Optical Design and Estimated Performance of LyRIC Spectroscopy

LyRIC：Lyman UV Radiation from Interstellar medium and Circum-galactic medium

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LyRIC: Mapping Diffuse O VI Emission

A compact external payload for the Chinese Space Station

O VI doublet
103.2 / 103.8 nm

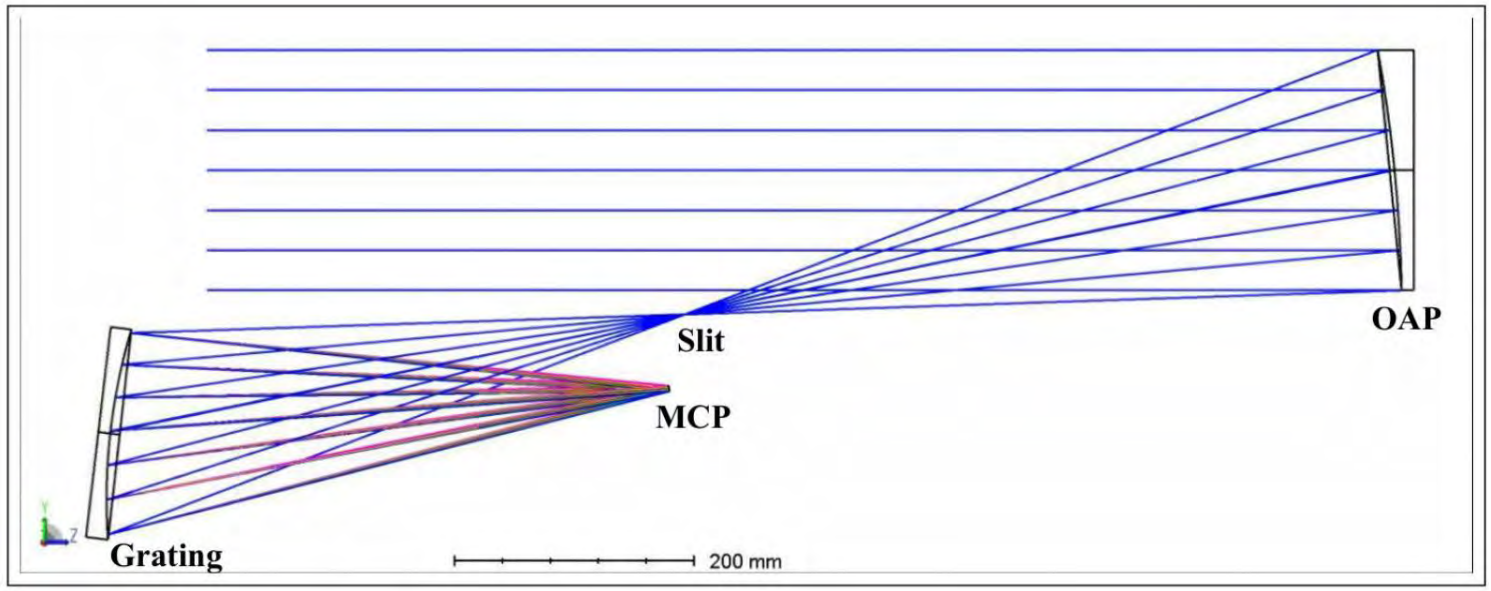
- Trace warm-hot gas
- Reveal spatial structure
- Probe gas dynamics

