Proposal for total reflectivity uniformity of EUV mask multilayer coatings

J Zimmerman

Motivation

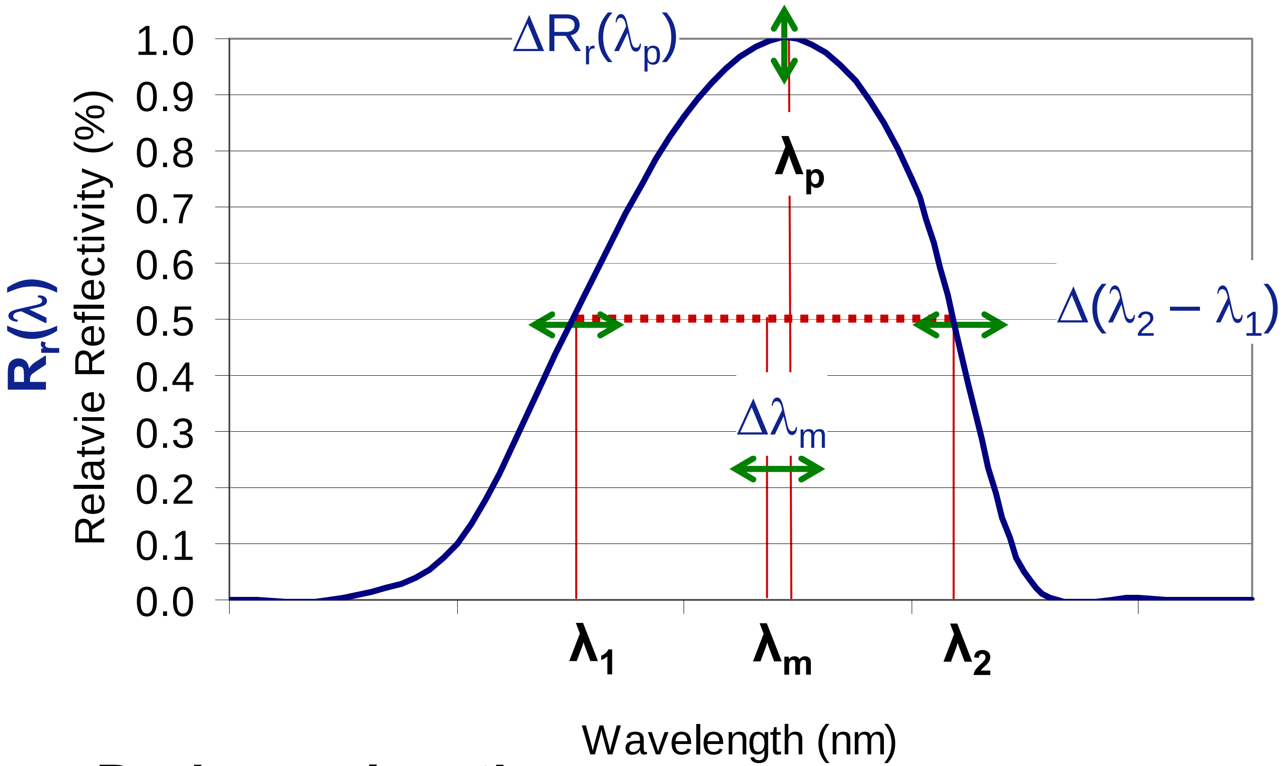
- Reticle multi-layer reflectivity uniformity directly impacts the system CD uniformity (Dose Control)
- Historically, the reflectivity uniformity is determined by the changes in peak reflectivity across the multilayer
- However, total reflectivity uniformity is determined by point-to-point variations of 3 parameters of the reflectivity curves:
  - the peak reflectivity $\Delta R_r(\lambda_p)$
  - the wavelength shift $\Delta\lambda_m$
  - the bandwidth $\Delta(\lambda_2 - \lambda_1)$ from point to point
- We propose a method that incorporates all 3 of the reflectivity characteristics simultaneously to determine the total reflectivity uniformity
- This method allows one to trade off all three parameters influencing total reflectivity uniformity

ASML

The total reflectivity across the blank is influenced by $\Delta\lambda_m$, $\Delta R_r(\lambda_p)$, and $\Delta(\lambda_2 - \lambda_1)$ from point to point

