X-UV Multilayer Optics for 4th generation sources

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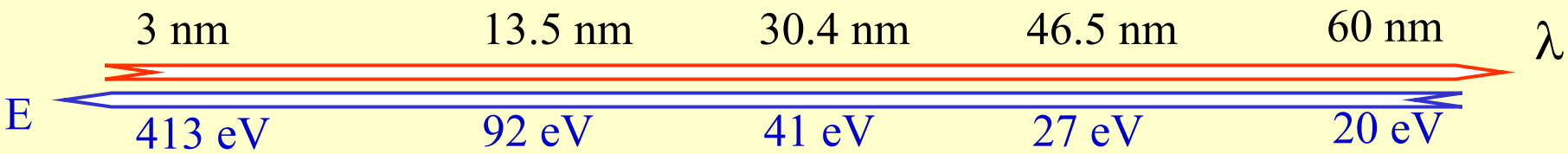
OUTLINE

Introduction : X-UV Multilayer Interference Mirrors

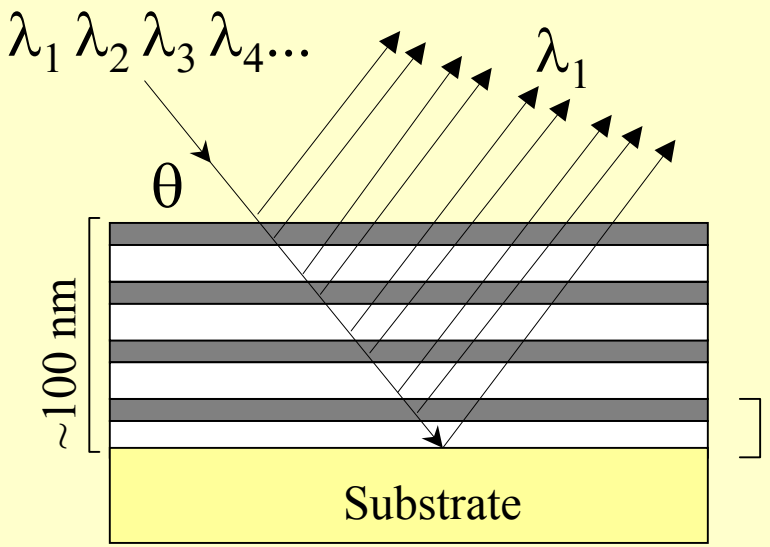
Exemples of Multilayer Optics produced at LCFIO by ion beam sputtering

Development of new multilayers by magnetron sputtering

Multilayer Interference Mirrors



complex refractive index of material : $n=1-(\delta+i\beta)$ with $\delta<<1$ and $\beta<\delta$



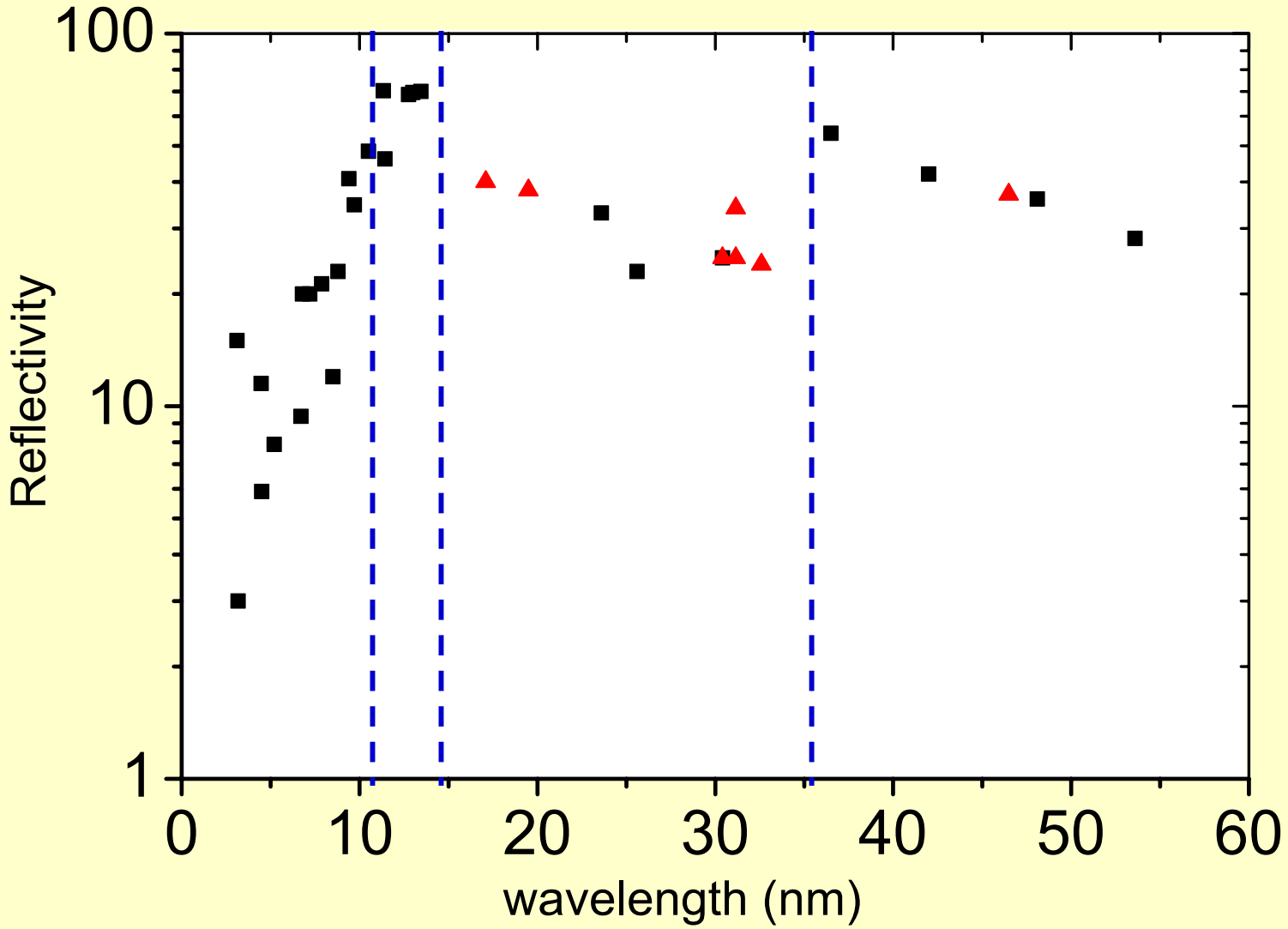
$$2d\sin\theta\sqrt{1-\frac{2\delta}{\sin^2\theta}}=k\lambda$$

period d : 1.5 to 30 nm

Absorber (High Z material)

Spacer (Low Z material)

Near-normal incidence reflectances ($80° < \theta < 90°$) measured on optimized multilayer mirrors



The Center of X-Ray Optics database on http://www-cxro.lbl.gov/multilayer/survey.html

