A Source for EUV Lithography

Jos Benschop

Rick Gontin

Vadim Banine

Noreen Harned

ASML

Outline of Presentation

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Importance of EUV Source Development to EUV Lithography

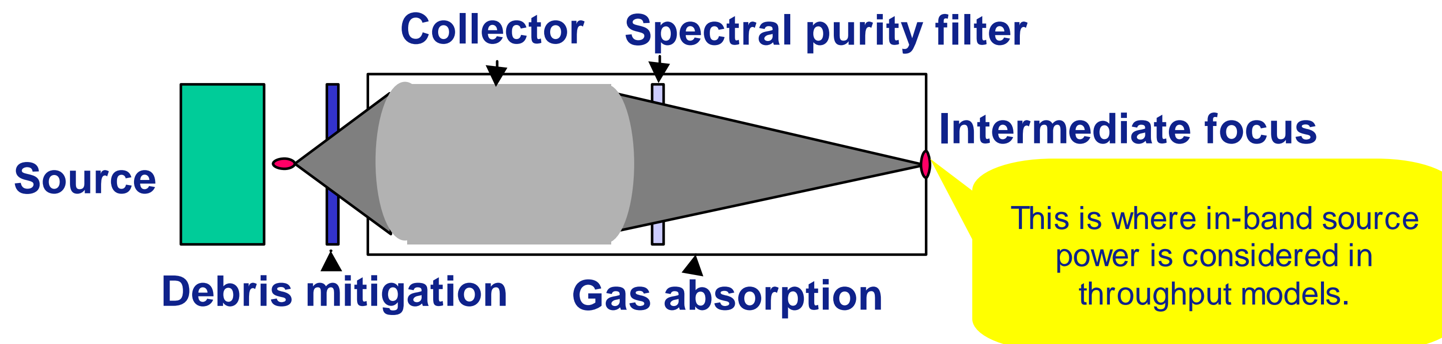
- The most critical challenges in the development of a commercial EUV lithography system concern the source of EUV light.
  - All four business drivers are directly affected by choice of source technology chosen for the tool:
    - Resolution (CD/Imaging)
    - Overlay
    - Productivity
    - Product Value
- Length of EUV source development cycle will ultimately make or break success of EUV lithography.