- Baryons cycle
- How gas accretion
- Feedback processes

Targets: CGM / Galactic halo / HVCs / SNRs / Superbubbles

Compact Optical Design

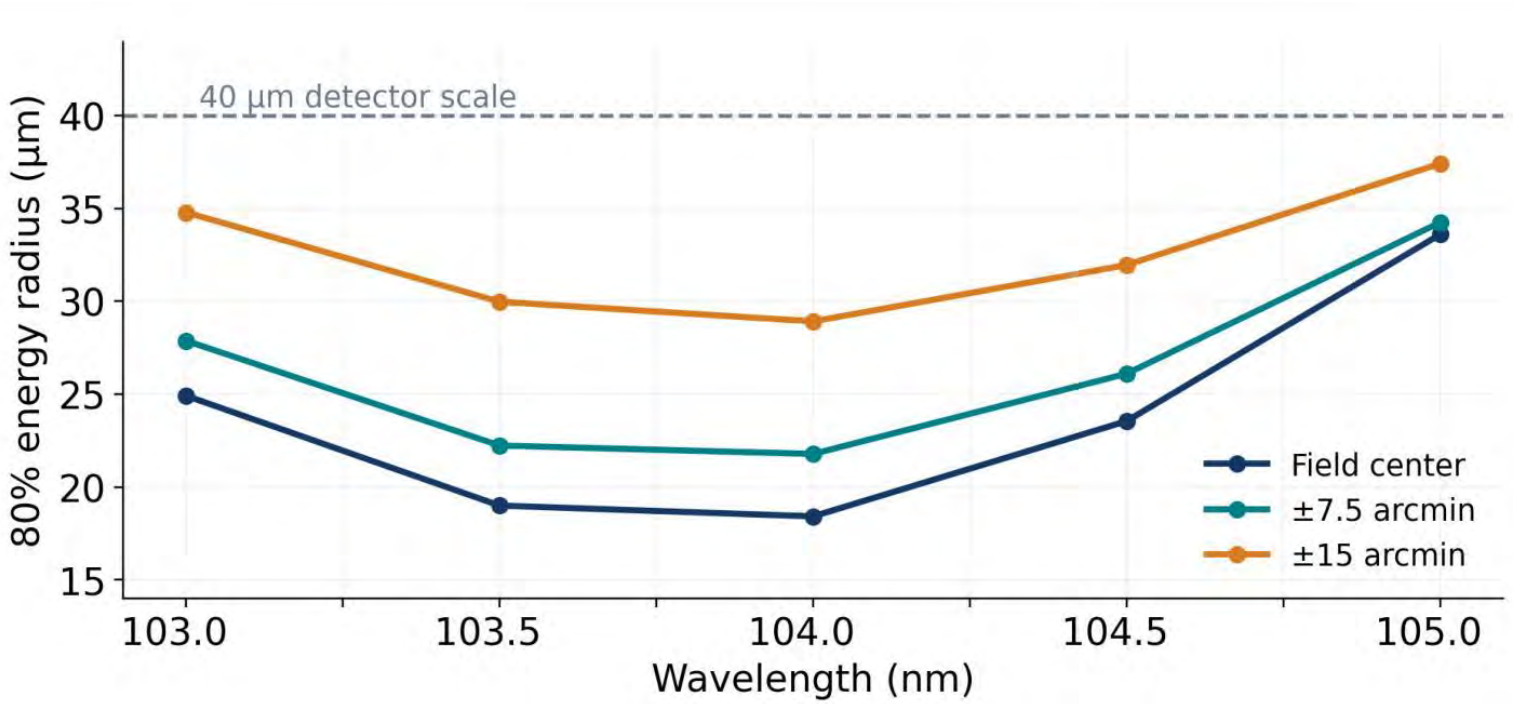
Designed within space-station payload size constraints



Parameter	Specification
Primary mirror	Off-axis parabola; 200 mm aperture
Focal length of primary mirror	600 mm (F/3.0)
Slit size	5.5 × 0.11 mm
Grating	Holographic VLS concave grating
Groove density / order	1205 grooves mm^{-1} / 4th order
Detector	Microchannel-plate detector; 40 μm pixel size

- Concave VLS grating combines dispersion and focusing
- Two optical surfaces reduce throughput losses

Predicted Optical Performance



80% encircled-energy radii remain below 40 µm across evaluated wavelengths and fields.

