



Rejecting Lyman- α with an innovative optical reflecting notch filter

An $(\text{Al/LiF})_n$ multilayer coating for next-generation UV space observatories

Alejandro García-Cañas, Ana Iglesias-Moreno, Francesc Valls-Vicent, Nuria Gutierrez-Luna, Juan Larruquert, Paloma Lopez-Reyes.
GOLD-FOTION, Instituto de Óptica (CSIC)

The technology described is the subject of pending patent application EP26382861



NUVA 2026



Thin-film coatings for the EUV, FUV and metrology



Madrid, Spain. Institute of Optics. CSIC



DAY 2

18:30-18:45 Dr. Nuria Gutiérrez Luna

Instituto de óptica-CSIC

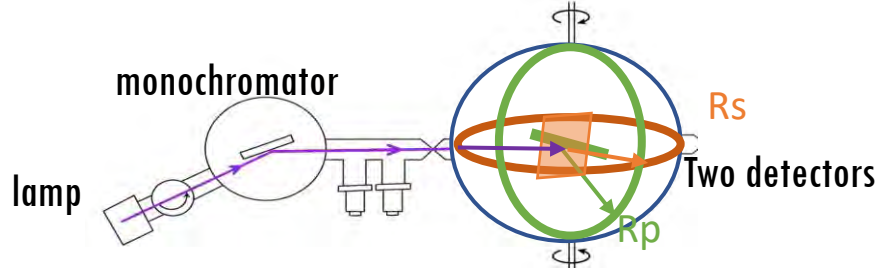
VUV Optical Technologies for Space Astrophysics

17:05-17:10 Ms. Ana Iglesias Moreno

Consejo superior de investigaciones científicas - Instituto de óptica

Environmental stability of extra narrowband for FUV instrumentation

Alejandro García-Cañas, Ana Iglesias-Moreno, Francesc Valls-Vicent, Nuria Gutierrez-Luna, Juan Larruquert, Paloma Lopez-Reyes. - GOLD-FOTION, Instituto de Óptica (CSIC)



GOLD reflectometer in an ISO-8 clean room

Reflectance 40–200 nm measurements

Climatic chamber

RH controlled

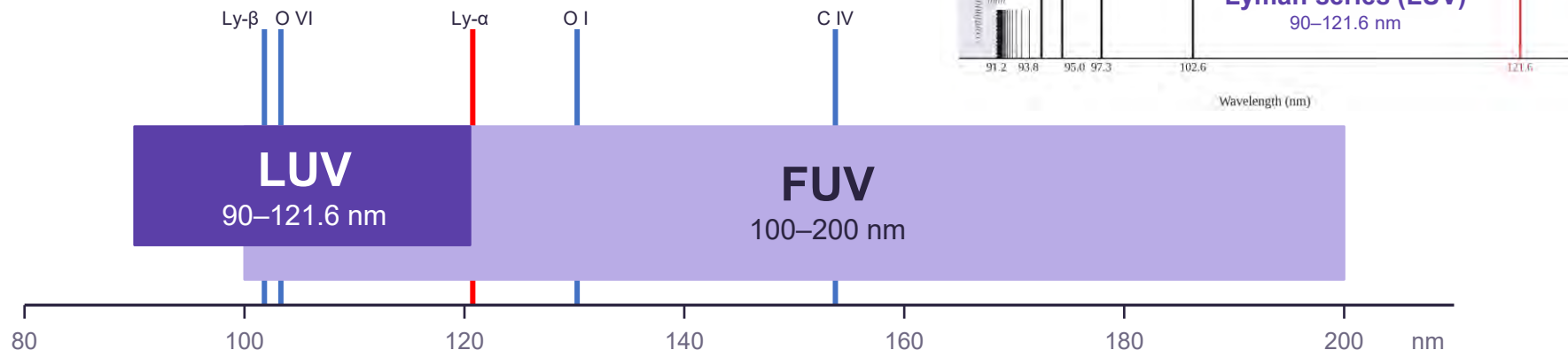
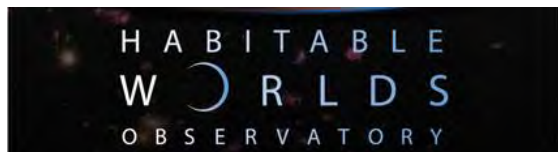


GOLD deposition chamber in an ISO-6 clean room

Thermal evaporation + sputtering

Al, B₄C, SiC, LiF and MgF₂, etc in high vacuum

Motivation: the LUV/FUV range



HWO

NASA's Habitable Worlds
Observatory aims to reach **~100 nm**

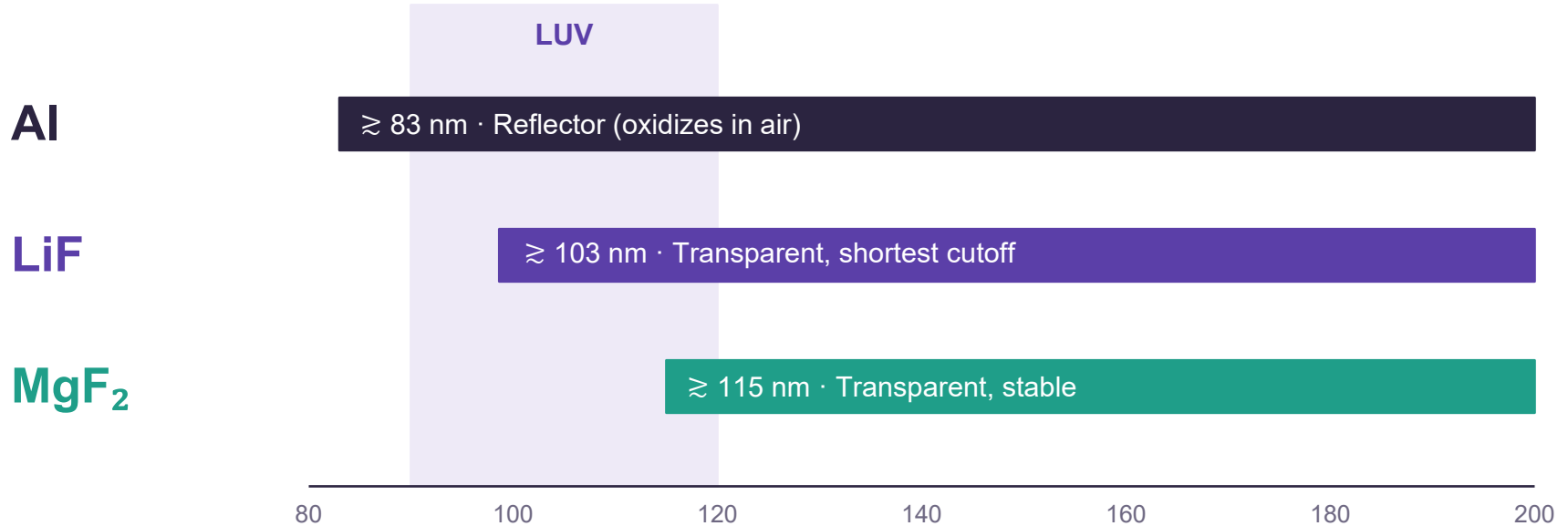
Circumgalactic medium & solar physics

Diagnostics below ~115 nm,
inaccessible at longer λ

Some key lines

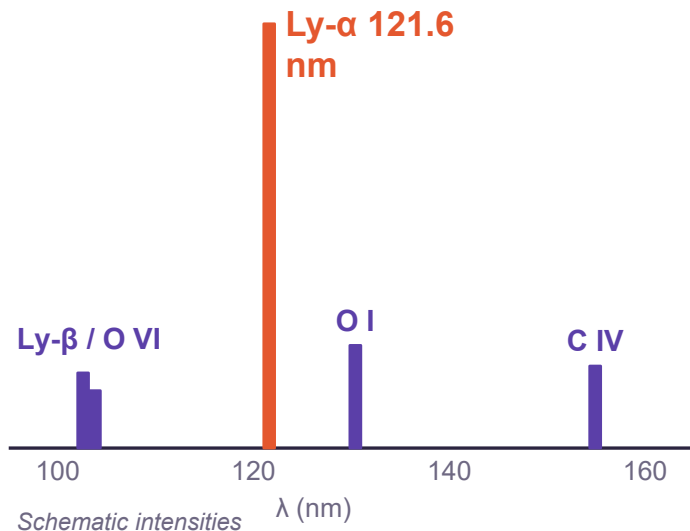
- Ly-β 102.6 nm
- O VI 103.2 nm
- O I 130.4 nm
- C IV 154.9 nm

