

# ***EUV Source Evaluation at the Intermediate Focus***

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For an exposure tool maker, evaluation of EUV sources at the intermediate focus is needed to judge if the sources satisfy requirements of EUV source before the tool maker introduce the sources. Therefore tool makers have some responsibility of proposing concepts of the evaluation, i.e., what items have to be measured and what accuracy is needed and some ideas to realize the concept. Canon have studied evaluation methods of EUV source and made some evaluation systems to realize the concept of the evaluation. We will show the concept and the evaluation systems.

# Joint Requirements for EUV Source

<u>SOURCE CHARACTERISTIC</u>	<u>REQUIREMENT</u>
•Wavelength	13.5 [nm]
•EUV Power (in-band)	115 [W] *
•Repetition Frequency	> 7-10 kHz ***
•Integrated Energy Stability	$\pm 0.3\%$ , $3\sigma$ over 50 pulses
•Source Cleanliness	$\geq 30,000$ hours **
•Etendue of Source Output	max 1 - 3.3 mm <sup>2</sup> sr ***
•Max. solid angle input to illuminator	0.03 - 0.2 [sr] ***
•Spectral Purity: 130-400 [nm] (DUV/UV) $\geq 400$ [nm] (IRVis) at Wafer	$\leq 3 - 7\%$ *** TBD ***

\* At IF

\*\* After IF

\*\*\* Design dependant

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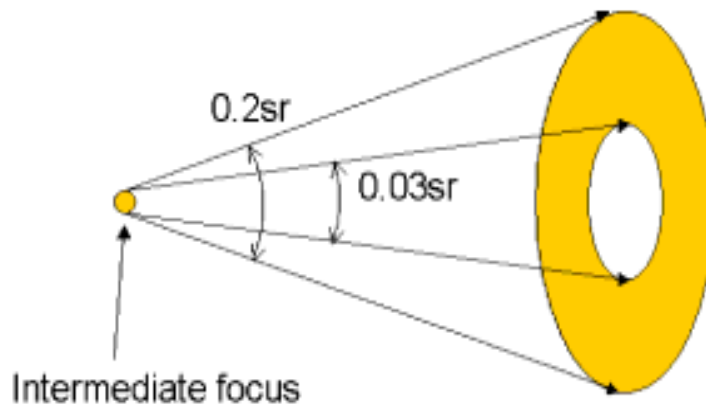


## Priority Items

Following items are specified at intermediate focus.

Source Characteristics	Requirement
Central wavelength	13.5 nm
In-band EUV power into illuminator	115 W
Pulse-to-pulse positional stability	< 10% ( $3\sigma$ ) of source size
Maximum solid angle input to illuminator	0.2 sr <sup>1) 2)</sup> (NA 0.25)
Nominal beam size <sup>3)</sup>	$\phi$ 2.5 mm
Etendue	1mm <sup>2</sup> sr <sup>4)</sup>
Angular distribution of power <sup>5)</sup>	TBD
Rotational symmetry of power <sup>5)</sup>	TBD

1) Canon only uses within the range of 0.03sr to 0.2sr <sup>2)</sup>.



2) 0.2 sr is preferable, but smaller value is acceptable if etendue requirement is satisfied.

3) Nominal beam size is determined by Etendue and Maximum solid angle input to illuminator.

4) Anisotropic source allows larger etendue.

5) Angular distribution of power must be axially symmetrical with respect to the optical axis.

## Other Items

Following Items are specified at intermediate focus.

Source Characteristics	Requirement
Integrated energy stability	+/-0.3% (3 $\sigma$ ) over 50 pulses
Long term power drift	< +/-2% / optical monitor module lifetime
Repetition rate	> 7-10 kHz
Stability of repetition rate	+/- 0.1% (long term)
Spatial distribution of power	TBD
Spectral Purity	
< 130 nm <sup>6)</sup>	< 100%
130-400nm <sup>6)</sup>	< 3%
400-800nm <sup>6)</sup>	< 10%
>800nm <sup>6)</sup>	< 0.2%
Source cleanliness (Lifetime of optics after intermediate focus)	> 30000 hour
Vacuum before intermediate focus	TBD

6) They depends both on spectral characteristics of resist sensitivity and material of capping layer which are not yet determined.

