Beryllium-based multilayer mirrors for EUV spectral range

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Multilayer mirrors for EUV

Motivation

- Increase the reflection coefficients
- Expand the operation range
- Increase the spectral resolution

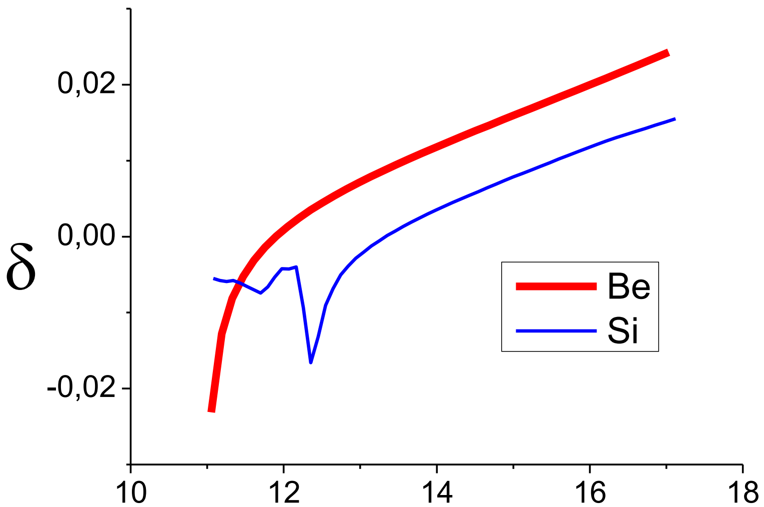
Ways how to solve the problems

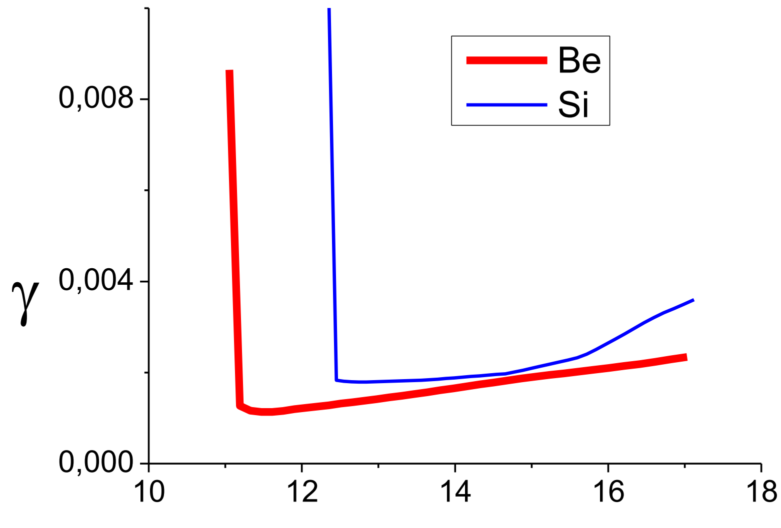
1. Improving existing approaches: Barrier layers, ion-assisted and ion polishing – effect is small!