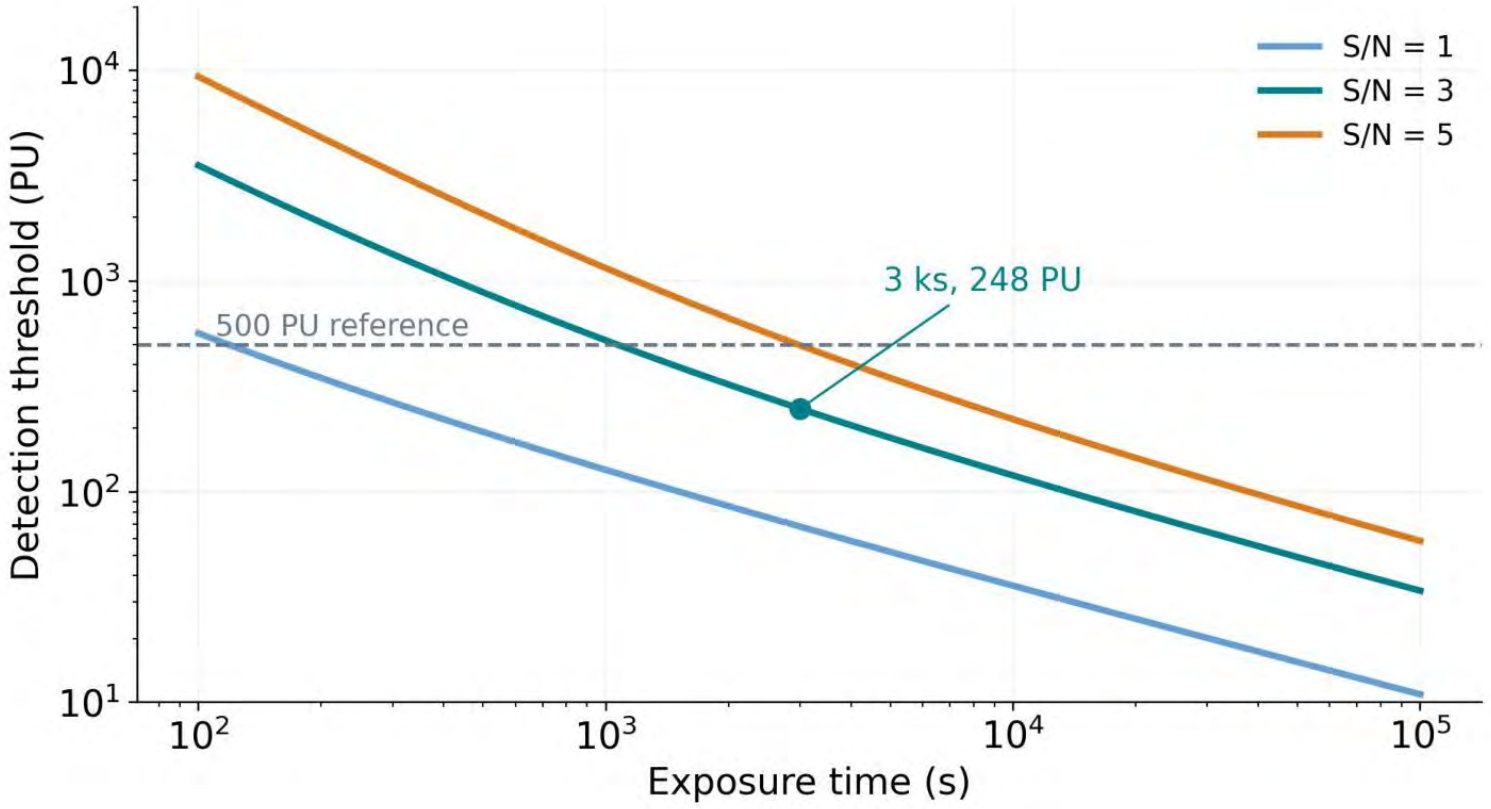
28.5″

Spatial resolution
30″ requirement

R ≈ 2986

≈ 100 km s^{-1} velocity
Near the O VI doublet
3000 requirement

Sensitivity to Diffuse Emission



Effective area ≈ 21.9 cm²

248 PU*

Detectable at 3σ
& 3 ks exposure
& R ~ 3000

Below the 500 PU surface-brightness requirement

*1 PU = 1 photon cm^{-2} s^{-1} sr^{-1}

Technology Development and Outlook

- **Lyman-UV coatings**

  >50% average reflectance over 102–108 nm

- **CAFE concave VLS grating**

  51% groove efficiency at 106.4 nm

- **Photon-counting MCP detector**

  Baseline for faint diffuse emission

Next stage: engineering verification

Credits: Ji et al. (2026); Lou, Ji & Wang (2019); Ren et al. (2023).

