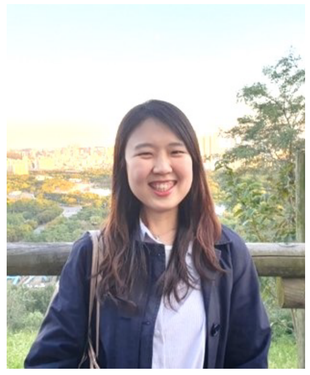

A Configurable Mode-based Imager Using an Active Photonic Integrated Circuit

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Summary

We demonstrated on-sky spatial-mode-based imaging with photonic lanterns and identified **key challenges**.

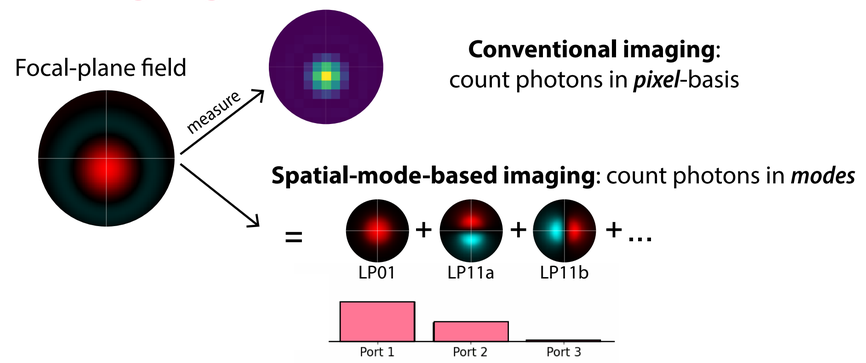
We propose a **photonic lantern + active photonic integrated circuit** architecture enabling configurable spatial-mode-based imaging, overcoming the challenges and allowing optimized measurements.

What is spatial-mode-based imaging?

Spatial-mode-based imaging is an alternative way of measuring light for recovering **sub-diffraction spatial information.**

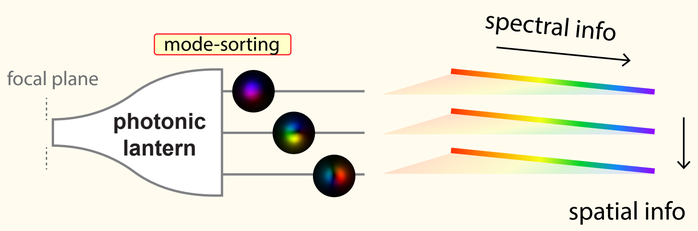
A mode-sorting device splits light according to spatial mode patterns, then photodetection follows.

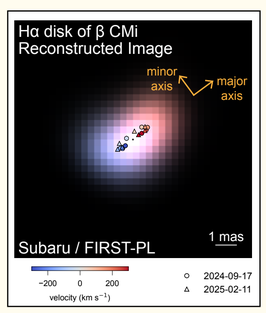
(Tsang et al. 2016; Kim et al. 2025)



Challenges identified from on-sky tests with *Passive* spatial-mode-based imaging

A standard photonic lantern was used as a mode-sorter to realize spatial-mode-based imaging spectroscopy at SCExAO.





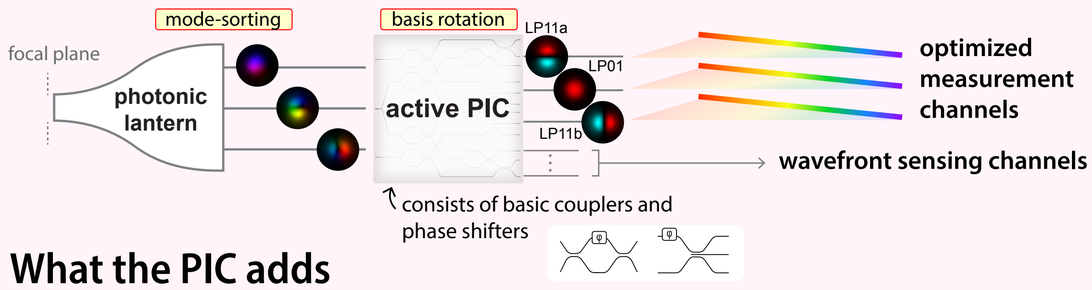
On-sky demonstration (Kim et al. 2025)

Challenges

1. Measurement modes are suboptimal
2. Misalignment and jitter introduce inefficiency and calibration challenges

Solution: *Configurable* spatial-mode-based imaging

An active photonic integrated circuit (PIC) enables rotation of the measurement basis via controlled interference between mode-sorter outputs.



What the PIC adds

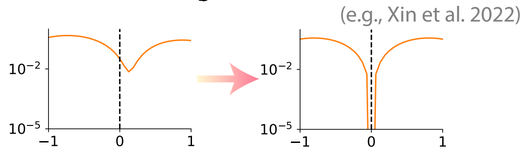
1. Measurement modes can be optimized by coherently mixing outputs
2. A fraction of light can be tapped and optimized for wavefront sensing to drive a control loop

Applications

Small-angle, moderate-contrast imaging

clean up mode-sorter imperfections to enable deeper **starlight suppression at small angular scales** (<λ/D)

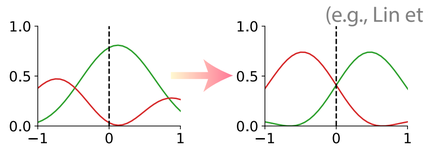
(e.g., Xin et al. 2022)



Wavefront sensing/control

introduce mixing to increase linearity & dynamic range for low-order wavefront sensing, enabling **closed-loop alignment control**

(e.g., Lin et al. 2023)



Superresolution imaging

optimize the measurement basis for recovering low-order image moments (e.g., centroid, extendedness) using symmetric & asymmetric modes

(e.g., Tsang 2018)

Efficient spectroscopy at high-contrast

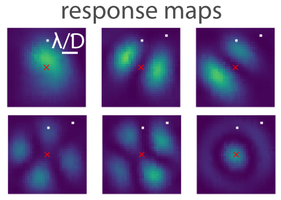
behind a coronagraph, optimize measurement modes for post-coronagraphic PSF near the inner working angle for efficient spectroscopic characterization of high-contrast sources (exoplanets)

(Guyon et al. in prep)

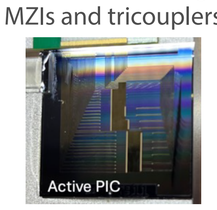
Laboratory Activity

We are working on demonstrating this concept in the PoRT testbed, combining a mode-selective photonic lantern (Xin et al. 2024) and an active PIC (Jovanovic et al. 2025).

6-port mode-selective lantern response maps



active PIC consisting of MZIs and tricouplers



(Jovanovic et al. 2025)

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- Xin et al. JATIS 10, 025001 (2024)

Acknowledgement

This work was supported by the National Science Foundation under Grant No. 2308360 and by NASA under Grant No. 80NSSC24K1559. We thank Sanny Ahmed and Greg Sercel for assistance with the laboratory setup and Harry-Dean Kenchington Goldsmith for simulations of PIC components. We also thank the SCExAO and FIRST team for on-sky operations that informed this work.

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