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Nikon EUVL Development Progress Update

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Precision Equipment Company
NIKON CORPORATION

Outline

- Nikon EUVL roadmap
- EUV1 Imaging / Overlay capability
- EUVL technology readiness
- EUV HVM tool
- Summary

Nikon Lithography Roadmap

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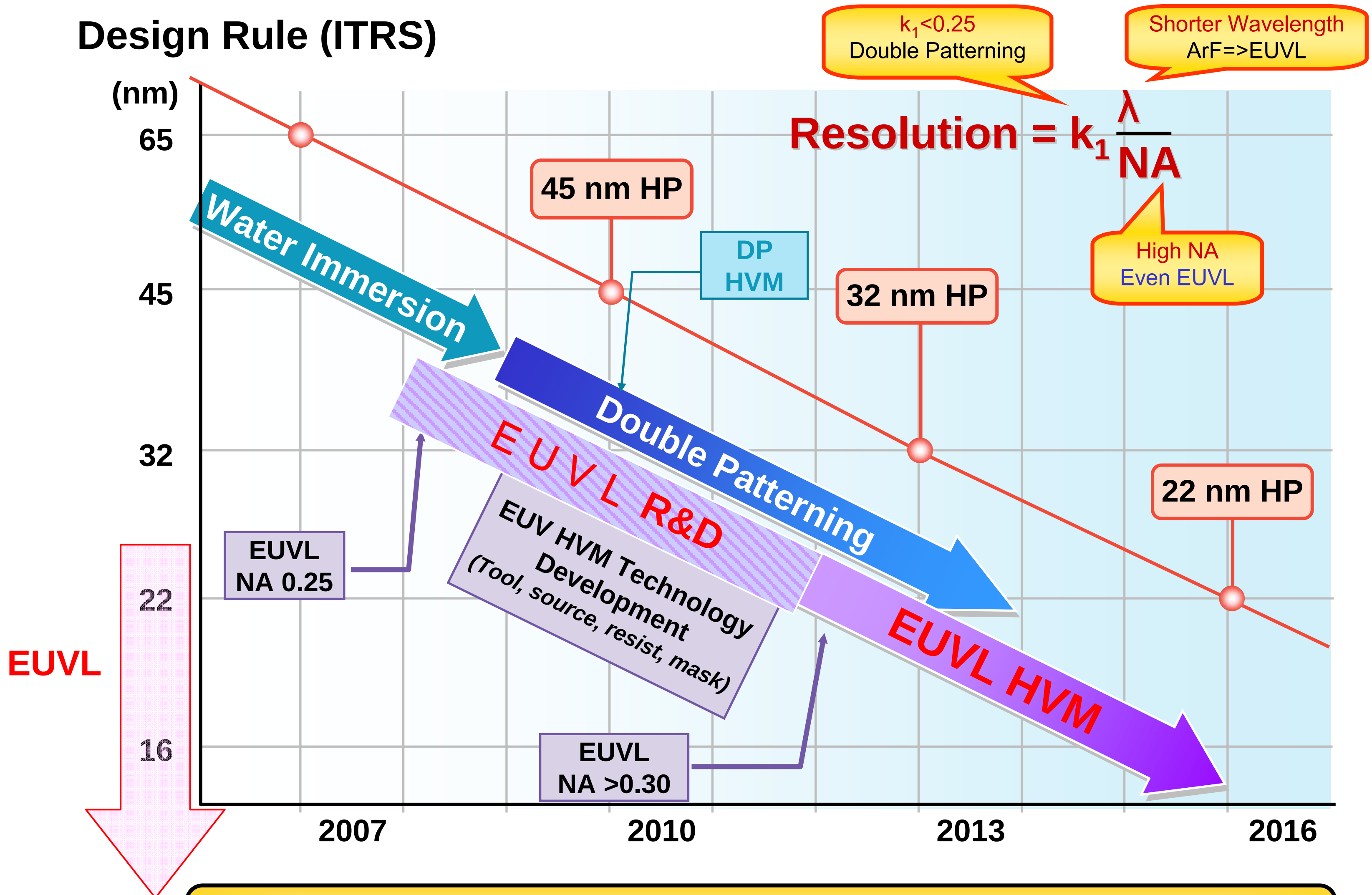
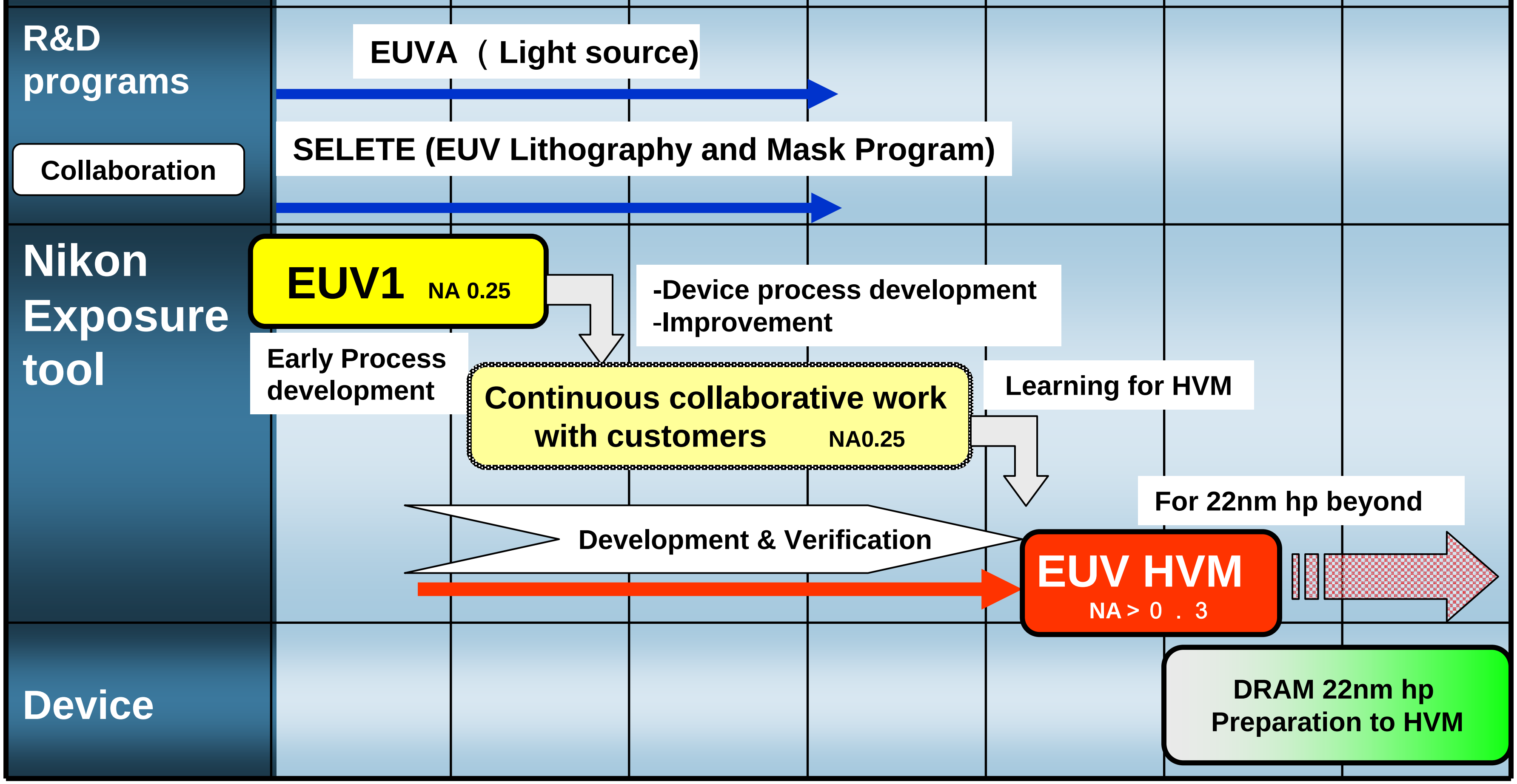


EUVL is the main candidate for ≤ 22 nm hp.

Nikon EUV Development Roadmap

Now ▼ (2009)

Cal. Year	2008	2009	2010	2011	2012	2013	2014
ITRS2007 DRAM ½ p	57 nm	50 nm	45 nm	40 nm	36 nm	32 nm	28 nm
Flash ½ p	45 nm	40 nm	36 nm	32 nm	28 nm	25 nm	23 nm
MPU C. Hole	73 nm	64 nm	56 nm	50 nm	44 nm	39 nm	35 nm



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- **EUV1 Imaging / Overlay capability**
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EUV1 Development Status

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Customer evaluations & device pattern exposures on going.

Now

- Static exposure
- Dynamic exposure
  - Imaging optimization
- Overlay exposure
  - Tool optimization
- Device test chip pattern exposures ongoing.

