

Closing the technology gap for the Extremely Large Telescope's Planetary Camera and Spectrograph (ELT-PCS): development of the coronagraph and focal plane wavefront control strategies

The team

S.Y. Haffert¹, A. Potier², L. Leboulleux³, B. Wehbe⁴, O. Absil⁵, P. Baudoz², A. Boccaletti², V. Chambouleyron⁶, C. Correia⁷, L. Desdoigts¹, V. Fonteneau⁸, R. Galicher², N. Gallan⁹, E. Huby², J. Kuehn¹⁰, C. Kulcsár⁹, I. Laginja¹¹, R. Landman¹, M. Langlois⁸, L. Marquis¹⁰, M. Mars¹, P. Martinez¹¹, D. Mawet¹², J. Mazoyer², M. N'Diaye¹¹, J. Nousiainen¹³, G. Orban de Xivry⁵, R. Pourcelot¹⁴, H. Raynaud⁹, C. Sallard¹¹, A. Taras¹, E. Tonucci¹, A. Vigan⁶, Y. Xin¹

Abstract

The Planetary Camera and Spectrograph (PCS) will be the ELT's dedicated instrument for exoplanet characterization, with a central goal of discovering and studying rocky exoplanets. To prepare for these ambitious objectives, the PCS R&D consortium, launched in January 2025 under ESO's leadership, was established to advance the conceptual design and bridge critical technology gaps. We will report on the progress of the coronagraph and focal-plane wavefront control work package. Our efforts focus on the development of coronagraphs tailored for PCS and on strategies for integrating wavefront control into their operation. A key component of this work is the PCS Coronagraph Evaluation Pipeline (PCS-CEP), designed to provide a uniform framework for assessing coronagraph performance and wavefront control, an approach inspired by the Habitable Worlds Observatory coronagraph design survey. PCS-CEP enables a fair comparison of diverse concepts, ensuring a level playing field for innovation.

PCS Work package 2 structure

The coronagraph is one of the crucial components for PCS. In Work Package 2 (WP2), we develop coronagraph and focal plane wavefront sensing concepts. We have adopted the following work package structure and goals:

| | |
|--|--|
| WP2 Leads Sebastian Haffert Axel Potier | |
| Sebastian Haffert PCS – Coronagraph Evaluation Pipeline | WP 2.1 Goal: Assess the performance of all coronagraphs in a uniform way. |
| Lucie Leboulleux Coronagraph design | WP 2.2 Goal: Propose coronagraph designs for PCS |
| Axel Potier Wavefront sensing and control algorithms | WP 2.3 Goal: Develop wavefront control strategies for all coronagraphs. |
| Bachar Wehbe ADC | WP 2.4 Goal: Develop ADC with active control for broadband observations. |
| Sebastian Haffert Optical design | WP 2.5 Goal: Develop and opto-mechanical design of the coronagraph |

Call for coronagraph concepts

Do you like coronagraphs? Would you like to develop one for PCS? Then you are at the right place. Join our coronagraph development team and submit your own design! Maybe it will be the coronagraph we will use for the actual instrument!

The current top-level coronagraph requirements are

| | Smallest | Largest |
|-------------------------|---------------------|---------------------|
| IWA | 6 mas | 10 mas |
| Field of view | 100 mas | 1000-1500 mas |
| Spectral range | V-band (500 nm) | K-band (2400 nm) |
| Spectral resolution | 10 | 100,000 |
| Post-processed Contrast | 10^{-8} at 10 mas | 10^{-9} at 30 mas |
| Coronagraphic DMs | One 60x60 DM | Two 64x64 DMs |

Do you enjoy a challenge? Send us an email:

luce.leboulleux@univ-grenoble-alpes.fr

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Contact



Looking for a postdoc? Contact me! Any other question? Contact me too!
haffert@strw.leidenuniv.nl

Affiliations

1. Leiden Observatory, 2. Observatoire de Paris 3. Université Grenoble Alpes, IPAG, 4. Instituto de Astrofísica e Ciências do Espaço, 5. University of Liege, 6. Laboratoire d'Astrophysique de Marseille, 7. Porto, 8. CRAL, Université de Lyon, 9. Institut d'Optique Graduate School, 10. University of Bern, 11. Université Côte d'Azur, OCA, 12. Caltech, 13. ESO, 14. MPIA