How We Define Source Characteristics

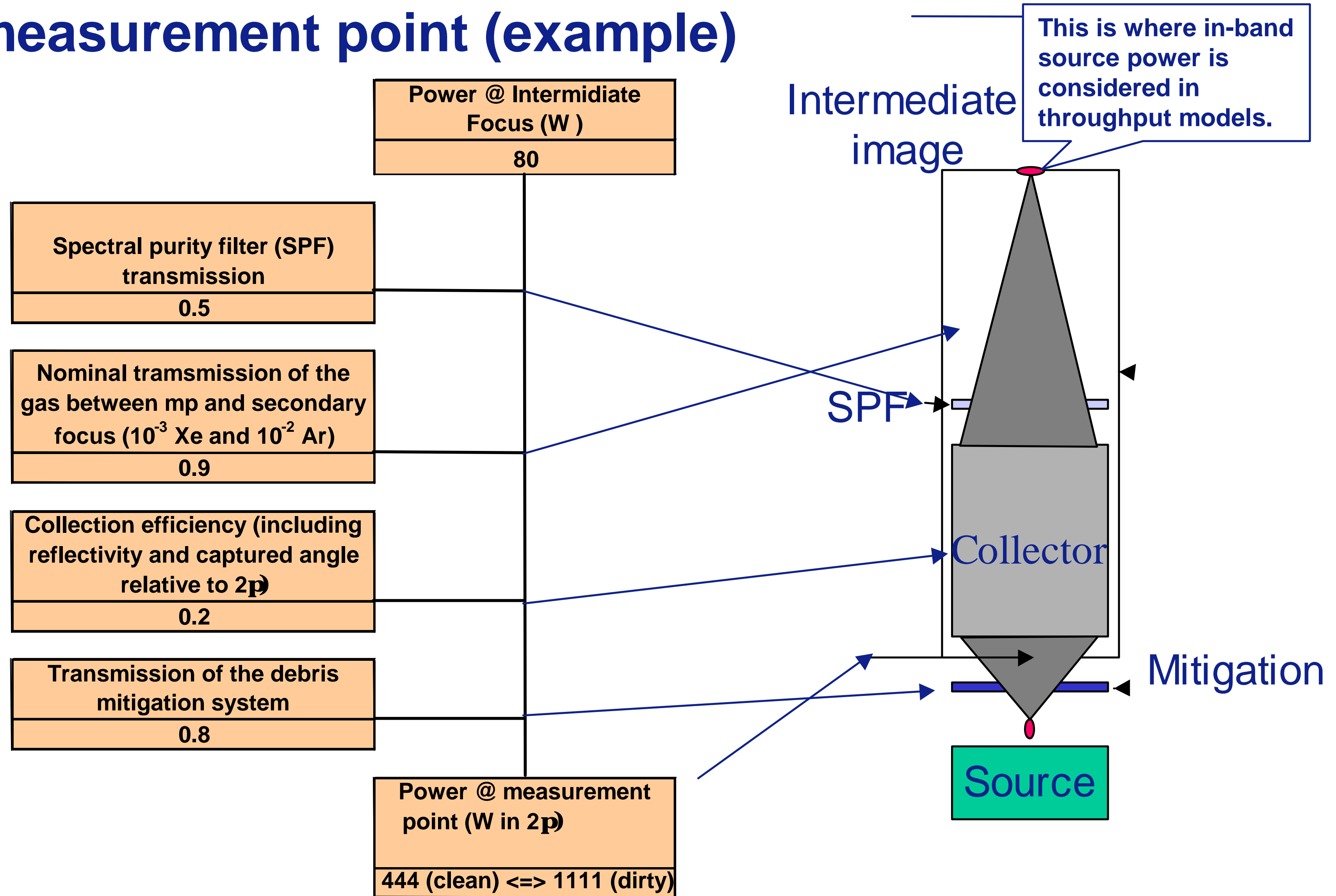
DESIGN PARAMETER	DESCRIPTION
•EUV Power	In-Band (13.5 [nm], 2% BW) Power available at intermediate image of source collector module (focus of condenser).
•Repetition Rate	EUV pulses emitted per second.
•Collectable Angle	Input solid angle of condenser
•Spatial Stability	$\pm 3\sigma$ variation in position expressed as fraction (percent) of nominal source size
•Angular Anisotropy	%P-V EUV intensity within collect. solid angle
•Pulse-Pulse Repeatability	$\pm 3\sigma$ variation in EUV pulse energy
•Source Cleanliness	Lifetime before replace of component until output decreased to 90% of initial value
•Spectral Purity (DUV & IR)	DUV/(total in-band EUV), IR/(total in-band EUV)

A Definition of EUV Source Power Meaningful to Us

- We consider only in-band (2% @ 13.5 [nm]) EUV at image formed by collector, with following effects already included:
  - solid angle of collection (includes obscuration effects)
  - collector ML reflectivity (with losses from polarization)
  - loss due to spectral purity filter (if one is needed)
  - absorption due to trace amounts of gas along the light path.
  - loss due to debris mitigation system (if required)



How to recalculate power to the measurement point (example)