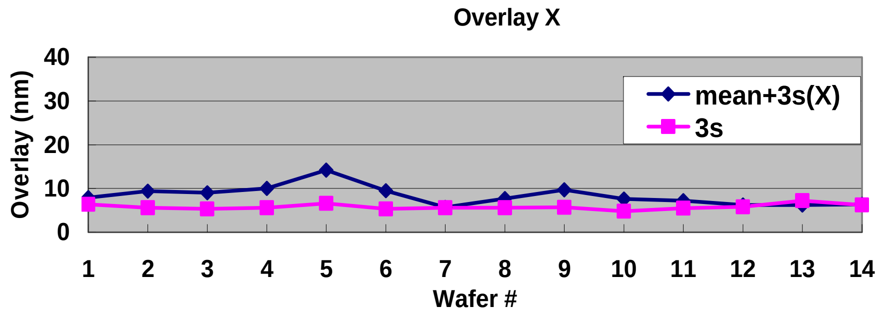
Learning for HVM

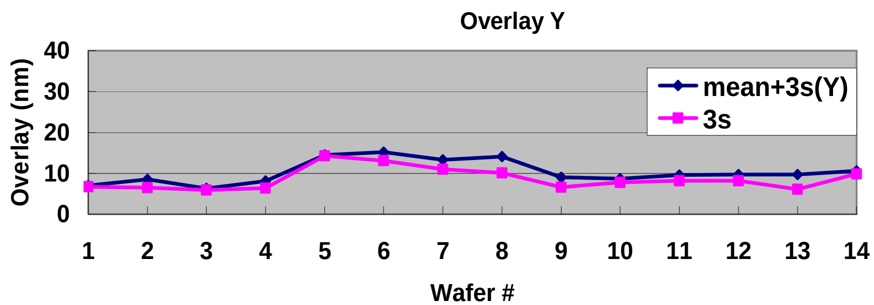
Field Size	26 x 33 mm^2
NA and Magnification	0.25, x1/4
Illumination Sigma	0.8 (OAI capability)
Overlay	10 nm

Overlay Evaluation on Actual Device Structure

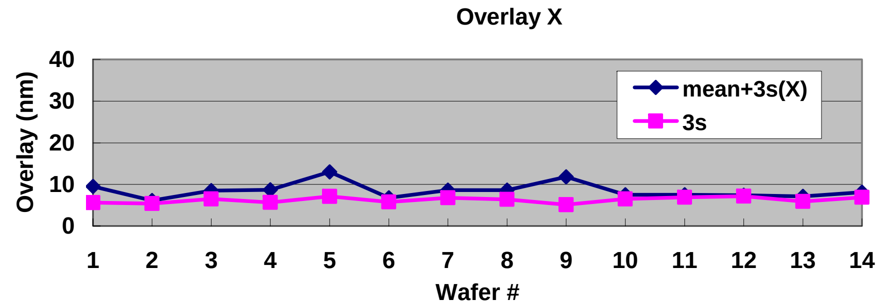
Courtesy of Selete

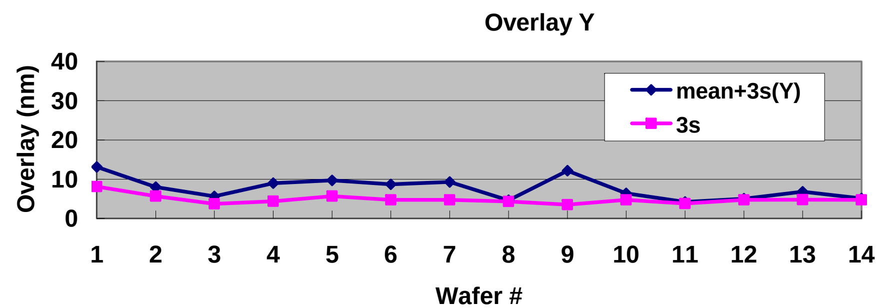
Layer 1 ← Layer 2





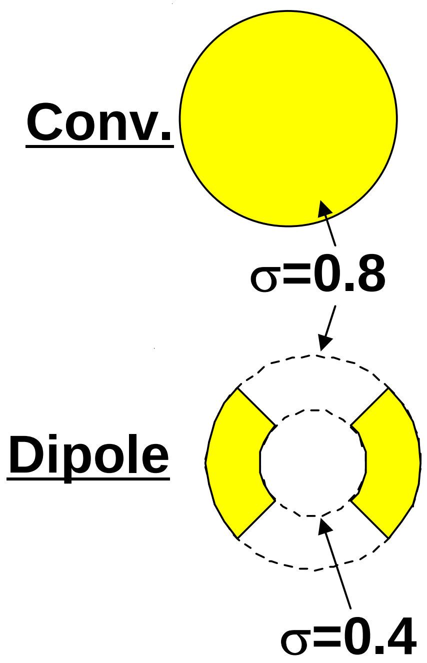
Layer 2 ← layer 3





Stable overlay performance achieved.

NA 0.25 Imaging Simulation (Conv. vs. Dipole)



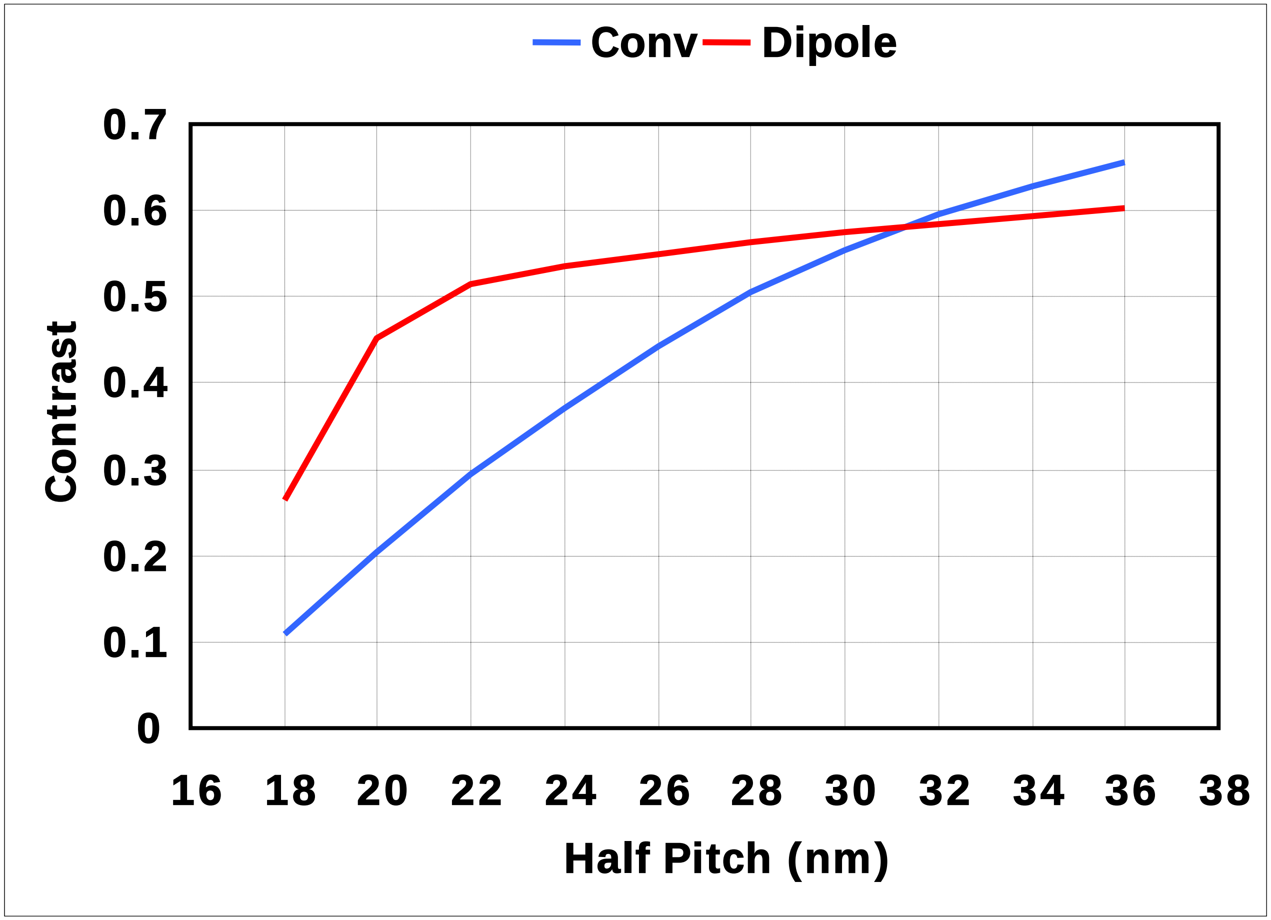


Image Quality:

Wavelength: 13.5 nm, NA: 0.25,
Mask contrast: 1:100, DC-Flare: 11%

NA 0.25 Imaging Data (Conv. vs. Dipole)