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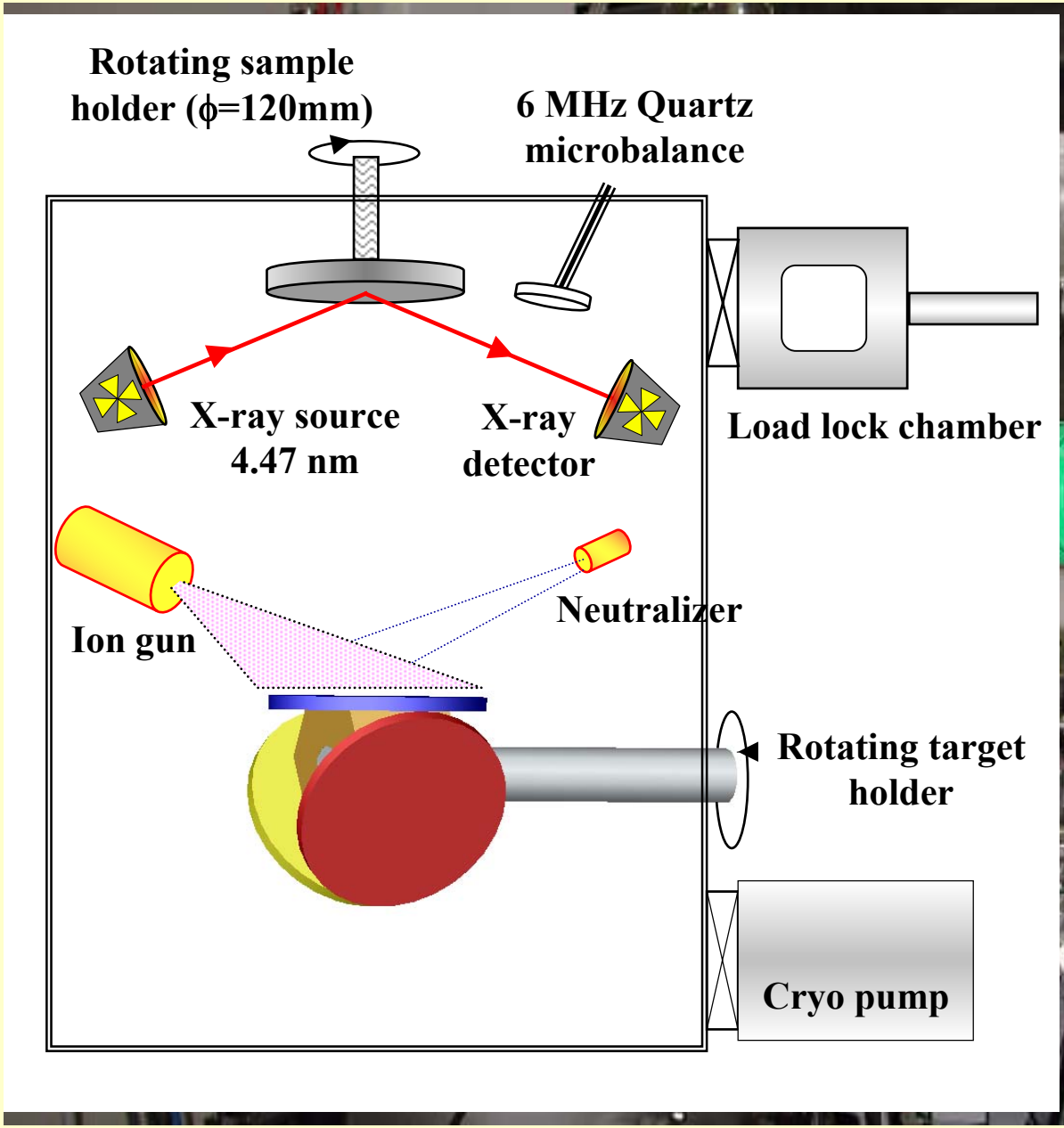
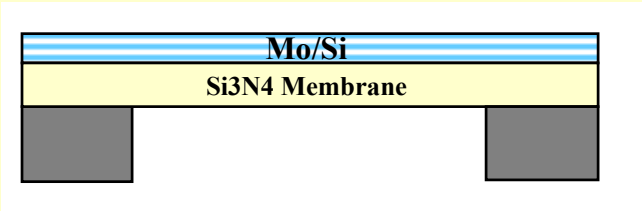
Multilayer deposition by Ion Beam Sputtering at LCFIO



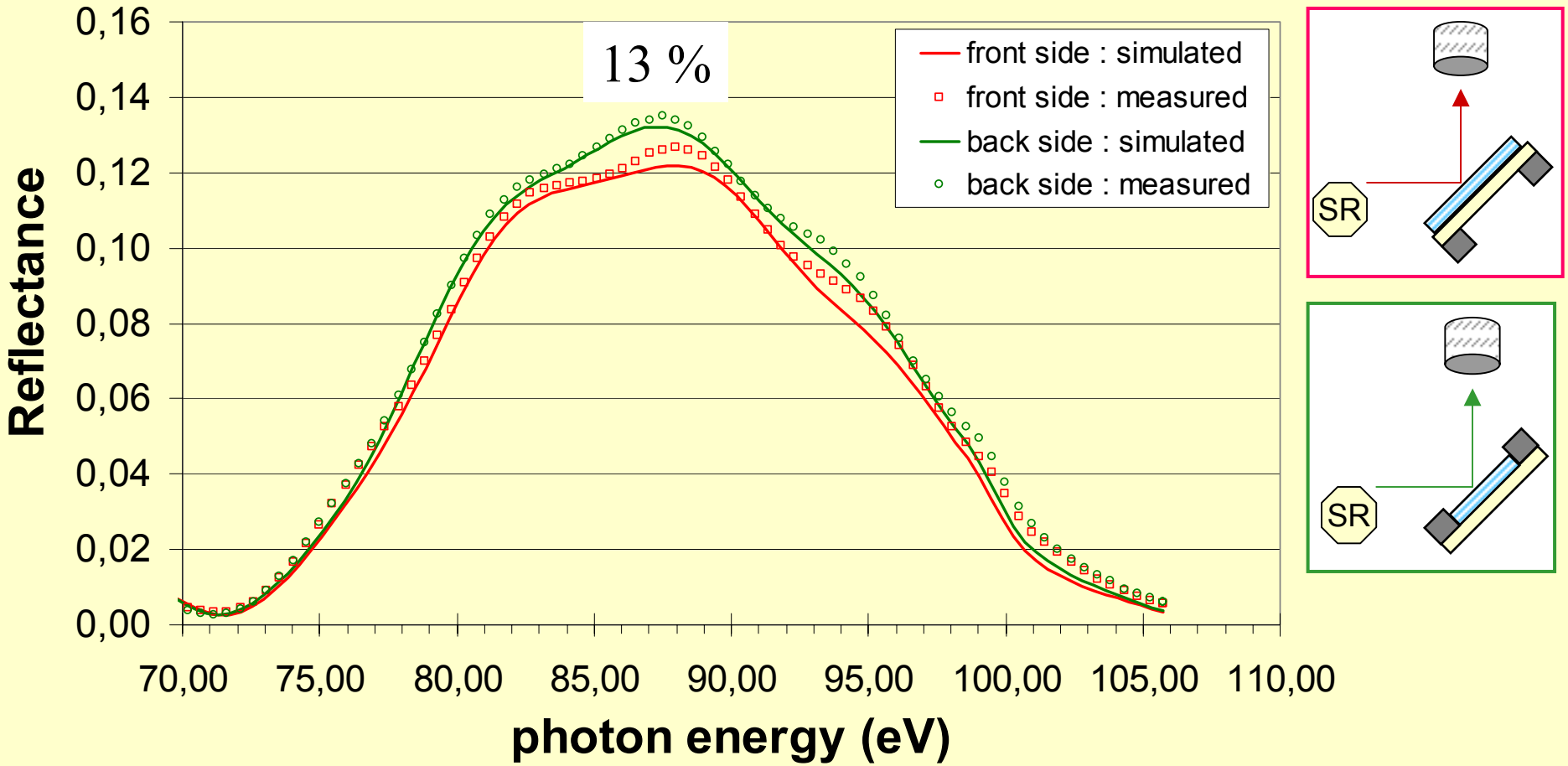
3 cm IonTech HC gun
HC neutralizer
In-situ X-Ray reflectometer
Residual pressure : 10^{-9} mbars
Sputtering gaz : Ar or Ar/H_2

