technologies
  - Multilayer Evaluation
  - Wavefront Error (WFE) Measurement
- Evaluation Results of PO1 Mirrors
  - Surface Figure
  - Multilayer (phase shift distribution)
- Optical Performance
  - WFE and Resolution
  - High-NA Projection Optics
- Exposure System Technologies
  - Spectral purity filter (SPF)
  - Optics Contamination Mitigation
- Summary

EUVL Exposure Tool Roadmap

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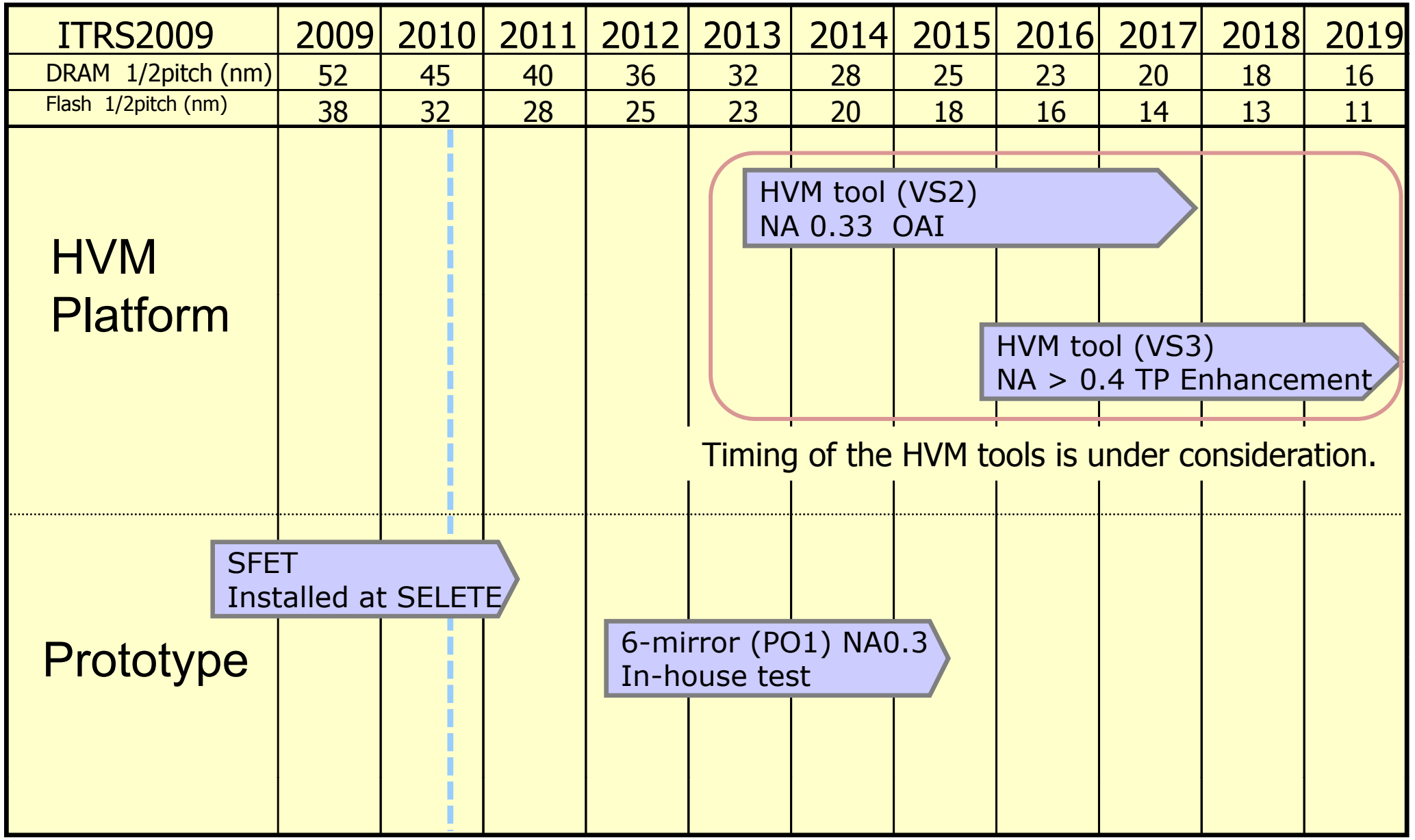
ITRS2009	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
DRAM 1/2pitch (nm)	52	45	40	36	32	28	25	23	20	18	16
Flash 1/2pitch (nm)	38	32	28	25	23	20	18	16	14	13	11



At-wavelength Multilayer Evaluation System

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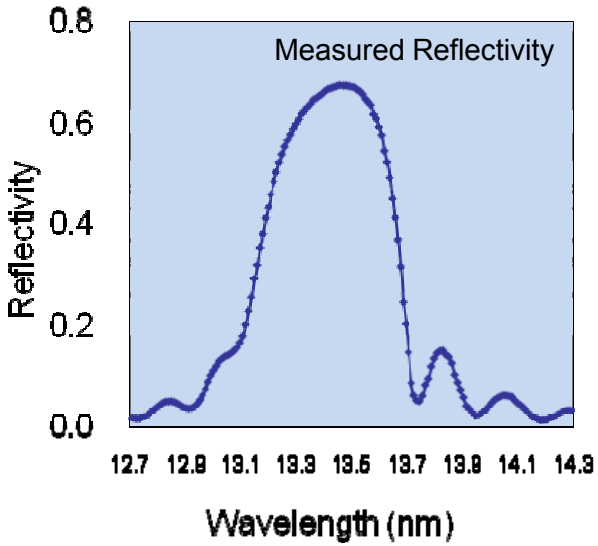
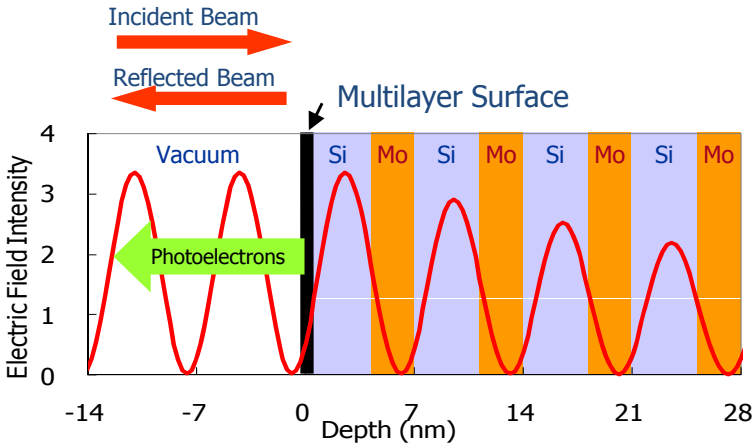
Mirror chamber Sample chamber Monochromator Controller EUV source

Reflectivity measurement

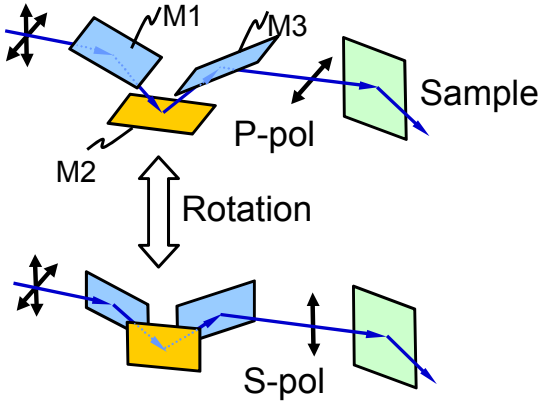


Phase measurement



photoelectron intensity depends on phase difference between incident beam and reflected beam.