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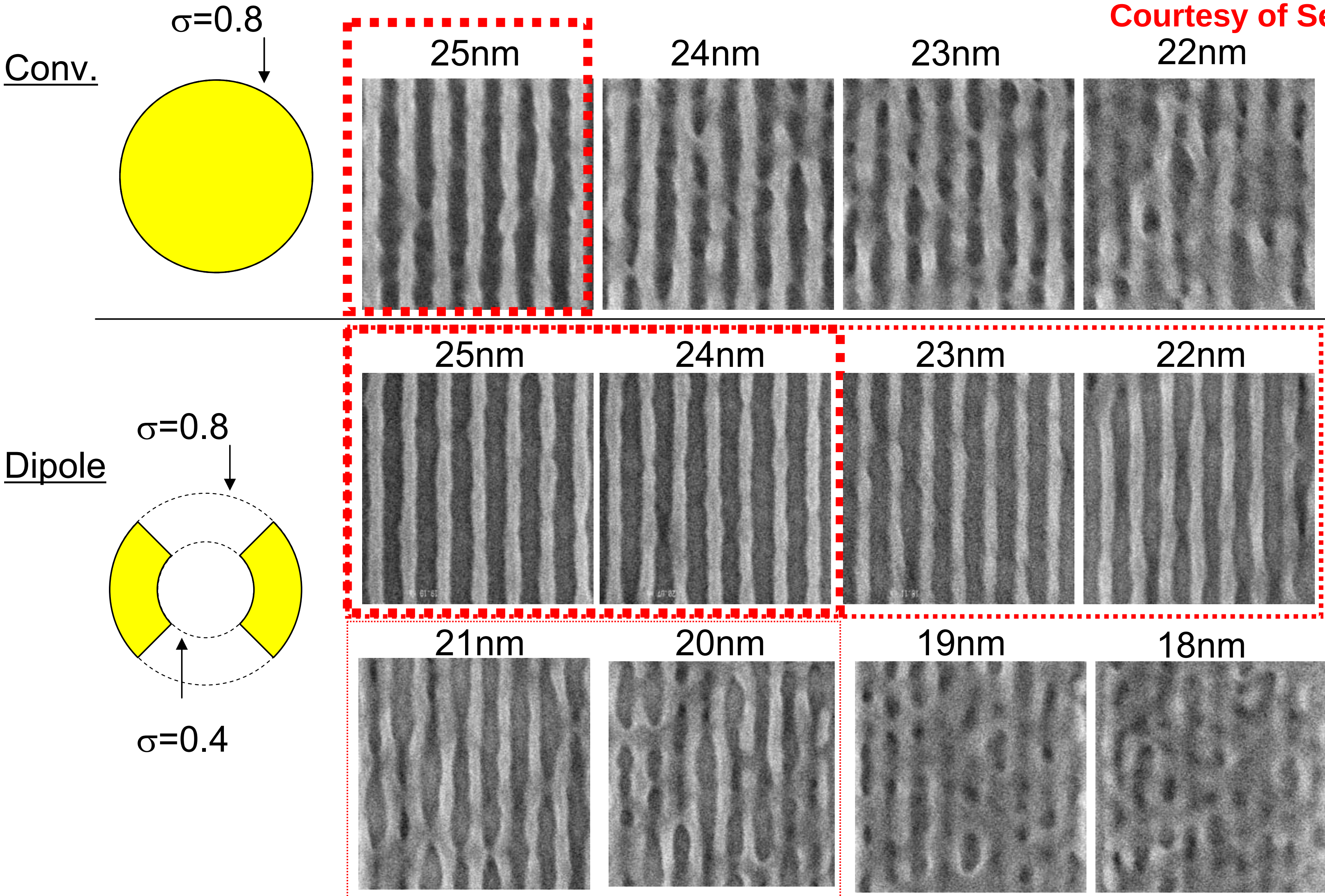
Courtesy of Selete



Refer to "Next Step for Beyond 22nm Node Application Using Full Field Exposure Tool" by K. Tawarayama, et al, on Oct. 20.

NA0.25 Imaging data

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Nikon EUV1 Lines (static exposures) *

Courtesy of Intel

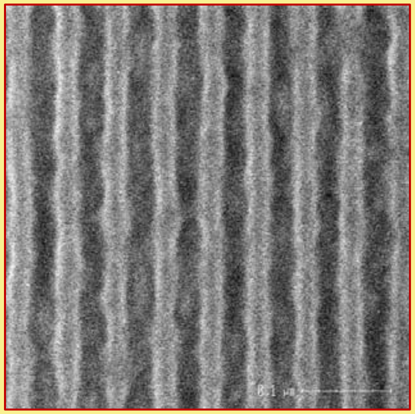
Ultimate resolution: 26nm HP

σ = 0.8

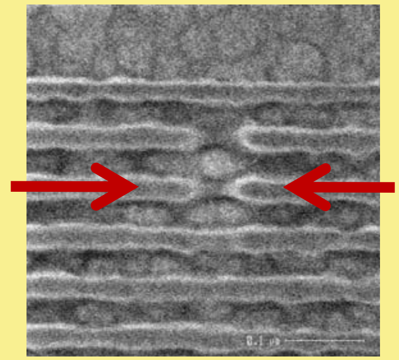
CD_{meas}: 25.91nm

LWR: 7.05nm

Esize: 17.8mJ/cm²



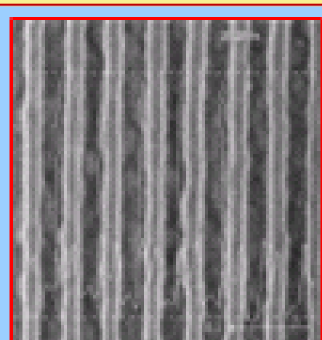
32/64 nm line-ends

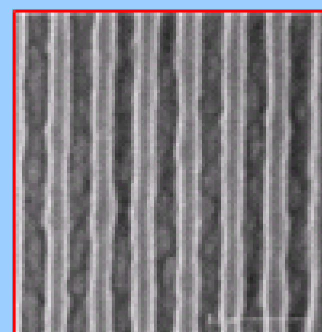


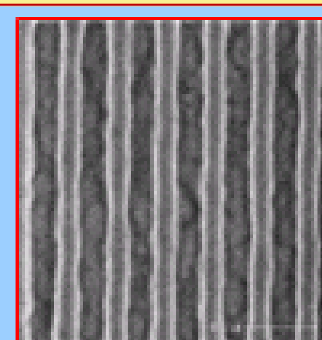
σ = 0.8

Measured 41nm
(drawn 14nm
on mask)

Vertical lines
through HP at
best dose/focus
σ = 0.8







CD (HP Target)	30 nm	32 nm	35 nm
CD (Meas.)	29.21 nm	30.9 nm	33.64 nm
Esize	15.4 mJ/cm²	15.0 mJ/cm2	14.2 mJ/cm2
LWR	4.76 nm	5.27 nm	4.84 nm
DOF	≥ 245 nm	≥ 245 nm	≥ 280 nm

Refer to poster presentation "Static Test Evaluation of EUV1 Full-Field Exposure Tool" by Y. Shroff, et al.

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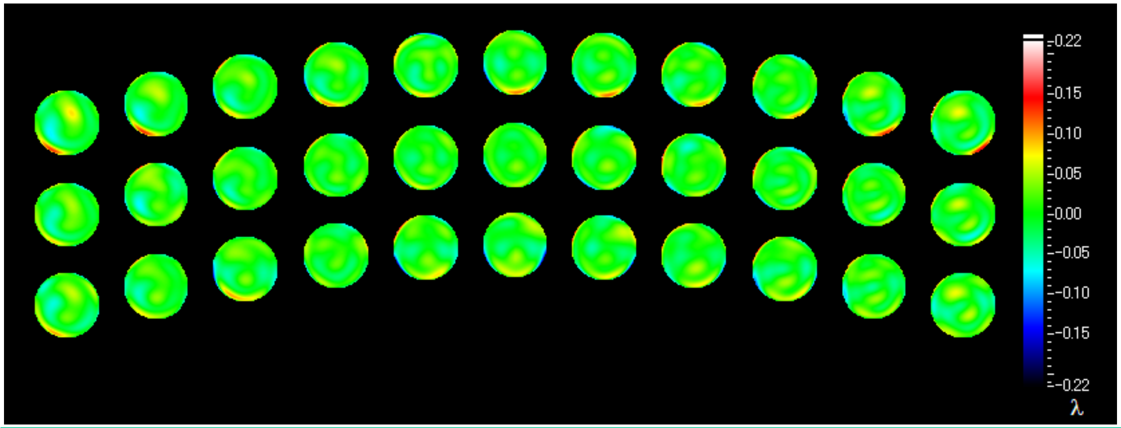
Evaluation of EUV Technology Readiness

Readiness classification for HVM implementation.	
Manufacturable solutions exist, and are being optimized.	Green
Manufacturable solutions are known but needing further development.	Yellow
Manufacturable solutions are not known. Not ready for HVM.	Red

	Item	Issue	Readiness	Remarks
Optics	PO	WFE	Green	EUV1 PO data
		Flare	Green	EUV1 PO data
		NA	Yellow	High NA. Fabrication and metrology
Platform	Overlay	Optics stability	Yellow	Thermal control
		Metrology stability	Yellow	Thermal control
		Reticle stability	Yellow	Chuck and particle control
	Imaging	CDU	Yellow	Focus and dose control
	Throughput	PO and IU transmittance	Yellow	Reflectivity and total efficiency
		Stages	Yellow	New platform No air fluctuation
	CoO	Optics lifetime	Yellow	Modeling, contamination control
		Optics consumable cost	Green	Cleaning and refurbishment

Optics: PO Readiness

EUV1 PO: WFE and Flare Performance



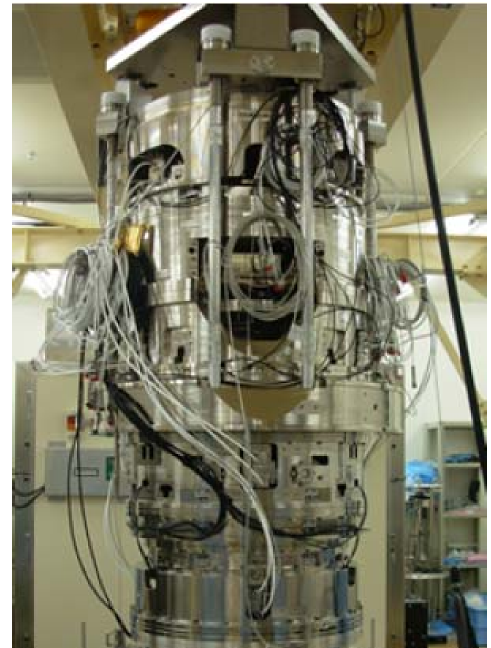
WFE: 0.4 nm RMS (average)

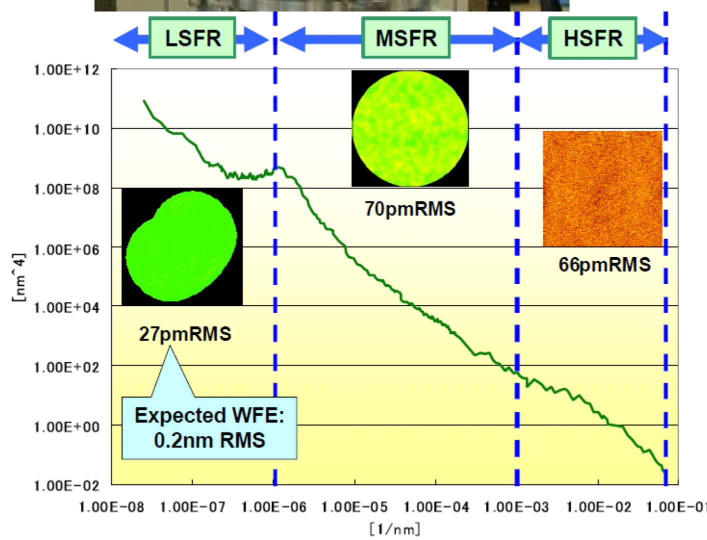
Min. 0.3nm RMS ~ Max. 0.5nm RMS

	Flare	Kirk flare (estimate/measure)
EUV1 PO#1	10%	15% / 16%
EUV1 PO#2	6%	8% / 8.5%

2μm Kirk pattern in bright field

EUV1 PO performance reaching close to HVM requirements.