Seven evaluation tools measure the characteristics of the EUV source which satisfies Canon's requirements.

- Total power measurement system
- Spatial distribution measurement system
- Angular distribution measurement system
- Fine spectrum measurement system
- Rough spectrum measurement system
- Debris and contamination measurement system
- Gas flow measurement system

In-band EUV power is obtained both by angular distribution and fine spectrum.

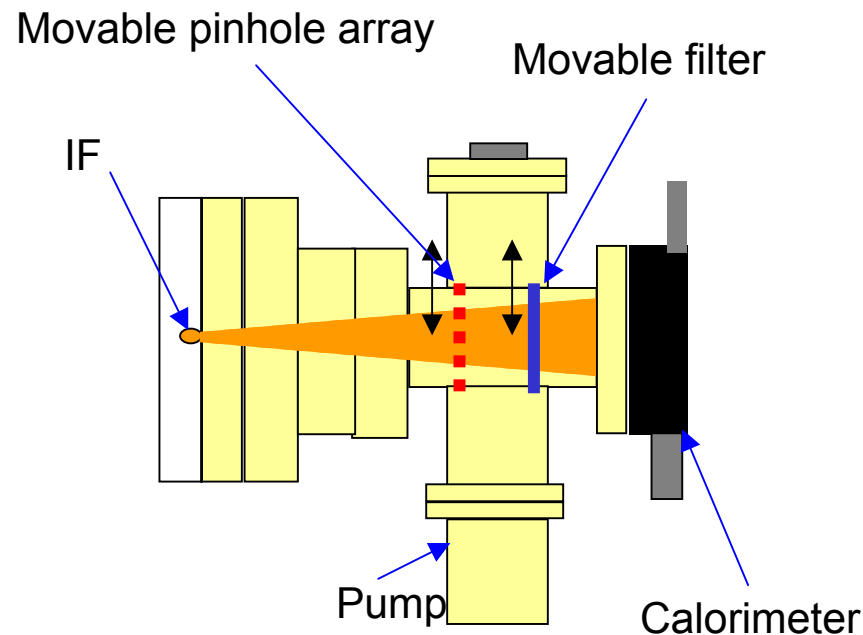
Etendue is obtained both by spatial distribution and angular distribution.

# Total power and Rough spectrum

Measurement of total power and spectral purity with a calorimeter and filters.

Pinhole array is used as an ND filter.

Several pinhole arrays can apply to a wide range of input power.

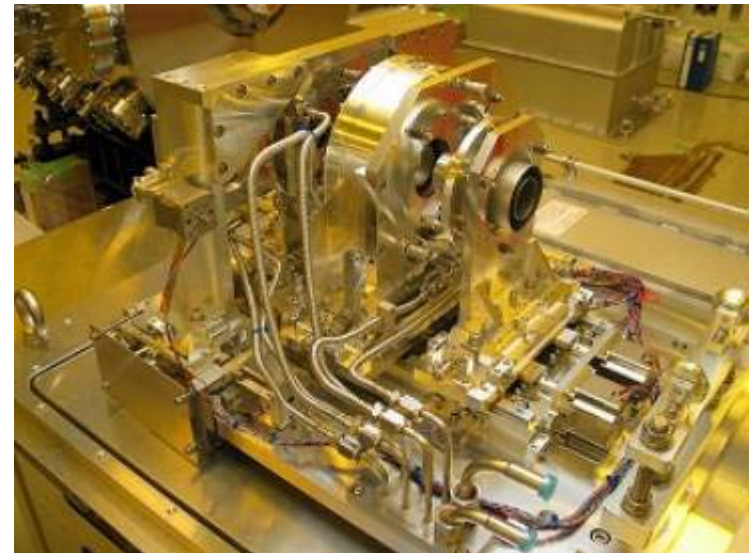
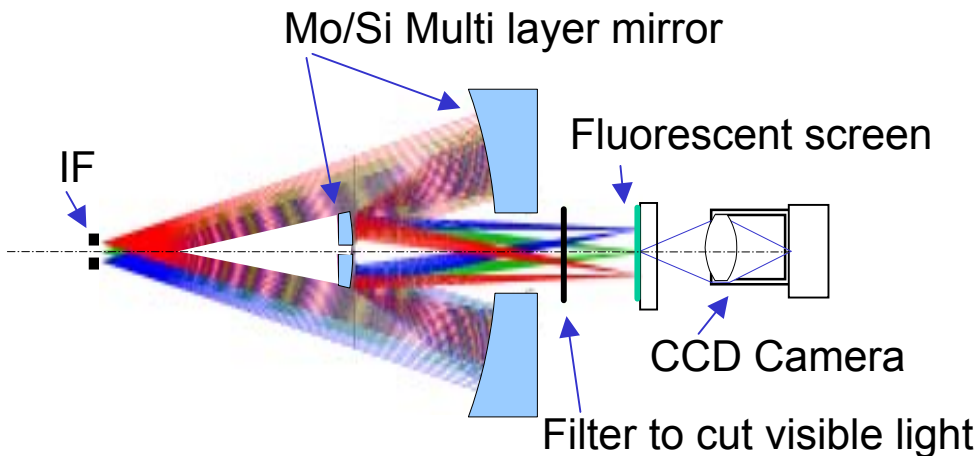