2. Looking for new materials – interesting and unpredictable!

Beryllium as spacer for λ=11-17 nm

$$\varepsilon = 1-\delta+i\gamma$$

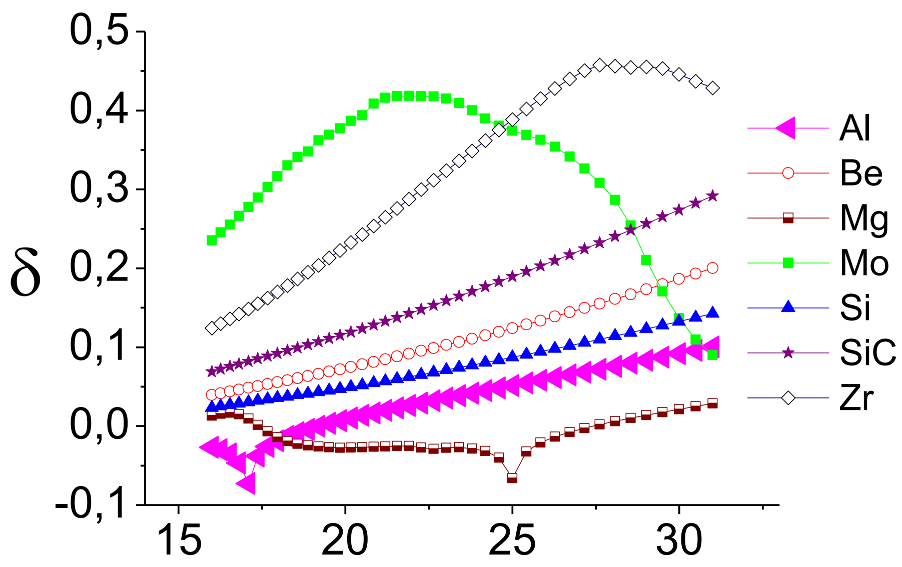


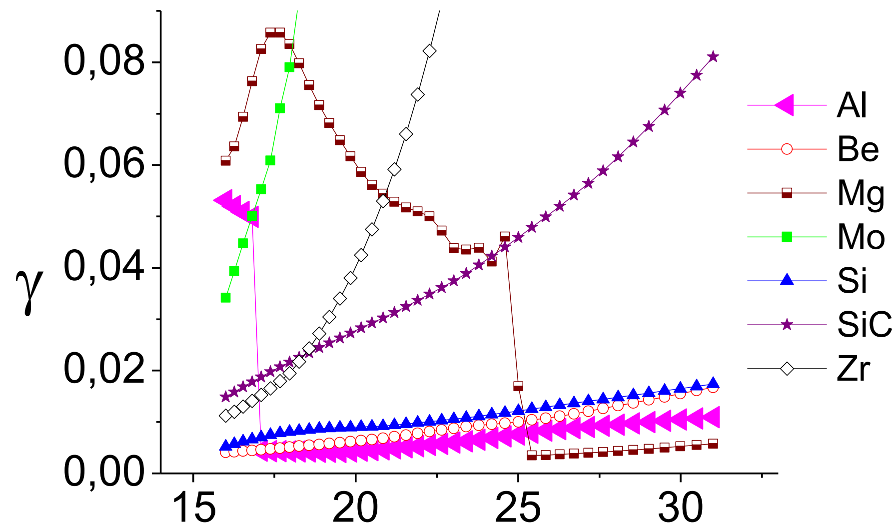


- **<u>No competitors</u> in the range of 11-12.4 nm**
- **<u>Smallest absorption</u> in the range of 11-17 nm**

Beryllium as the scattering (contrast) material in 17-30 nm range

$$\varepsilon = 1-\delta+i\gamma$$





➤ **Better than of Si and close to SiC optical contrast and lower absorption make Be as VERY attractive contrast material for EUV range!**

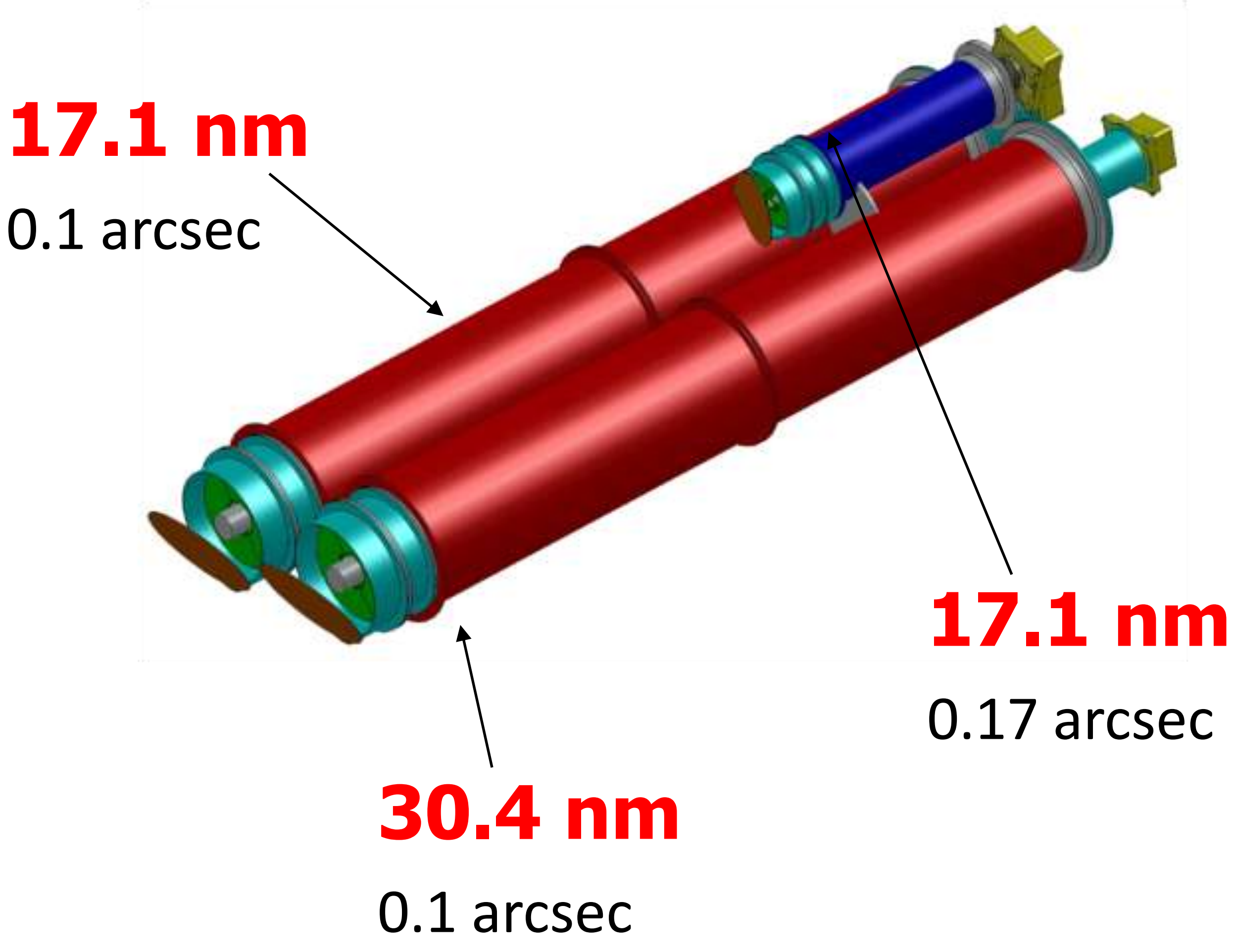
Mirrors for Astrophysics in EUV

Requirements:

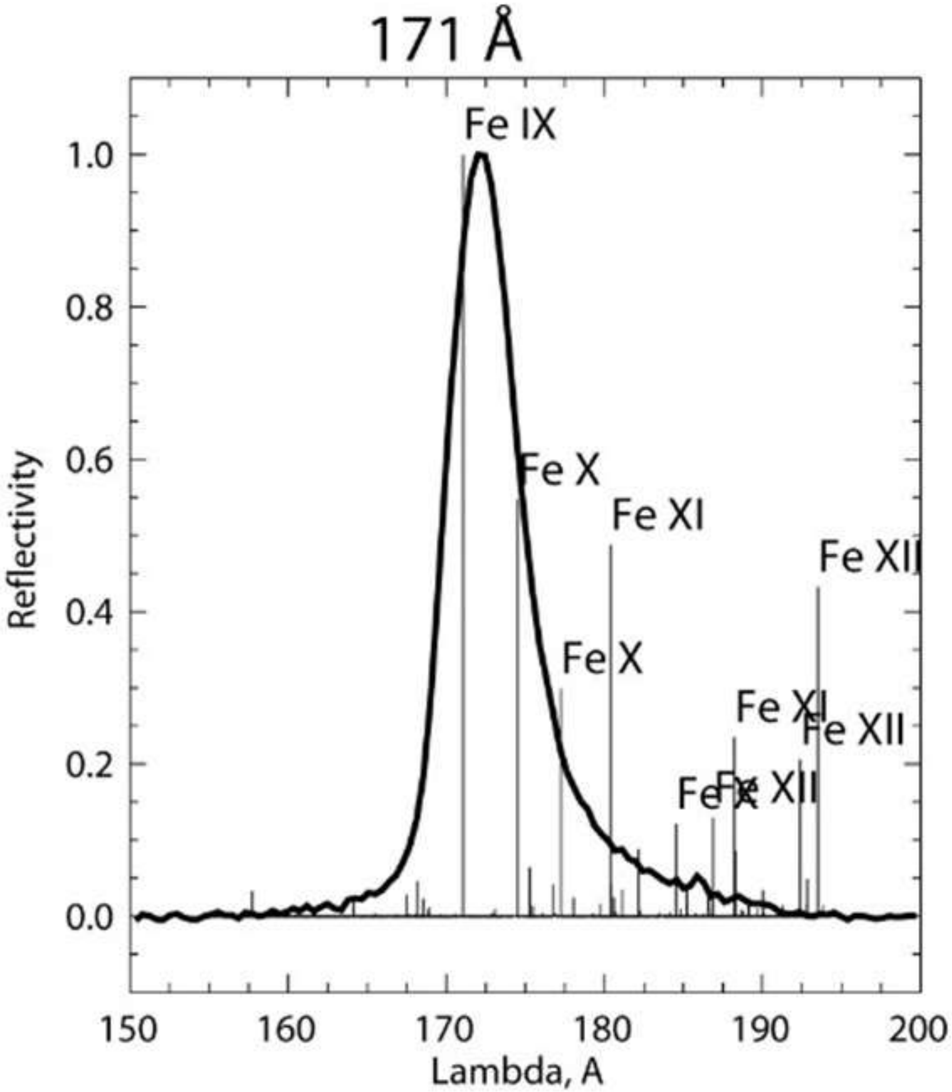
1. **High reflection coefficients**
2. **Narrow spectral band-pass**
3. **Stable operation at least for 5 years**

The ARKA instrumentation

Three Ritchey–Chrétien telescopes



Requirements for λ=17.1 nm



Spectral selectivity:

For single MLM

Δλ < 0.42 nm

For telescope

Δλ <0.3 нм

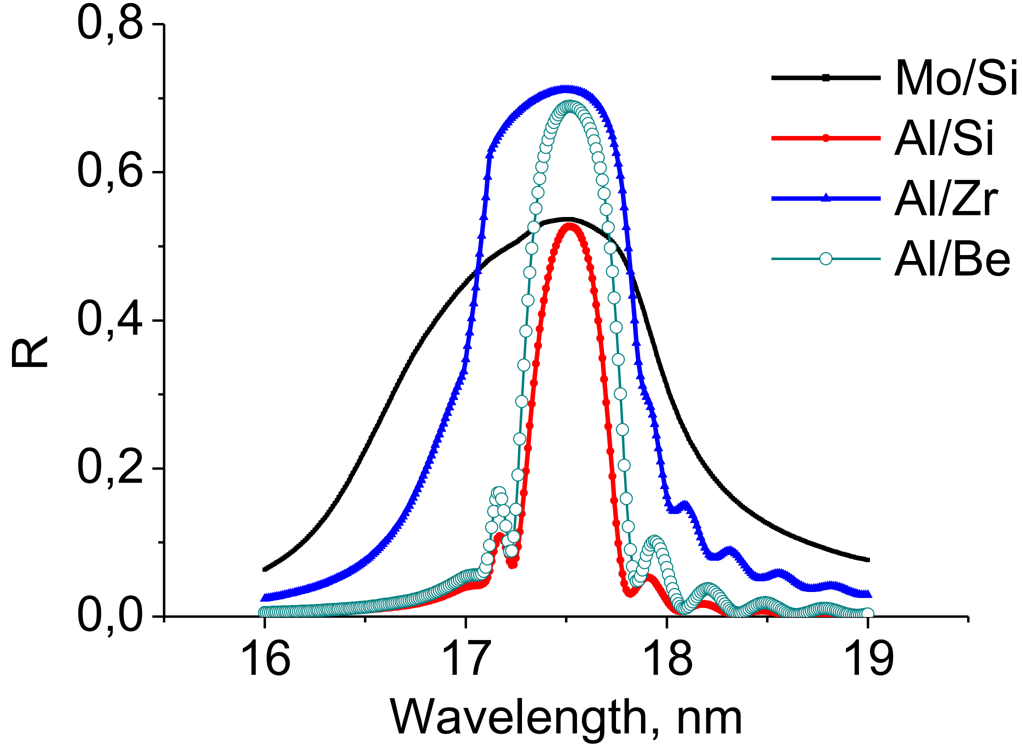
R_{peak} > 45%

Measured characteristics of MLMs at λ=17.1nm

Requirements: Δλ<0,42 nm, R>45%

MLMs	R,%	Δλ, nm
Si/Mo2C	52	1
Al/SiC	38	0.6
Al/Mo/SiC	53.4	0.76
Al/Mo/B4C	55.5	0.875
Mo/Si	54	0.875
Al/Zr	56	0.6
Al/Si	48	0.35