Mirror polishing status

Optics: Metrology

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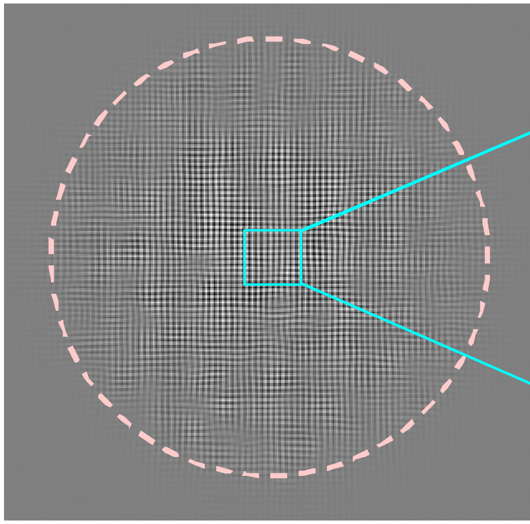
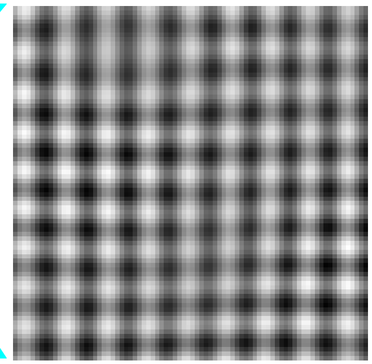
EUV wavefront metrology system (EWMS)

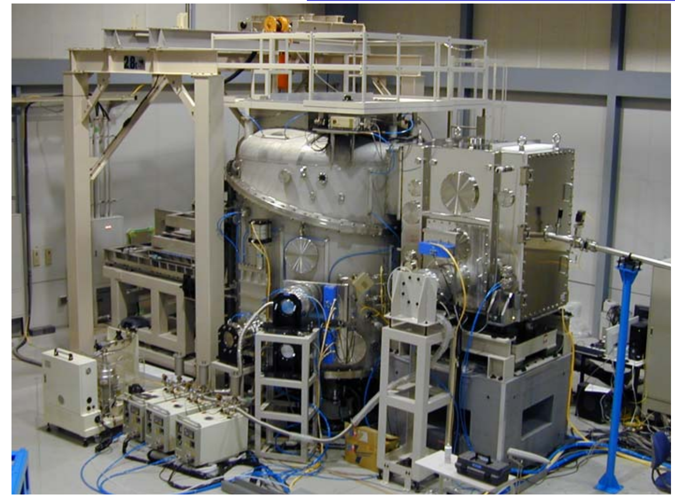
Supported by NEDO

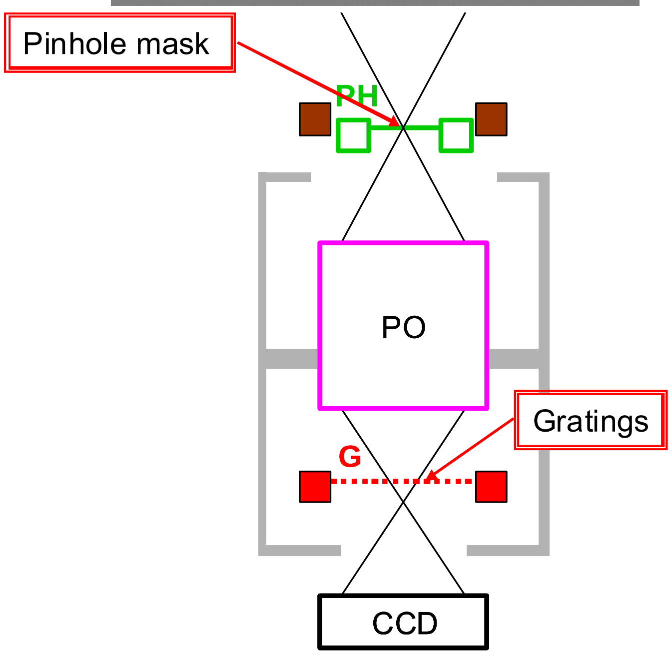
Development work with Canon



DTI (digital Talbot interferometry)

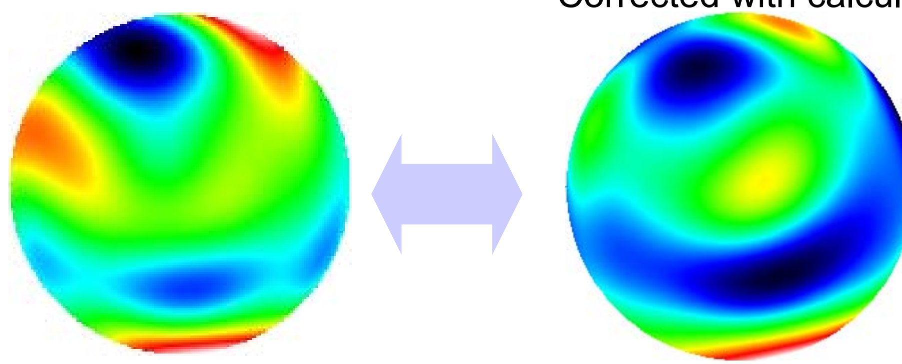






Measured with EUV (EWMS)

Measured with visible light
Corrected with calculation



97.5 mλ RMS
(1.32 nm RMS)

154.5 mλ RMS
(2.09 nm RMS)

Optics: High NA Imaging Simulation

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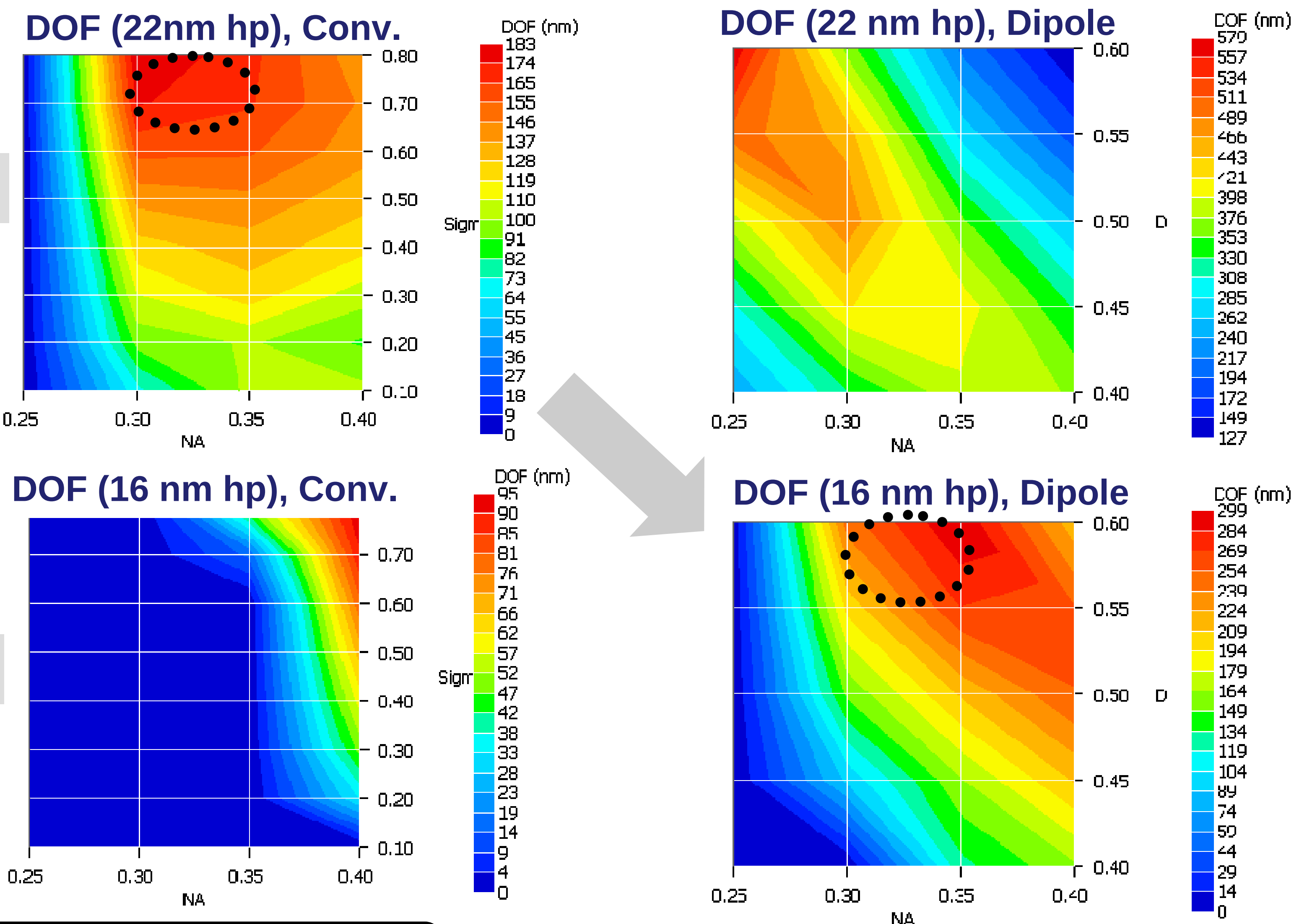
22 nm hp

16 nm hp



16nm hp can be achieved with NA>0.3 and off-axis illumination.