Median wavelength of EUV reflectivity of mask:

$$\lambda_m = (\lambda_1 + \lambda_2)/2$$

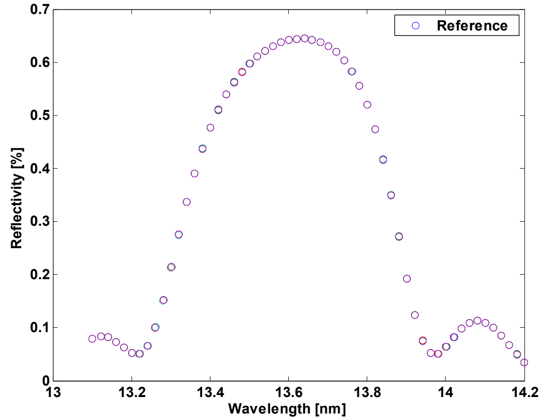


λ_p = **Peak wavelength**

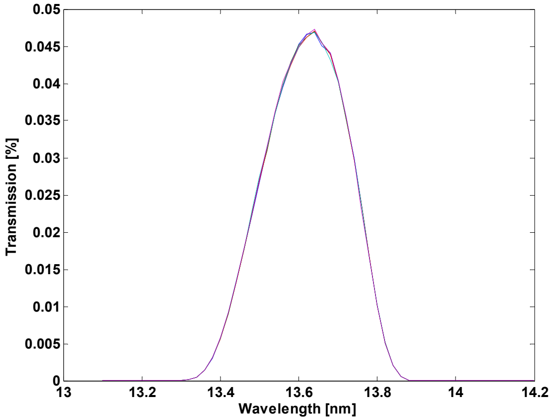
$\lambda_m = (\lambda_1 + \lambda_2)/2$

ASML

The total reflectivity uniformity can be determined by calculating the transmission at any point across the multilayer