# Spatial distribution

Measurement of spatial distribution and pulse-to-pulse positional stability of power at IF.

This system is comprised of

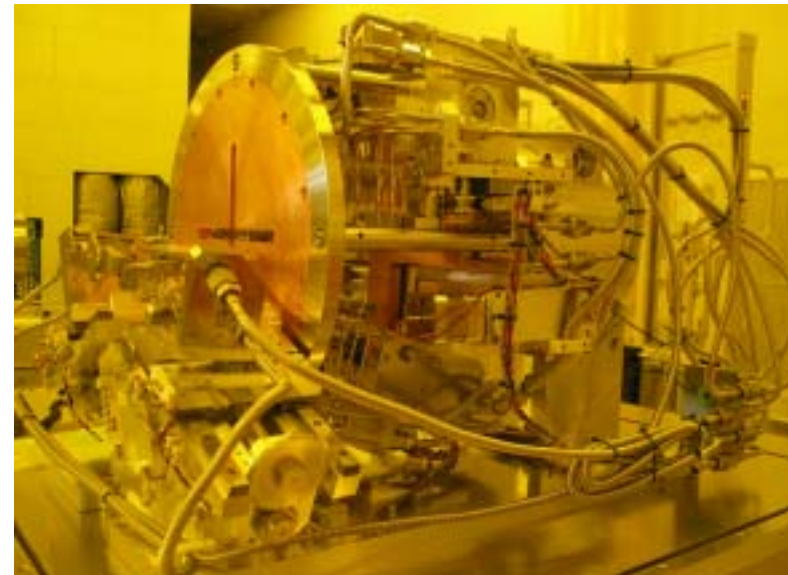
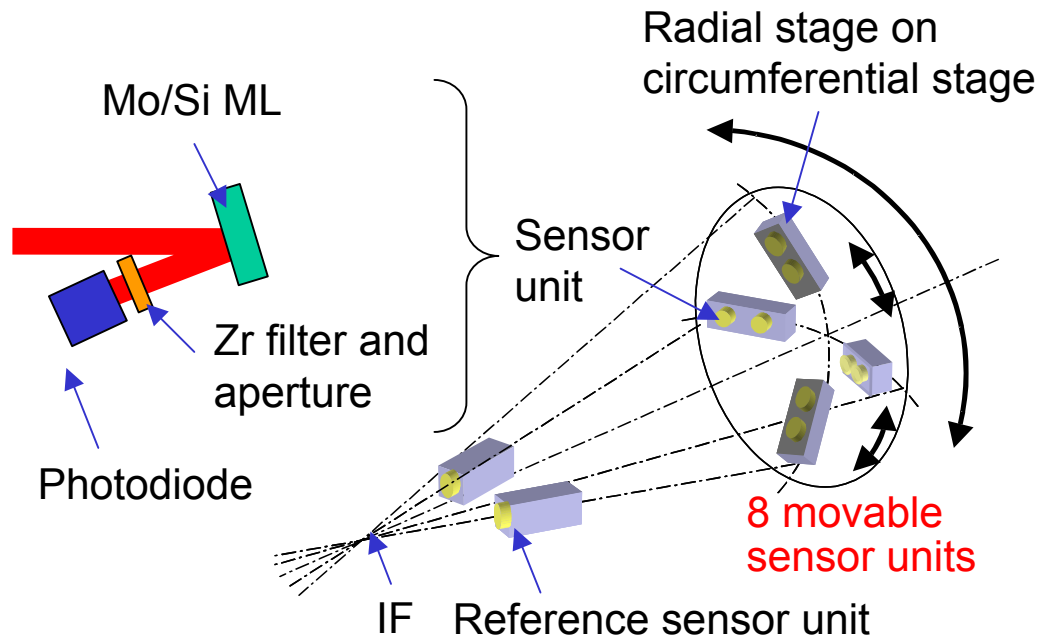
- Schwartzchild optics to project in-band EUV over all solid angle input into illuminator. Pinhole camera is not suitable for this purpose.
- a fast fluorescent screen to measure an image profile of a few pulses.