Simulation conditions: Aerial image simulation; Dipole (R=0.2), delta CD +/-10% of CD, Mask CD error +/-3% of CD, Mask contrast 1:100, Flare 8%

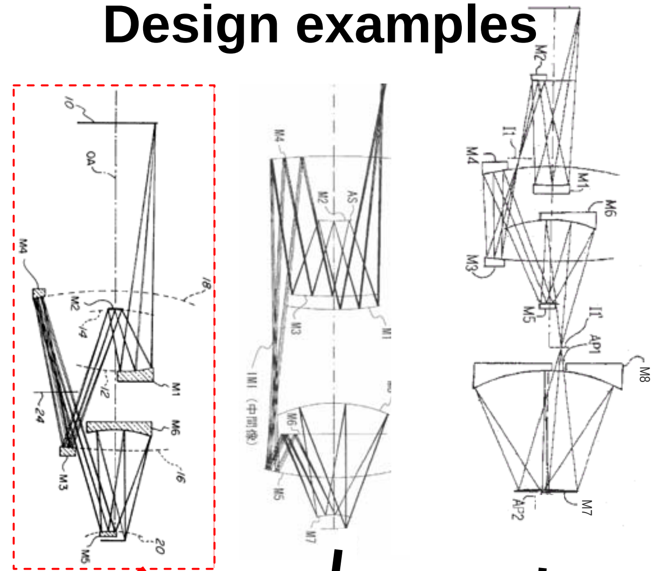
Optics: NA vs. Number of Mirrors

NA vs. number of mirrors

$CD=k_1\lambda/NA$ $DOF=\lambda/NA^2$

	K1				DOF (nm)
HP	45nm	32nm	22nm	16nm	
NA0.25	0.83	0.59	0.41	0.30	216
NA0.30		0.71	0.49	0.36	150
NA0.35		0.83	0.57	0.41	110
NA0.40			0.65	0.47	84
NA0.45			0.73	0.53	67
NA0.50			0.81	0.59	54

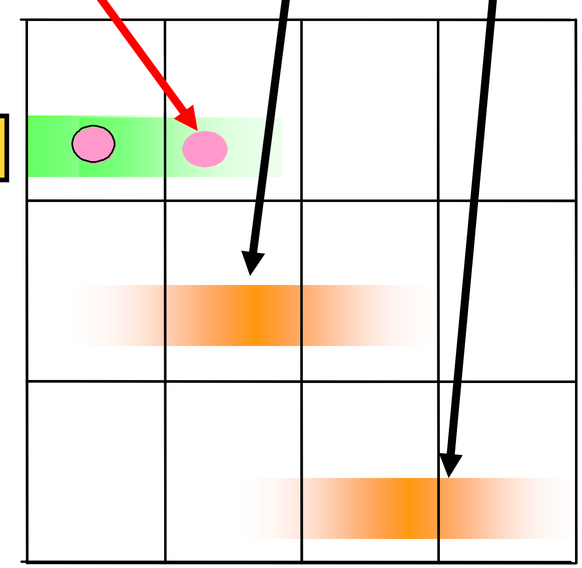
Design examples



6 mirror system

8 mirror system

8 mirror system
(center obscuration)



General issues:

1. DOF reduction
2. Flare increase
3. Transmittance
4. Obscuration
5. Manufacturing difficulty

6 mirror system with NA >0.3 under study.

CoO: Contamination Control Strategy

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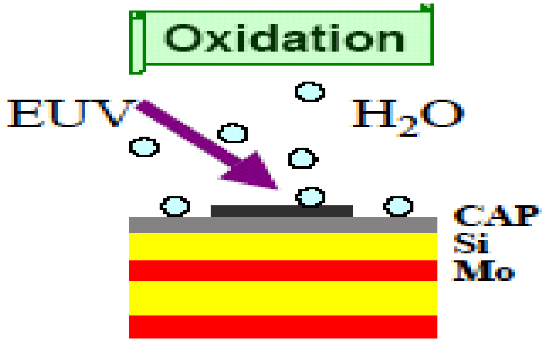
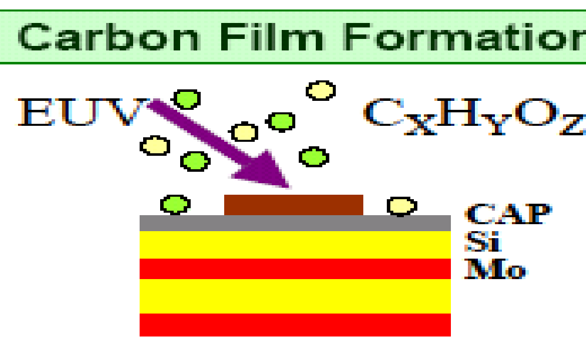


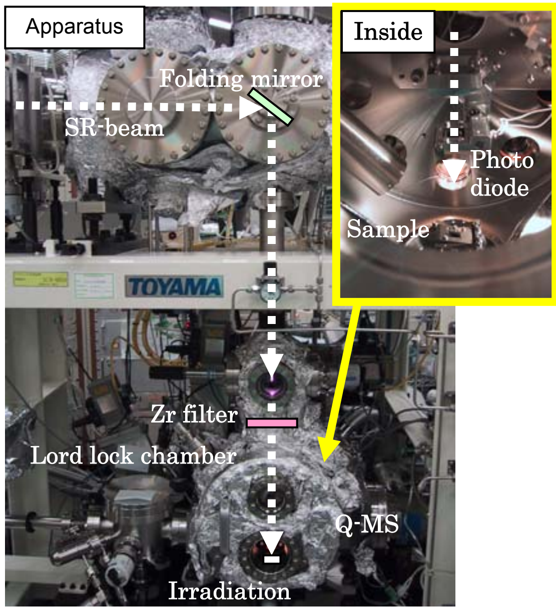


1. **Long-life anti-oxidation capping layer**
2. **Carbon contamination modeling**
3. **Carbon-film suppression and removal using EUV+O_2 in-situ cleaning**

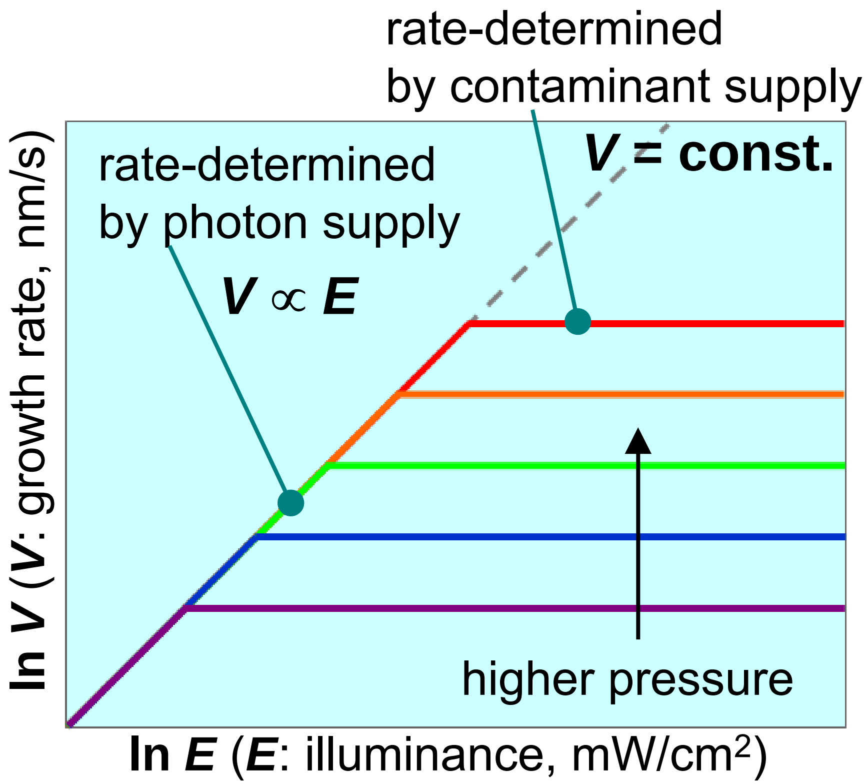
   -Oxygen gas introduction under EUV irradiation can suppress carbon deposition onto mirrors.