Reference Reflectivity Curve



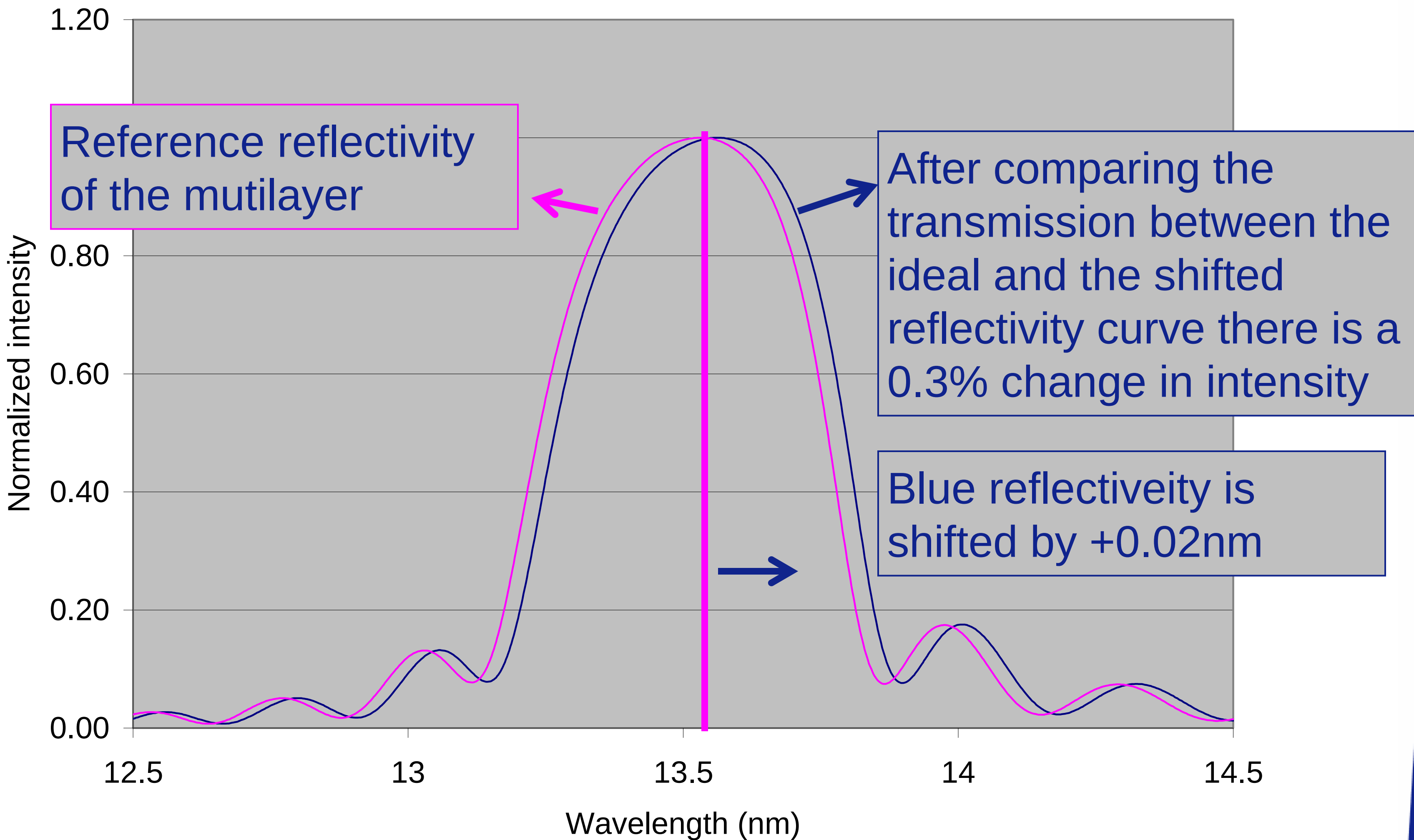
Reflectivity Curve for optical system

- Assumptions
  - The ideal reticle reflectivity is known
  - The optical system is perfect – no reflectivity changes across the image field

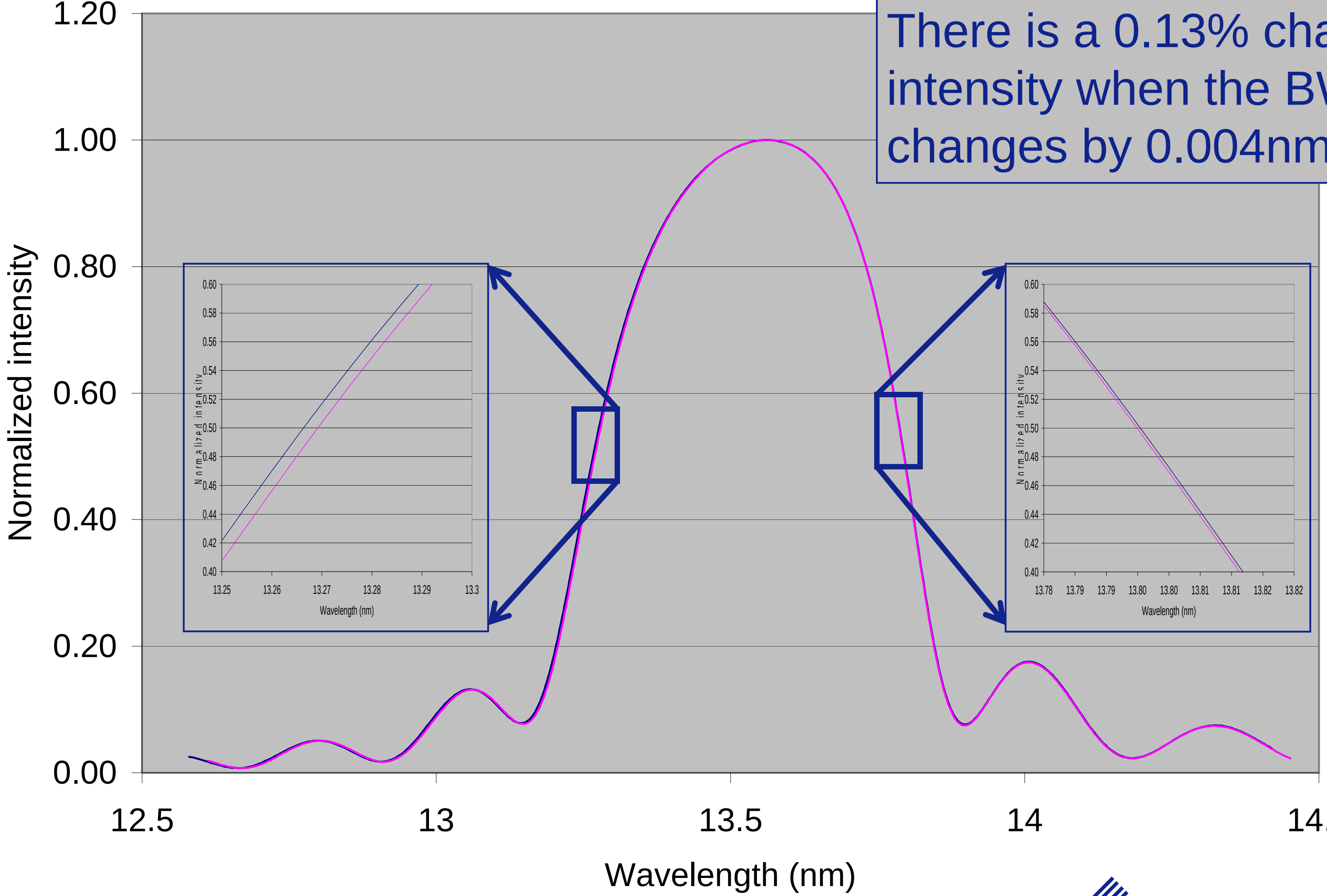
Example of wavelength shift $\Delta\lambda_m$ and bandwidth changes on reflectivity uniformity