Available materials below 120 nm



Limitation: LiF is hygroscopic. Humidity degrades its transparency.

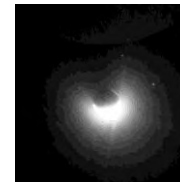
The Lyman- α problem



Ly- α intensity becomes a problem for specific optical space systems

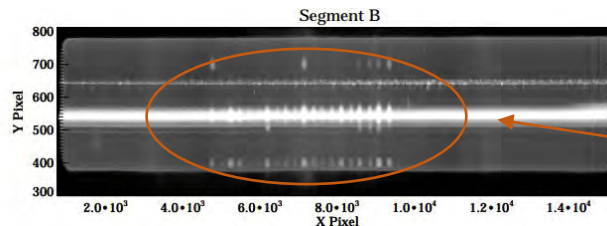
Geocorona

Ly- α halo extending beyond the lunar orbit



Detector ageing

Ly- α "burns" the FUV detector (HST/COS; Sahnou et al. 2011) and is responsible for most of the damage to the detectors. These Lyman- α airglow regions lose gain more rapidly than the rest of the detector



Count images for B segments of the COS (Hubble) FUV detector, constructed by coadding all FUV science exposure Ly- α HST/COS; Sahnou et al. 2011

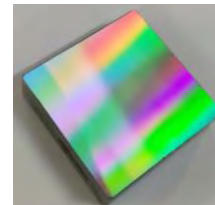
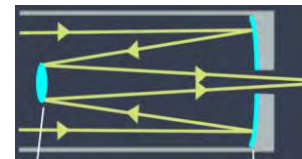
Interplanetary background

Diffuse Ly- α remains even at L2 (HWO)

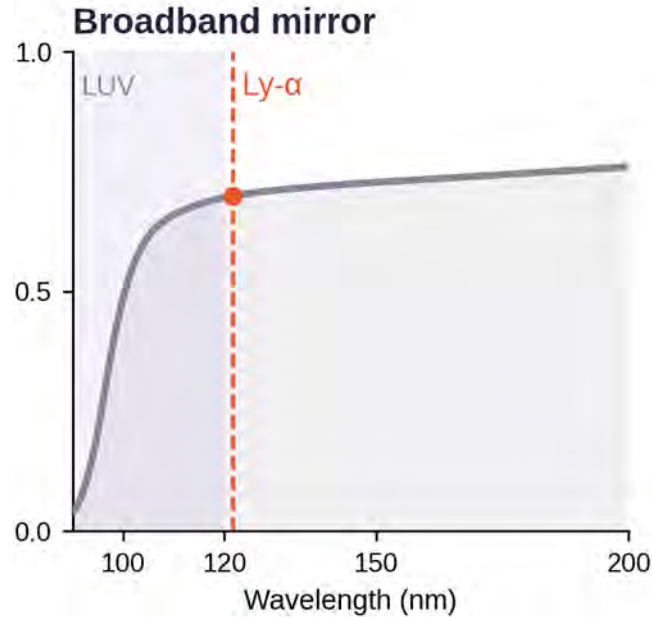
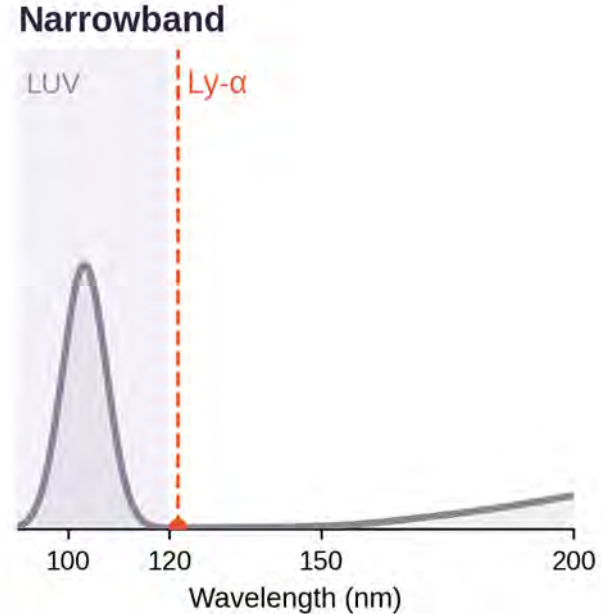


Inside instruments

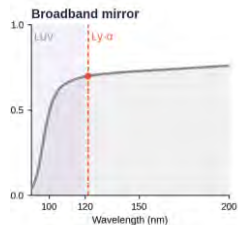
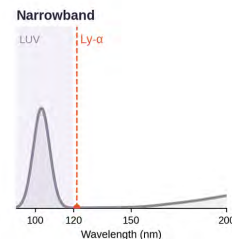
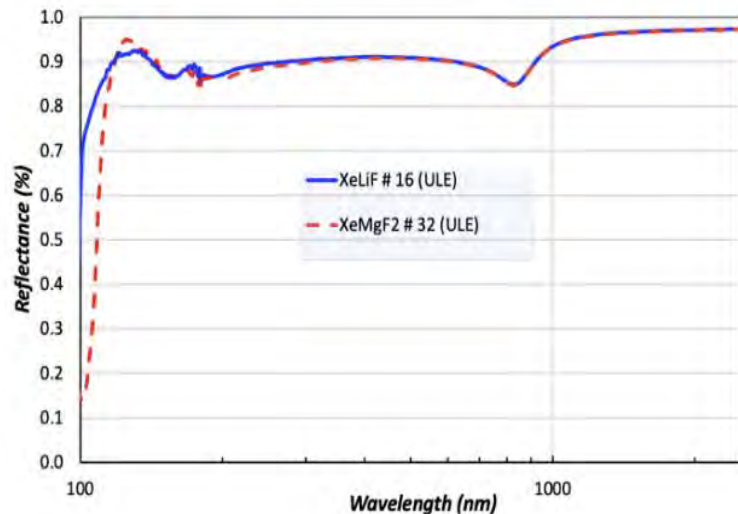
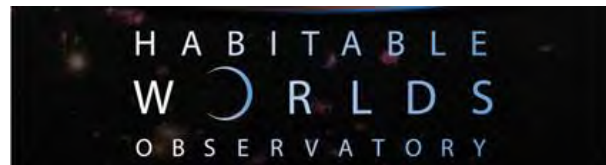
Gratings scatter Ly- α onto the detector



