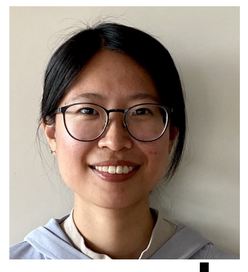
Future Exoplanet Direct Imaging Instruments:
Simulating spatial light modulator-based pixelated focal-plane coronagraphy



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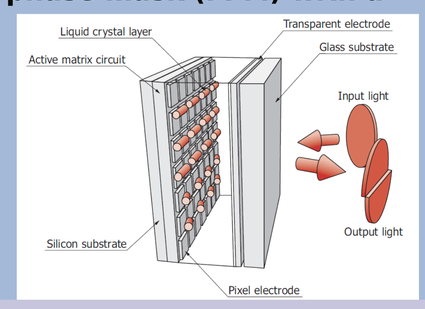
Introduction

The Programmable Liquid-crystal Active Coronagraphic Imager for the DAG telescope (PLACID) instrument is a novel exoplanet direct imaging facility [1], which was recently delivered to the Turkish 4-m DAG telescope with first light anticipated by the end of 2024. We hereby present our early simulation results obtained with our Python-based toolbox, exploring the impacts of various design parameters to generate a pixleated focal-plane phase mask (FPM) with a Spatial light modulator (SLM):



Various design choices:

1. Spatial sampling (per λ/D units in the focal plane)
2. Phase resolution (a typical SLM has 8-10 bits grey level)

Assumptions:

1. Monochromatic Light
2. Perfect linear 0-2π phase mapping of n bits grey levels
3. Perfect wavefront (no WFE, SR = 1)
4. No 2nd effects (e.g. ghost reflection, pixel crosstalk etc.)

Spatial Sampling

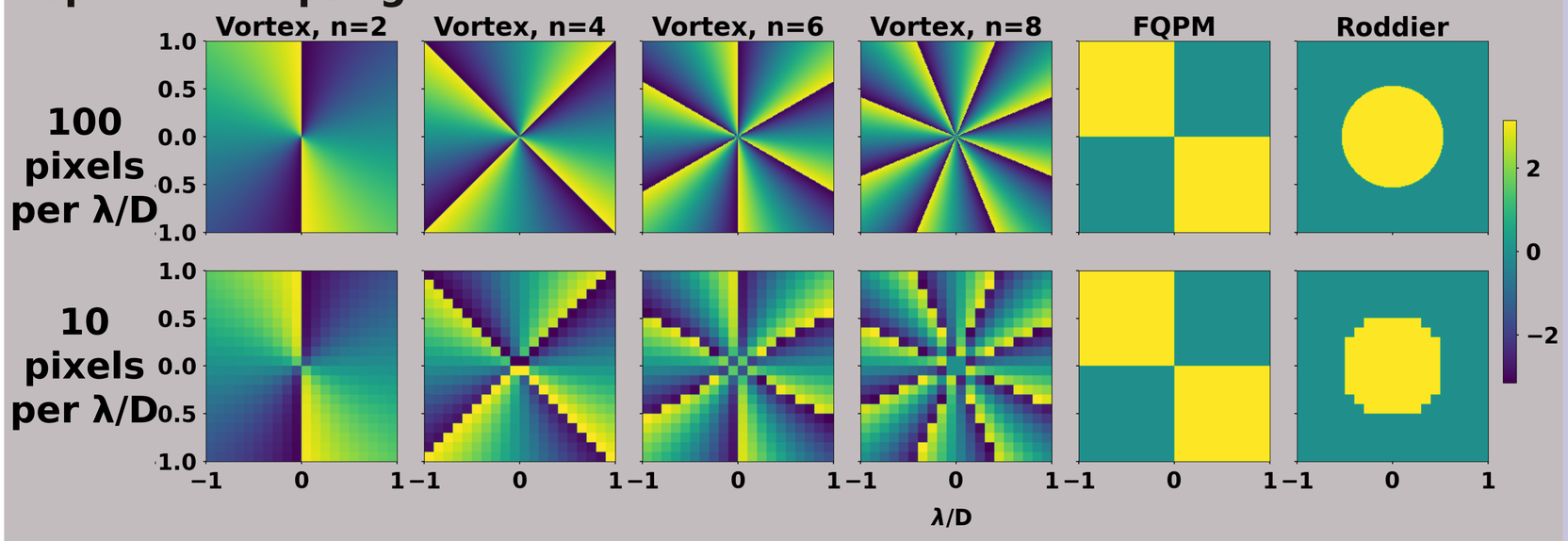


Figure 1, Example of most commonly used FPMs with two different spatial samplings in the focal-plane. The top row FPMs are displayed with 100 pixels per λ/D (max. allowed in our simulations), while the bottom row FPMs are generated with 10 pixels per λ/D (actual PLACID configuration).