- The transmission of 6 mirrors and one reticle is examined in the next 2 slides
- The 6 mirrors have identical reflectivity curves and it is the same as the reference reflectivity curve
- For the shift in $\Delta\lambda_m$, the reflectivity curve of the reticle is shifted by 0.02nm and the transmission with the 6 mirrors is calculated
- For the change in bandwidth, a second reflectivity curve was generated with a bandwidth change of 0.004nm and the transmission with the 6 mirrors is calculated
- We compared the transmission of the shifted wavelength and the changed bandwidth to a reference reflectivity curve
- The same process can be repeated for reflectivity peak changes $\Delta R_r(\lambda_p)$ across the reticle

Modeled reflectivity curve and the effective transmission of a single point on the reticle with different λ



Modeled reflectivity curve and the effective transmission for a point on the reticle with different BW



There is a 0.13% change in intensity when the BW changes by 0.004nm

ASML

The system transmission is calculated for all points on the reticle

- The system transmission is calculated by multiplying all the reflectivity curves of the 6 mirrors and mask
- For a 6 mirror system, calculate the effective transmission T for each point on the reticle by taking the sum of the product of the 6 mirrors and reticle
- Transmission

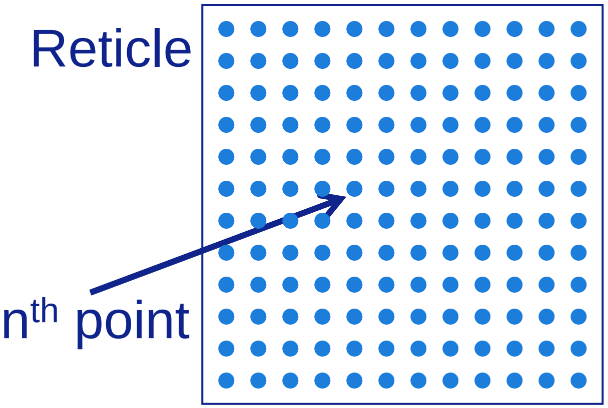
$$T_n = \sum M_1(\lambda) * M_2(\lambda) * M_3(\lambda) * M_4(\lambda) * M_5(\lambda) * M_6(\lambda) * R_n(\lambda)$$

$$T_n = \sum M^6(\lambda) * R_n(\lambda)$$

- Each T_n is compared to a reference reflectivity curve

$$T_r = \sum M^6(\lambda) * R_r(\lambda)$$

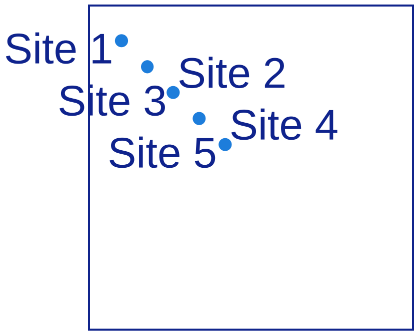
This is the “Ideal system”