Broadband mirror - Narrowband mirror - Notch mirror



Broadband mirror - Narrowband mirror - Notch mirror

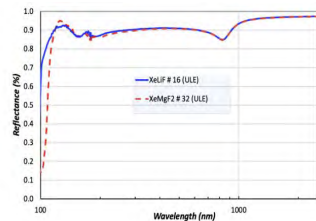
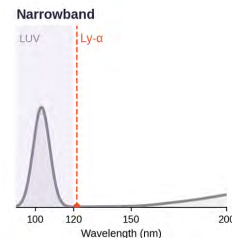
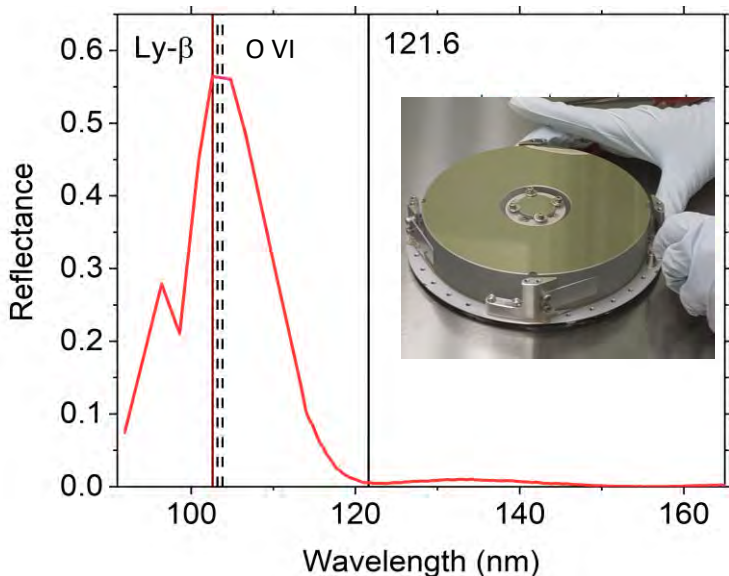
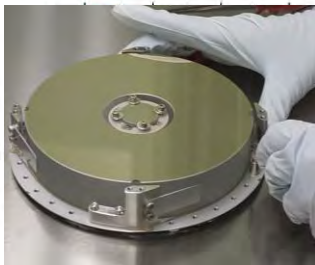


Broadband mirrors

Example of XeLiF and XeMgF₂ broadband mirrors made for NASA's Habitable Worlds Observatory. (Quijada et al. 2025)

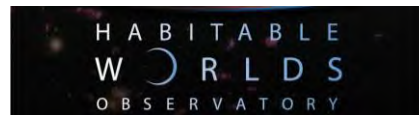
*Quijada, M. A., Del Hoyo, J. G., Rodríguez de Marcos, L. V., Wollack, E. J., Batkis, M. F., Lewis, D. M., ... & Allred, D. D. (2025). Far-ultraviolet optical properties and performance of physical vapor deposited aluminum mirrors protected with XeLiF and XeMgF₂. *Journal of Astronomical Telescopes, Instruments, and Systems*, 11(4), 042209-042209.

Broadband mirror - Narrowband mirror - Notch mirror

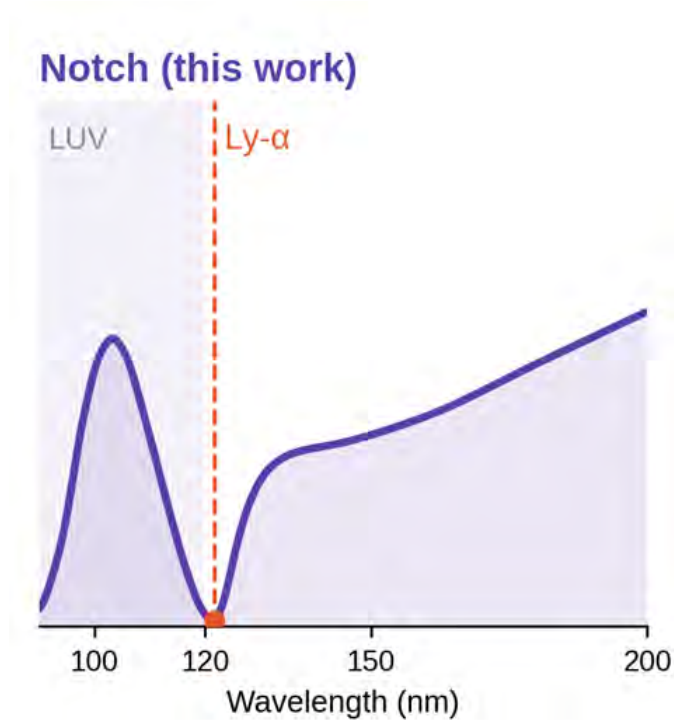


Narrowband mirrors

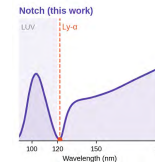
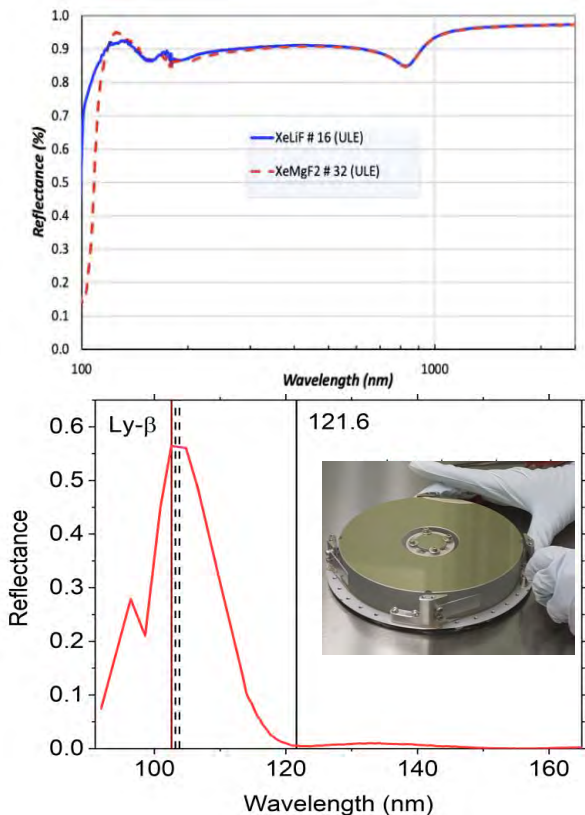
Mirrors for Ly- β made at the GOLD group for the FLUID rocket: Far and Lyman UV Demonstrator. Pathfinder for HWO (Rodríguez De Marcos 2018)