Beamsplitter for metrology at 13nm

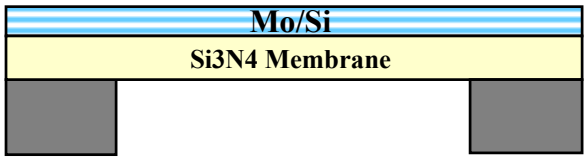


One side coated SiN membrane

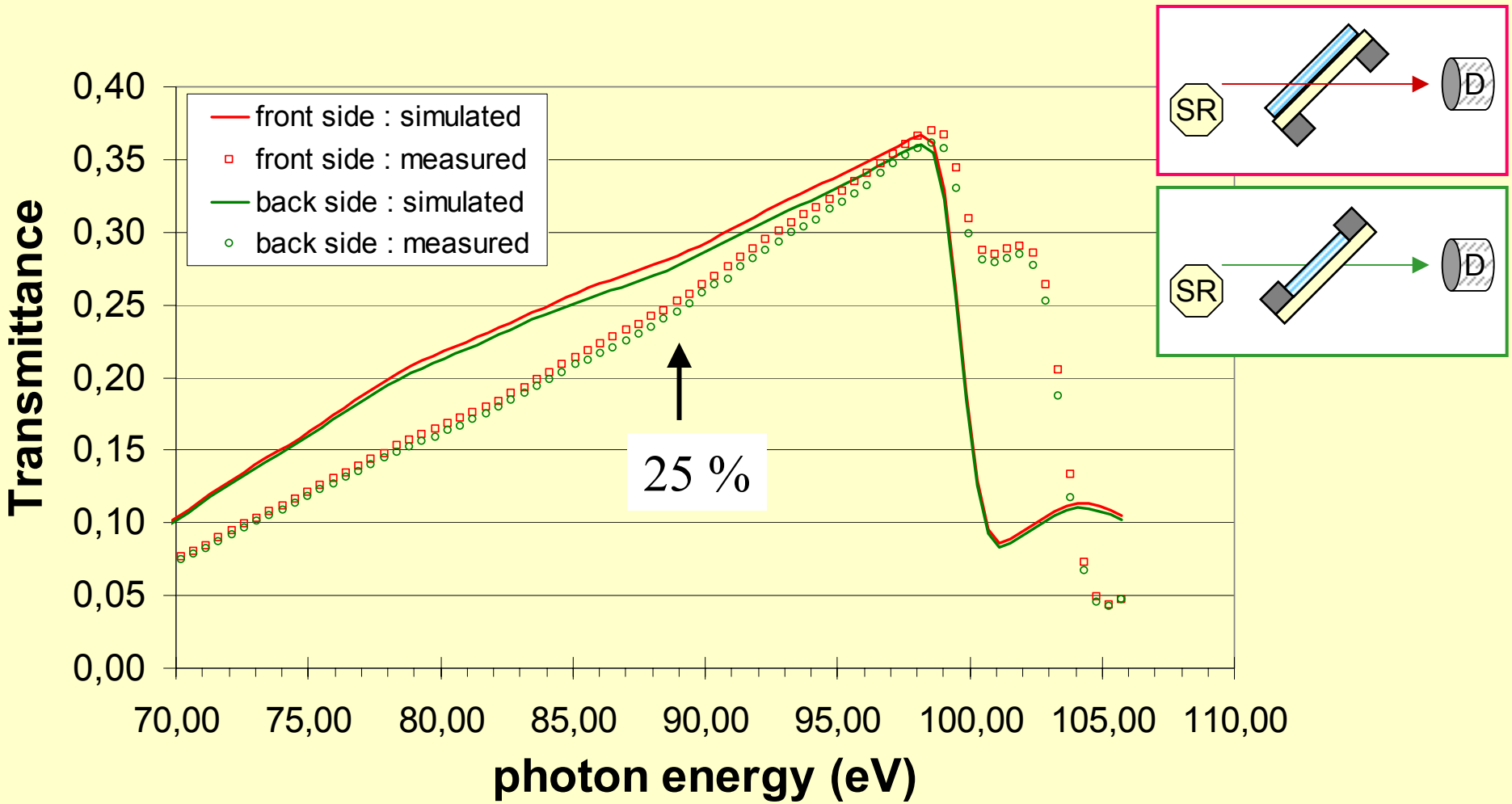
Synchrotron radiation measurements (SA23 beamline - LURE, Orsay)
col. P. Troussel



Beamsplitter for metrology at 13nm



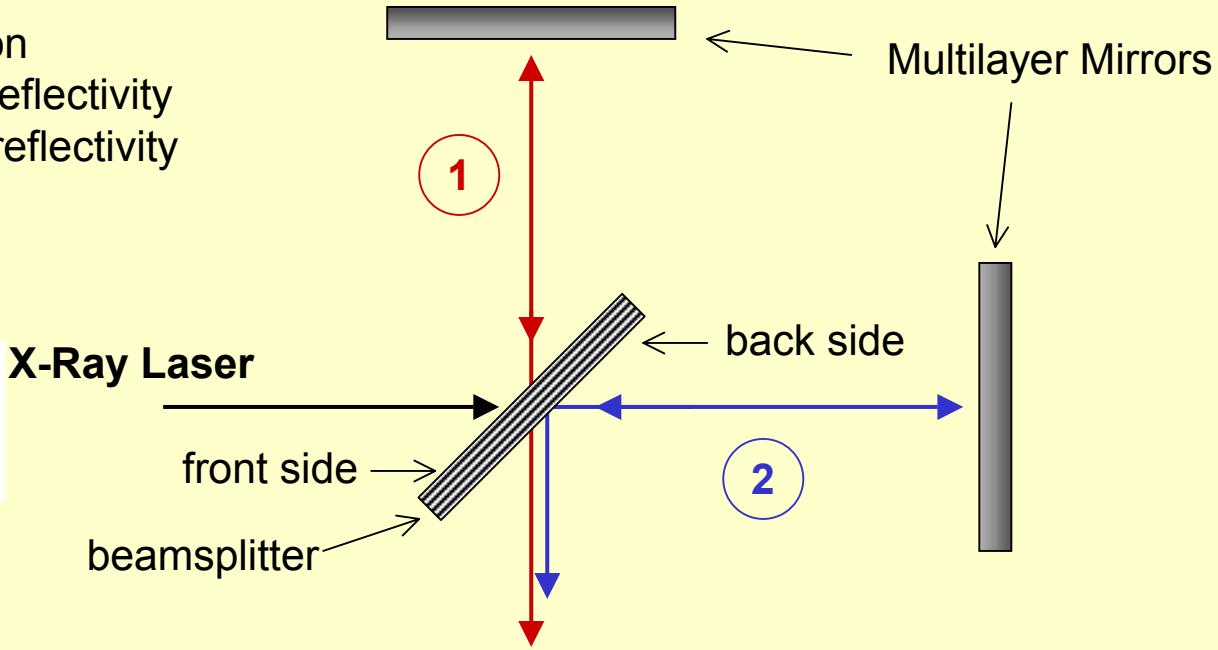
One side coated SiN membrane



X-ray laser Michelson interferometer

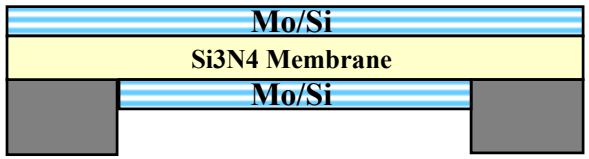
T_B : beamsplitter transmission
R_{FS} : front side beamsplitter reflectivity
R_{BS} : back side beamsplitter reflectivity
R_M : mirror reflectivity

Angle of incidence = 45°
λ=13.9 nm (Energy ≈ 89 eV)



Total transmission = $\mathbf{R_{FS}} \times R_M \times T_B$ in case 1
$T_B \times R_M \times \mathbf{R_{BS}}$ in case 2