Polarization control



extinction factor <1E-3

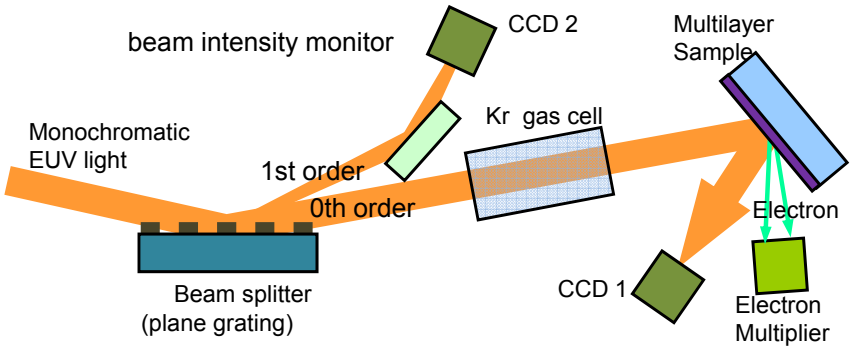
Wavelength Calibration

Real-time wavelength calibration

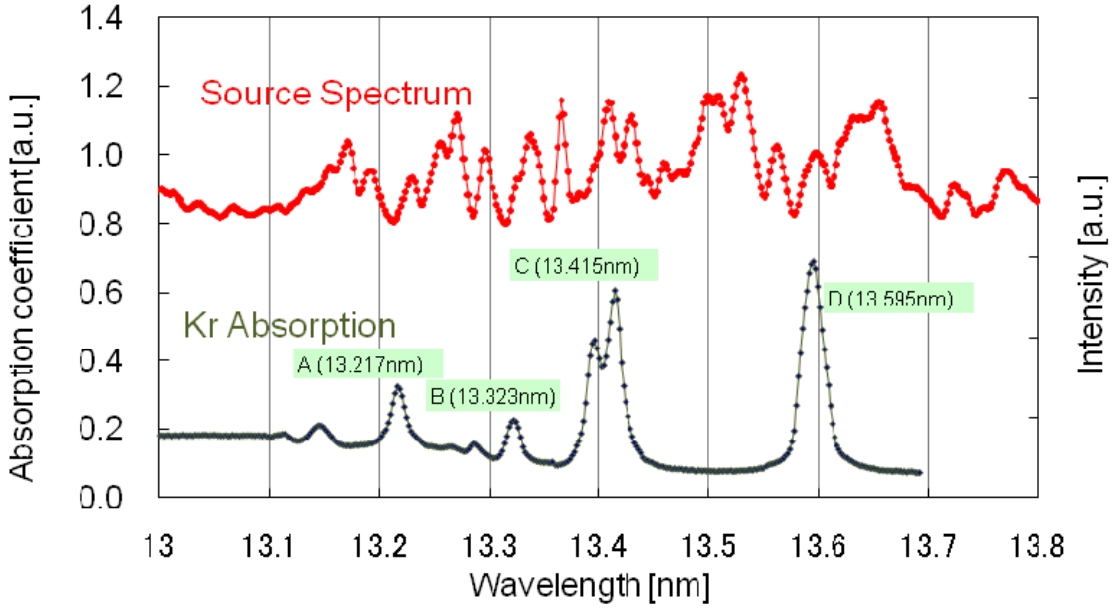
Primary standard:
Krypton absorption lines

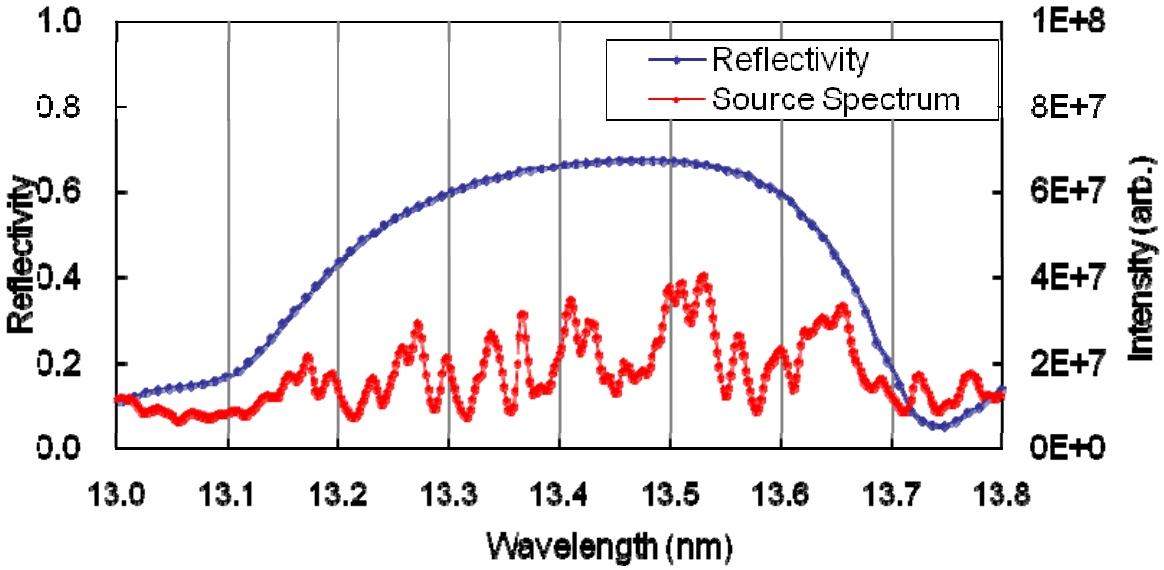
Secondary standard:
Xenon emission lines

Reflectivity of multilayer mirror and source spectrum are measured simultaneously.