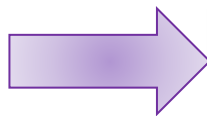
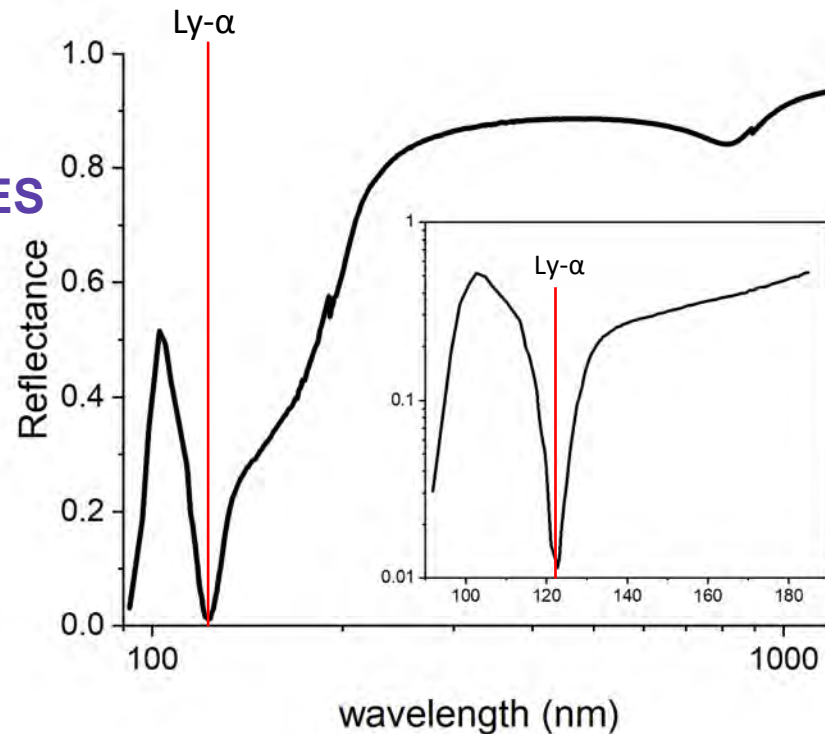
Broadband mirror - Narrowband mirror - Notch mirror



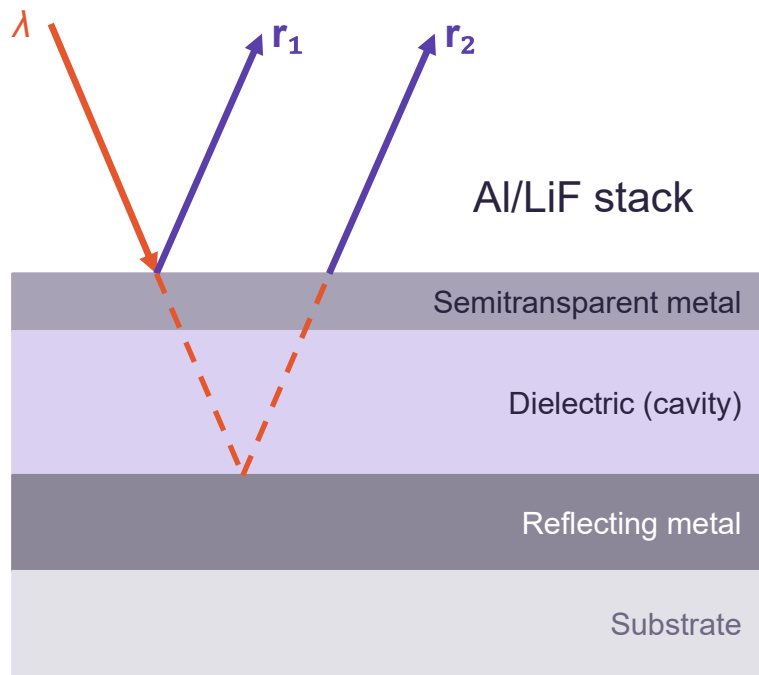
Broadband mirror - Narrowband mirror - Notch mirror



COMBINING
BOTH
PERFORMANCES



Principle: metal–dielectric–metal Fabry-Pérot cavity



$$|r_1| = |r_2|$$

equal amplitudes

Metal thickness (Al) $\rightarrow$ depth

$$\Delta\phi = \pi$$

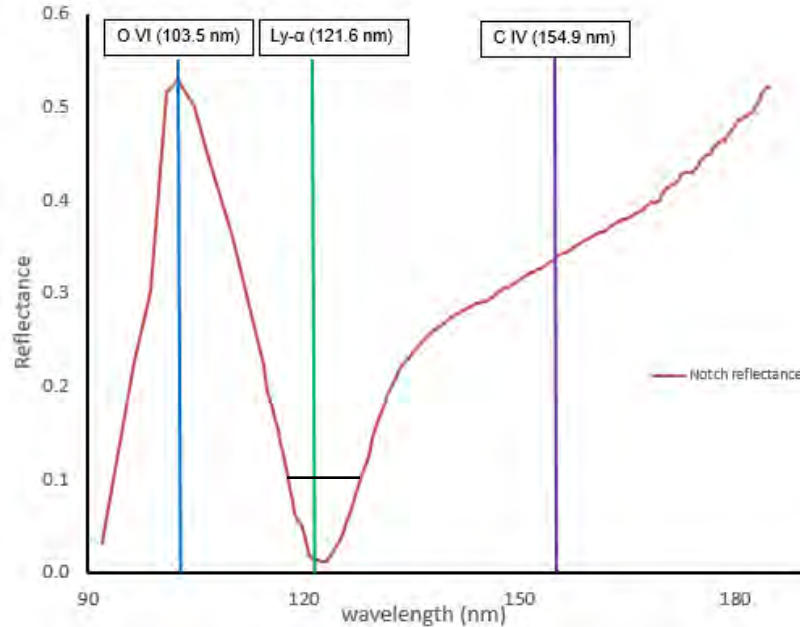
opposite phases for r_1
and r_2

Dielectric thickness (LiF) $\rightarrow$ position

destructive interference **only at a wavelength**

Physical principle (sketch). Implemented as an $(\text{Al/LiF})_n$ multilayer.

Reflectance of the fresh sample



53%

reflectance at Ly-β / O VI

~1%

reflectance at Ly-α

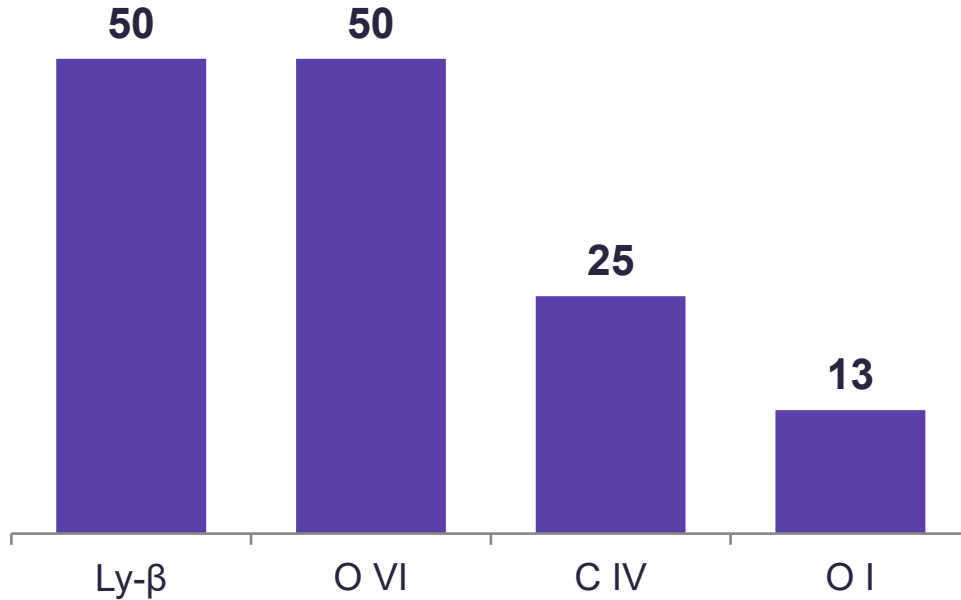
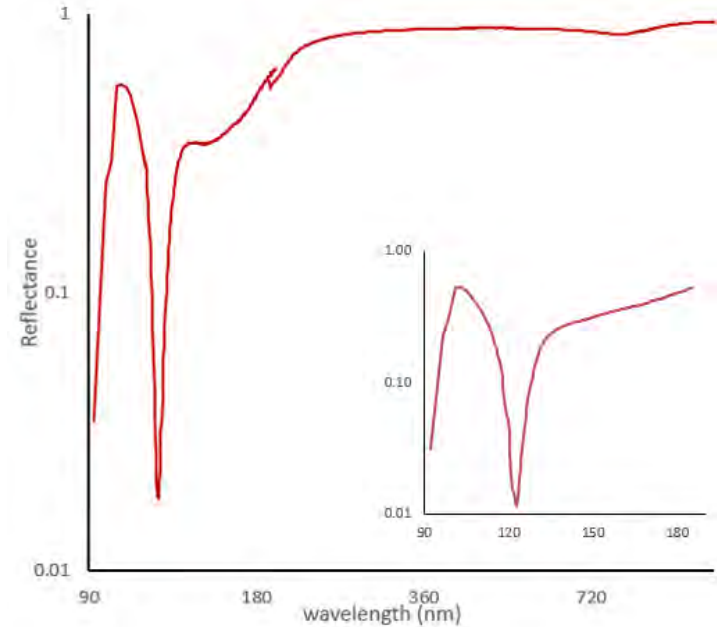
10 nm