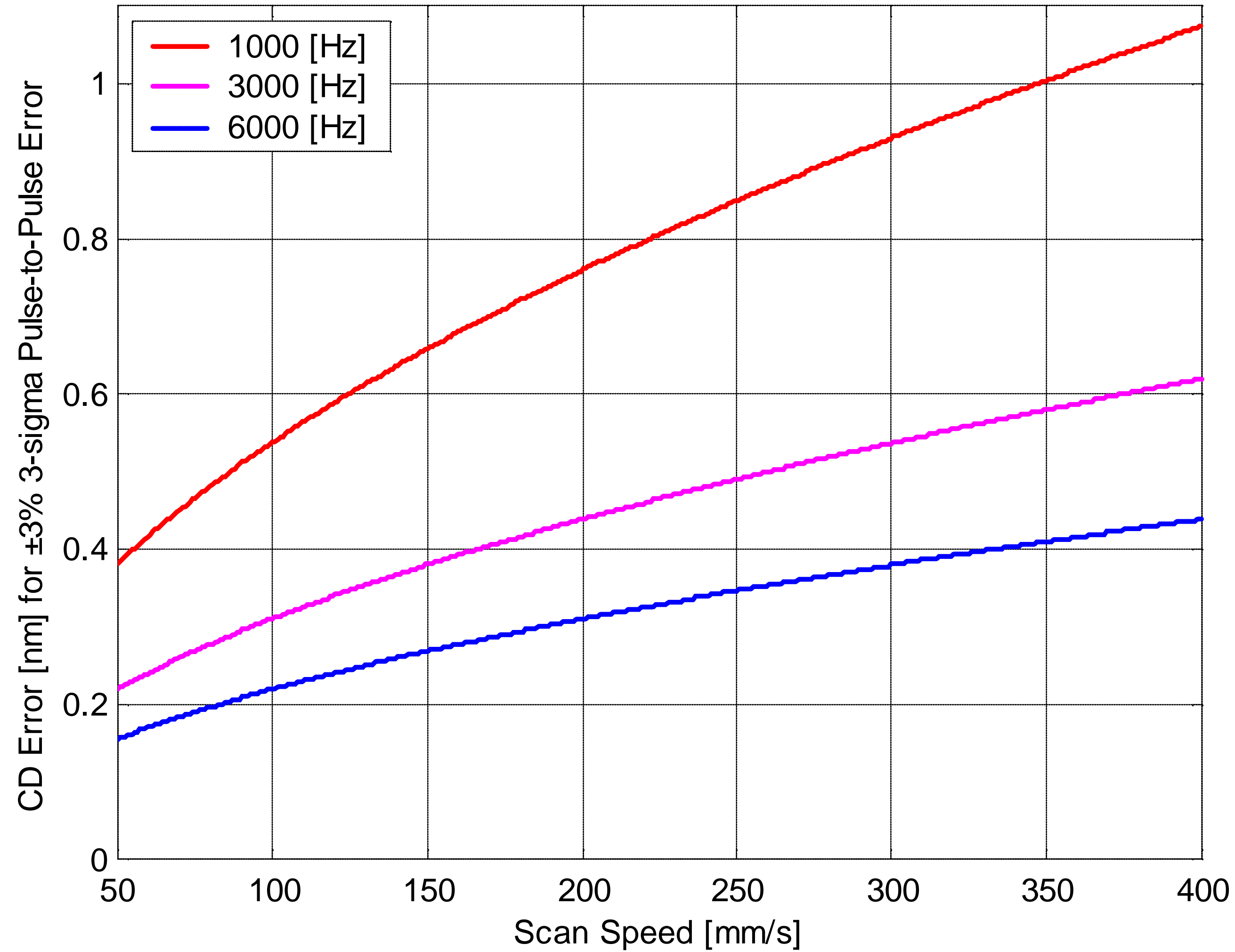
Relation Between Characteristics of Source and Lithography Tool

- Source performance characteristics can be “mapped” to performance of the lithography tool.