# Angular distribution

Measurement of angular distribution and rotational symmetry of power, pulse-to-pulse angular distribution and rotational symmetry stabilities.

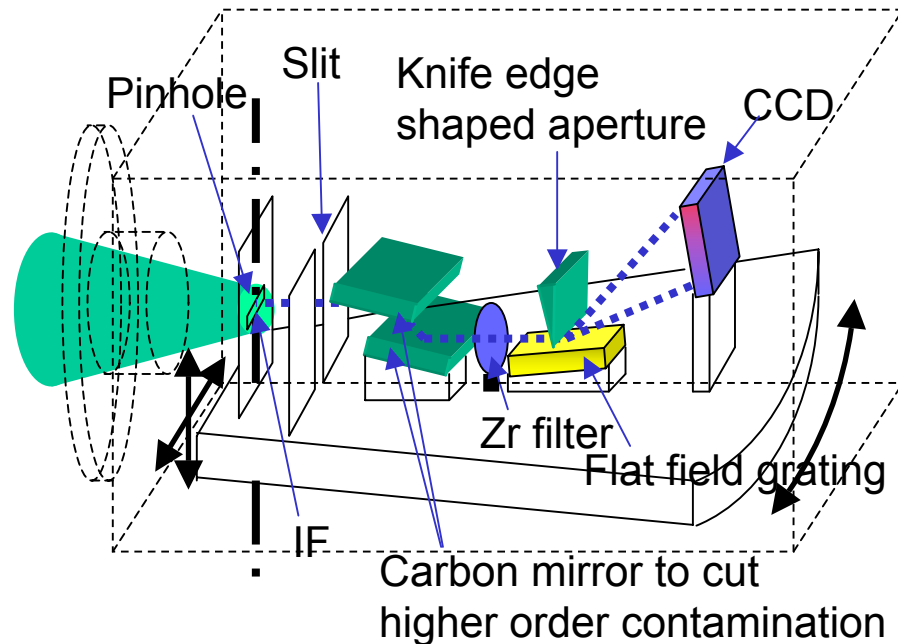
Each sensor unit comprises a Mo/Si ML, a Zr filter and a photodiode. There are eight movable sensor units in this measurement system. Angular distribution is utilized to obtain in-band EUV power.



# Fine spectrum

Measurement of fine spectrum of 11-19 nm.

Fine spectrum is measured to obtain in-band EUV power. The spectrometer is placed on x, y and  $\omega$  stages because angular dependence of in-band EUV has to be measured.