PCS Block Diagram

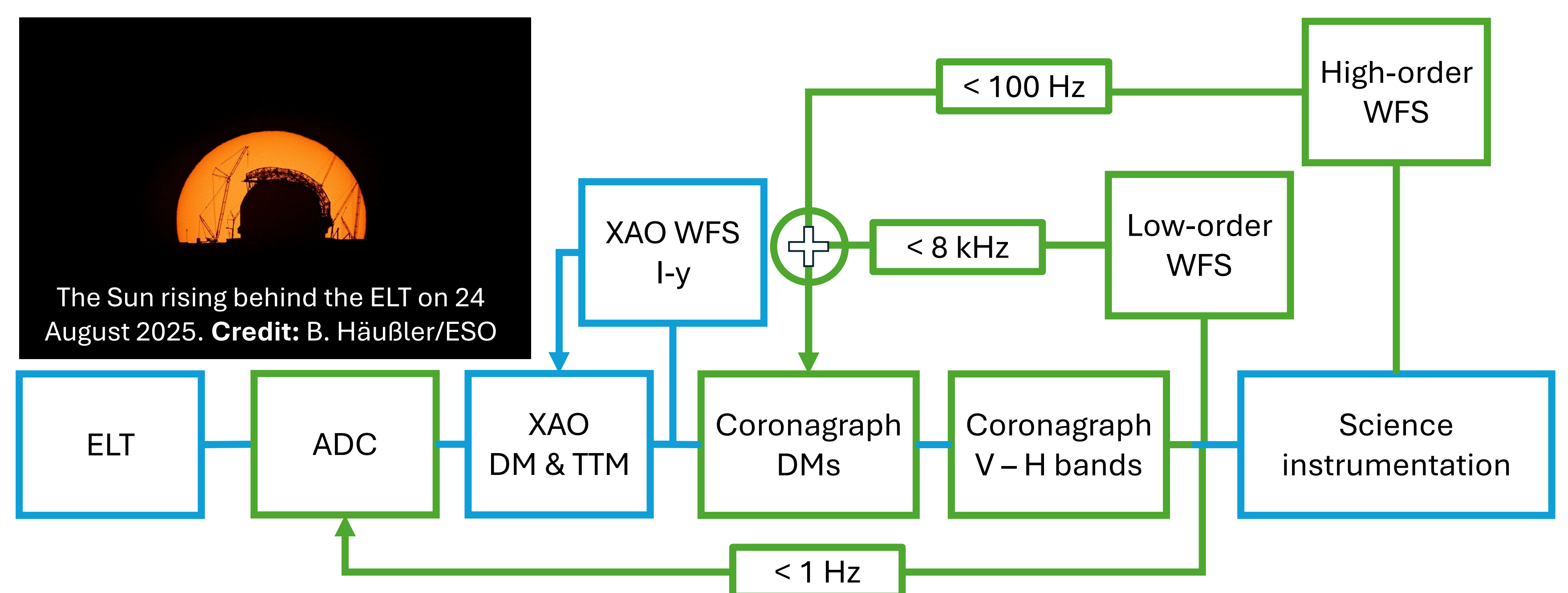


Figure 1. The proposed block scheme of PCS. PCS will consist of an eXtreme AO (XAO) system that provides well corrected wavefronts to the coronagraph sub-system. The coronagraph sub-system will handle non-common path aberrations using dedicated DMs. There will be multiple wavefront control loops for low-order stabilization and high-order dark hole digging. The green boxes are the parts that the coronagraph work package is responsible for.