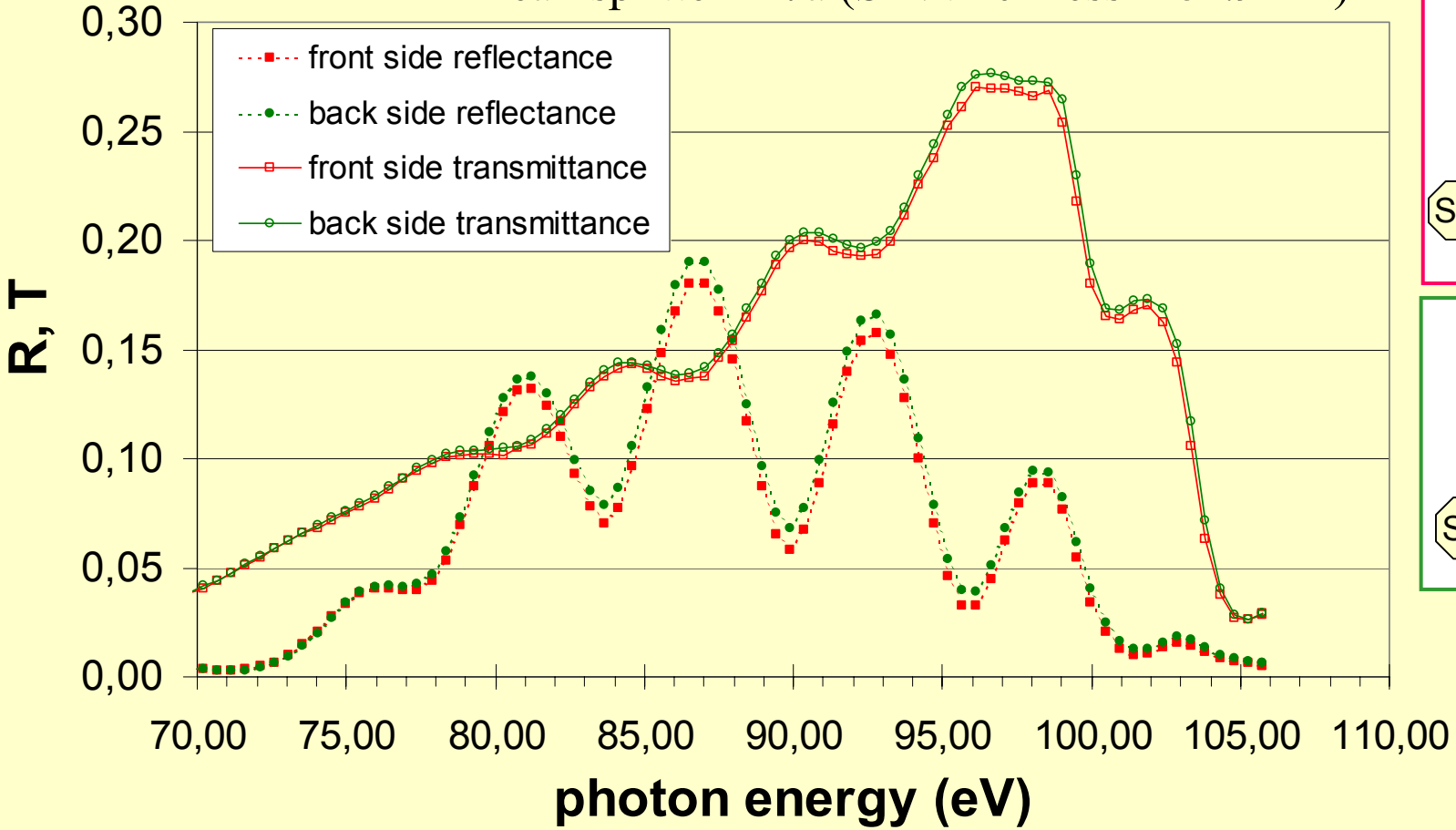
<u>Requirements</u> : Same reflectance on both side
Total transmission required > 1% in both cases

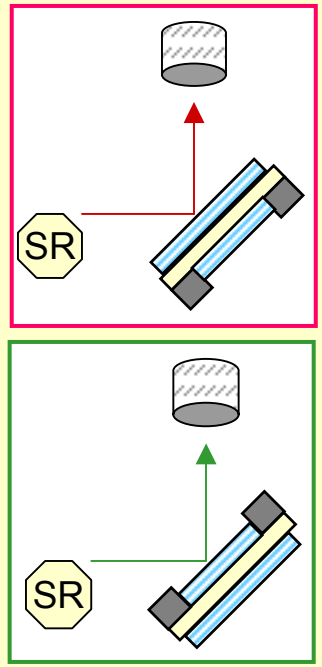


Both sides coated SiN membrane

Symetry of beamsplitter optical properties

Beamsplitter n°7a (SiN thickness = 84.9 nm)





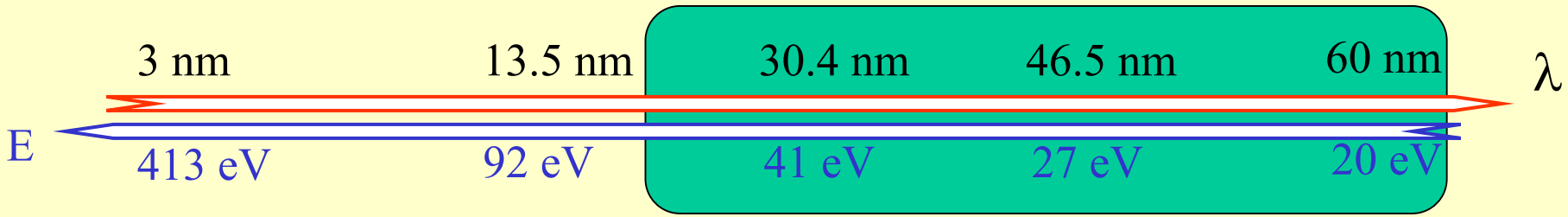
Application to Michelson Interferometry

The interferogram (screenshot) recorded at 13.9 nm with the Michelson interferometer with a zero difference path difference.

Contrast ranging from 76 % up to 92 %, over the whole aperture of the beamsplitter (5×5 mm^2).

P. Zeitoun, S. Hubert & co

Region λ > 14 nm



Main applications

X-UV Imager for Astronomy, High Harmonic Generation and X-ray laser sources, plasma diagnostics.

Region IV

Mo/Si multilayers are the well known high reflectance (R > 25%) mirror for wavelengths ranging from 12.5 nm to 25 nm.

Around 30 nm, new multilayer structures have been developped :low-Z materials multilayers and multi component multilayers.

Region V

35 nm - 60 nm

Sc/Si multilayers present high reflectivity.

optical constant of most materials are not well known.

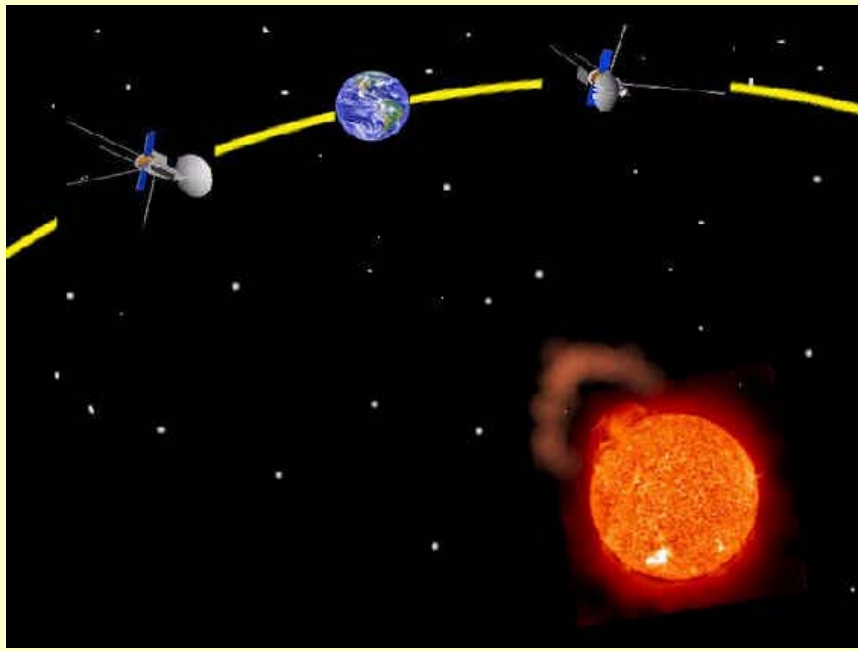
Issue : long-term stability, determination of optical constants

Astrophysics : imaging the Sun in the X-UV domain

Multilayer coatings have already been used to select emission lines from the solar plasma in the 15-30 nm region (SOHO, TRACE and other missions).