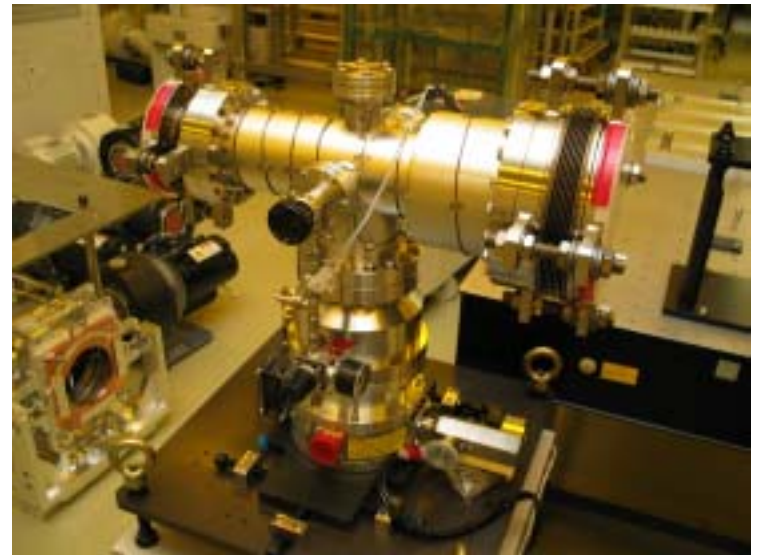
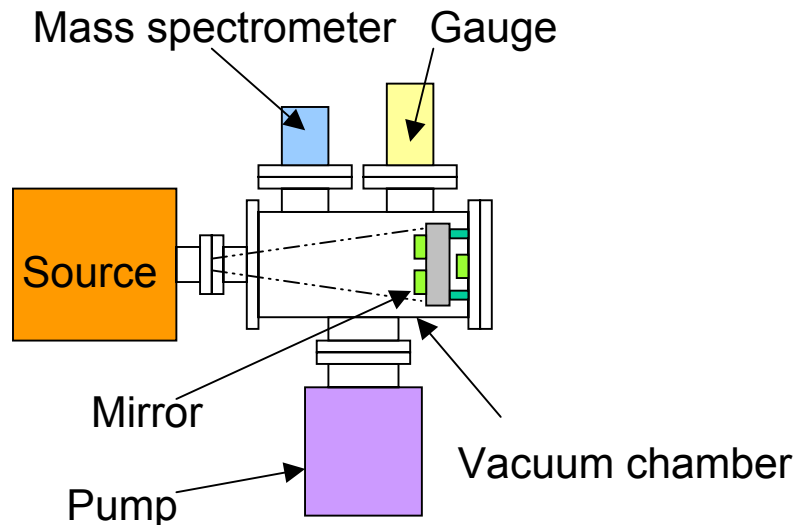


# Debris and contamination

Measurement of deposited debris and contamination onto multilayer mirrors to measure an optics lifetime after IF.

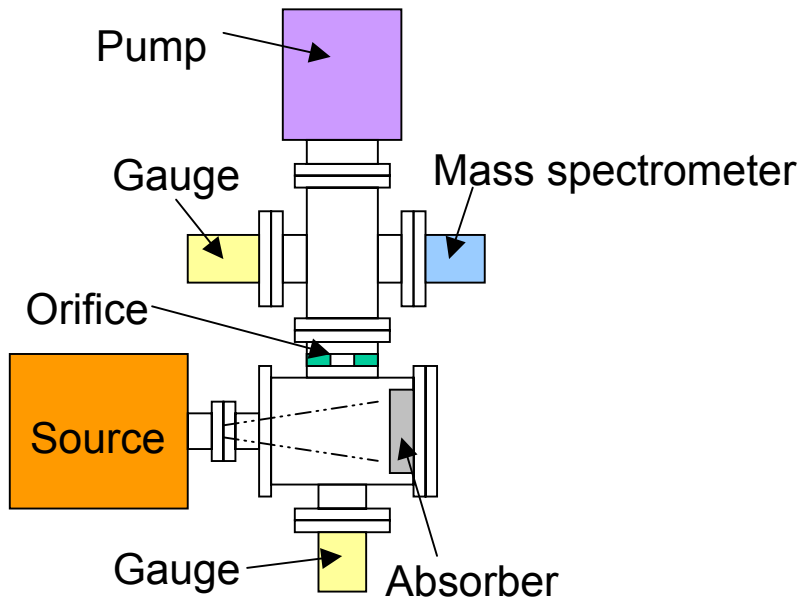
This chamber is very clean and has very low degasification in order to estimate mirror lifetime caused by source.

Total pressure  $< 1 \times 10^{-7}$  Pa



Measurement of gas flow rate through an aperture at IF, composition of gas and partial pressure.