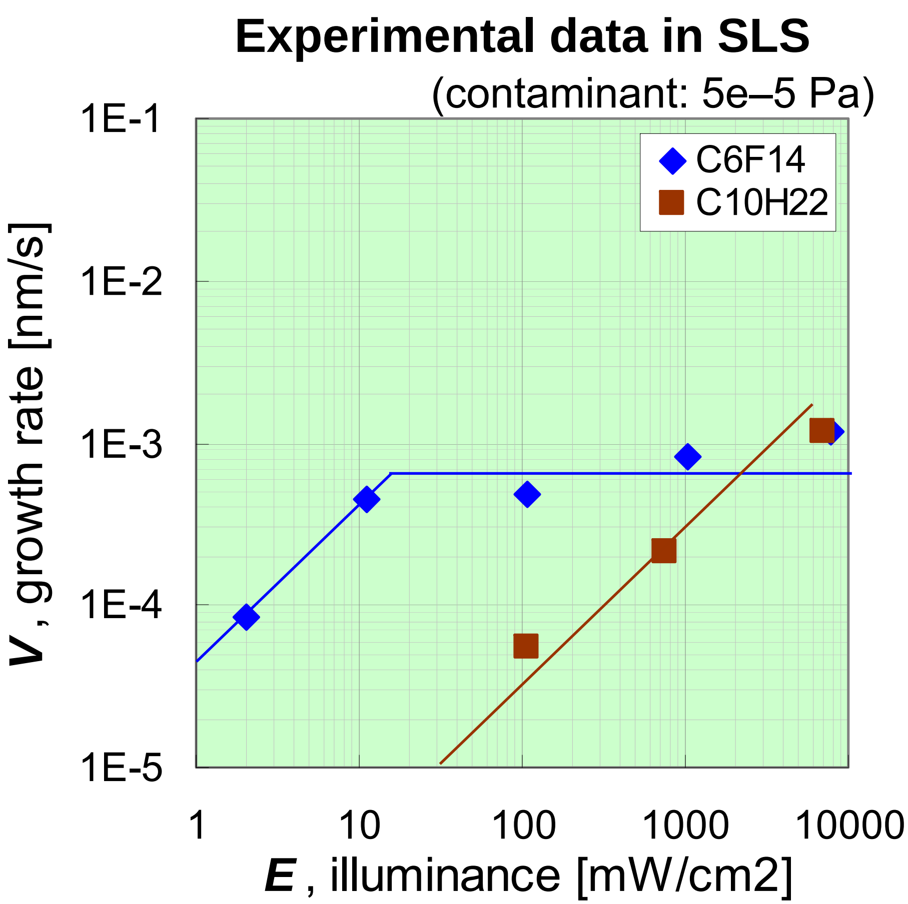
4. **Experimentation facilities**
   - **"New SUBARU" in Himeji (Univ. of Hyogo)**
   - **Currently shifted to new SLS facility "SAGA-LS" in Kyushu for experiments.**

SR-beam: SAGA-LS BL18
Light intensity:70mW/mm^2



CoO: Carbon Contamination Modeling



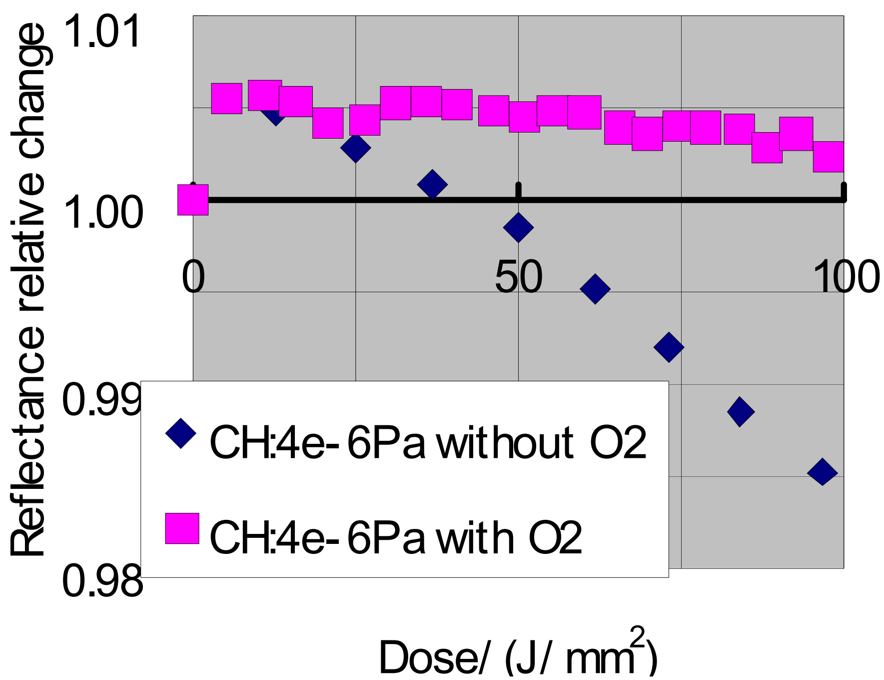


- Carbon contamination growth rate depends on photon supply and contaminant material supply.
- The lesser of two supplies determines the growth rate.
- Such a behavior was confirmed with experimental data using a synchrotron source.

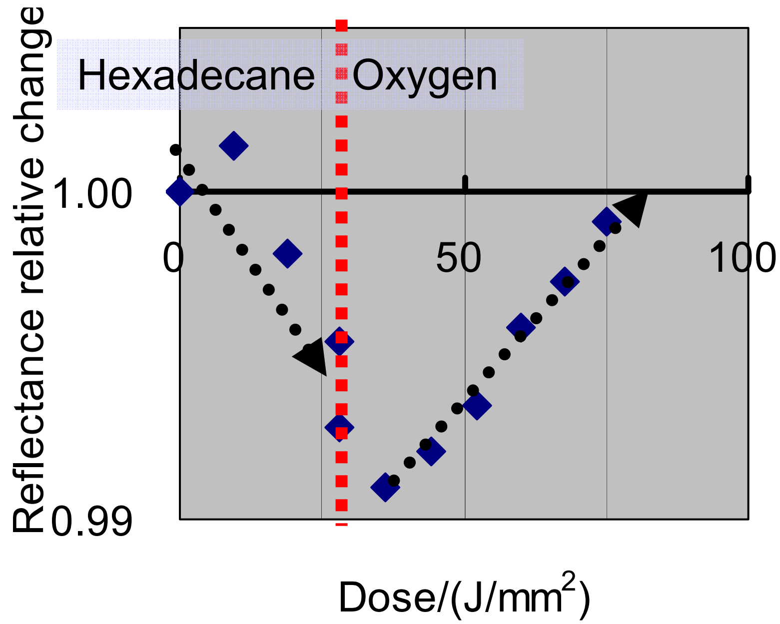
CoO: Carbon Contamination Control

Ru capping layer

Mitigation



Cleaning



- Carbon contamination deposition is suppressed by O2 injection.
- Deposited carbon can be removed by O2 injection.

CoO: Anti-oxidation Capping Layer

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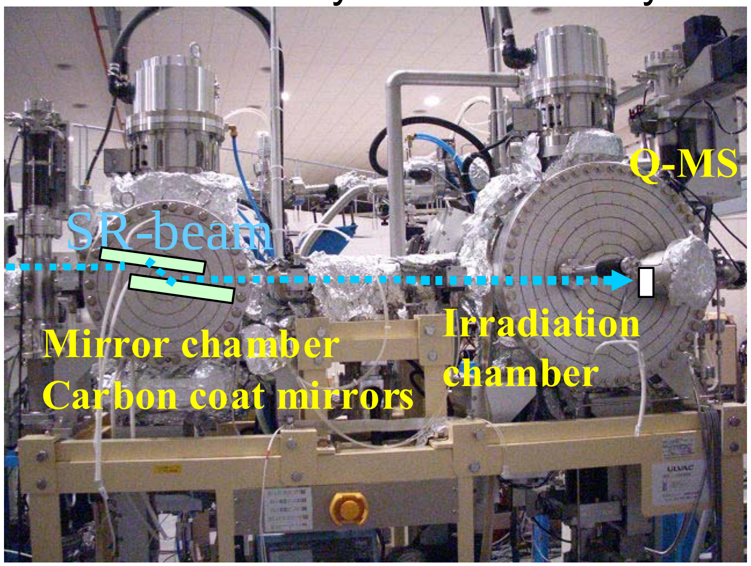
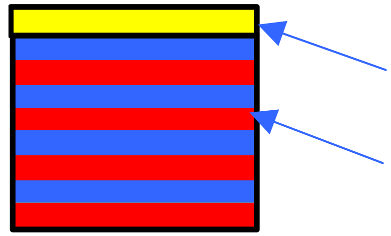
Supported by NEDO

New SUBARU synchrotron facility

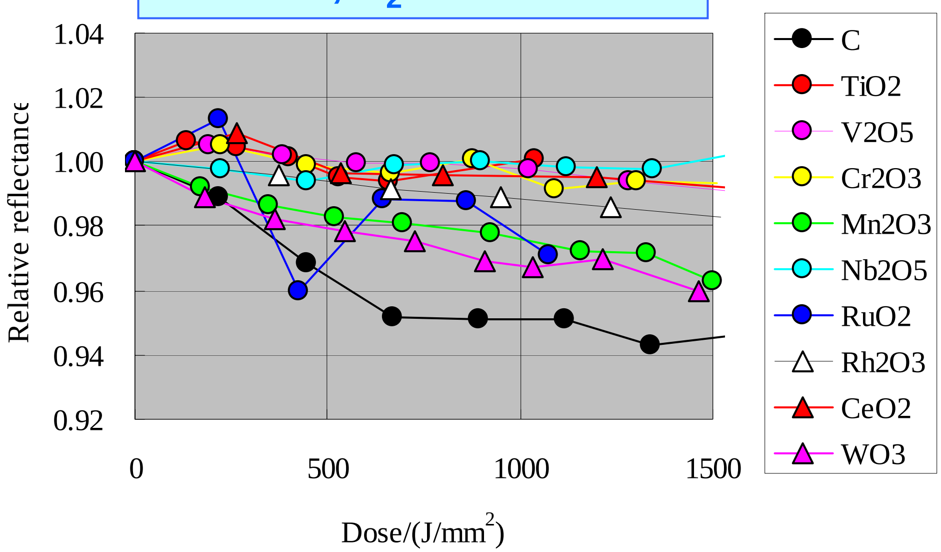




	Cap	$(\Delta R/Ro)/(1kJ/mm^2)$
1	Nb_2O_5	-0.19×10^{-2}
2	TiO_2	-0.07×10^{-2}
3	Cr_2O_3	0.43×10^{-2}
4	CeO_2	0.53×10^{-2}
5	V_2O_5	0.59×10^{-2}
6	Rh_2O_3	1.12×10^{-2}
7	Mn_2O_3	2.48×10^{-2}
8	RuO_2	2.67×10^{-2}
9	WO_3	2.73×10^{-2}
10	C	3.55×10^{-2}