Calculated reflectivities



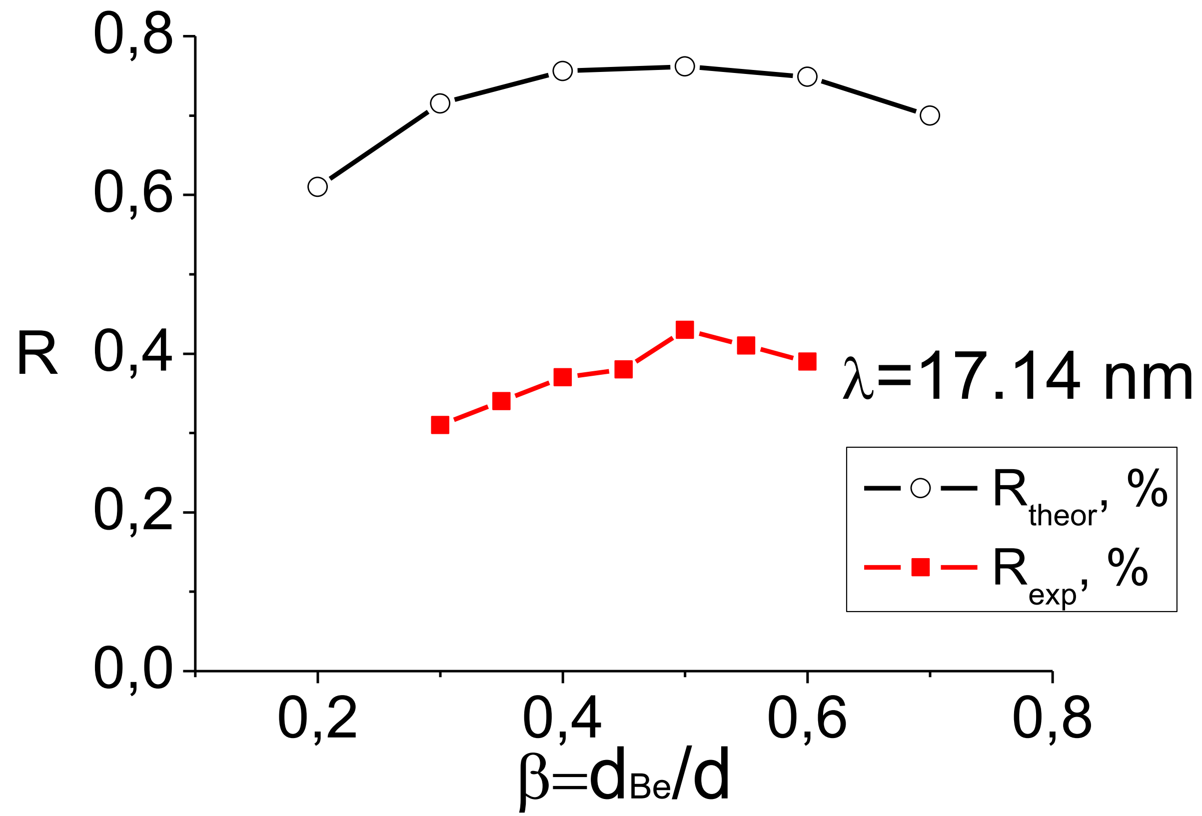
For Al/Be

at λ=17.5 nm

R=69%

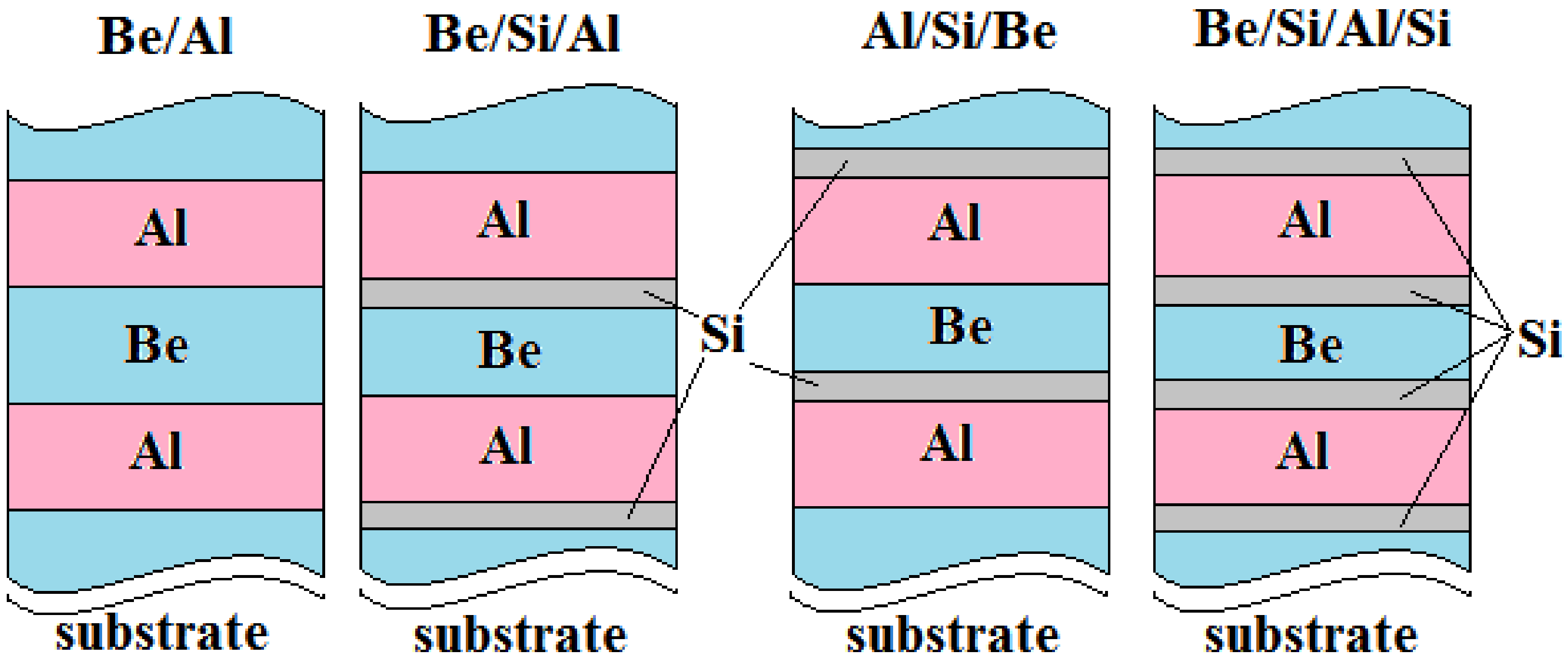
Δλ=0.45 nm

Dependences R(β)



Theoretical and experimental dependences of peak reflection coefficients on the proportion of Be in the period

Investigated kinds of MLMs



Comparison of reflectivity

MLMs	R_{theor}	R_{exp}
Be/Al	76.3%	46%
Al/Si/Be	75.3%	51%
Be/Si/Al	73.5%	61%
Be/Si/Al/Si	73.7%	56%