Schematic view of the beam intensity Monitor



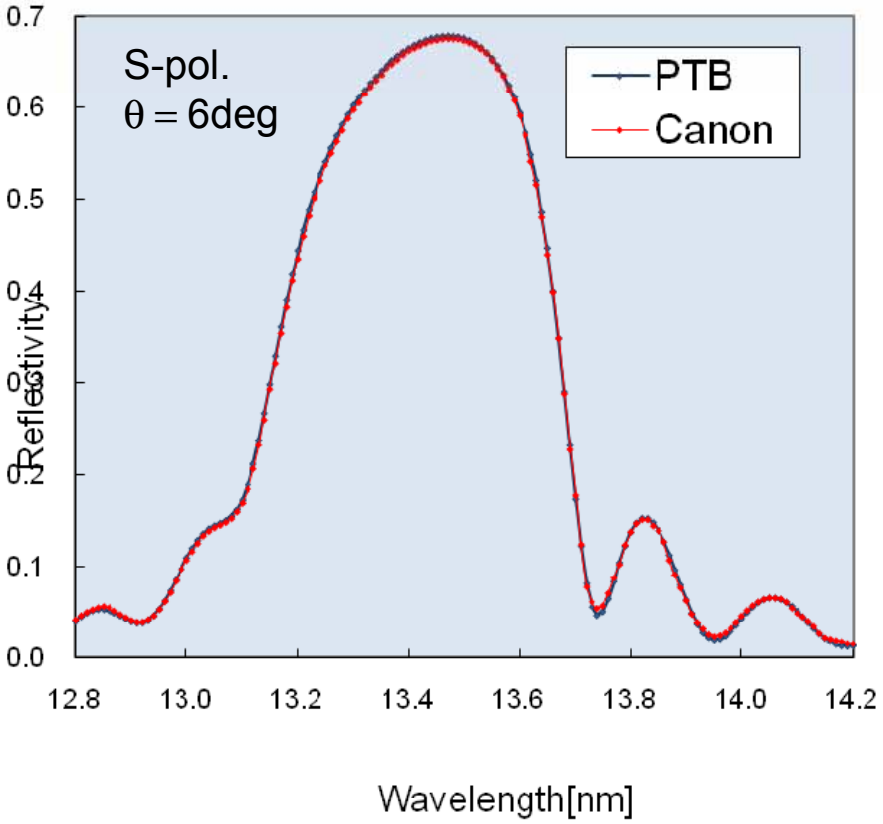


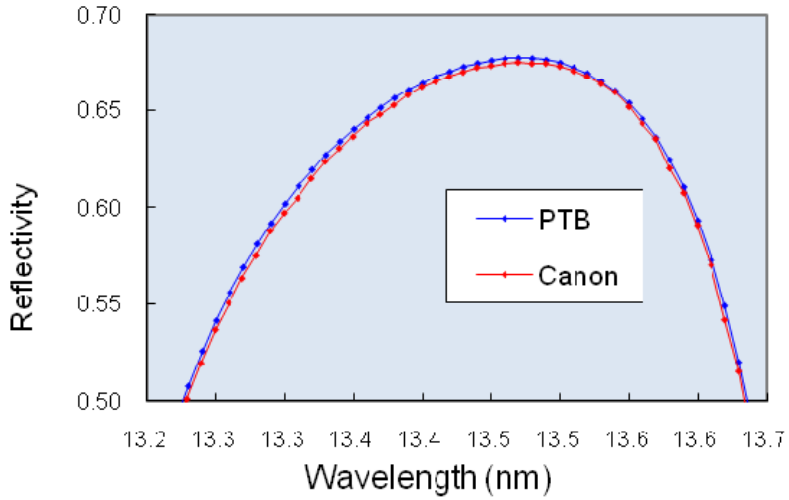
◆Using the Real-time wavelength calibration method, wavelength precision can be maintained constantly.

EUV Reflectometer Round-Robin

EUV reflectometer cross calibration (Round-Robin) conducted by Selete

participant: Selete, Canon, HOYA, NIKON, PTB





Difference between Canon and PTB
CWHM : <1pm
Peak Reflectivity : <0.2%

◆Measurement results by Canon and PTB show good agreement.

Poster : ML-P05 M. Amemiya et al., Selete, Canon, HOYA, NIKON, PTB

WFE measurement using low brightness source

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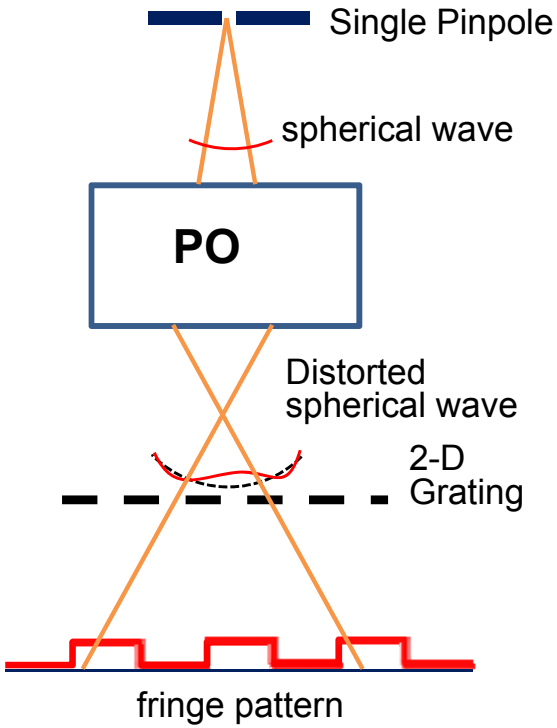
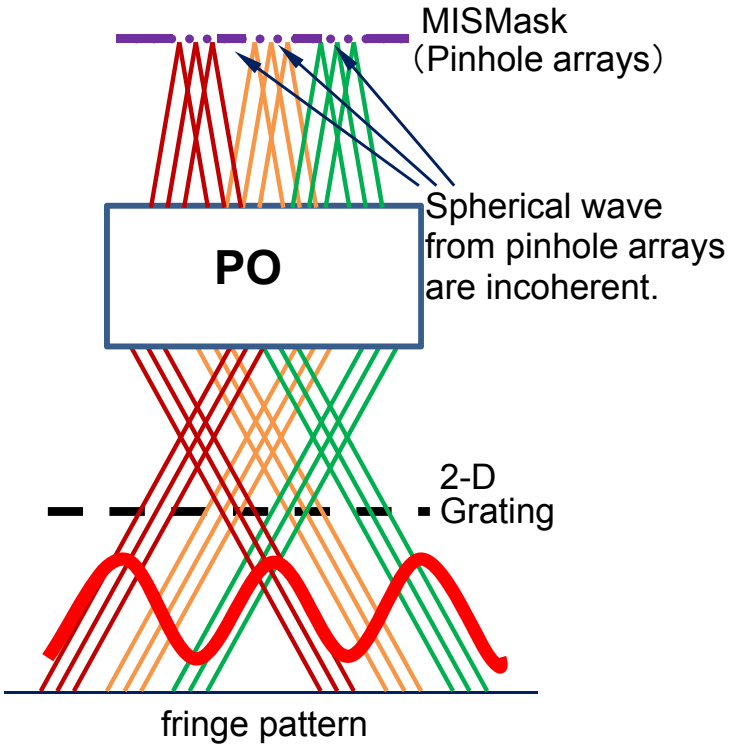
Talbot Interferometer (conventional)