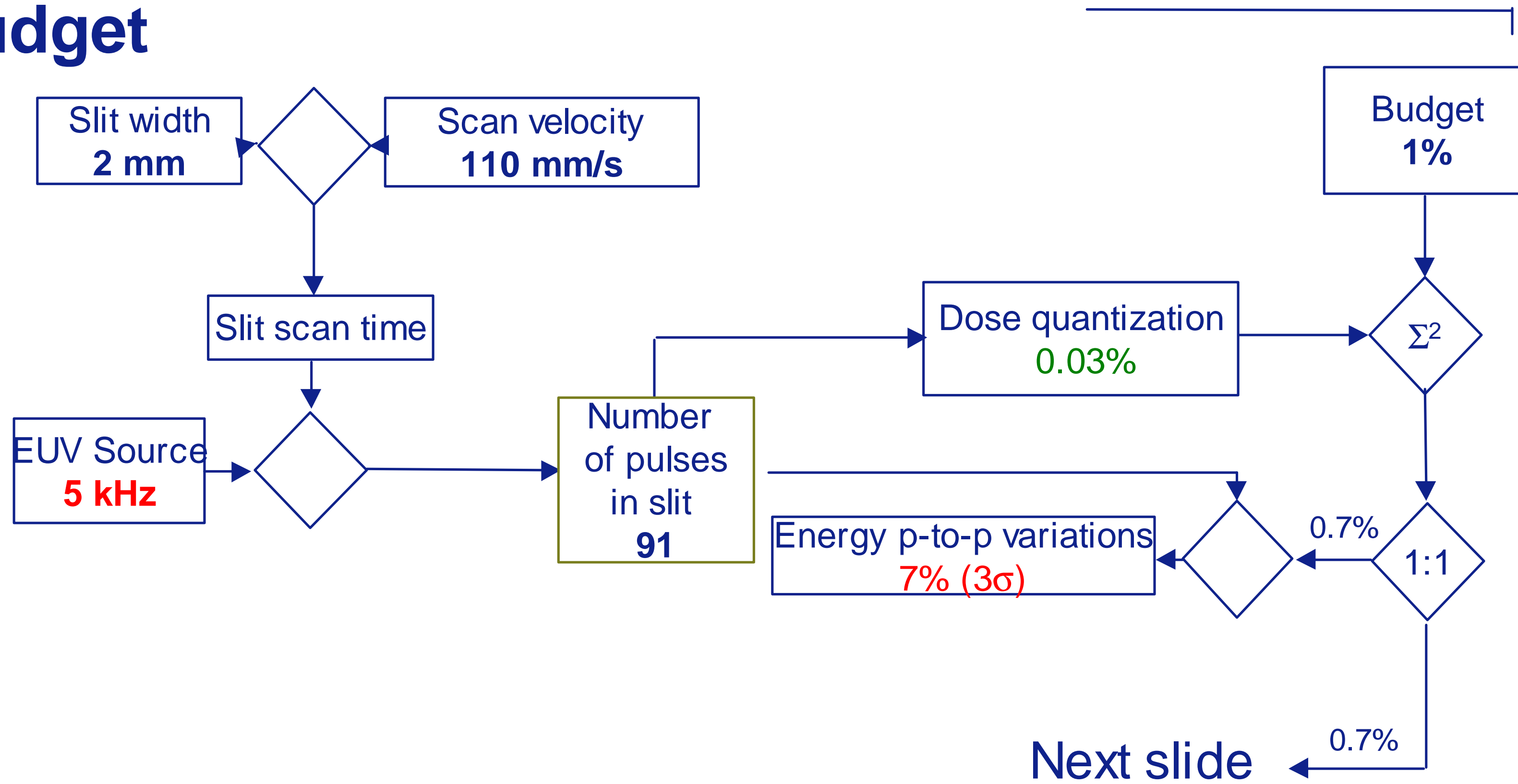
PERFORMANCE PARAMETER	Throughput	Image Quality	Cost of Ownership	Design Complexity
EUV Power	X		X	
Source Size/Collectable Angle	X		X	O
Spectral Purity	X	O	X	O
Repetition Rate		X		
Pulse/Pulse Repeatability		X		
Source Cleanliness			X	
Cost of Consumables			X	
Power Consumption			O	