PCS – Coronagraph Evaluation Pipeline

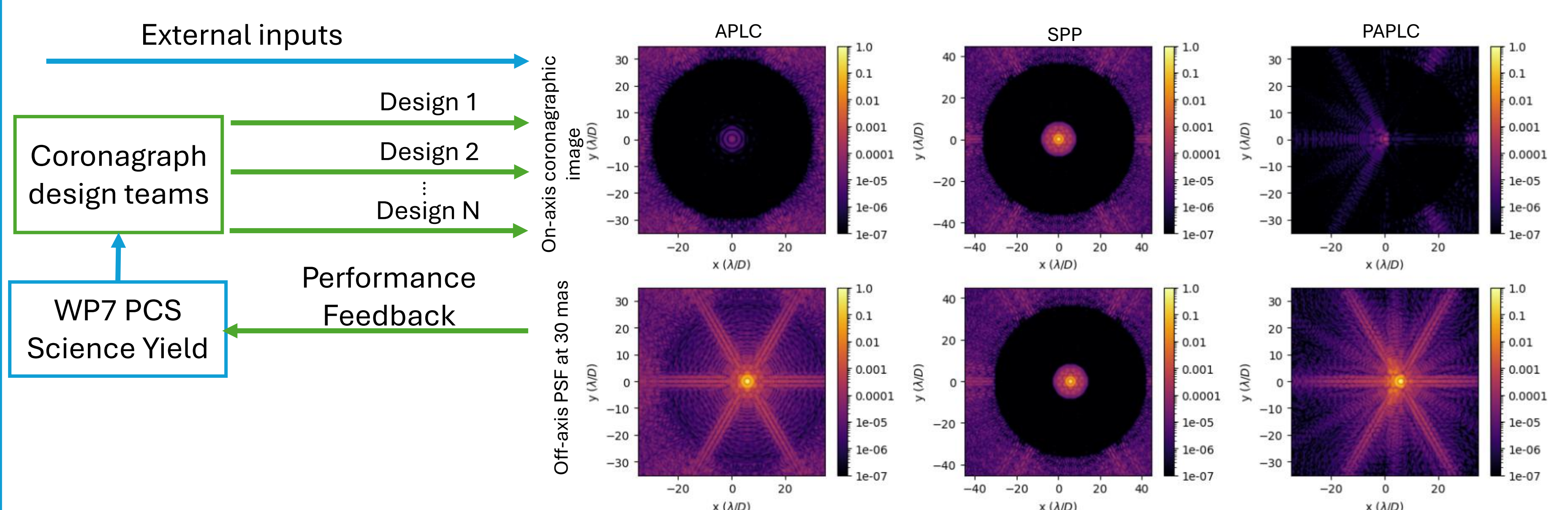


Figure 2. The structure of the PCS Coronagraph Evaluation Pipeline (PCS-CEP) and example outputs.

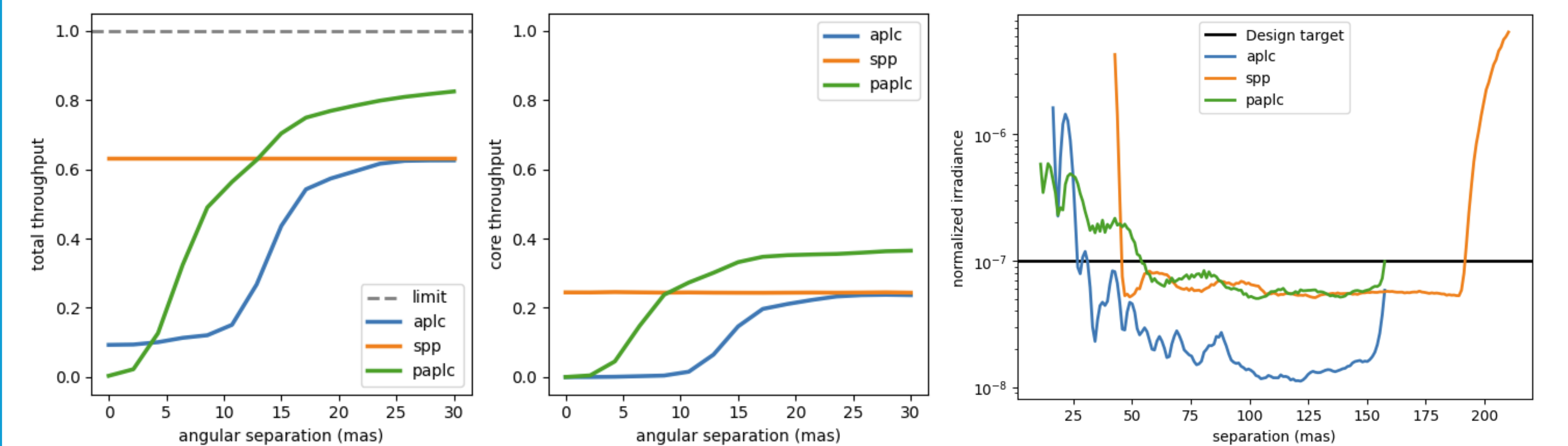


Figure 3. Performance of the first three submitted designs. The left figure shows the total throughput and the middle figure shows the core throughput (1.4 λ/D diameter). The figure on the right is the normalized irradiance, which has been corrected for the peak flux reduction of the apodizers.