SOHO mission (NASA/ESA- launched in 1995)
Extreme UV Imager Telescope (EIT) for solar corona imaging

Multilayers deposited in 1991 at LCFIO by Jean-Pierre Chauvineau & co.

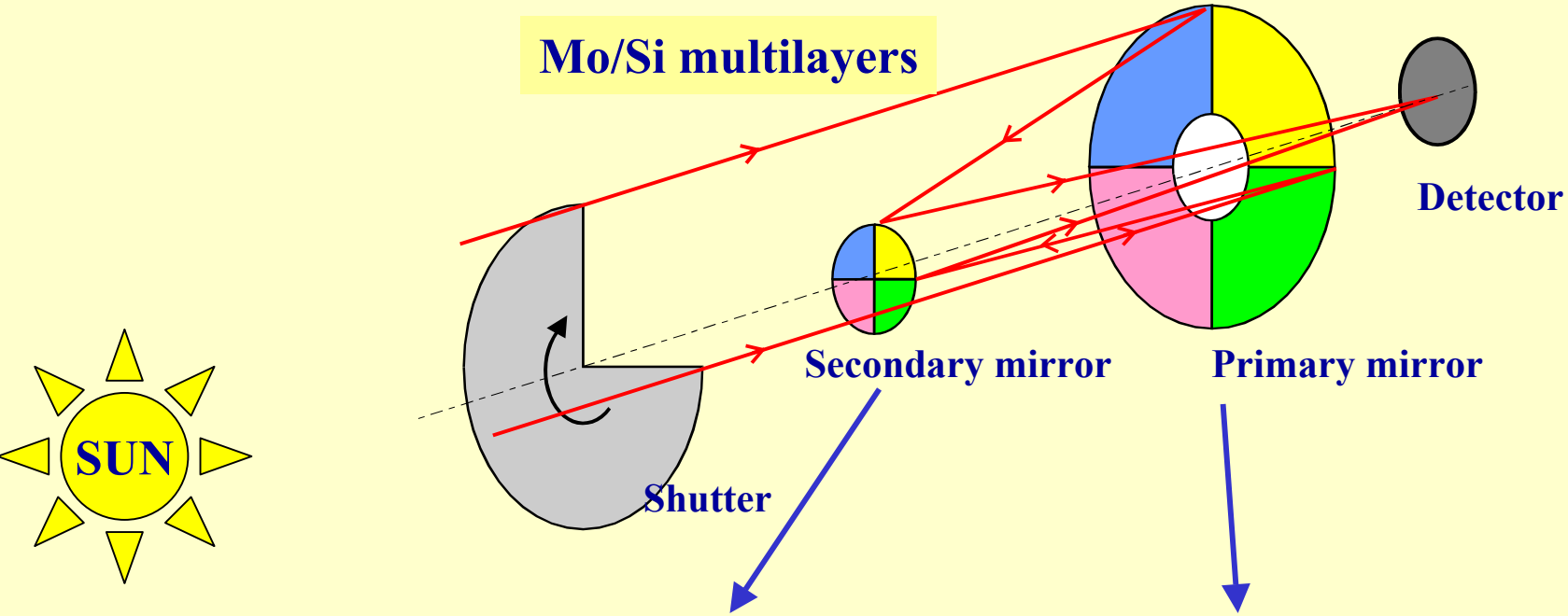


STEREO mission (NASA/ launch in 2006)
EUV Imager (EUVI)
for 3D solar corona imaging

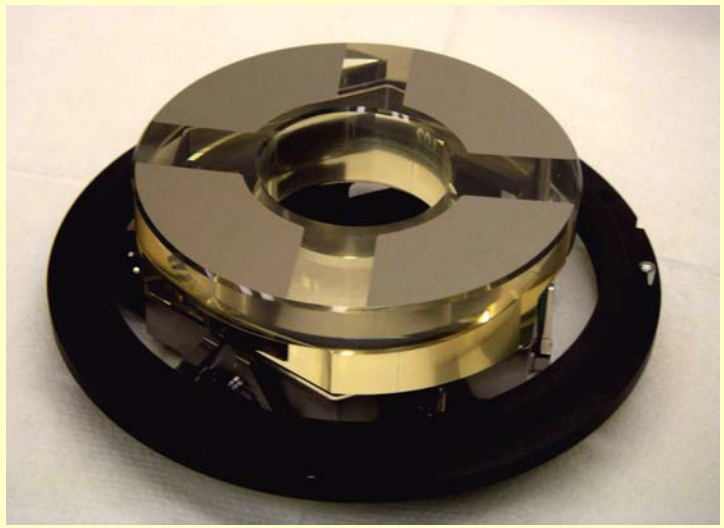
Requirements for the multilayers :

- uniform deposition on large mirrors (< 1% on ϕ=100 mm)
- long term stability (on scale of years)
- high reflectance and high selectivity