Gas flow rate is measured by differential pressure between two chambers with known gas conductance of an orifice between the chambers.



# Chamber for evaluation tools

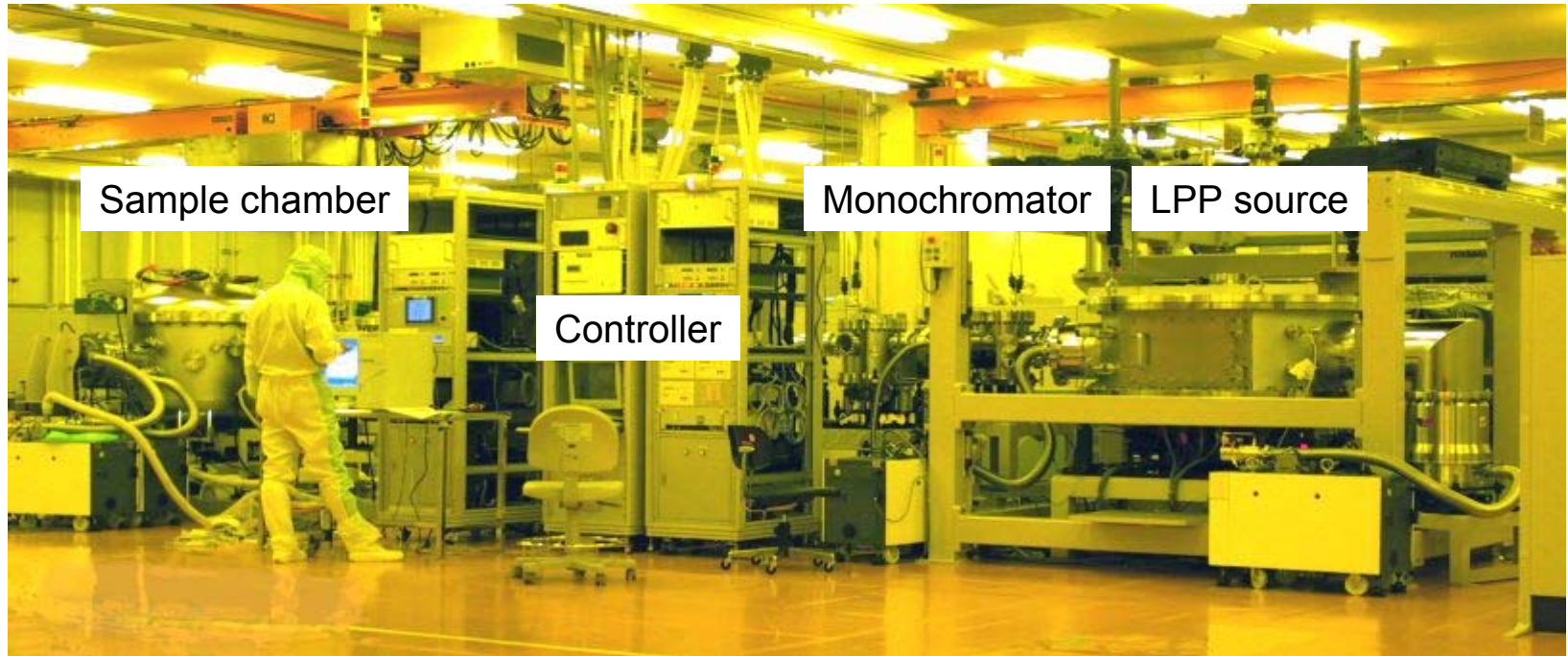
An vacuum chamber is shared for measurements of spatial distribution, angular distribution and fine spectrum measurements.

Each measurement system is positioned to the same datum in the chamber.



# Optical element calibration

The LPP-based reflectometer.