| Coronagraph | IWA (λ/D) | OWA (λ/D) | Bandwidth | Peak core throughput | Robust? |
|-------------|---------------------|---------------------|-----------|----------------------|-----------|
| APLC | 2.7 | 30 | 20% | 0.23 | Lyot-stop |
| SPP | 8.0 | 40 | 20% | 0.23 | |
| PAPLC | 1.4 | 30 | 20% | 0.38 | |

First demo of the PCS-CEP - WFSC

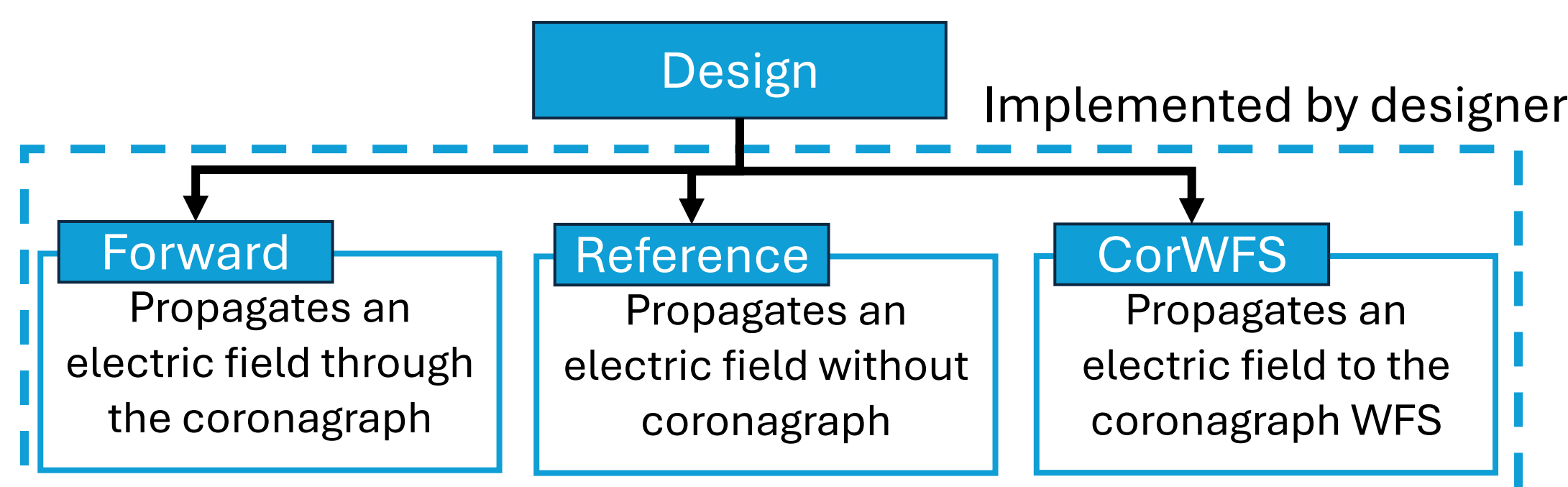


Figure 4. Inclusion of the lowfs propagator allows us to also uniformly evaluate various coronagraphic wavefront sensors.

Example: reflective focal plane mask coronagraphic WFS

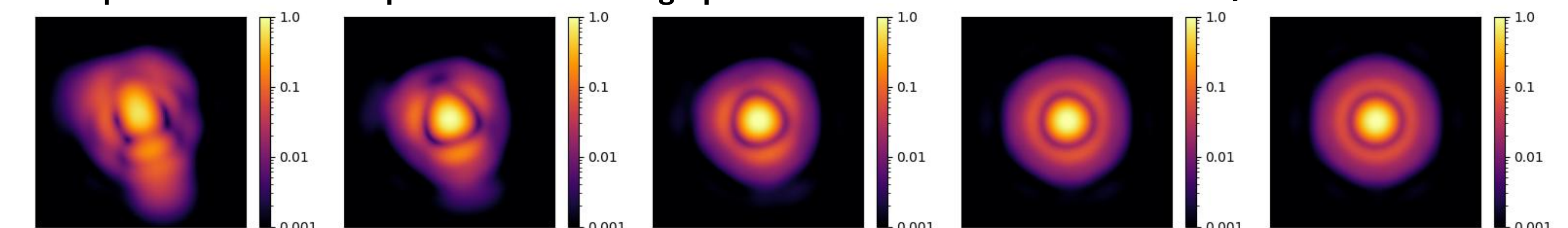


Figure 6. Closed loop run of the CLC-LOWFS where 100nm of low-order wavefront error is corrected in 5 iterations.