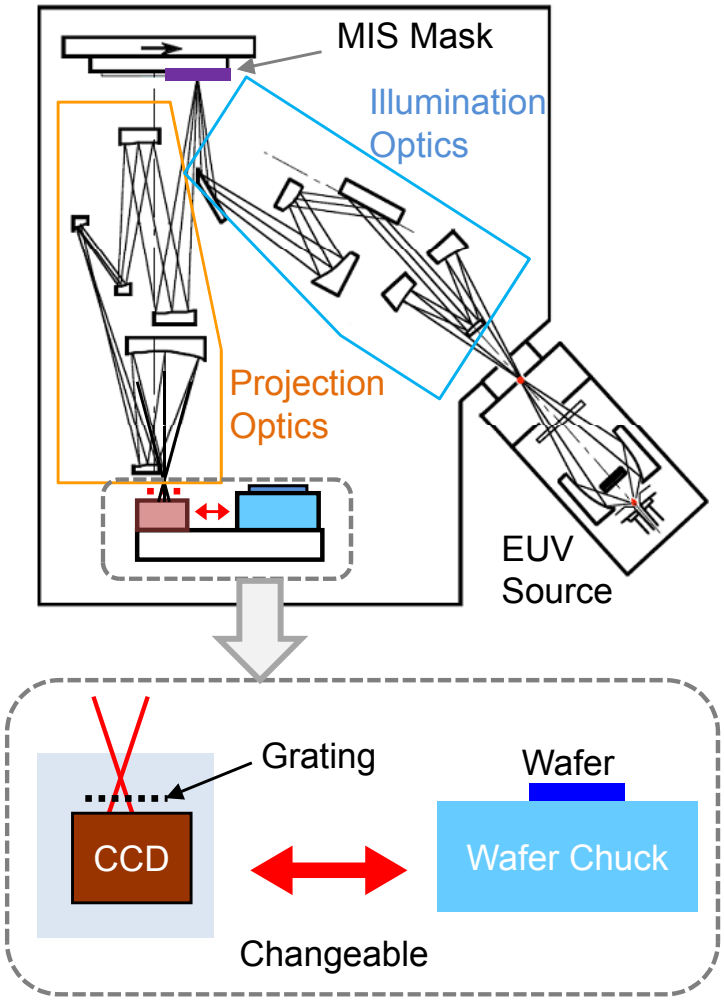


Wavefront error of the PO can be derived from analyze of the fringe pattern.

MISTI (Multi Incoherent Source Talbot Interferometer)



Position of fringe pattern is maintained. EUV flux is multiplied by number of the pinholes.(X10^5)

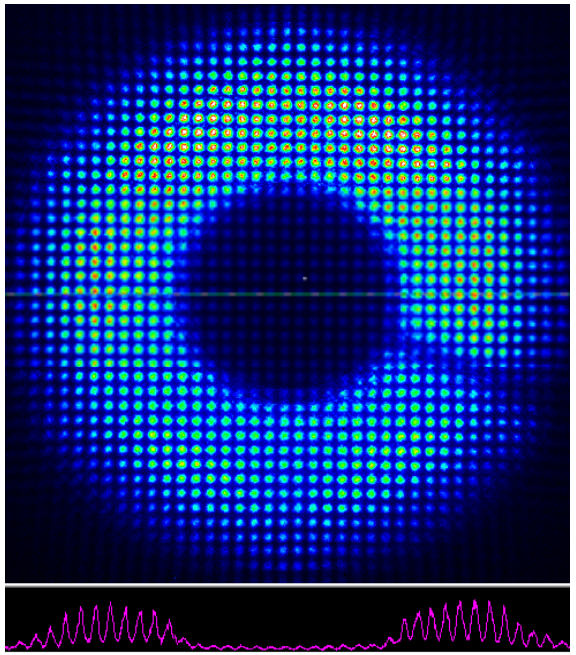


◆WFE of PO can be measured using light source for exposure

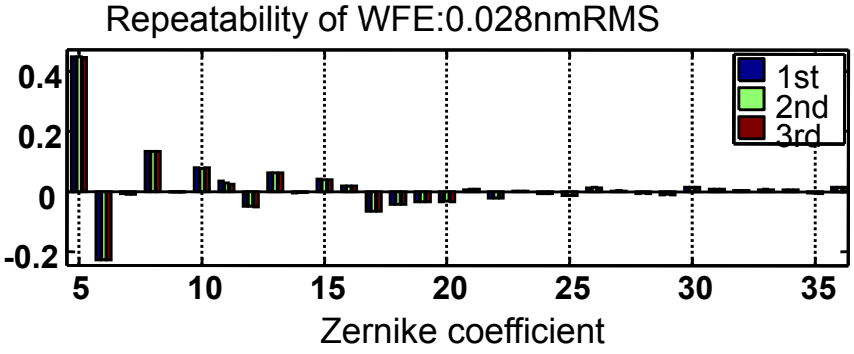
◆Applicable for on-machine measurement of projection optics WFE

Experimental results of WFE Measurement

Experimental Tool using 2-Mirror PO



Fringe pattern
exposure time : 5sec



WFE was measured 3 times. Optical elements (MIS mask, Grating, Illuminator) are re-aligned for each measurement.

- ◆WFE of a PO was measured using a compact DPP source.
- ◆Repeatability of WFE : 28 pm rms

This experiment was performed as a collaboration work of Canon, Nikon and University of Electro-Communications.