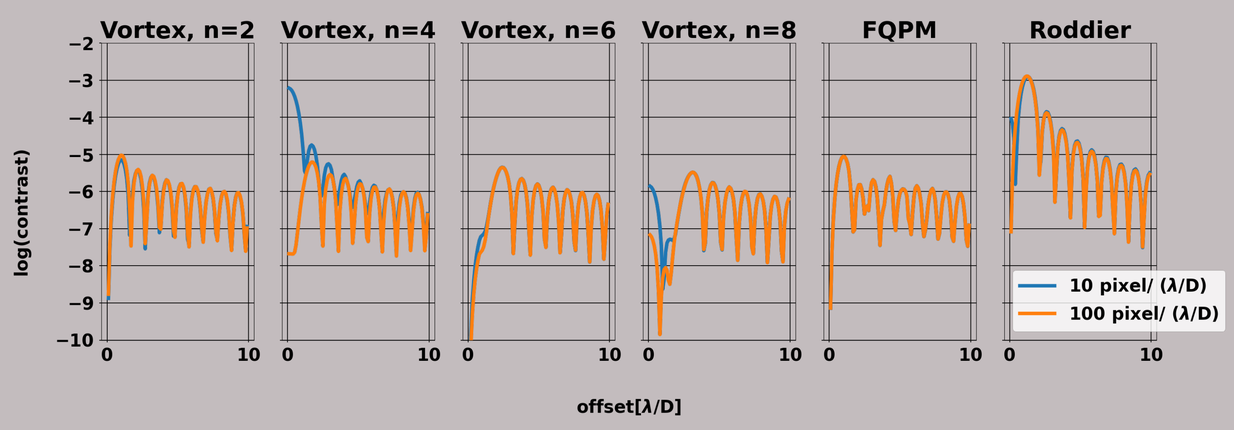


Figure 3, Post-coronagraphic focal-plane contrast for the 2x6 different FPMs of Figure 1.

- **A sampling of 10 SLM pixels per λ/D seems sufficient in most cases.**
- **Vortex phase masks with charge 4 and 8 on-axis are most affected by poorer spatial sampling.**

Phase Resolution

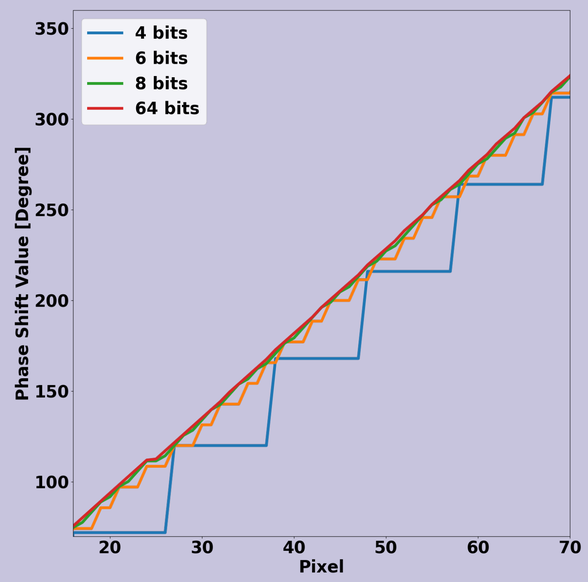


Figure 2, Impact of limited phase resolution for generating e.g. a phase ramp. Most commercially-available SLM panels (include the one in PLACID) have 8-bits resolution (10 bits in rare instances).