STEREO mission
EUV Imager (EUVI) for 3D solar corona imaging



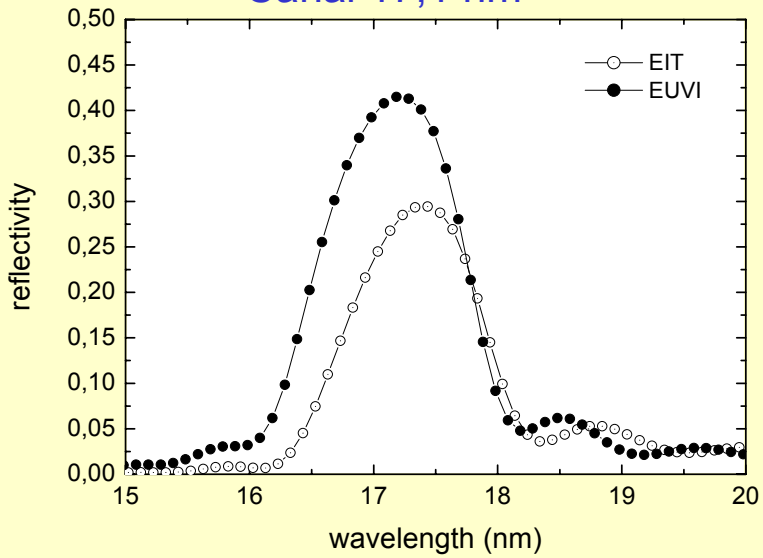
Diameter
48 mm



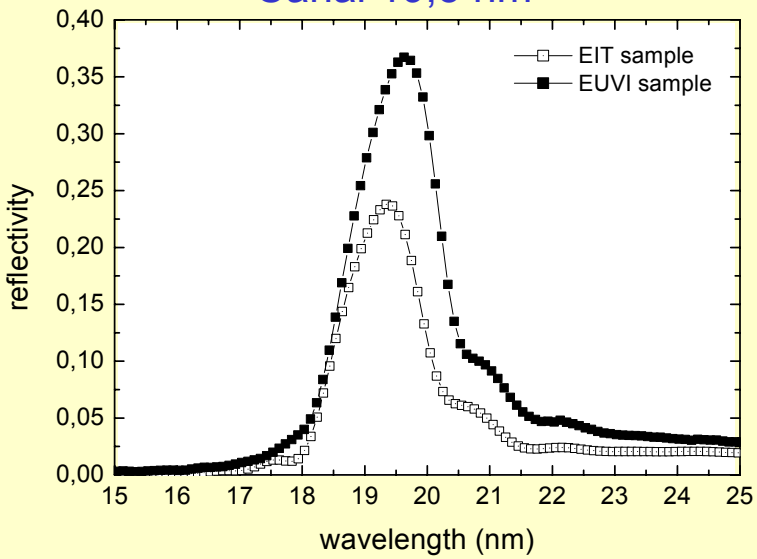
Diameter
105 mm

Reflectivity of witness samples :
comparison STEREO (EUVI) / SOHO (EIT) *

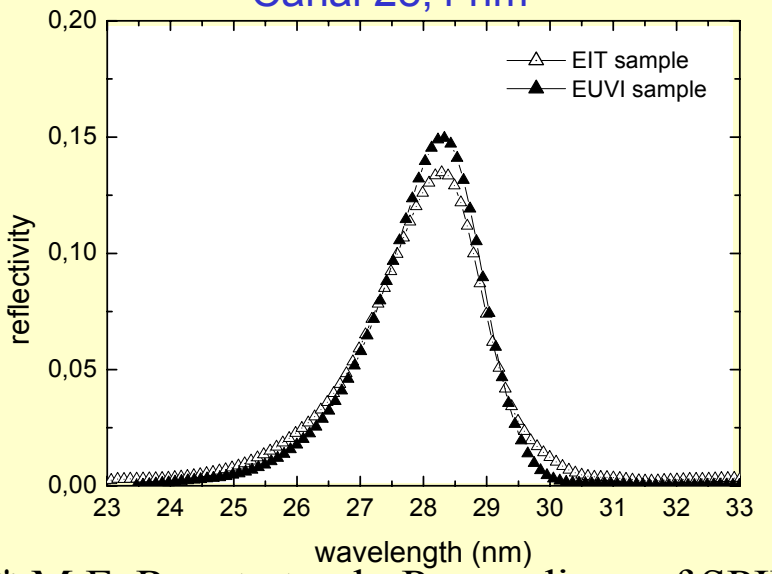
Canal 17,1 nm



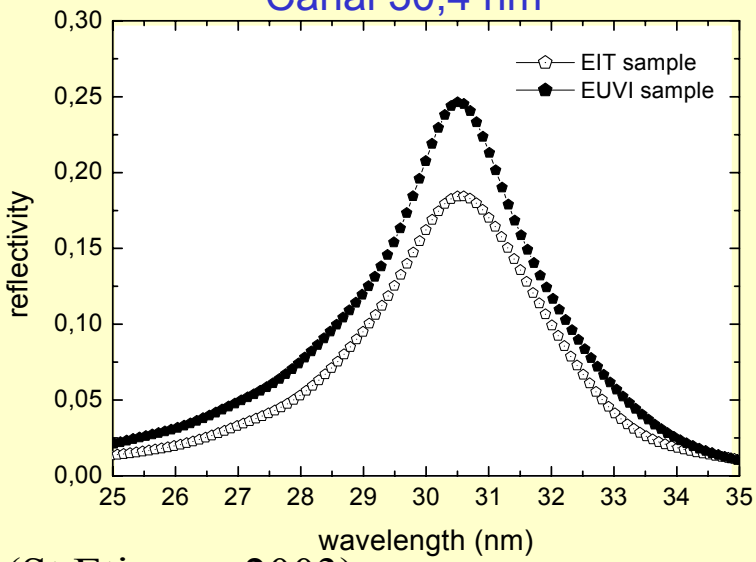
Canal 19,5 nm



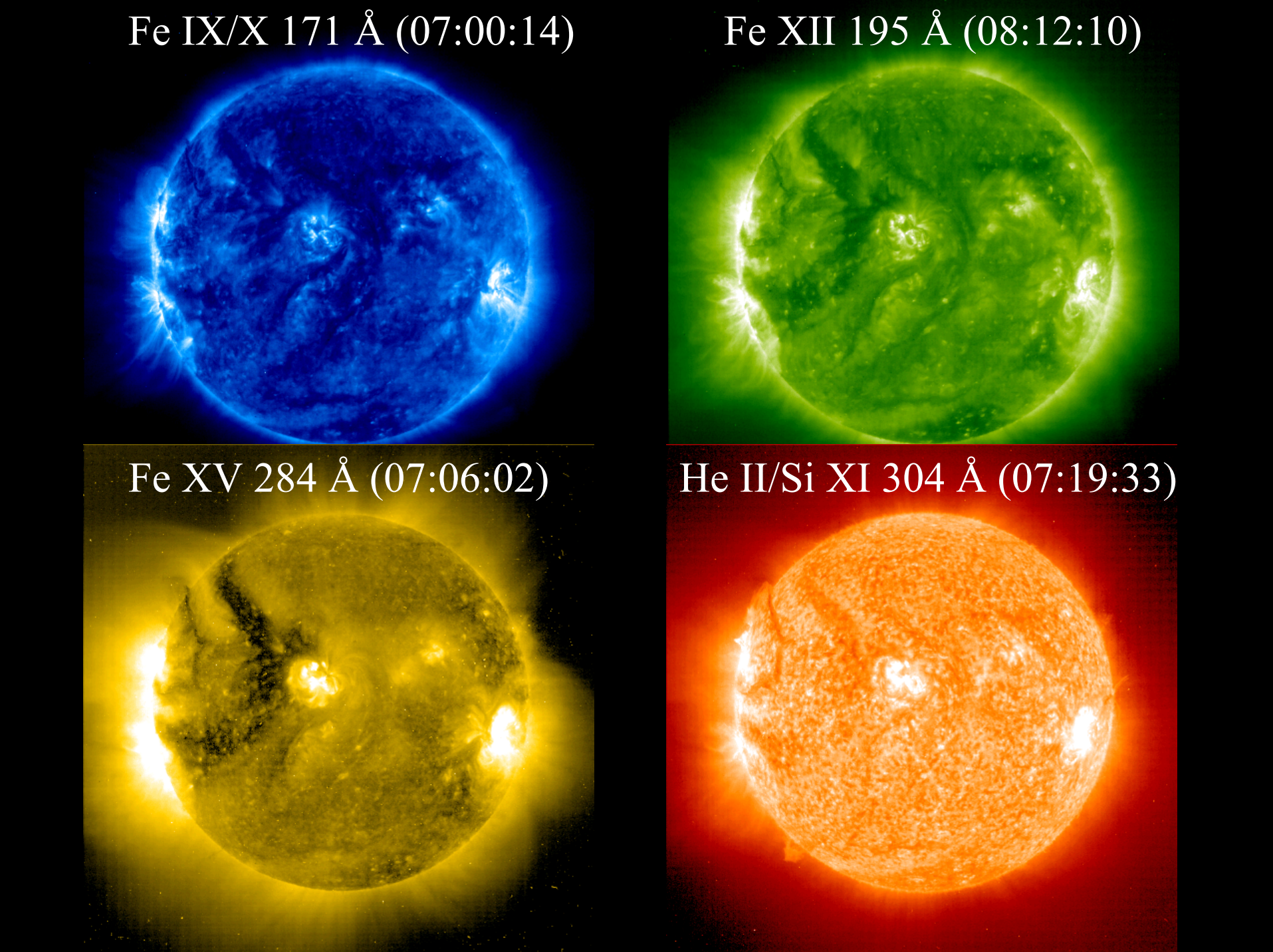
Canal 28,4 nm



Canal 30,4 nm



* M.F. Ravet et col., Proceedings of SPIE 5250-12 (St Etienne, 2003)


Fe IX/X 171 Å (07:00:14)
Fe XII 195 Å (08:12:10)
Fe XV 284 Å (07:06:02)
He II/Si XI 304 Å (07:19:33)