Mirror Surface Accuracy

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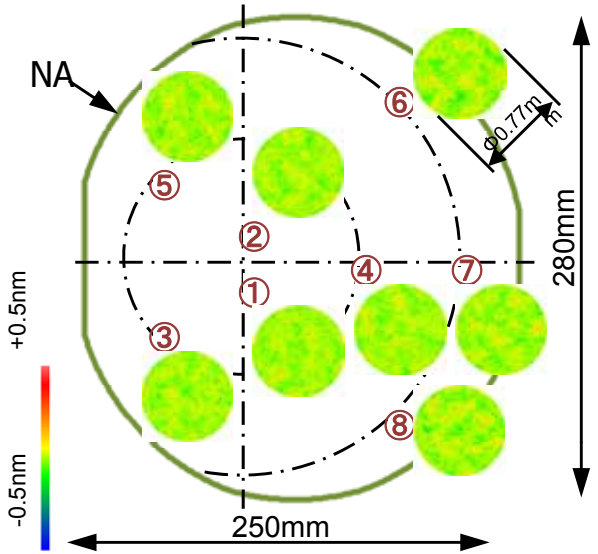
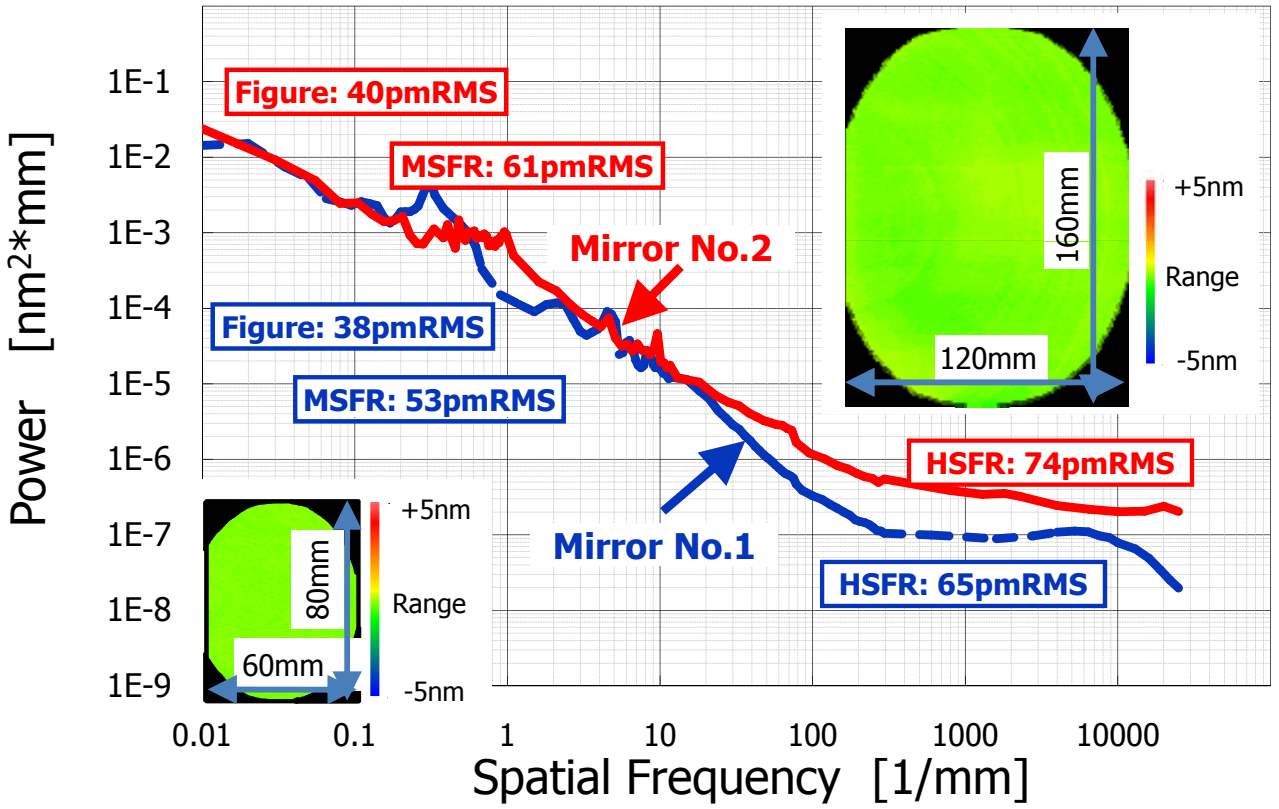
Surface roughness Map



Measured roughness (pmRMS)

Area	Measuring Point								Average
	①	②	③	④	⑤	⑥	⑦	⑧	
Φ5.0mm	41	41	51	41	40	42	41	45	43
Φ0.77mm	55	56	56	55	56	60	58	60	57
Φ0.15mm	35	34	36	35	37	38	41	38	37

Power Spectrum Density



- Improved polishing technology on large-area EUV mirrors have been demonstrated.
- The technology meet the 5% flare specification in 4.5 decades in spatial frequency.

Mo/Si multilayer coating

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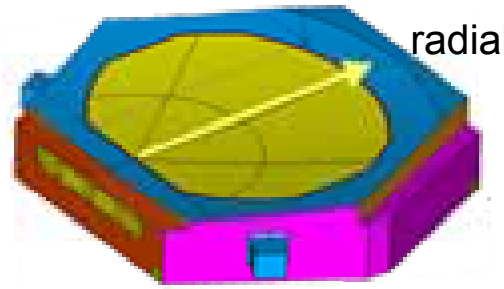
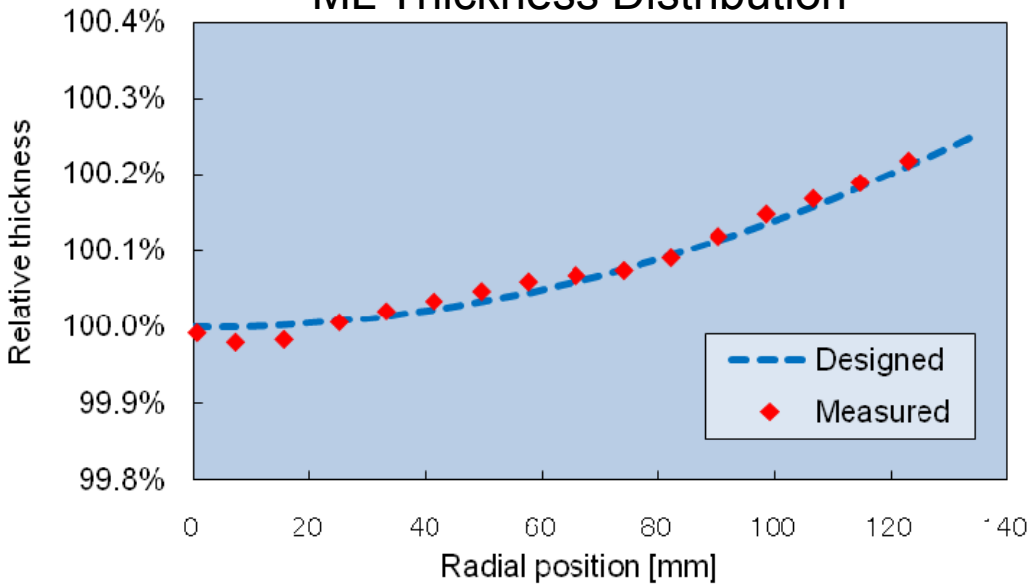
Multilayer thickness distribution and reflection phase shift distribution of a mirror of projection optics were evaluated.

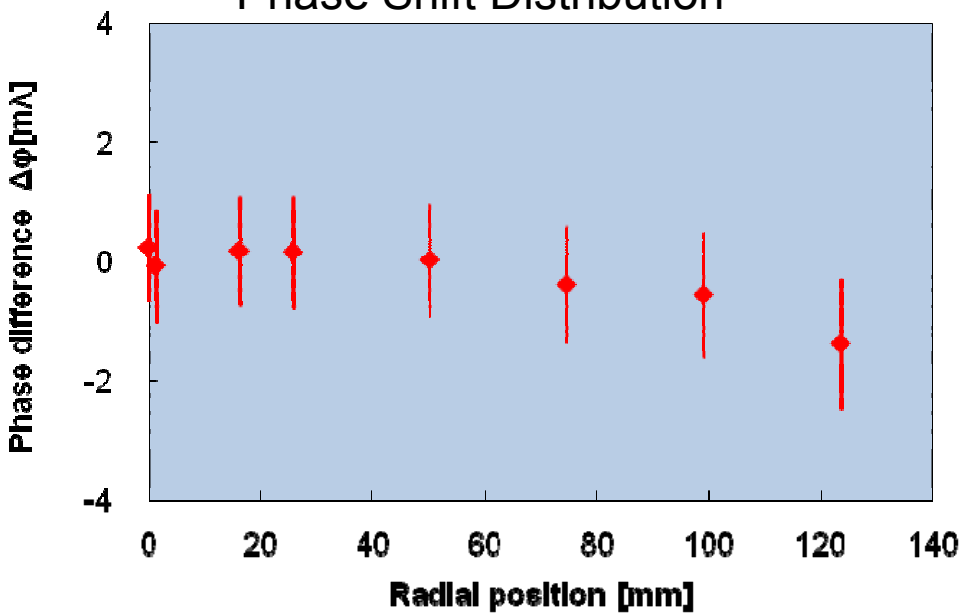


ML Thickness Distribution



Thickness variation ≦0.032%

Phase Shift Distribution



Uncorrectable phase error ≦2mλ

◆Multilayer Coating performance necessary for HVM exposure tool is achieved.