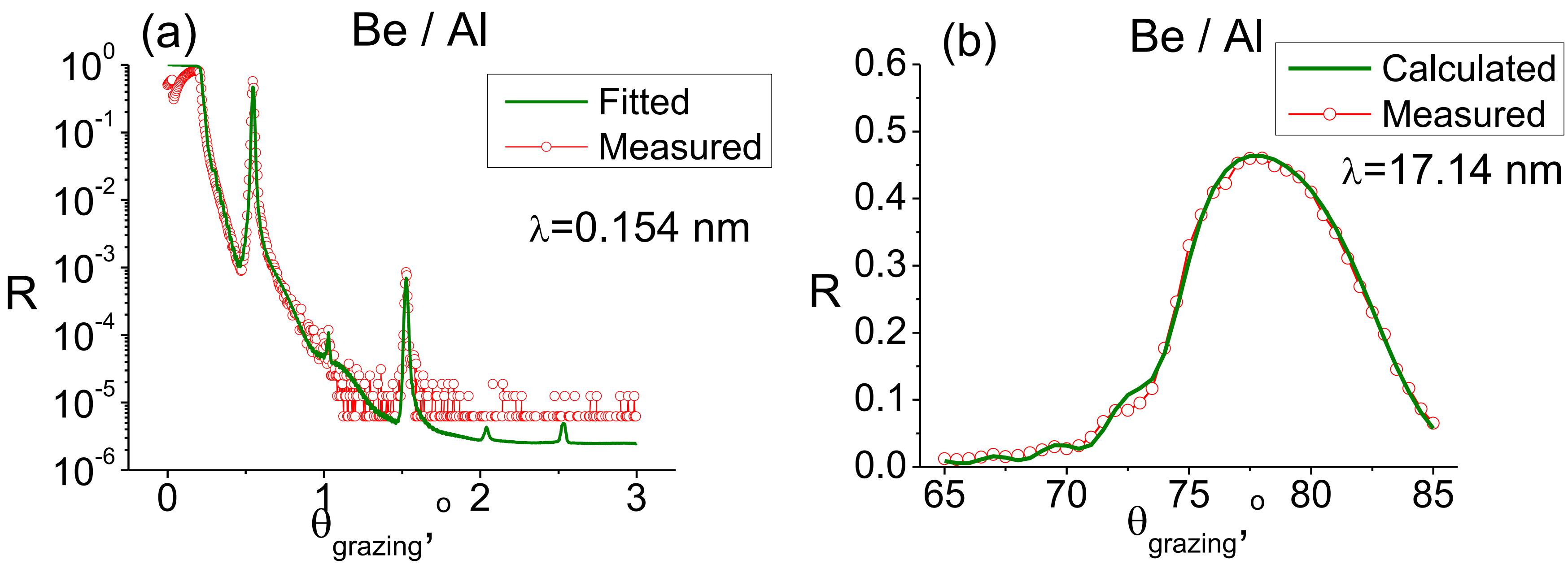
Measured: $\Delta\lambda \sim 0.4$ nm

Measured reflection coefficients of Be/Si/Al

R_{max}	46%	55%	59%	61%	59%	59%	58%
d(Be)	4.8	4.8	4.45	4.25	4.05	3.85	3.65
d(Si)	0.45	0.6	0.8	1	1.2	1.4	1.6
d(Al)	3.65	3.5	3.65	3.65	3.65	3.65	3.65

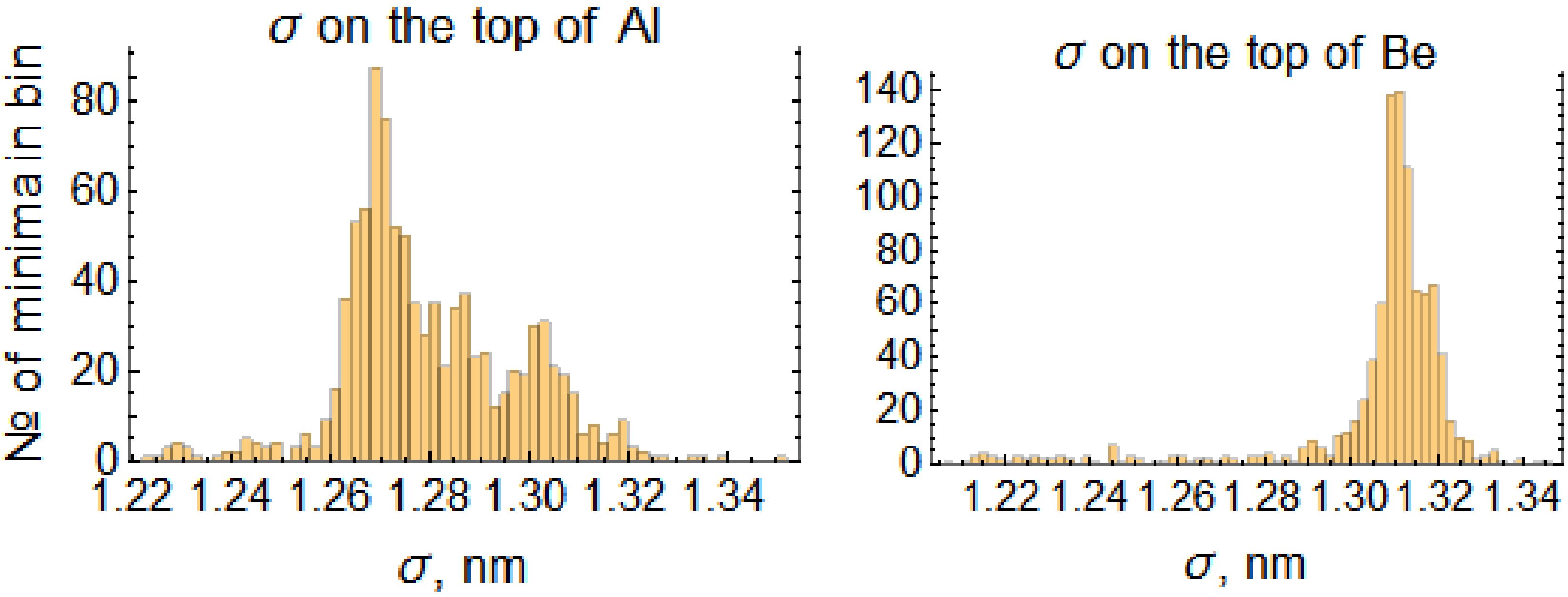
Measured reflection coefficients of Be/Si/Al mirrors with various thicknesses of Be, Si and Al layers at λ=17.14 nm