notch width at R= 0.1 (10%)

*Fresh sample (< 1 h in air), 5° incidence. *Width: interval over which R equal 0.1.*

Contrast relative to Ly- α

Reflectance ratio line / Ly- α



High reflectance extends into the near IR (90–1200 nm, log scale)

Humidity stability: half-masked capping

**TRL
Increase**

Outer layer of the design is LiF

Hygroscopic: degrades during storage and integration in humid environments

MgF₂ capping

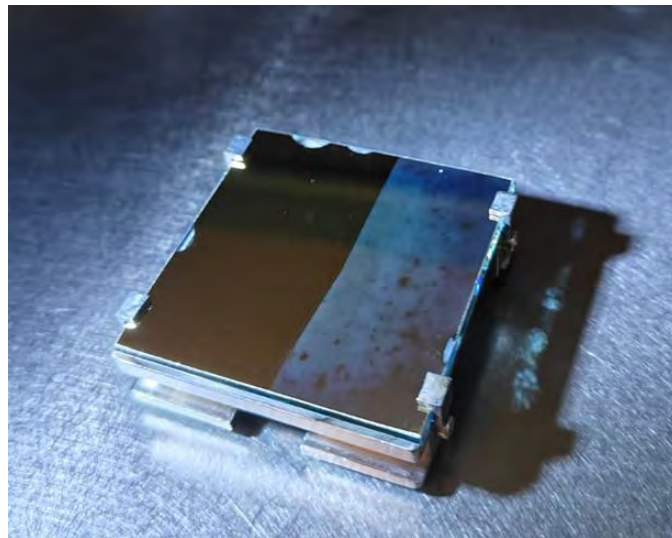
Non-hygroscopic, thin enough to not affect the LUV performance

Half-masked, single run

Capped and uncapped areas on the same sample to avoid different runs imperfections

30%, 40% and 50% RH for 40 days

Mimics the instrument integration period



Humidity stability: half-masked capping

**TRL
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Outer layer of the design is LiF

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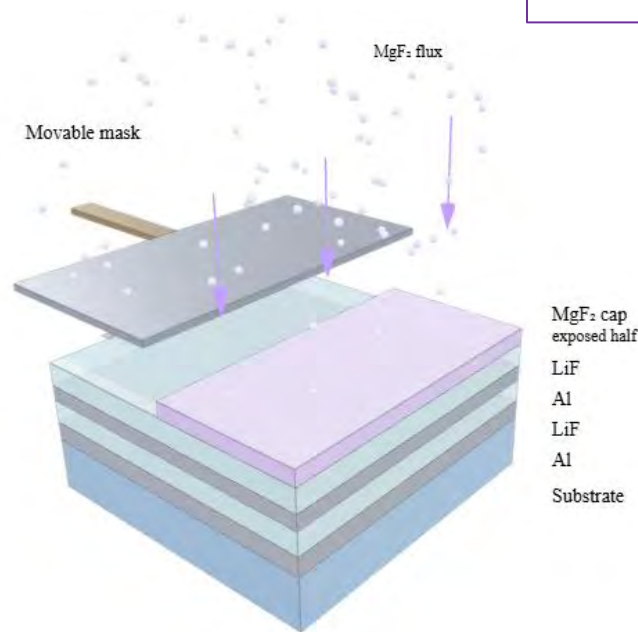
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Half-masked, single run

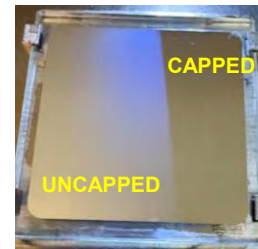
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30%, 40% and 50% RH for 40 days

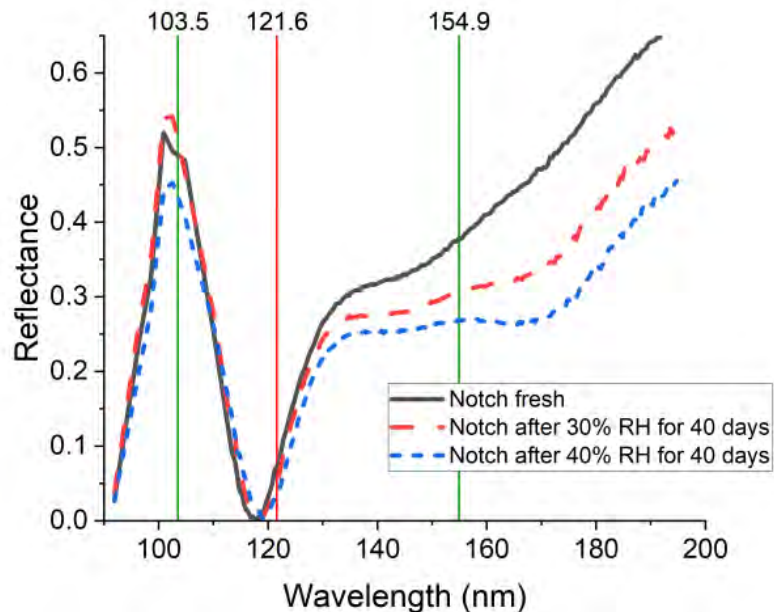
Mimics the instrument integration period



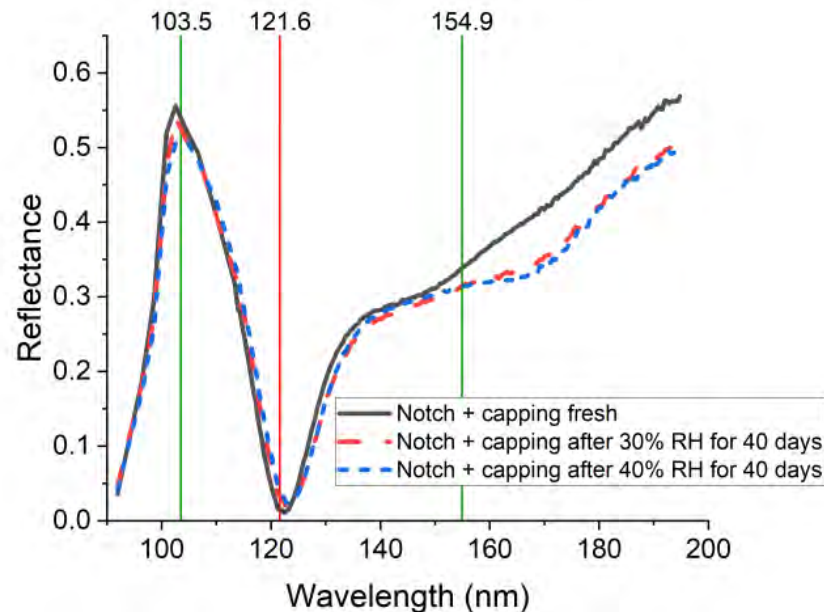
Effect of the MgF_2 capping under RH conditions