Wavefront Error of a 6-Mirror Projection Optics

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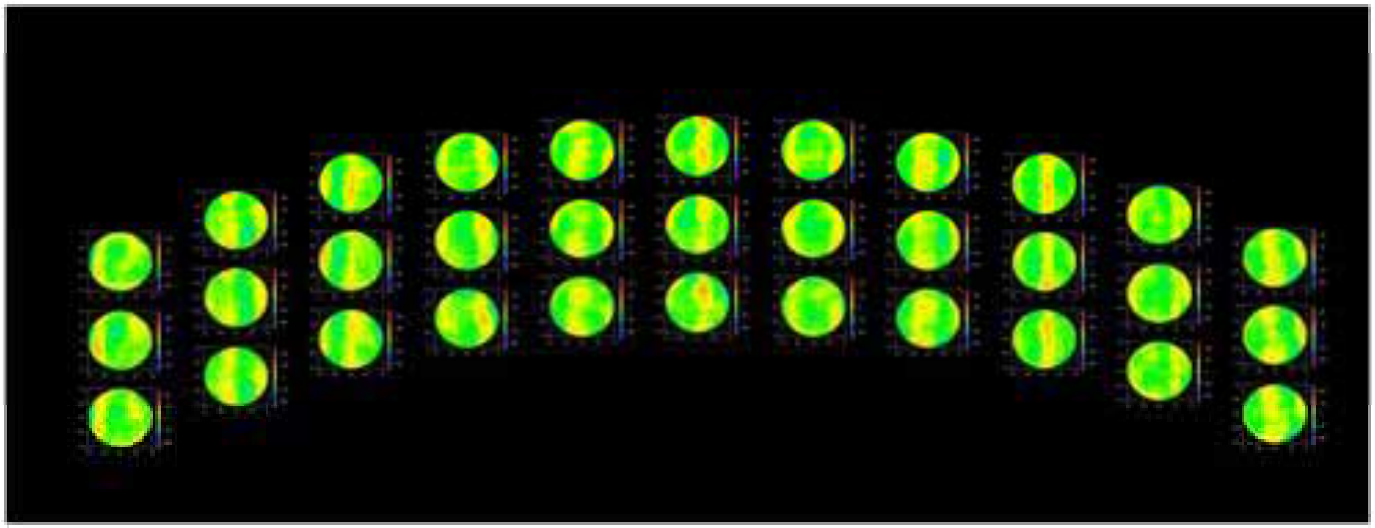
Wavefront error of 0.33NA projection optics is estimated based on evaluation results of PO1 Mirrors. In the estimation, following factors are considered.

- mirror surface figure errors based on measured data of PO1 mirror
- coating errors based on measured data of PO1 mirror
- alignment errors of mirrors (positions, tilt)

Estimated wavefront error (WFE) Map



2mm

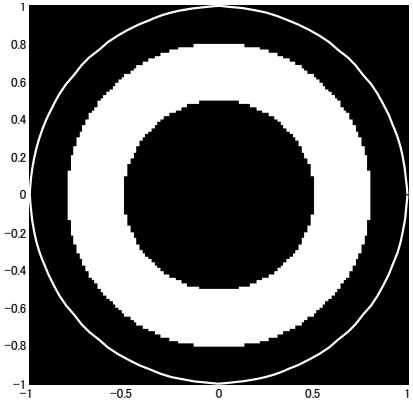
26mm

Z4-36RMS (worst) : 0.5 nm for 33 fields

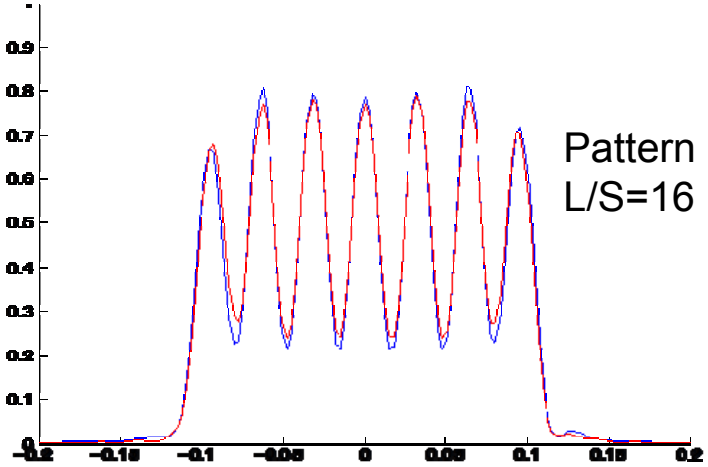
Estimated performance for hp16nm

NA0.33 PO with Off Axis Illumination (OAI)