X = Primary Effect O = Secondary Effect

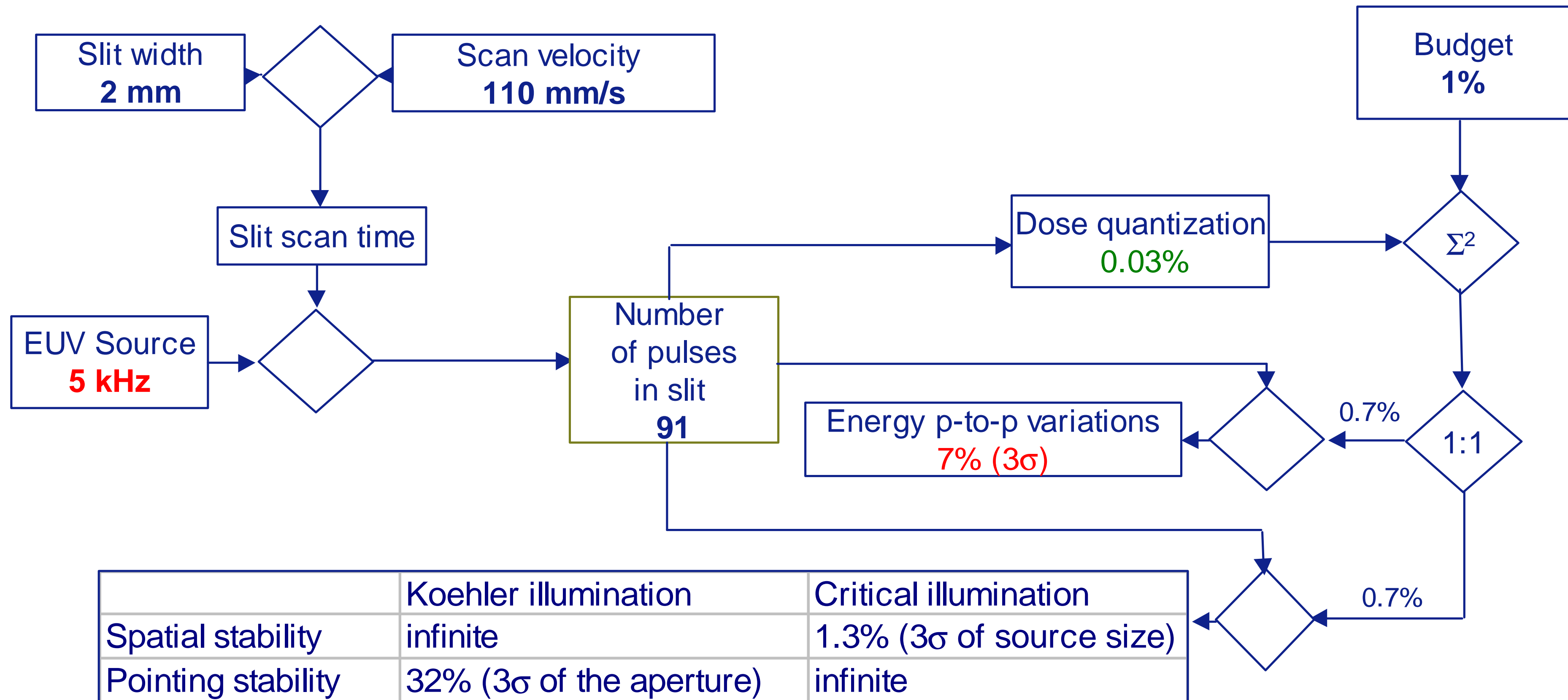
Repetition Rate Drives CD Control



Example of the energy reproducibility budget



Example of the spatial/ pointing stability budget (dose driven)