UNCAPPED

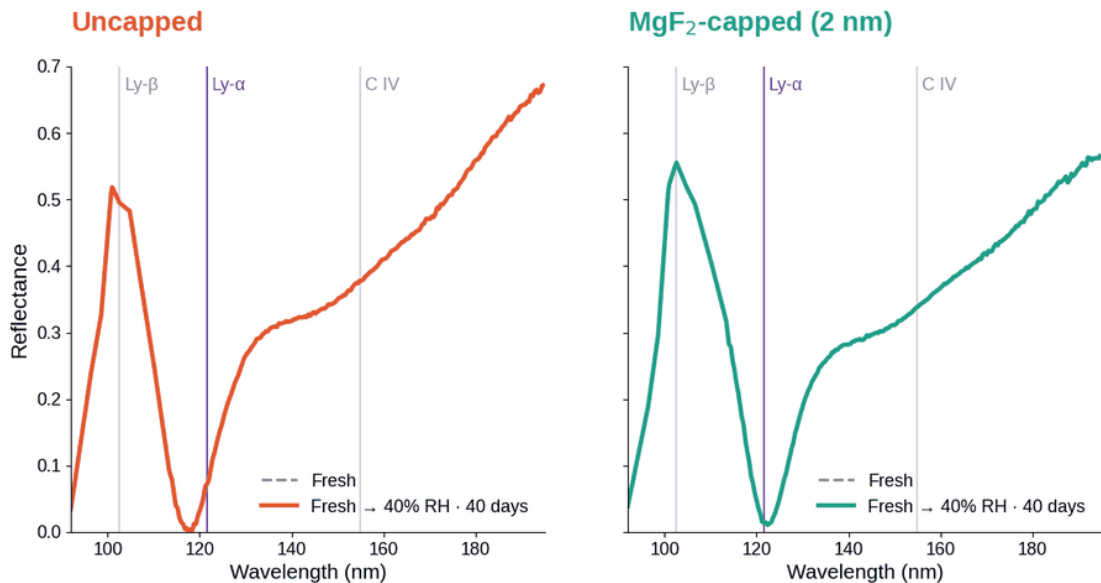


MgF_2 -CAPPED



Reflectance loss after 40 days at 40% RH

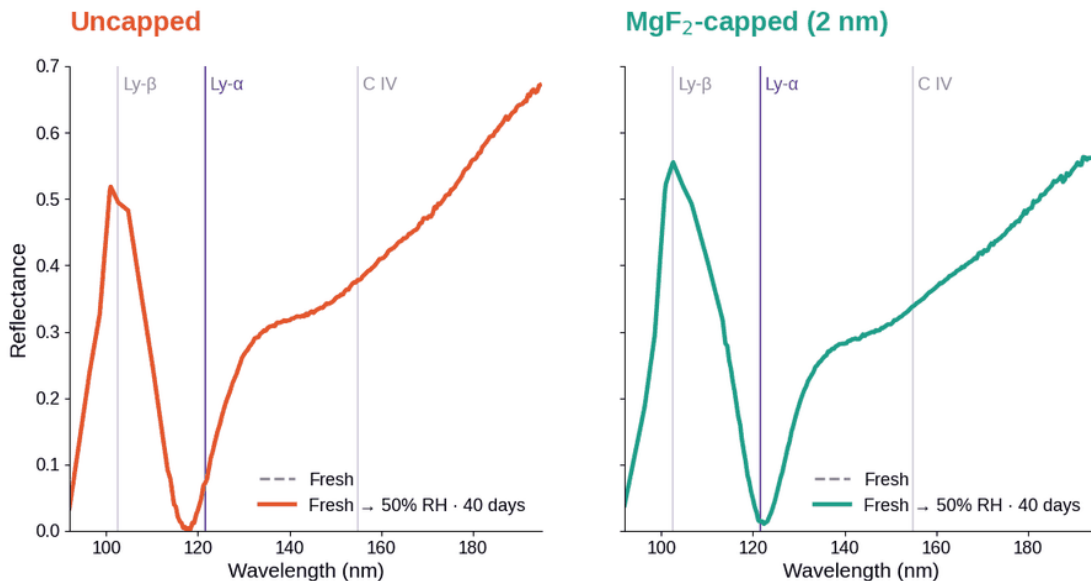
Fresh → 40% RH · 40 days



Capped Notch filter performs better either for 40% and 50% RH

Reflectance loss after 40 days at 50% RH

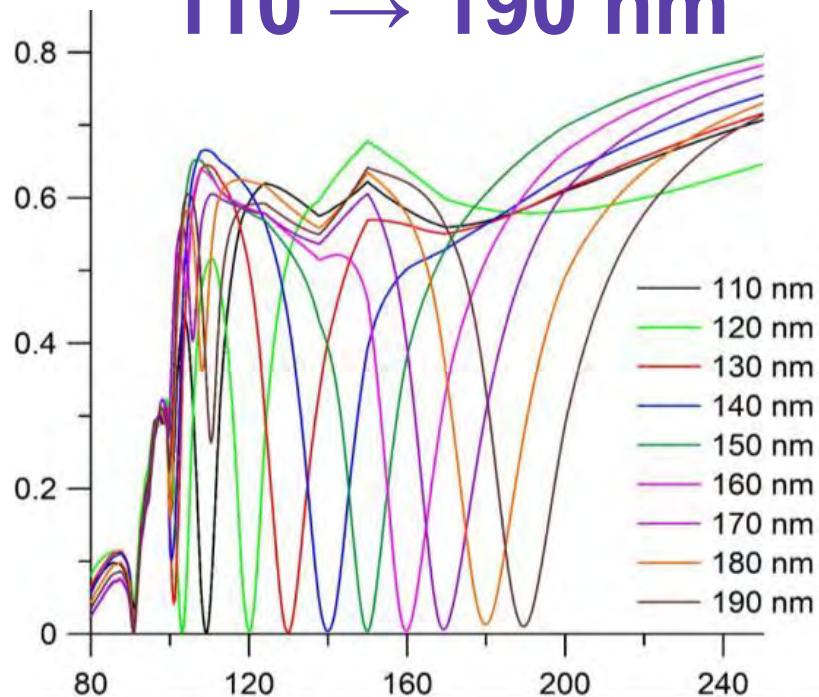
Fresh → 50% RH · 40 days



Capped Notch filter performs better either for 40% and 50% RH

Notch tunability

110 → 190 nm

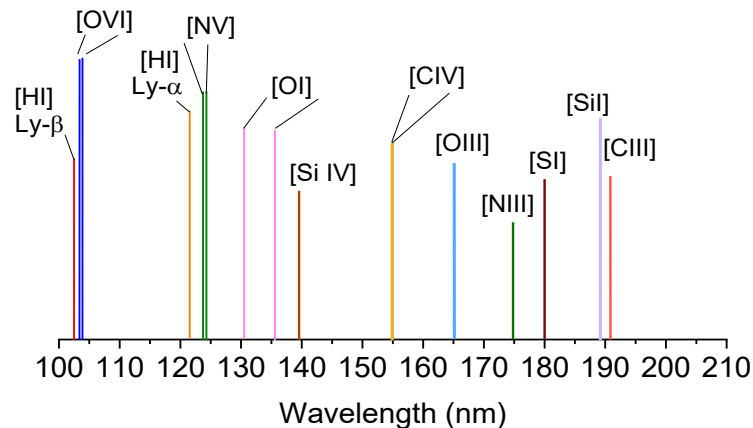


Theoretical simulations (x: wavelength in nm, y: reflectance)