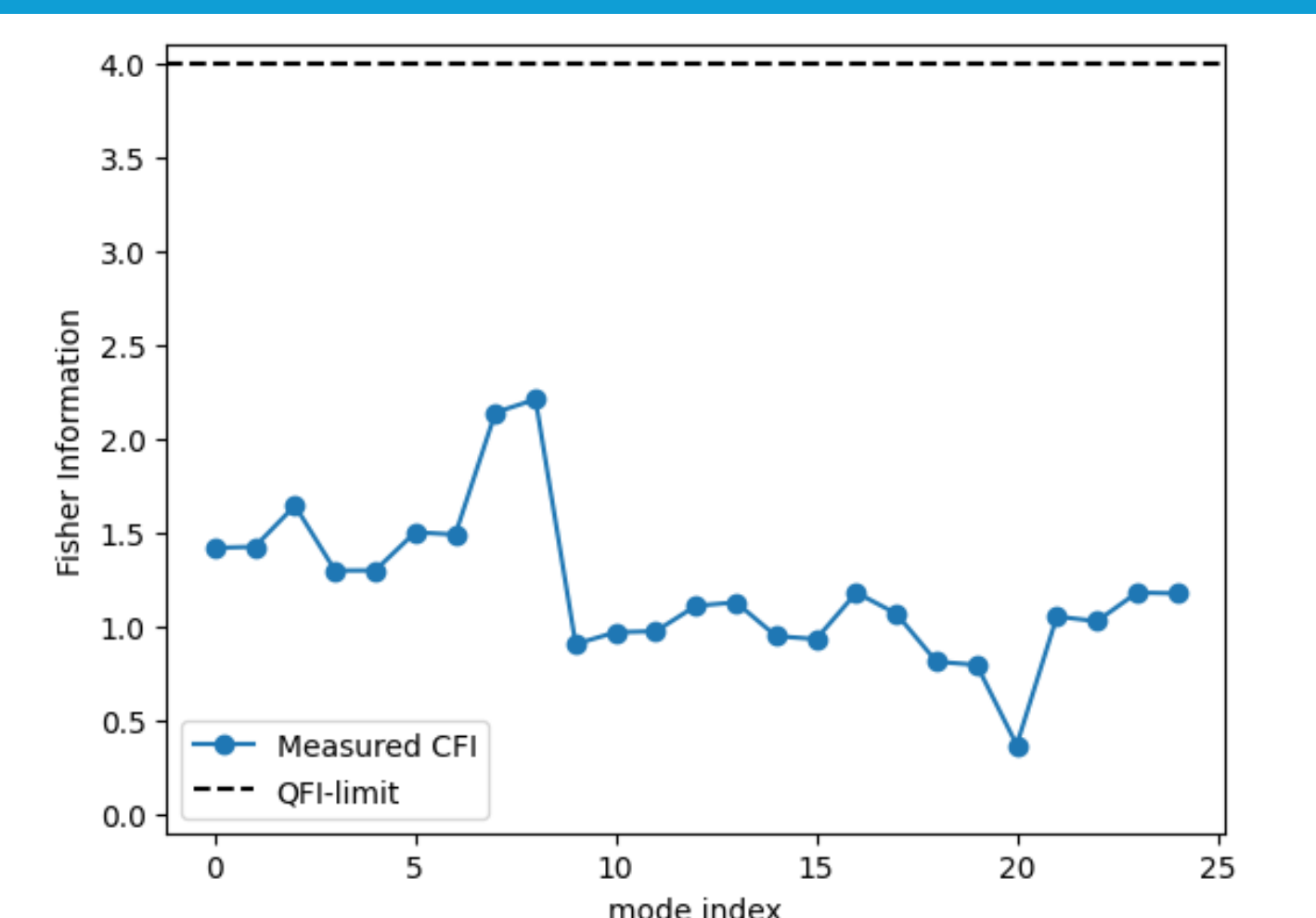


Figure 5. Measuring the photon noise sensitivity for different modes.