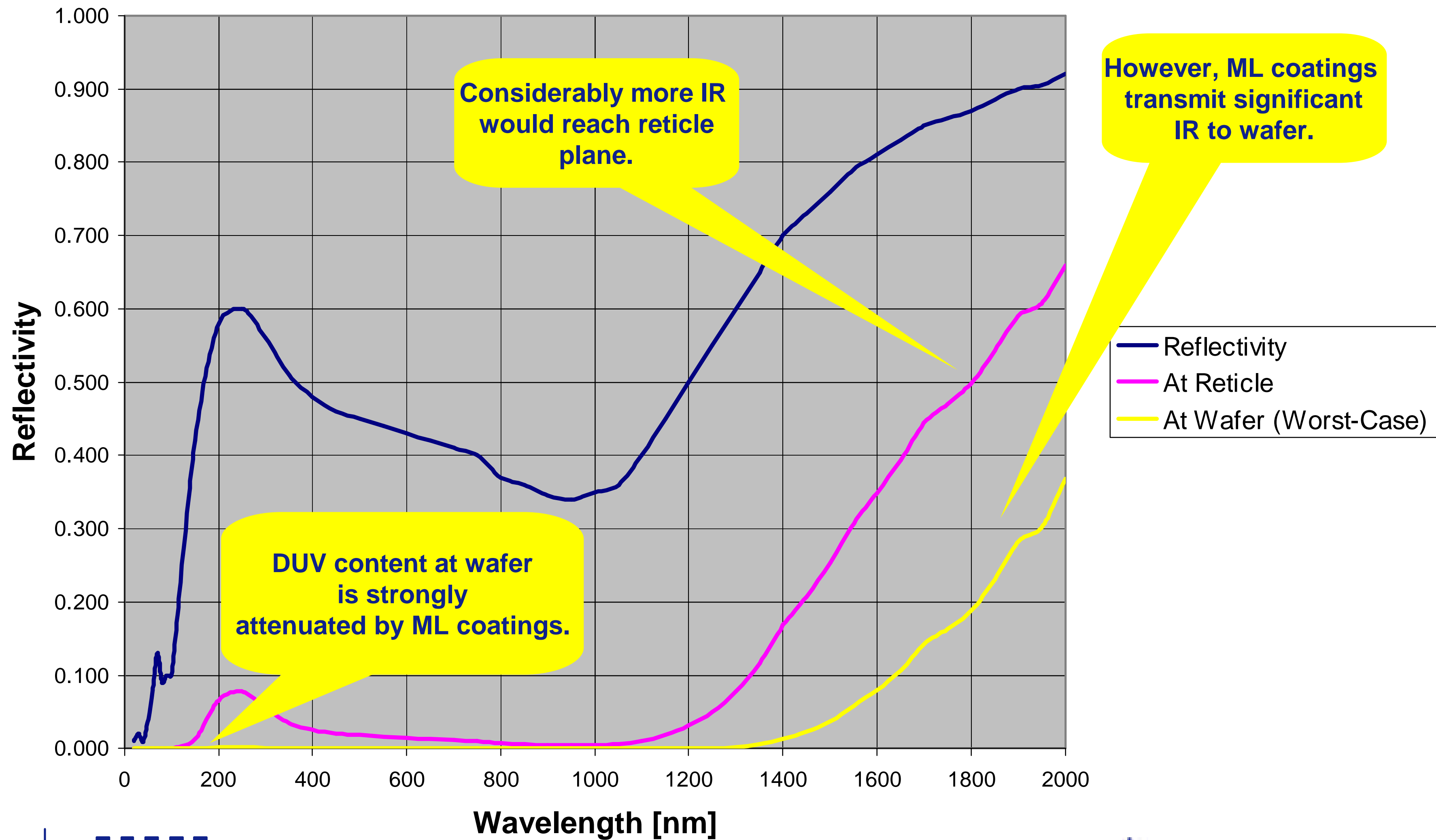
	Koehler illumination	Critical illumination
Spatial stability	infinite	1.3% (3σ of source size)
Pointing stability	32% (3σ of the aperture)	infinite

For more information please refer to Banine et al at SPIE 2000

Good Imaging Requires a Spectrally Pure EUV Source

- Two areas of source out-of-band spectrum must be minimized:
  - Deep Ultraviolet (DUV), 130 [nm - 300 [nm]
    - Imaging at wafer can be ruined by DUV, since EUV resists are sensitive to this wavelength region.
    - Fortunately, DUV is strongly attenuated by ML coating reflectance. Ultimately, the tool will tolerate a DUV spectral purity of <5%.
  - Infrared (IR), > 1000 [nm]
    - Mo/Si EUV multilayer coatings reflect strongly in the IR region.
    - Resulting heat load reaching reticle or wafer will overtax thermal management system of lithography tool.
- <u>Preferable solution</u>: Use source of inherently good spectral purity.
- <u>Alternative</u>: Add spectral filter to illuminator design.
  - Some technical challenges involved:
    - Loss of about 50% EUV power at wafer.
    - High thermal load on filter

Multilayer Reflectance



Our Requirements for an EUV Source

MAIN SOURCE CHARACTERISTIC	ULTIMATE REQUIREMENTS
•EUV Power (in-band)	80 [W]
•Repetition Frequency	> 5000 [Hz]
•Collection Angle	≥ 2 [sr], min., π [sr] max.
•Spatial Stability	2% of nominal source size
•Pulse-Pulse Repeatability	3%, 3σ
•Angular Anisotropy	≤ 10%
•Source Cleanliness	≥ 5000 hours
•DUV Spectral Purity	≤ 5%

Timing for Source Development (Our Roadmap)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007

Few Watts

Alpha tool

Few ten's of Watts

Beta / pilot production tools

Many ten's of Watts

Volume production tools

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