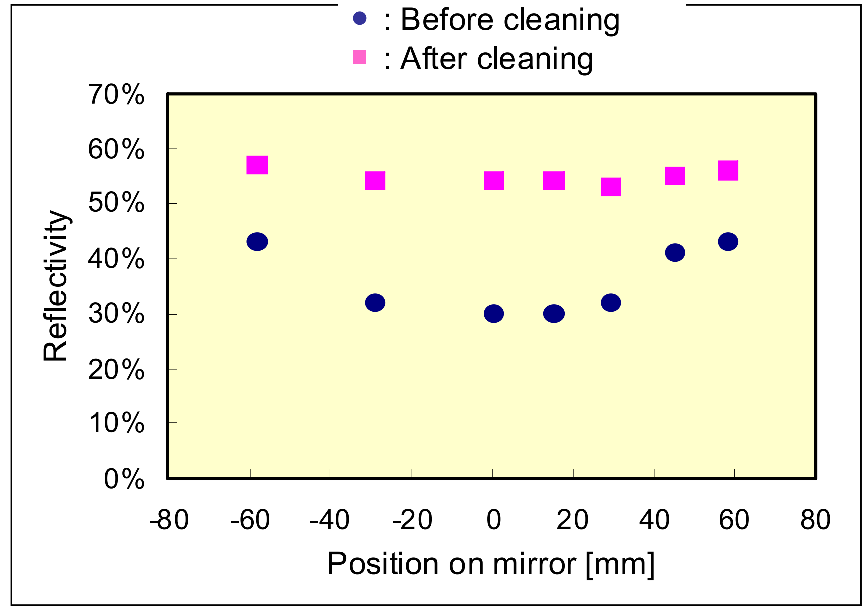
Higher durability to Oxidation

9×10^{-4}Pa, H_2O 1000J/mm^2



In EUV irradiation test of oxide materials, Nb2O5 and TiO2 showed good durability to oxidation.

CoO: UV Dry Carbon Cleaning



Contaminated mirror recovered its initial reflectivity after UV dry cleaning.

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- **EUV HVM tool development**
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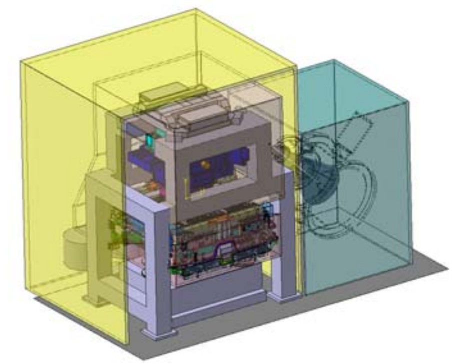
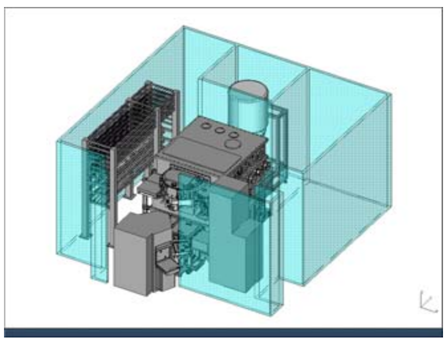
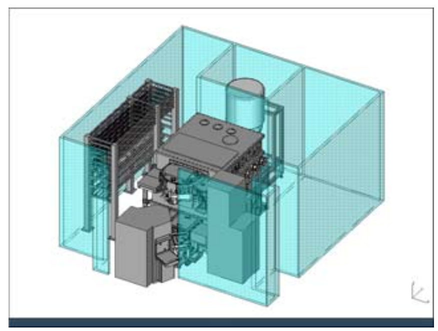
EUV Development Scenario

Specification	EUV1	EUV HVM
Field Size	26 x 33 mm^2	26 x 33 mm^2
NA and Magnification	0.25, x1/4	>0.3, x1/4
Flare	10 %	5 %
Overlay	10 nm	<3 nm
Throughput	5-10 WPH @10W IF,5mJ/cm2	100 WPH @180W IF,10mJ/cm2







Hi-NA3
Small field

EUV1
First full-field tool

Improvement Verification

EUV1
Collaborative programs with customers

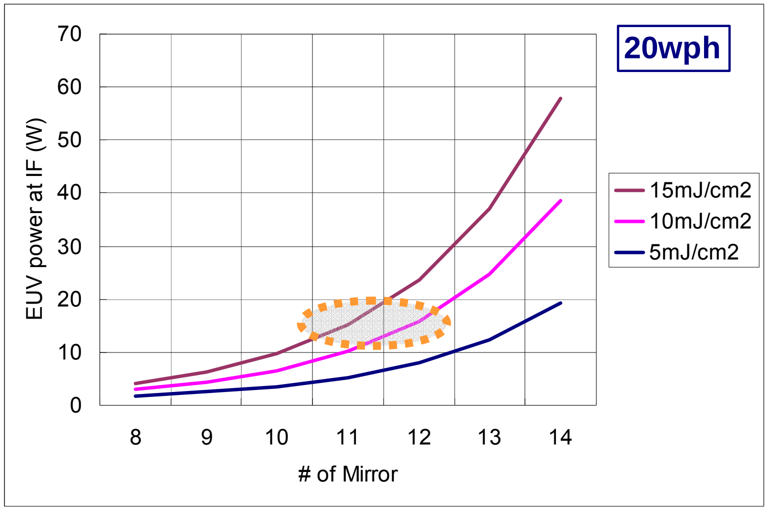
Feedback

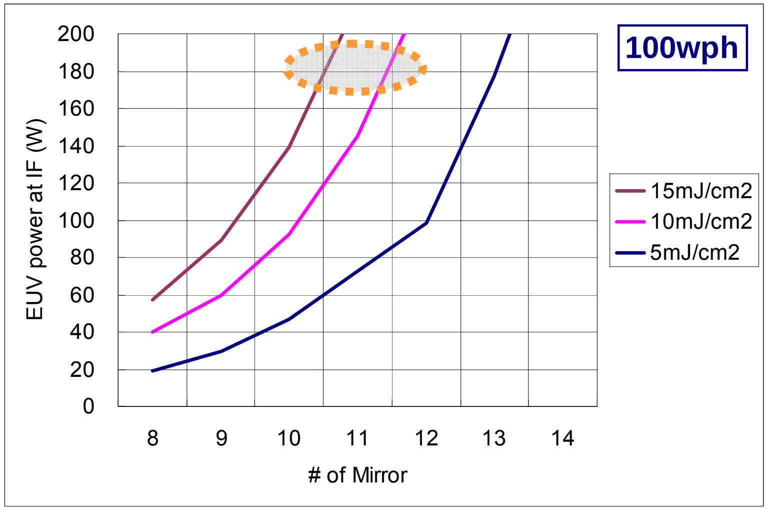
EUV HVM (EUV3)
- High throughput and good OL platform
- PO： NA>0.3
- Light source: >180W IF
- Maximum optical transmittance

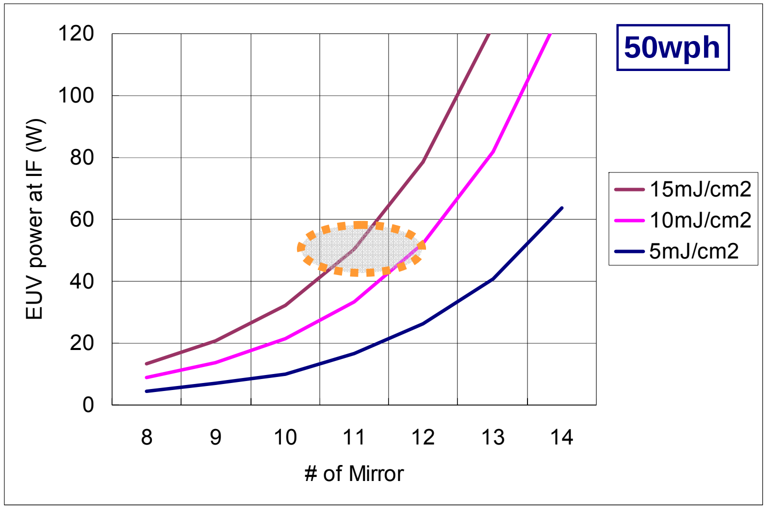
Basic R&D **Learning (Now)** **Common Platform**

Throughput Evolution

Total Number of Mirrors vs. Throughput







Condition;

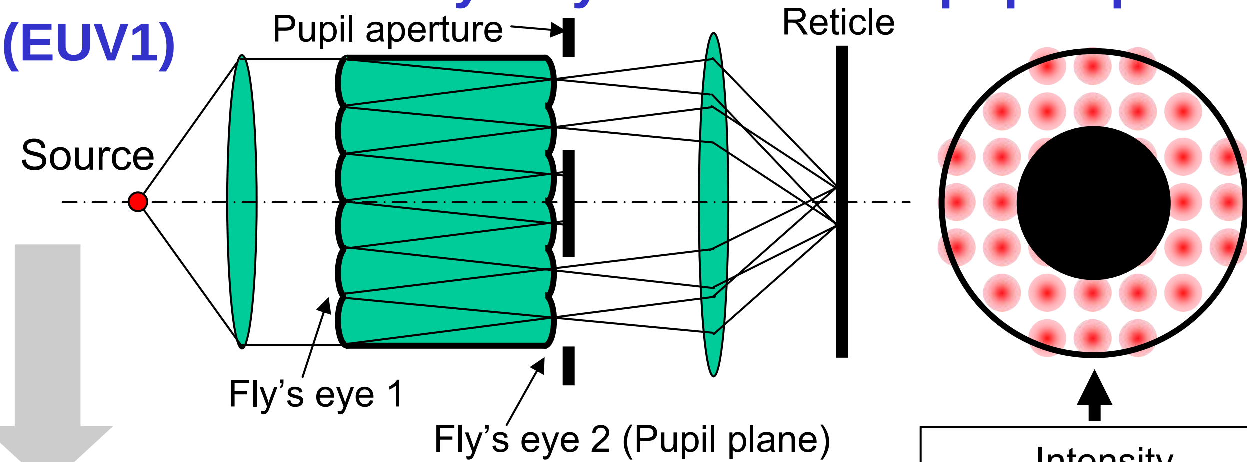
- ■ Mirror reflectance: 64%
- ■ Shot number: 76 shots