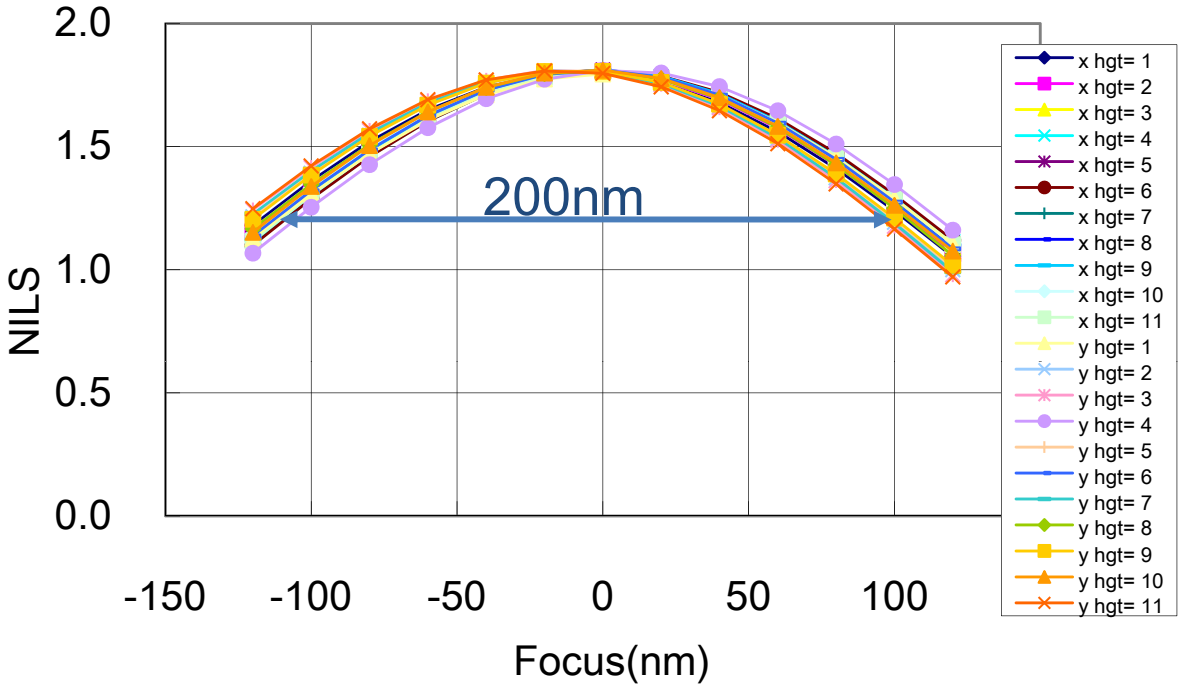
Illumination condition



σout=0.8
σin =0.5



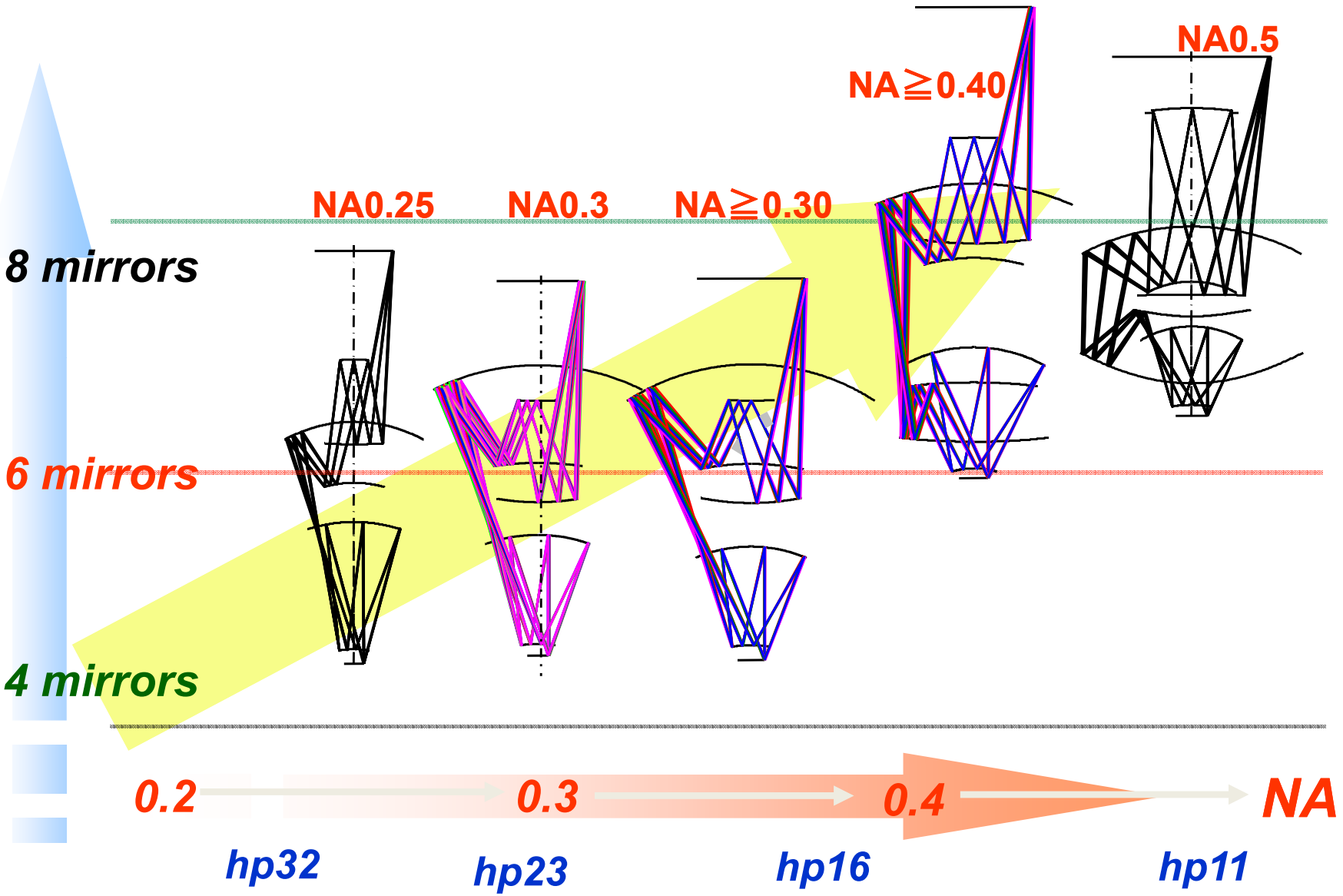
Pattern
L/S=16 nm



DOF >200nm for NILS>1.2 (16nm pattern)

- ◆Performance of NA0.33 PO was estimated.
- ◆Predicted resolution is enough for 16nm pattern printing.

High NA PO Design



Spectral Purity of LPP Source

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Spectral purity part of "Joint Requirements for EUV Source"

Source Charqacteristic	Requirement
Spectral purity:	
130-400 [nm] (DUV/UV)	<1% at wafer values at IF-design dependent
≥400 [nm] (IR/Vis) including 10.6 μm [3]	<10 – 100% at wafer values at IF-design dependent

[3] Assuming 10.6 mm being the excitation laser wavelength

"Joint Requirements for EUV Source" Nikon, ASML, Canon EUVL symposium 2009

Measured out-of-band spectrum

Parameter, Dimension	Measurement conditions or Measured Data
OOB EUV (5-130nm excluding On Band) at IF	3.3% for EUV band from 9 to 21 nm
DUV(130-400nm)	40-70% of IB in plasma (extrapolation of exponential fit)
VIS-NIR(400nm-1.5 mm)	6% of IB in plasma. MLM has low R for this band
IR (1.5-10μm)	<0.01% in plasma using exponential fit
10.6μm Reflection	50% of Inband EUV

Cymer Inc. Igor V. Fomenkov et al, Proc. SPIE 7271-119

Assumptions
10.6mmradiation at IF : 50%
(ratio to in-band EUV)
Mirror Reflectivity@13.5nm : 65%
Mirror Reflectivity@10.6μm : 90%
Number of reflection : 12

Estimated IR power @ wafer is 25X of in-band EUV.

◆Spectral purity filter eliminating 10.6μm radiation is needed for CO_2 Laser LPP source.