Theoretical calculations

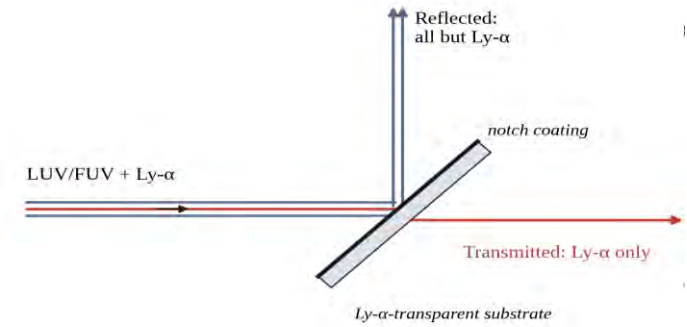
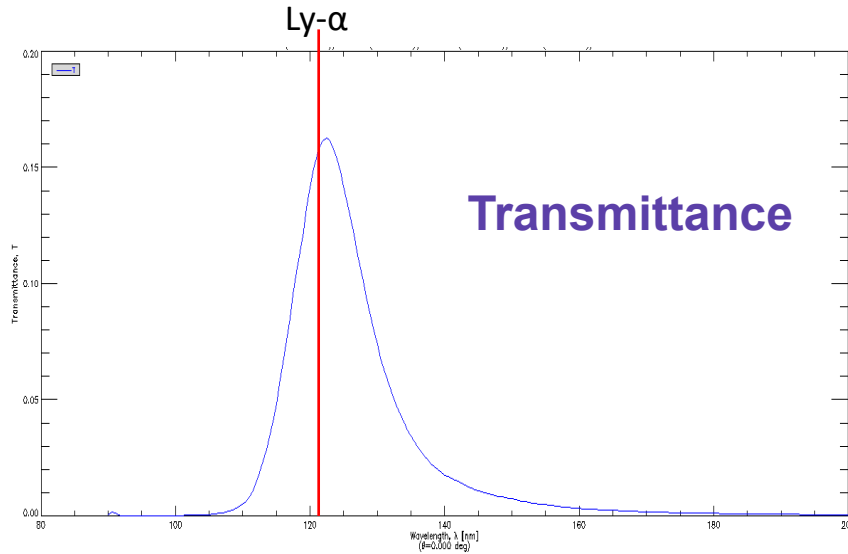
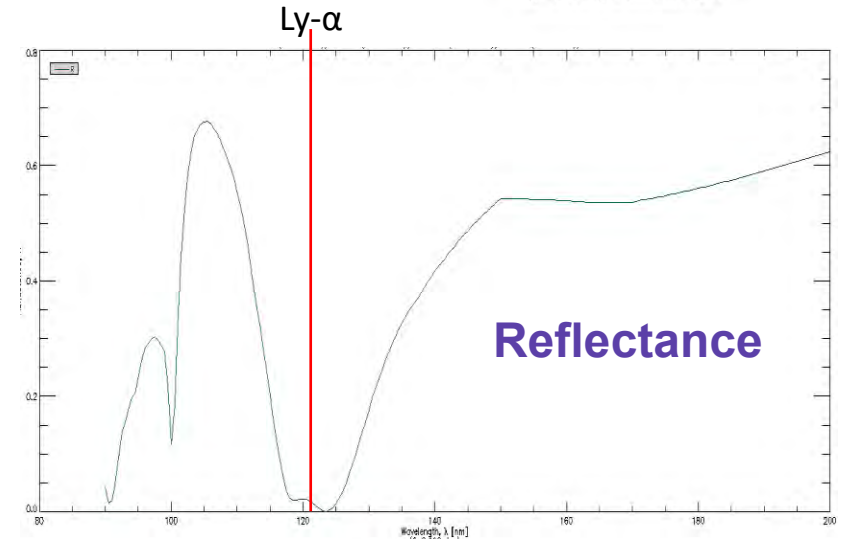
Changing the Al and LiF thicknesses moves the minimum from 110 to 190 nm.

Eliminate O I



Theoretical calculations

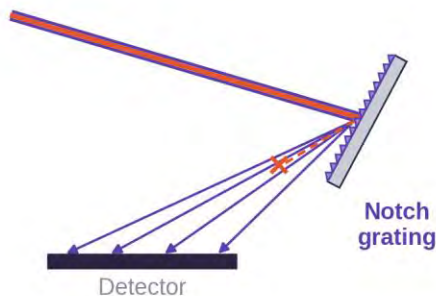
Changing the Al and LiF thicknesses creates a **constructive interference in transmittance**.



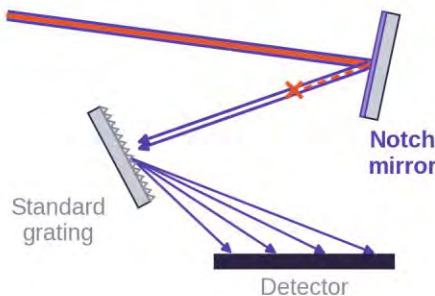
Theoretical simulations blue:(x: wavelength in nm, y: transmittance) green:(x: wavelength in nm, y: reflectance)

Applications

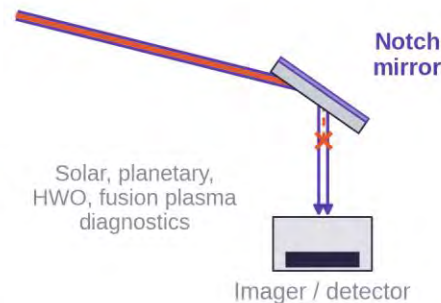
1 · On the grating



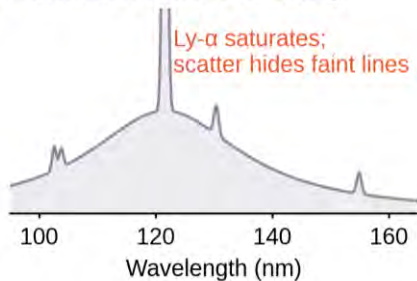
2 · On a mirror before the grating



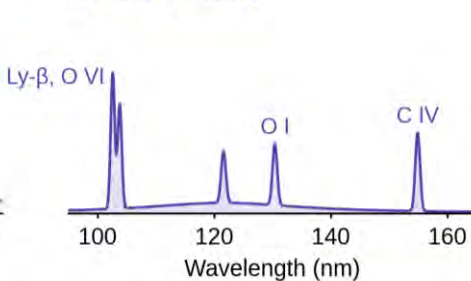
3 · Anywhere Ly- α is unwanted



Standard mirror coating



Notch coating

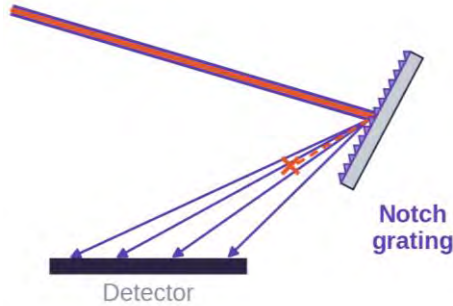


SUSHI – PROPOSAL (If approved)