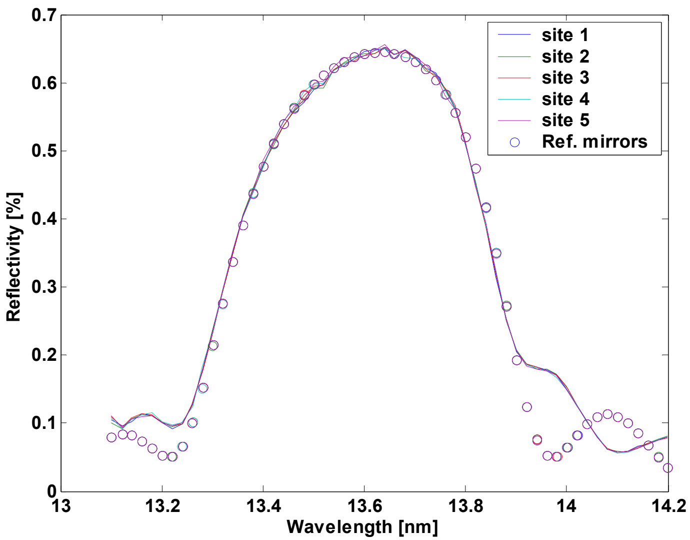
Sample Layout

ASML

Currently, peak reflectivity uniformity is used along with separate requirements for BW and Centroid