Fitting Al/Be



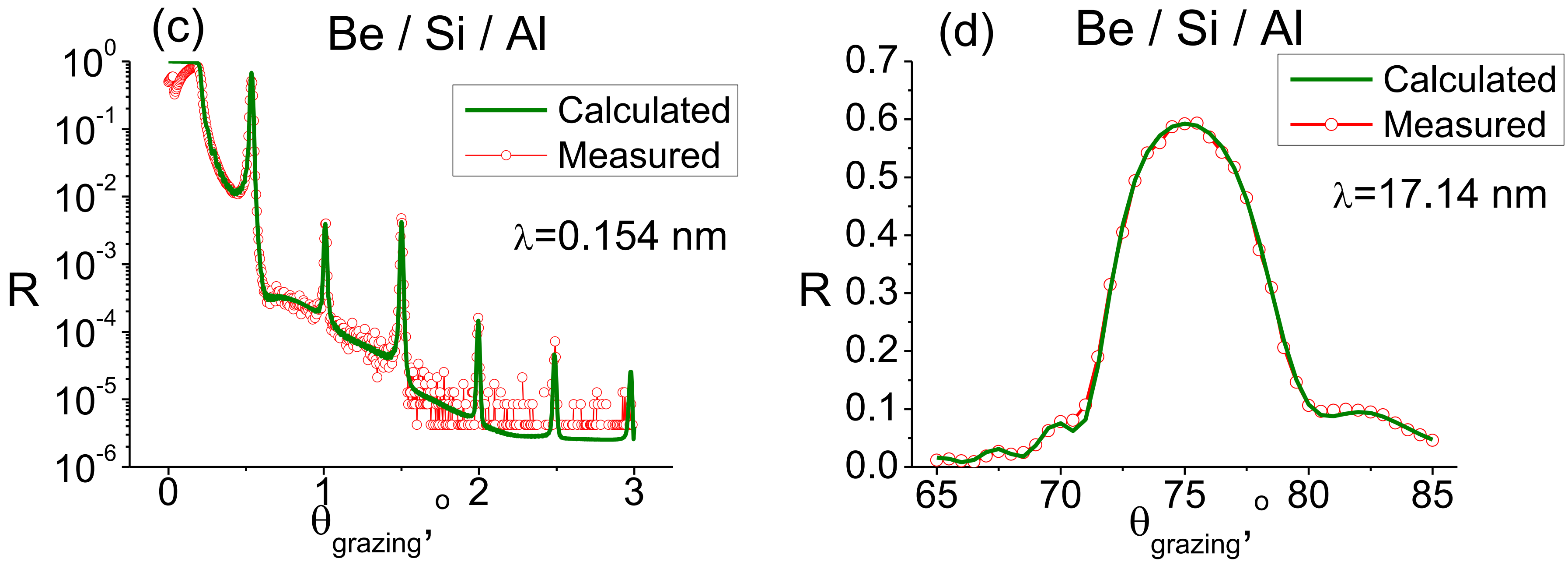
Measured and fitted angular dependencies of the reflectance at λ = 0.154 nm and λ = 17.14 nm for the MLM Be/Al.

Interlayer widths Al/Be



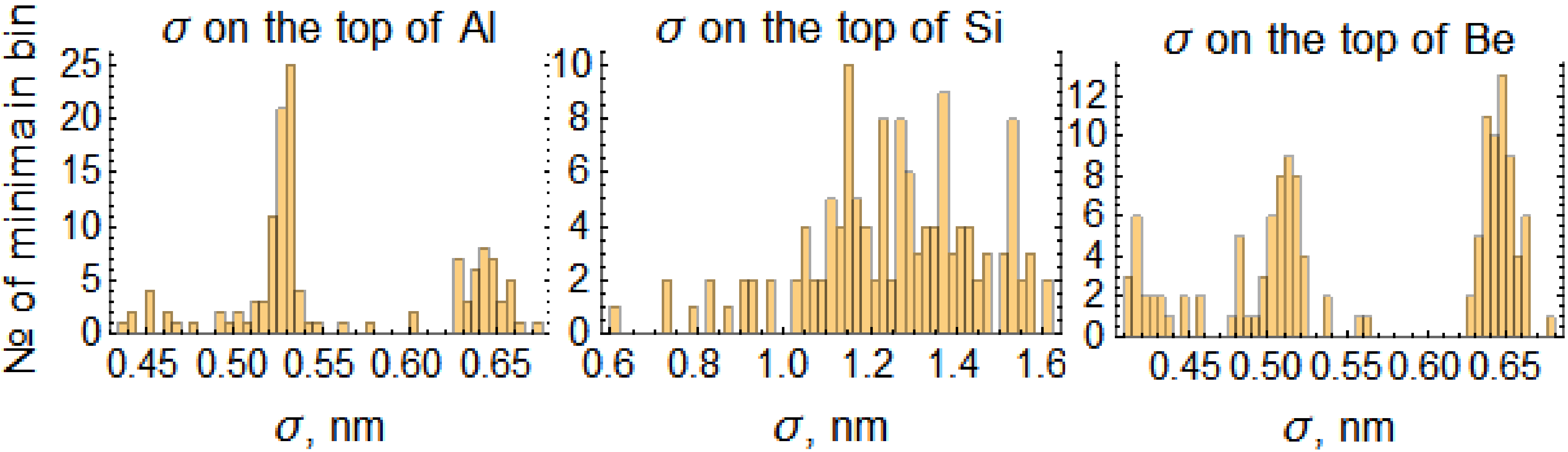
$\sigma_{Be/Al}$(Al) ≈ 1.25–1.32 нм, $\sigma_{Be/Al}$ (Be) ≈ 1.29–1.33 нм

Fitting Be/Si/Al



Measured and fitted angular dependencies of the reflectance at λ = 0.154 nm and λ = 17.14 nm for the MLM Be/Si/Al.