Key issues:

- **Source power improvement**
- **Optics efficiency improvement**

Throughput: High-efficiency RET

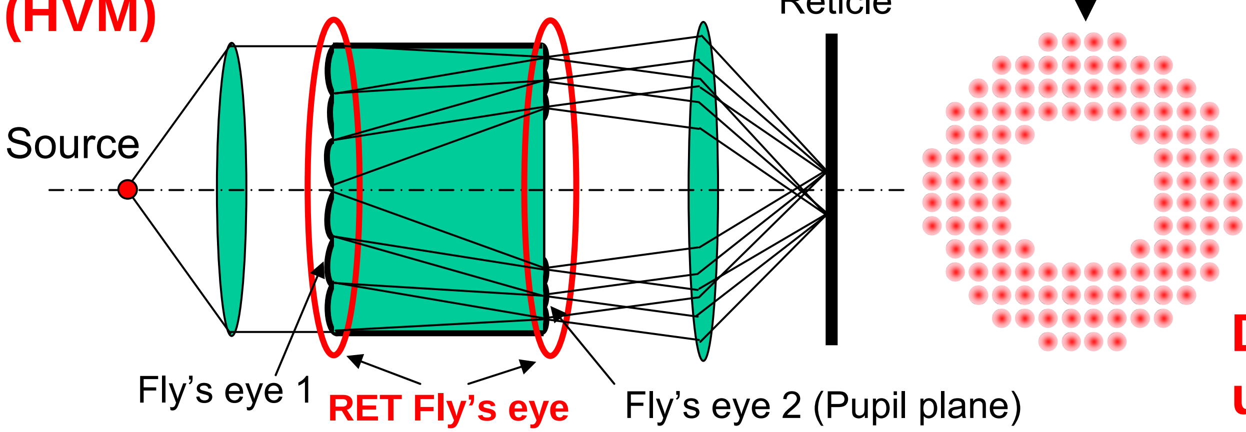
◆ Conventional fly's eye mirror with pupil aperture (EUV1)



+ Easy
- Power loss
- Degrade uniformity on reticle

Intensity distribution in pupil

◆ RET fly's eye mirror system (HVM)



+ No power loss
+ No uniformity change on reticle
- Manufacturability

Different concepts under study.

- Specially designed RET fly's eye mirror system minimizes photon loss.
- Small etendue of source is preferable.

EUV Light Source Status

Up to EUV Source WS, May 2009

	CYMER	GIGAPHOTON	Philips/Xtreme
Type	LPP Sn, Droplet	LPP Sn, Droplet	DPP Sn, Rotating disc
Rep. rate	50 kHz	100 kHz	12 kHz Demonstrated 40 kHz Feasibility of 100 kHz
Drive laser power	12 kW CO_2	13kW CO_2	-
EUV power*	100W @IF 1ms burst, CE=3.0% 51 hours run 20W@IF, duty 80% 400ms on	60W@IF burst, CE=2.5% 4 hours run Magnetic field DMT Double pulse	500W@plasma 50W@IF, duty 100% Increased CE to 3-4% 1 hour run
Plasma size	210 um (1/e2)	(~100 um)	< 1.3 mm Possible ~ 0.5 mm
Collector mirror	Multilayer	Multilayer	Grazing incidence

* Estimated IF power based on a transmissibility of a collector mirror.

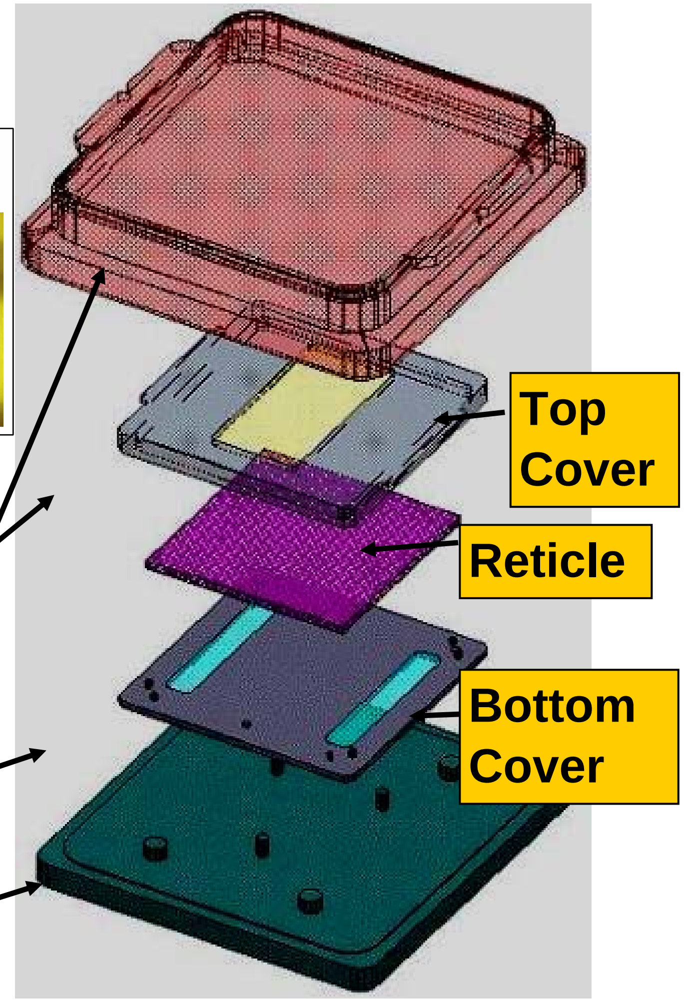
- **System integrated performance with long term operation must be demonstrated.**
- **Joint requirement: >115W@IF(5mJ/cm2), >180W@IF(10mJ/cm2)**

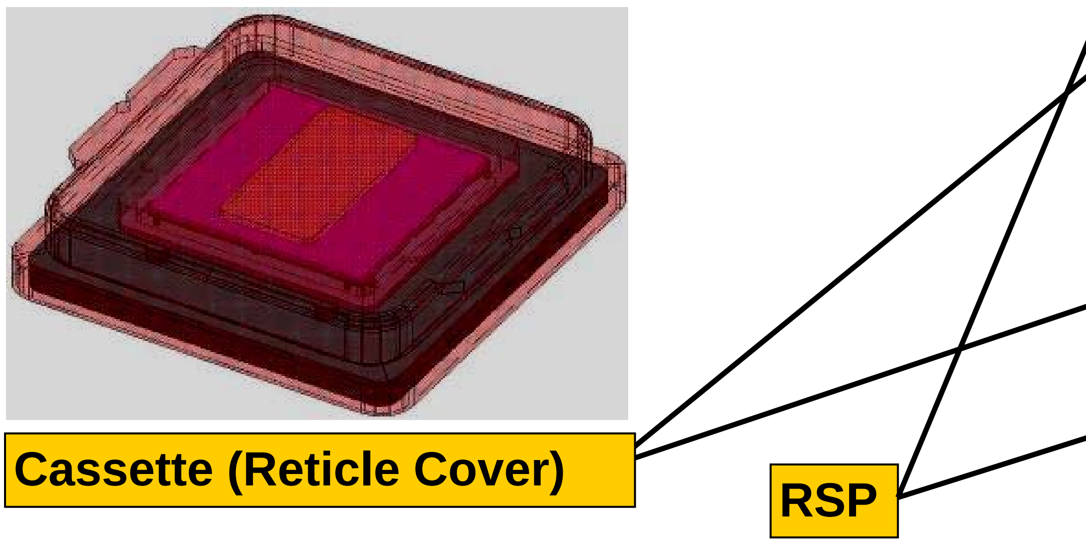
Reticle Particle Protection

Dual Pod Concept by Canon and Nikon

1. Reticle in Cassette (RC) in Carrier (RSP200).
2. Cassette protects the reticle in load locks.
3. Top cover stays with reticle during in-tool handling.
4. Reticle remains in RC in library to protect against vacuum accidents and contamination.

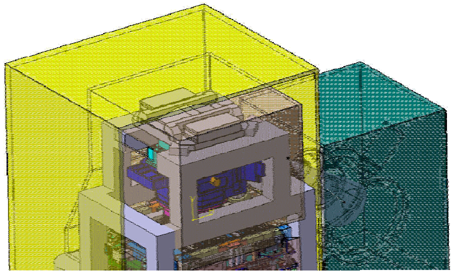
Reticle Carrier for EUV1 (Dual Pod)





SEMI standardization completed.

EUVL HVM Development Issues



- **Optics improvement**
  - NA, WFE, flare, RET, distortion
- **Throughput improvement**
  - Optical transmittance
  - Mirror contamination control
  - High speed platform
- **CoO issue**
  - Consumable cost and lifetime
- **Overlay improvement**
  - Thermal stability, heat rejection and cooling
  - Mask and chuck (OPD and IPD)
- **Facility issues**
  - Light source utility and space