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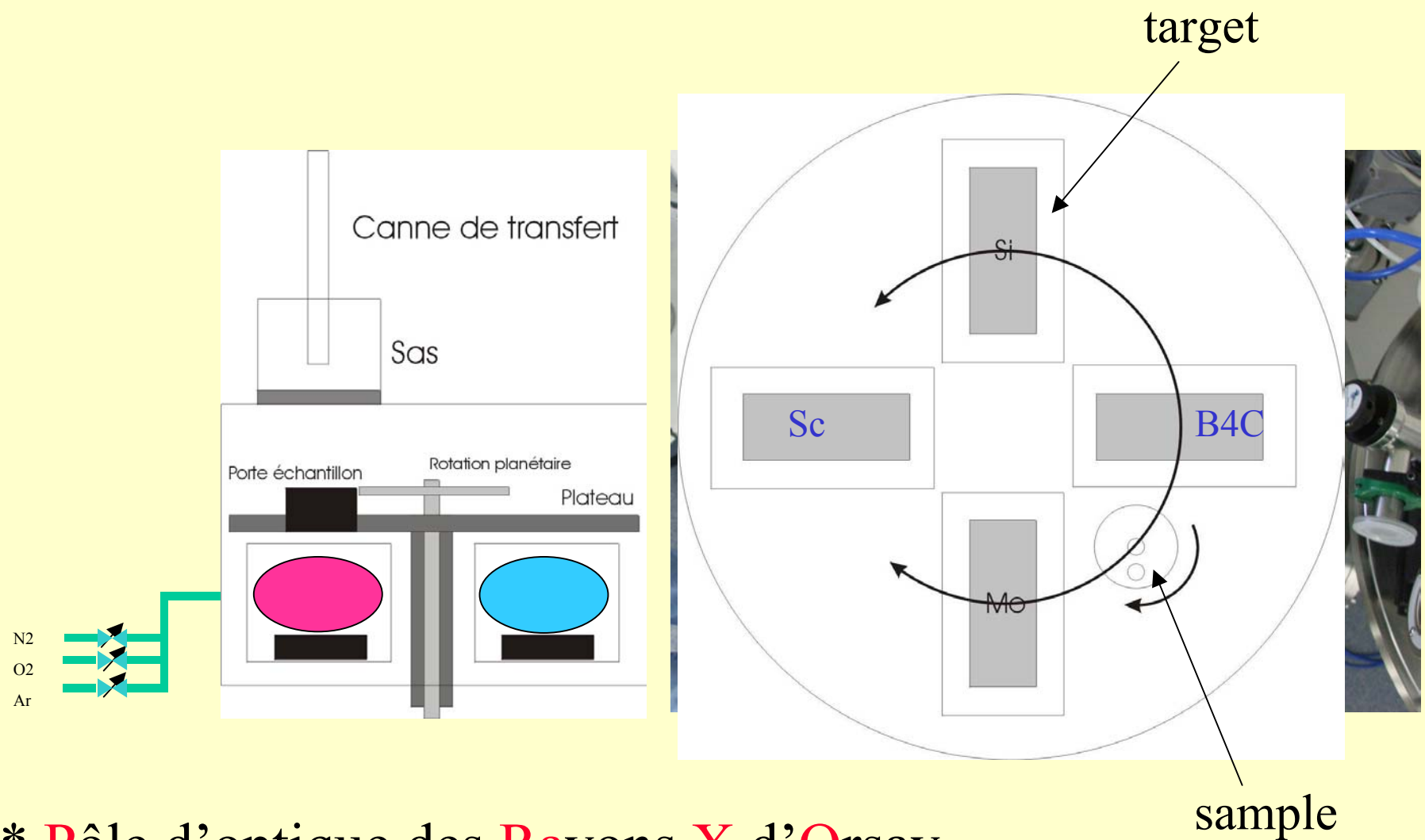
PRaXO* 4 targets Magnetron sputtering system