Reticle

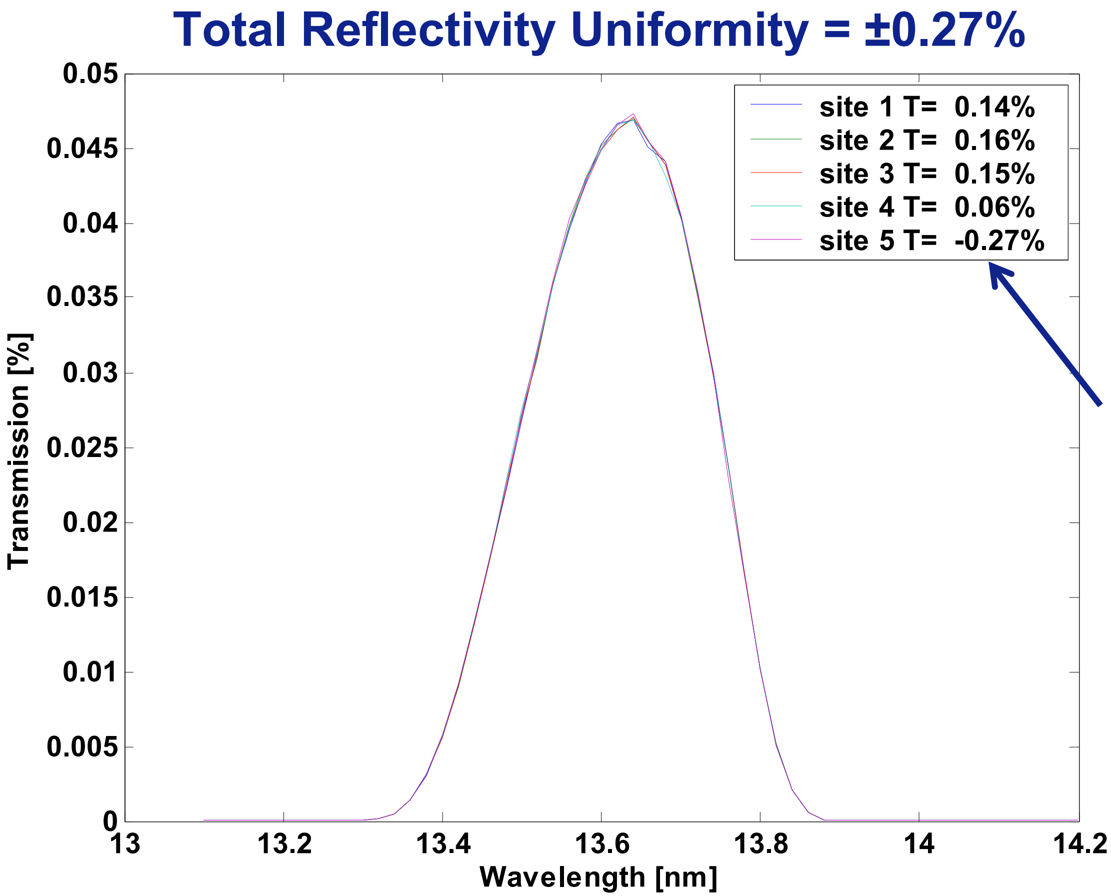


Reflectivity curves

- **Reflectivity data from 5 sites**
- **BW and Centroid from reflectometer software**

Site	Peak (%)	BW (nm)	Centroid (nm)
1	65.29%	0.5258	13.5940
2	65.26%	0.5279	13.5950
3	65.29%	0.5276	13.5950
4	65.37%	0.5287	13.5950
5	65.58%	0.5287	13.5950
Average	65.36%	0.5277	13.5948
Range	0.32%	0.0030	0.0010

Calculating total reflectivity uniformity eliminates the need for 3 separate specifications



The total reflectivity uniformity of the 5 sites trades off peak reflectivity, bandwidth and centroid shifts

Transmission relative to reference transmission for each site

Summary

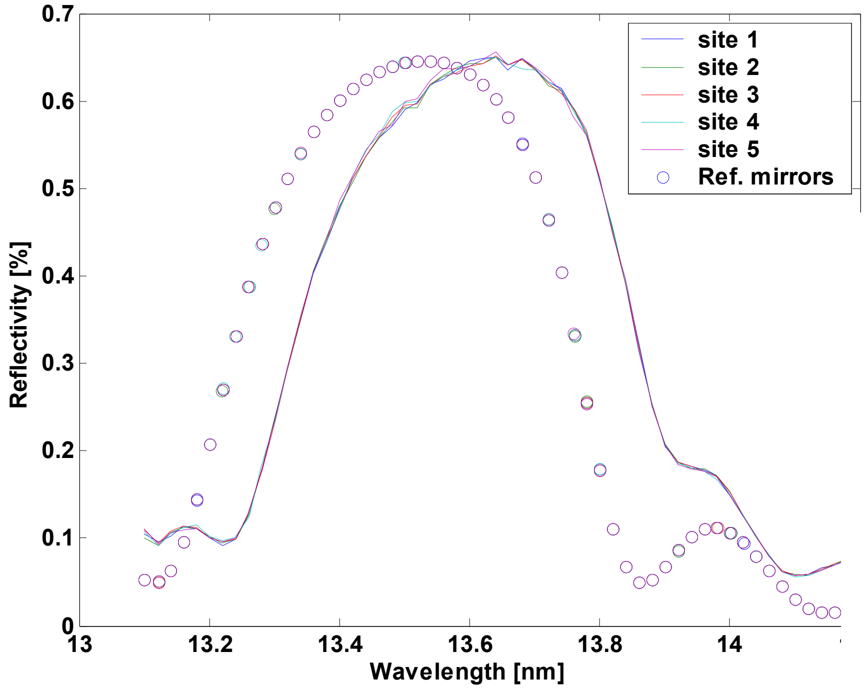
- One number can be used to specify ML reflectivity uniformity
- The analysis automatically includes wavelength shifts $\Delta\lambda_m$, reflectivity changes $\Delta R_r(\lambda_p)$ and bandwidth $\Delta(\lambda_2 - \lambda_1)$ changes from point to point on the reticle
- It allows a trade-off between all 3 parameters affecting <u>total reflectivity uniformity</u>

Backup

Proposal for Total Reflectivity Uniformity

- Calculate the “Reference” Mirror (@ 13.5nm) from CXRO website
- For each point on the reticle calculate the point by point transmission by multiplying each of the reflectivity curves with that of the 6 “reference” mirrors (weighting factor)
- Compare each point to the reference reflectivity curve

This method is sensitive to wavelength shifts



Effective 6% drop in total intensity in addition to the uniformity change