Optical Design and Predicted Performance of LyRIC Spectroscopy

LyRIC: Lyman UV Radiation from Interstellar Medium and Circum-galactic Medium

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103–105 nm
O VI wavelength range
103.2 / 103.8 nm doublet

R ≈ 2986
Spectral resolution
≈ 100 km/s velocity scale, 3000 requirement

28.5″
Spatial resolution
0.5′ × 0.5′ slit field, 30″ requirement

248 PU*
Detectable surface brightness
3σ · 3 ks · R ~ 3000, 500 PU requirement

01 Why map O VI emission?

SCIENTIFIC MOTIVATION

- **Trace warm-hot gas**: The O VI doublet is the best tracer of warm-hot diffuse gas in the ISM and CGM.
- **Reveal spatial structure**: Emission mapping complements absorption sightlines by revealing the morphology and distribution of gas.
- **Probe gas dynamics**: Spatially resolved spectra help characterize kinematics linked to accretion, outflows, and feedback.

Targets: CGM / Galactic halo / HVCs / SNRs / superbubbles

02 Compact optical design

LONG-SLIT IMAGING SPECTROSCOPY

- LyRIC's compact optical design meets the **size constraints** for an external payload on the Chinese Space Station.

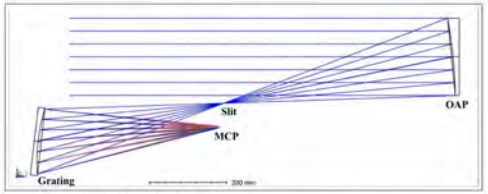

Fig. 1. Optical layout of LyRIC

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Detector	Microchannel-plate detector; 40 μm pixel size

- Two optical interactions limit throughput losses.
- The grating combines dispersion, focusing and aberration correction.

03 Predicted optical performance

ZEMAX + PHYSICAL-OPTICS MODELING

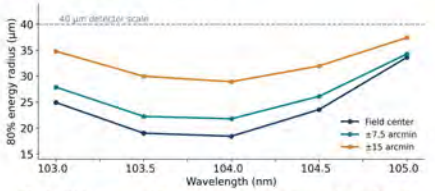

Fig. 2. 80% energy radii remain below 40 μm across the evaluated wavelengths and field of views.

- With an 80 μm line FWHM and 0.432 nm/mm dispersion, $\Delta\lambda \approx 0.0346$ nm and **R ≈ 2986 at 103.2 nm.**
- **Spatial resolution ≈ 28.5″.**

04 Sensitivity to diffuse emission

PHOTON-COUNTING MODEL — PREDICTION

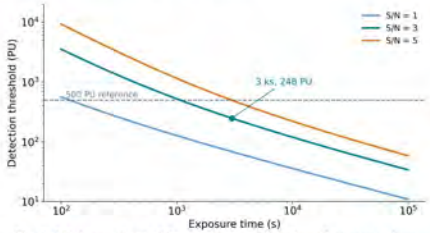

Fig. 3. Minimum detectable radiance as a function of exposure time for different signal-to-noise ratio (S/N) requirements.

- **$A_{e\Omega} \approx 21.9$ cm²**
- A photon-counting sensitivity model yields a 3σ detection of approximately **248 PU for a 3 ks exposure at R ~ 3000**, reaching well below the 500 PU surface-brightness requirement.
- Mirror reflectance: 60%, grating efficiency: 30%, MCP QE: 43%, contamination loss: 10%.

05 Technology developments

TOWARD ENGINEERING VERIFICATION

Lyman-UV coatings: Al/LiF/eMgF$_2$ achieved >50% average reflectance over 102–108 nm.
Gratings: The CAFE concave VLS blazed grating achieved 51% groove efficiency at 106.4 nm.
UV Detectors: Photon-counting MCPs remain the baseline for faint diffuse emission.

SUMMARY

LyRIC is a compact Lyman-UV long-slit spectrograph designed as an external payload for the Chinese Space Station, mapping diffuse O VI emission in the Milky Way and nearby galaxies. The optical design minimizes reflections while providing a predicted spatial resolution of ≈ 28.5″ and spectral resolution of R ≈ 2986. LyRIC can detect diffuse emission with a surface brightness of approximately 248 PU at 3σ over a 3 ks exposure, supporting future studies of warm-hot gas distribution, kinematics, and galactic baryon cycle.

References: Ji et al. (2020), arXiv:2012.07384; Lou, Ji & Wang (2019), Applied Optics 58, 1016; Ren et al. (2023), Applied Optics 62, 9414.
* 1 PU = 1 photon cm^{-2} sr^{-1} s^{-1}