Spectral Purity Filter

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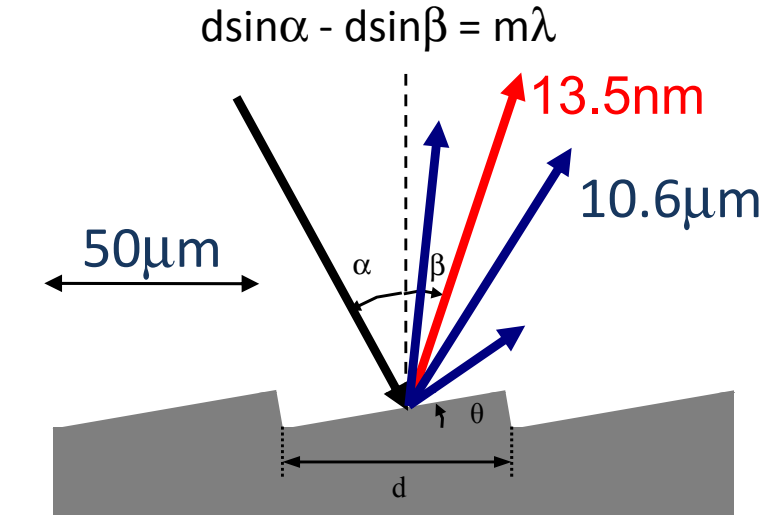
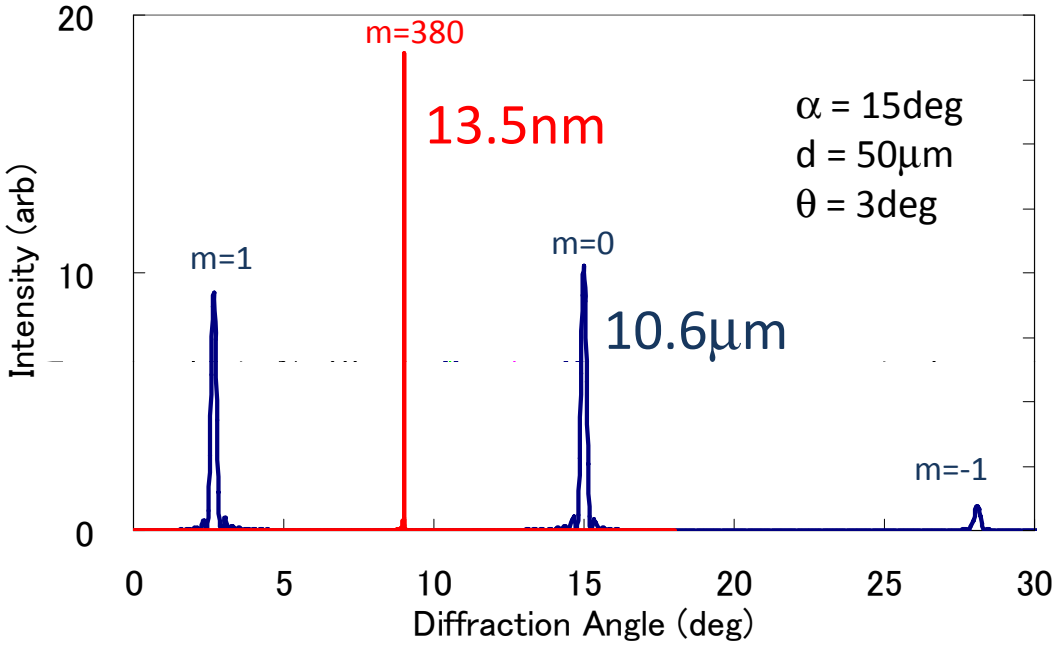
Reflection type spectral purity filter (ML coated blazed grating)



Grating Parameters

Incident angle	α
Diffraction angle	β
Grating pitch	d
Braze angle	θ
Diffraction order	m



- A reflection type blazed grating can work as a spectral purity filter eliminating 10.6μm radiation.
- Advantage of heat load durability

Optics lifetime/Carbon deposition Mitigation

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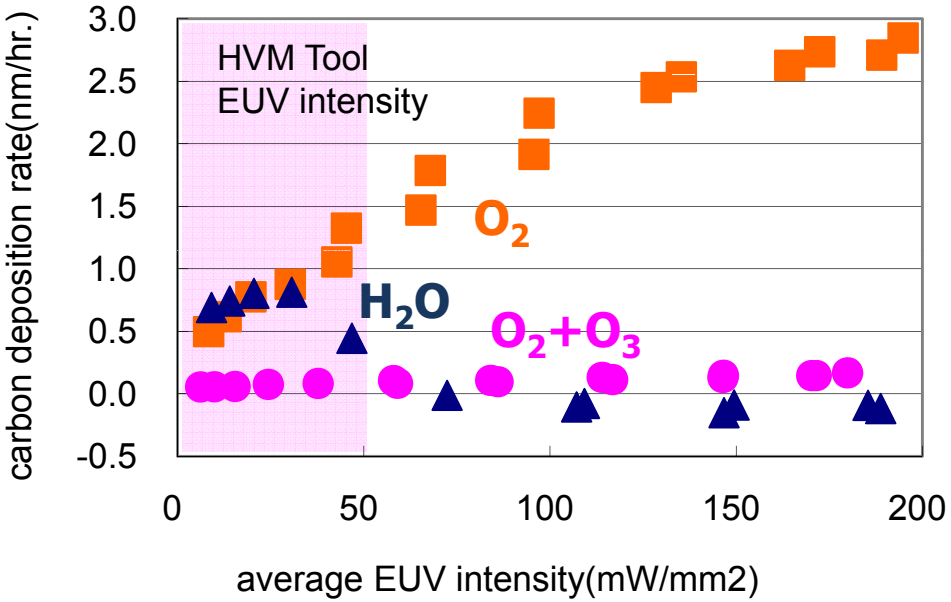
Carbon deposition on EUVL exposure tool optics degrades throughput and imaging quality. Mitigation method of carbon deposition has been developed.

Mitigation effect of oxidizing gas



- decane(~E-6 Pa)+$\mathbf{O_2}$(1E-2 Pa)
- decane(~E-6 Pa)+ $\mathbf{H_2O}$(1E-2 Pa)
- decane(~E-6 Pa)+ [$\mathbf{O_2+O_3}$](1E-2 Pa)

EUV source: NewSUBARU
Sample: [Si(4.2nm)/ Mo(2.8nm)]^{50}
Irradiation time: 3 hr.

- O_2+O_3 is effective as the mitigation gas in the region of HVM Tool EUV intensity.

This experiment was performed as a collaboration work of Canon, Nikon and University of Hyogo.

Poster : OC-P06 T. Nakayama et al.,Canon, NIKON, LASTI

Summary

◆ Key technologies for HVM EUVL exposure tools have been developed.

- Multilayer evaluation (reflectivity, phase shift)
- Wavefront measurement using low brightness source
- Mirror figuring and ML deposition satisfying HVM tool requirements
- Reflection type spectral purity filter
- Mitigation of carbon deposition

◆Timing of HVM EUVL exposure tools is under consideration.

Acknowledgment

Parts of this work were performed under the management of Extreme Ultraviolet Lithography System Development Association (EUVA) in the Ministry of Economy Trade and Industry program supported by New Energy and Industrial Technology Development Organization (NEDO).

Thank you for your attention!