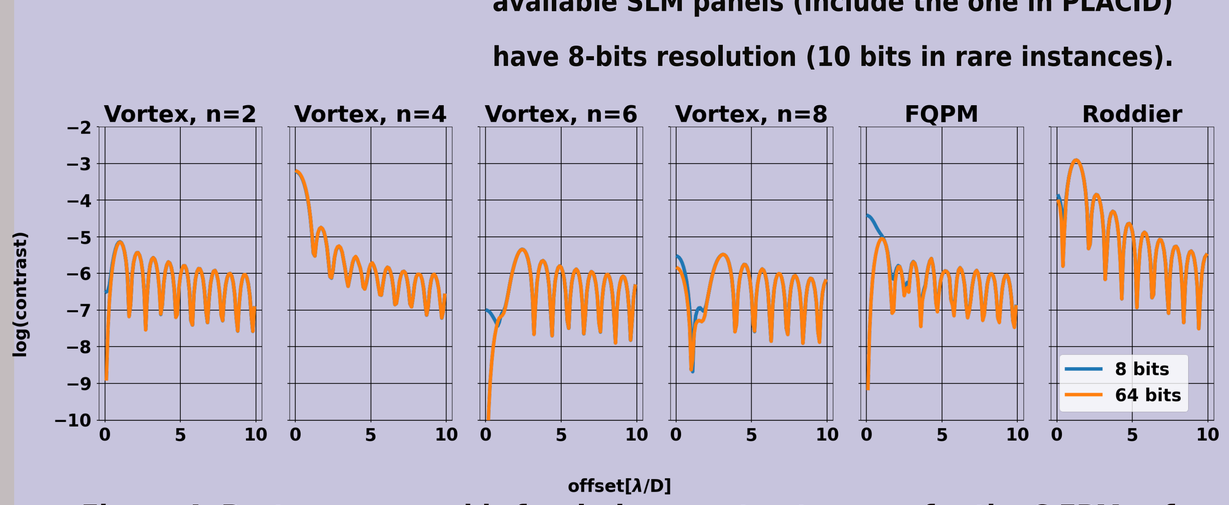


Figure 4, Post-coronagraphic focal-plane contrast curves for the 6 FPMs of Figure 1 bottom row (10 px per λ/D) for 8 bits and 64 bits (Python floating number precision).

- **There is no significant contrast penalty to use 8 bits phase.**

Lyot stop sizing and SNR

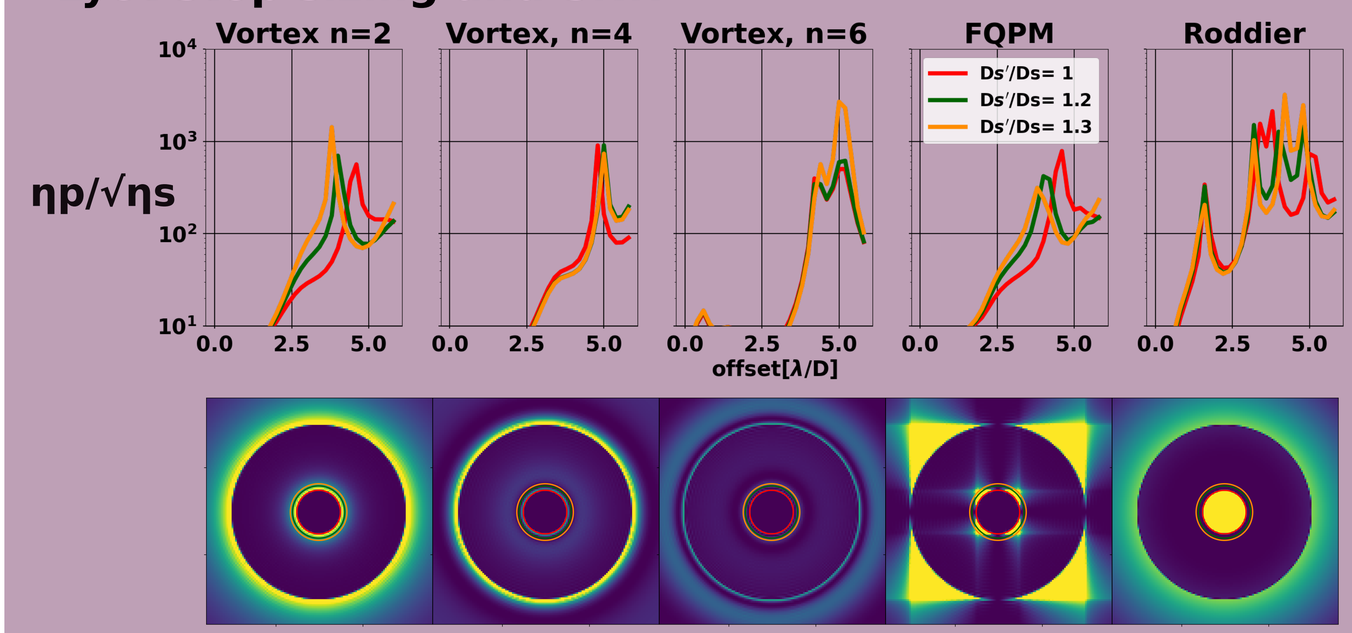


Figure 5,
(Top row) ηp/√ηs ~SNR [2] with different lyot central obstruction oversizing factors Ds'/Ds for the DAG telescope pupil, with ηp being the throughput of the planet, and ηs the one of the central star.

(Bottom row) Post coronagraphic intensity distribution in the Lyot pupil-plane (before the lyot stop), with the coloured circles depicting the Lyot stop secondary masks for the various cases.

- **Each FPM coronagraph has a different optimal Lyot Stop.**

Future works

- **Broadband simulation(typ. 20%).**
- **Impacts of WFE, SLM calibration errors, pixels-level phase jitter, pixel crosstalk etc..**
- **Zonal temporal phase-shifting for time-domain CDI.**

References:
[1]Kühn, J., Jolissaint, L., Bouxin, A., & Polychronis Patapis, Proceeding of SPIE, 114511S, (2021), https://doi.org/10.1117/12.2562579
[2]Ruane, G., Riggs, E., Mazoyer, J., Por, E. H., Mamadou N'Diaye, Huby, E., ... Guyon, O.Proceeding of SPIE, 106982S, (2018), https://doi.org/10.1117/12.2312948

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