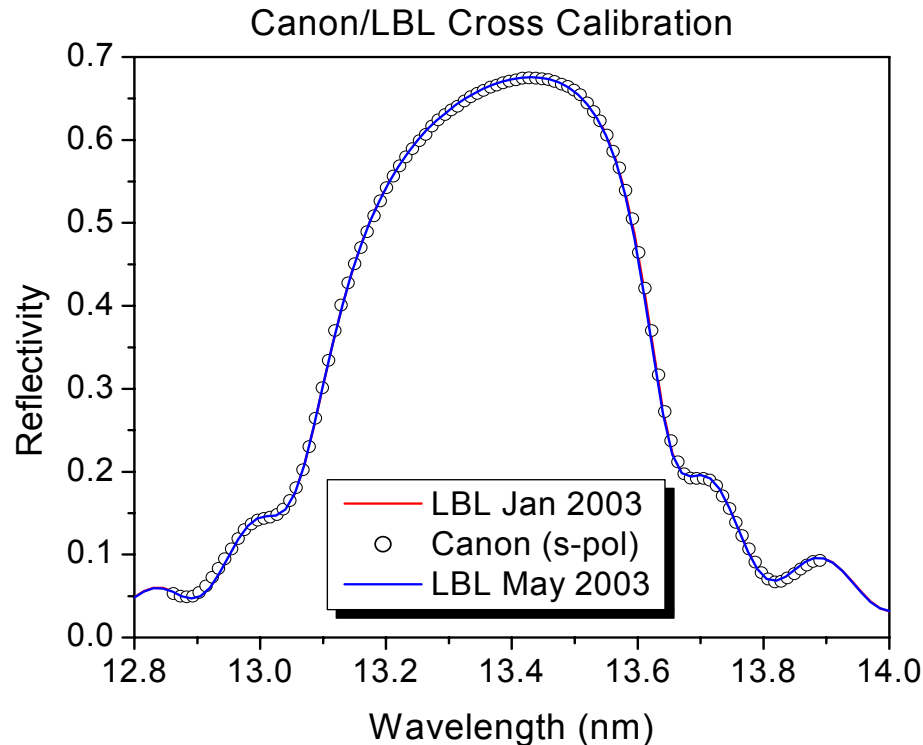
## Features

- A polarizer using three multilayer mirrors makes it possible to measure with a linearly polarized beam and the polarization state is easily switched.
- Beam instability can be compensated to  $<0.1\%$  with a beam intensity monitor.

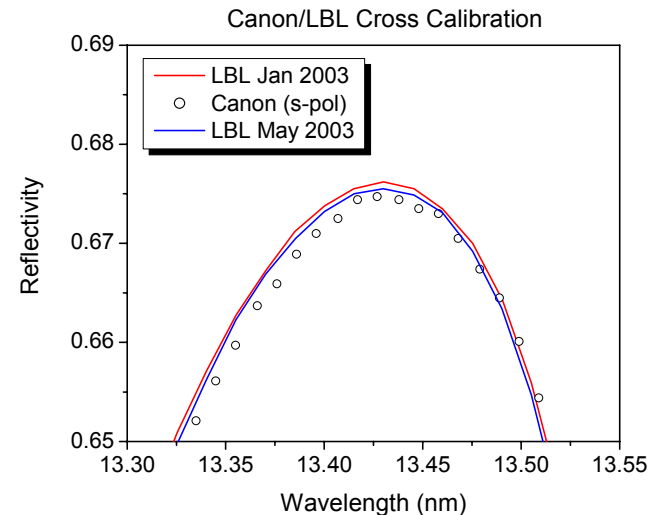
A. Miyake, T. Miyachi, M. Amemiya, T. Hasegawa, N. Ogushi, T. Yamamoto, F. Masaki, and Y. Watanabe, Proc. SPIE, **5037**, 647 (2003)

# Optical element calibration

Canon/CXRO reflectivity cross calibration of reflectivity.



Sample : Mo/Si multilayer  
Incident angle : 3.5degree  
Polarization : s-polarized



Accuracy of absolute reflectivity was evaluated by cross calibration with LBL reflectometer. The difference of peak reflectivity was about 0.1% and the difference of the wavelength at peak reflectivity was about 0.004nm.

The cross calibration was executed by courtesy of Dr. Eric Gullikson.

# Summary

1. Canon already provided EUV source evaluation system at the intermediate focus.
2. The evaluation system which is comprised of seven measurement systems can measure the characteristics of the EUV source which satisfies Canon's requirements.
3. Calibration of optical elements is important for accurate source evaluation. In our facility we can use one of the reflectometers which achieve the highest accuracy in the world.