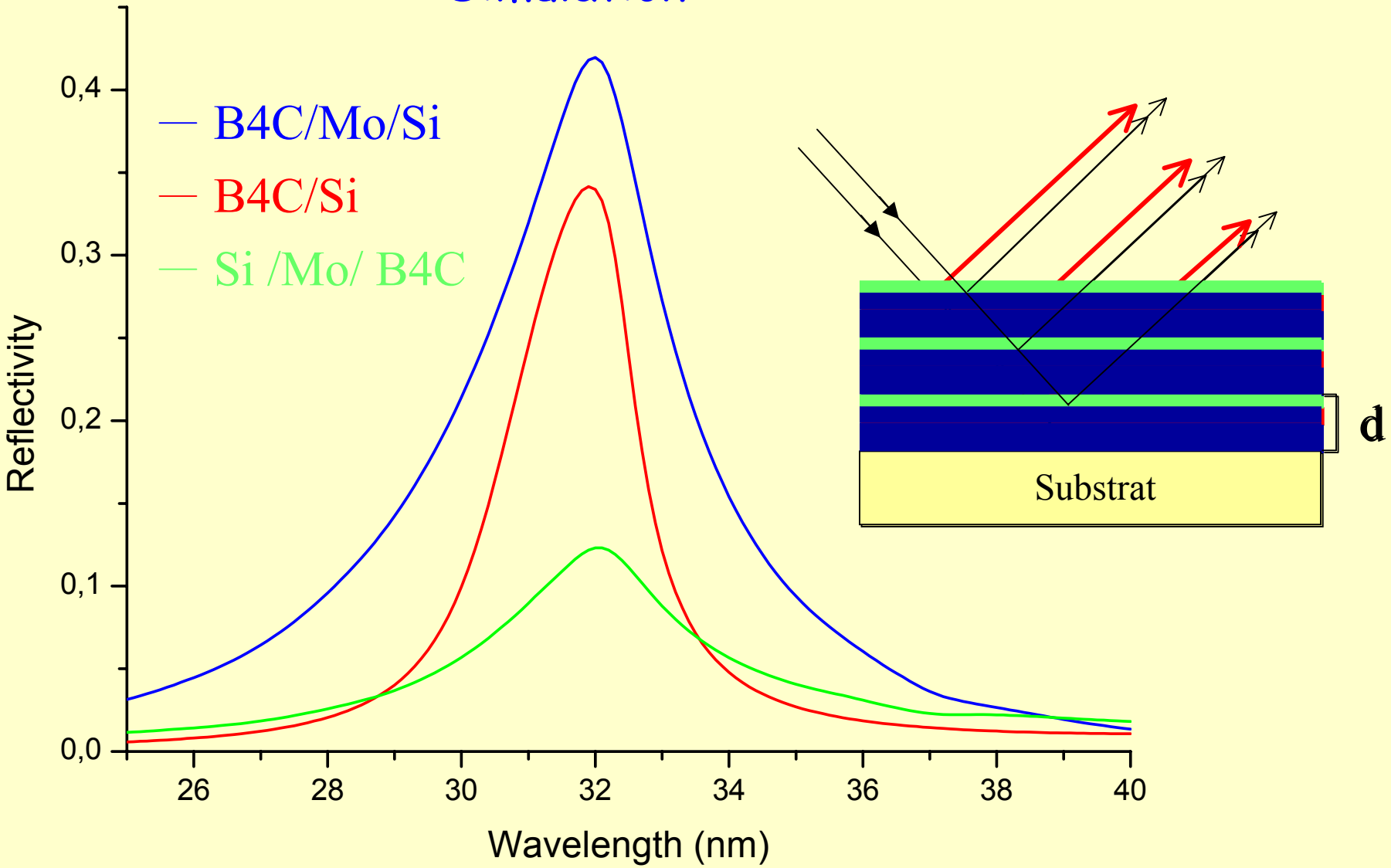


* Pôle d'optique des Rayons X d'Orsay

In col. with M. Roulliay - M. Idir - P. Zeitoun - J. Underwood

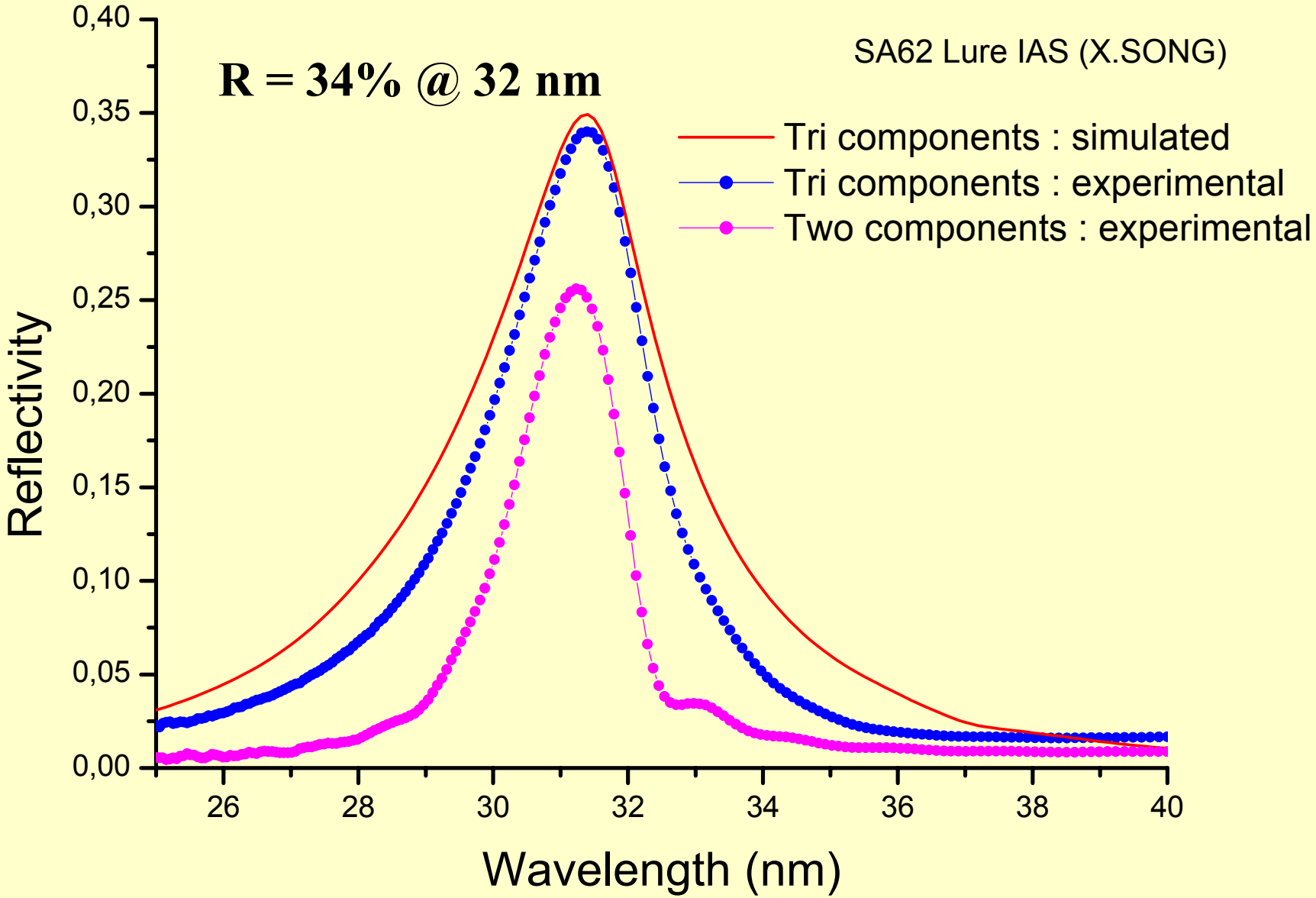
Three Component Multilayers

Simulation



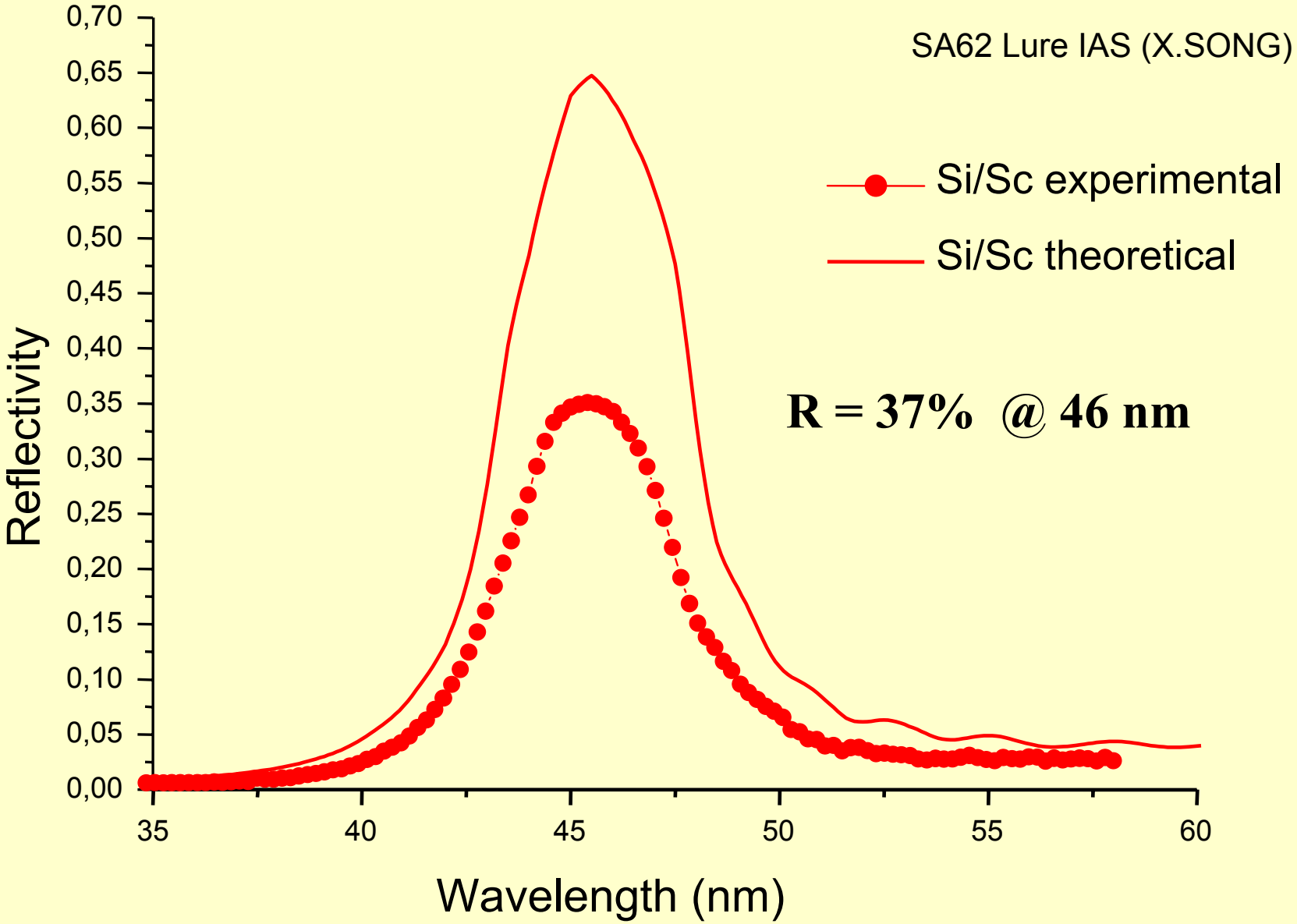
Synchrotron Radiation Measurement

B4C/Mo/Si compared to B4C/Si



Synchrotron Radiation Measurement

Sc/Si



CONCLUSION

- Multilayer Mirrors with high reflectance (25% to 70%) and long-term stability are now available in the 12.5 - 30 nm range.
- In near future, we plan to develop stable Multilayer Mirrors in the 30 - 60 nm range.
- There is also an important research effort in the low wavelength region (3 - 11 nm).
- Design of « special » multilayer is possible (line rejection, sheer side, broad band, …).

Interfacial layers & capper layer

Ion beam deposited multilayers designed for λ about 30 nm
measurements at IAS/LURE beam line of SuperACO synchrotron