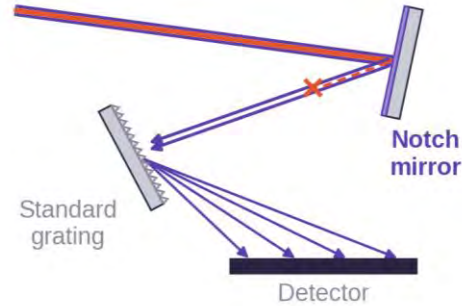
Notch mirror coating on a grating surface to reduce Ly- α scatter.
Towards Juniper Cubesat (JHU, LASP)

Applications

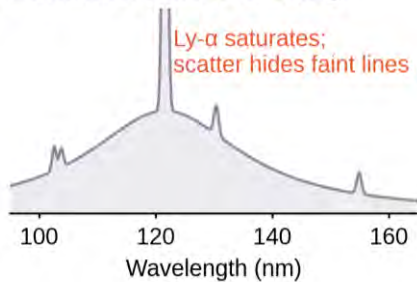
1 · On the grating



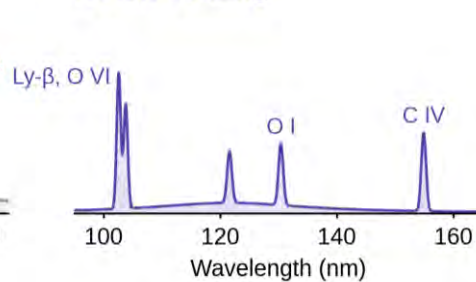
2 · On a mirror before the grating



Standard mirror coating



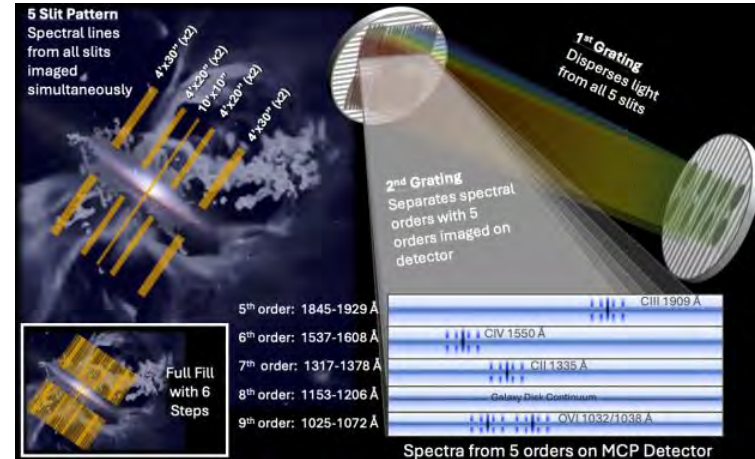
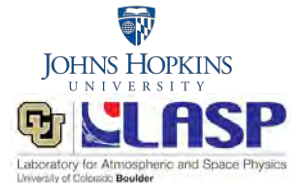
Notch coating



SUSHI – PROPOSAL

(If approved)

Notch mirror coating on a grating surface to reduce Ly-α scatter.
Towards Juniper Cubesat (JHU, LASP)



Conclusions

- Reflective $(\text{Al/LiF})_n$ **notch**: 1% at Ly- α and 53% at Ly- β (ratio 50), with broadband reflectance over 95–200 nm and the vis-IR.
- Narrow notch: 10 nm wide at 0.1 R tuned at the desired wavelength.
- A 2 nm MgF_2 capping reduces the reflectance loss and the notch shift after 40 days at 40% RH.
- Simulations predict notches tunable between 110 and 190 nm.

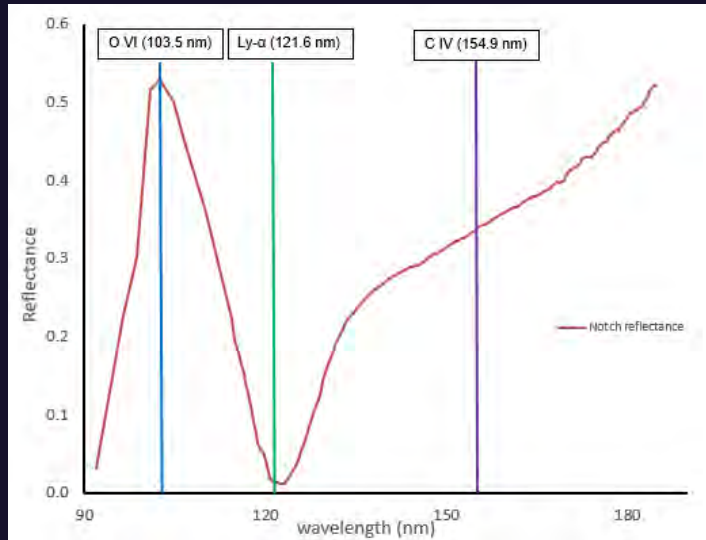
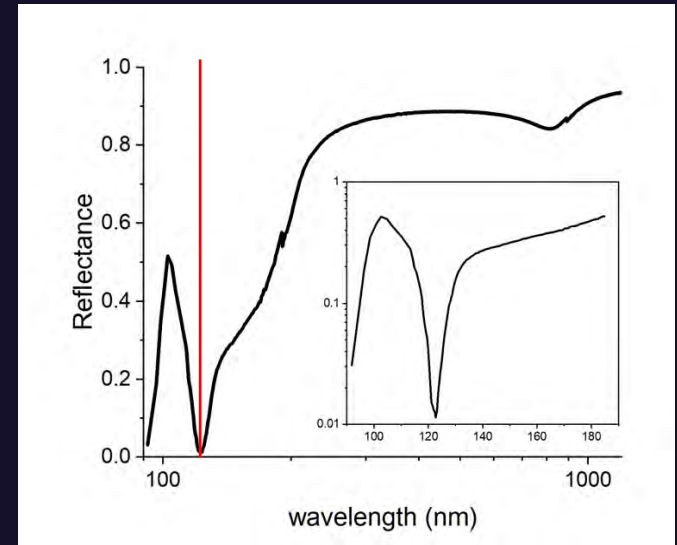
Conclusions

STABLE
NARROW

TUNED AT
Ly- α

93-200+ nm
REFLECTANCE

ADAPTABLE



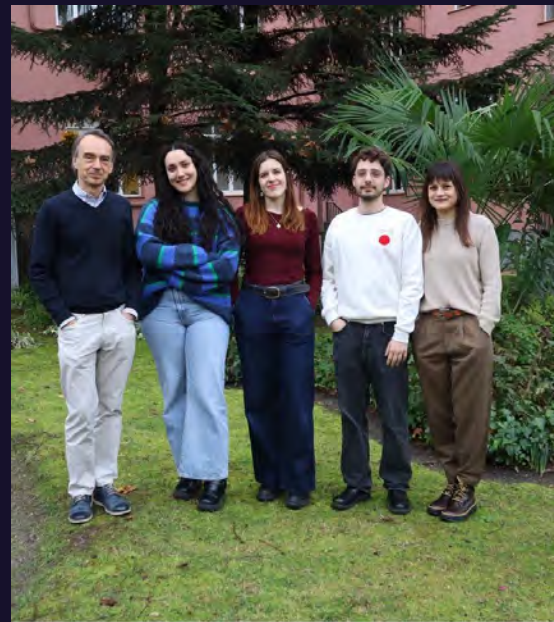
Thank you

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