Interlayer widths Be/Si/Al



$\sigma_{Be/Si/Al}$(Al)≈0.5–0.66 нм, $\sigma_{Be/Si/Al}$(Be) ≈ 0.45–0.66 нм

Be-based MLSs for 30.4 nm (HeII). Theory and experiment

MLS	R,%	Δλ, nm
Mo/Si	22	~4
Mg/SiC	40 (30)	1.5
Mg/Si	40 (30)	1
Al/Be	27	0.8

Be-based MLSs (theory):

R(Al/Be)=46%, Δλ=1nm

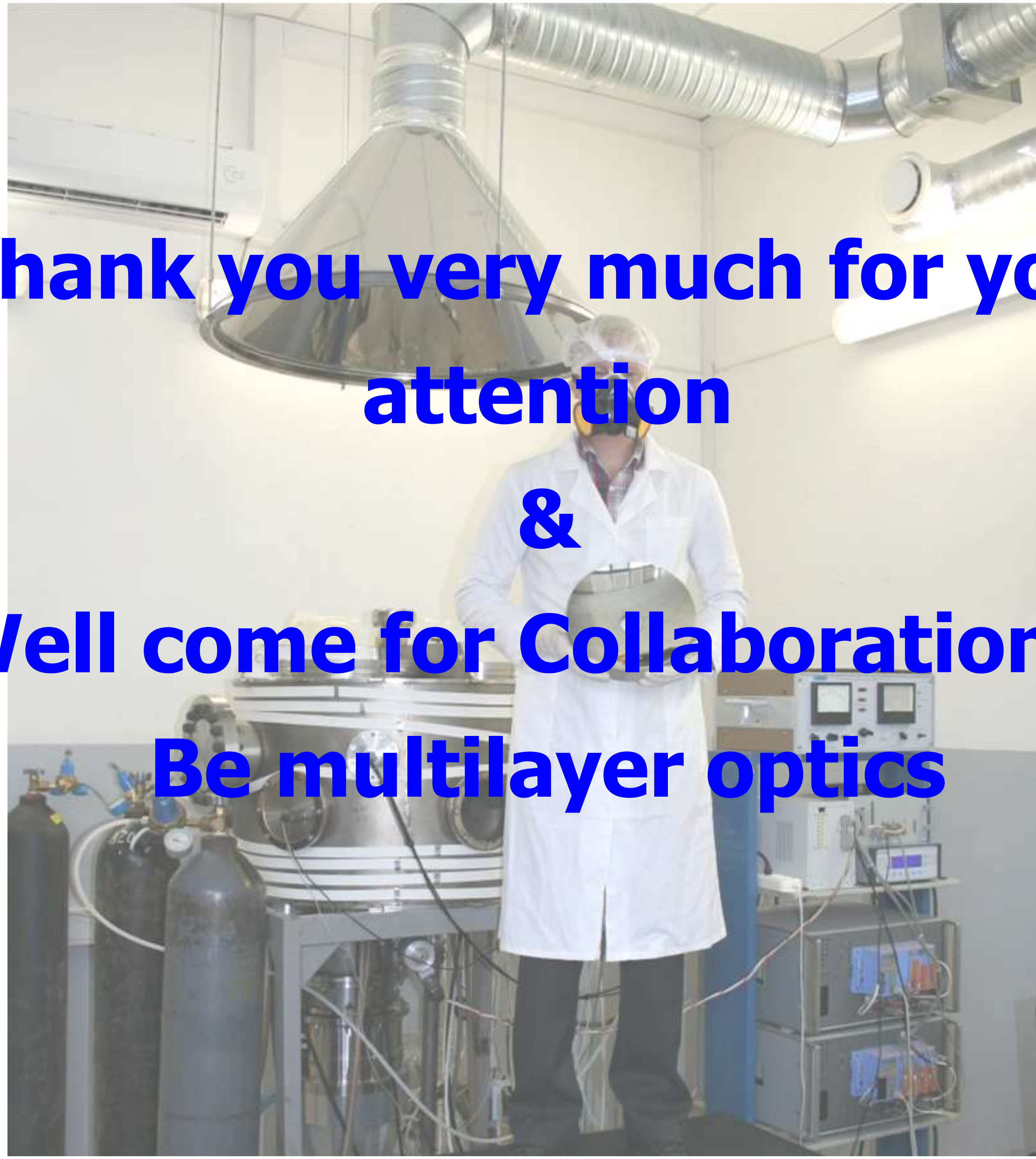
R(Mg/Be)=73%, Δλ=1.6nm

Conclusion

1. We have run certified Be- laboratory for deposition of multilayer mirrors

2. Calculation show that Be-based multilayers are most of interest in spectral ranges of 11-31 nm

3. First experiments demonstrate that in EUV range Be-containing multilayers have better resolution or both better resolution and reflectivity as compared with traditional multilayers



Thank you very much for your attention

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Well come for Collaboration in Be multilayer optics