Photonic-Enabled ExoPlanet Spectroscopic Sensor (PEEPSS) for Wavefront Sensing and Imaging Spectroscopy on HWO

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HWO will need precise wavefront sensing to find exoplanets.

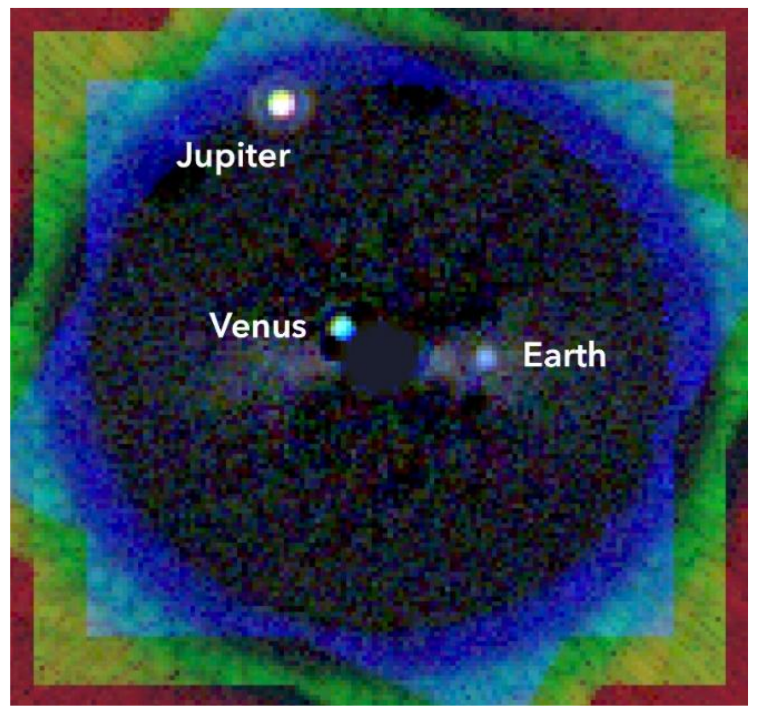

Fig. 1: Simulated HWO coronagraph image. The coronagraph redirects light from the host star to the inner (blocked in this image) and outer regions of the image. In between, there is an annulus where the contrast is maximized, called the "dark hole," containing the area of interest where we will look for exoplanets.

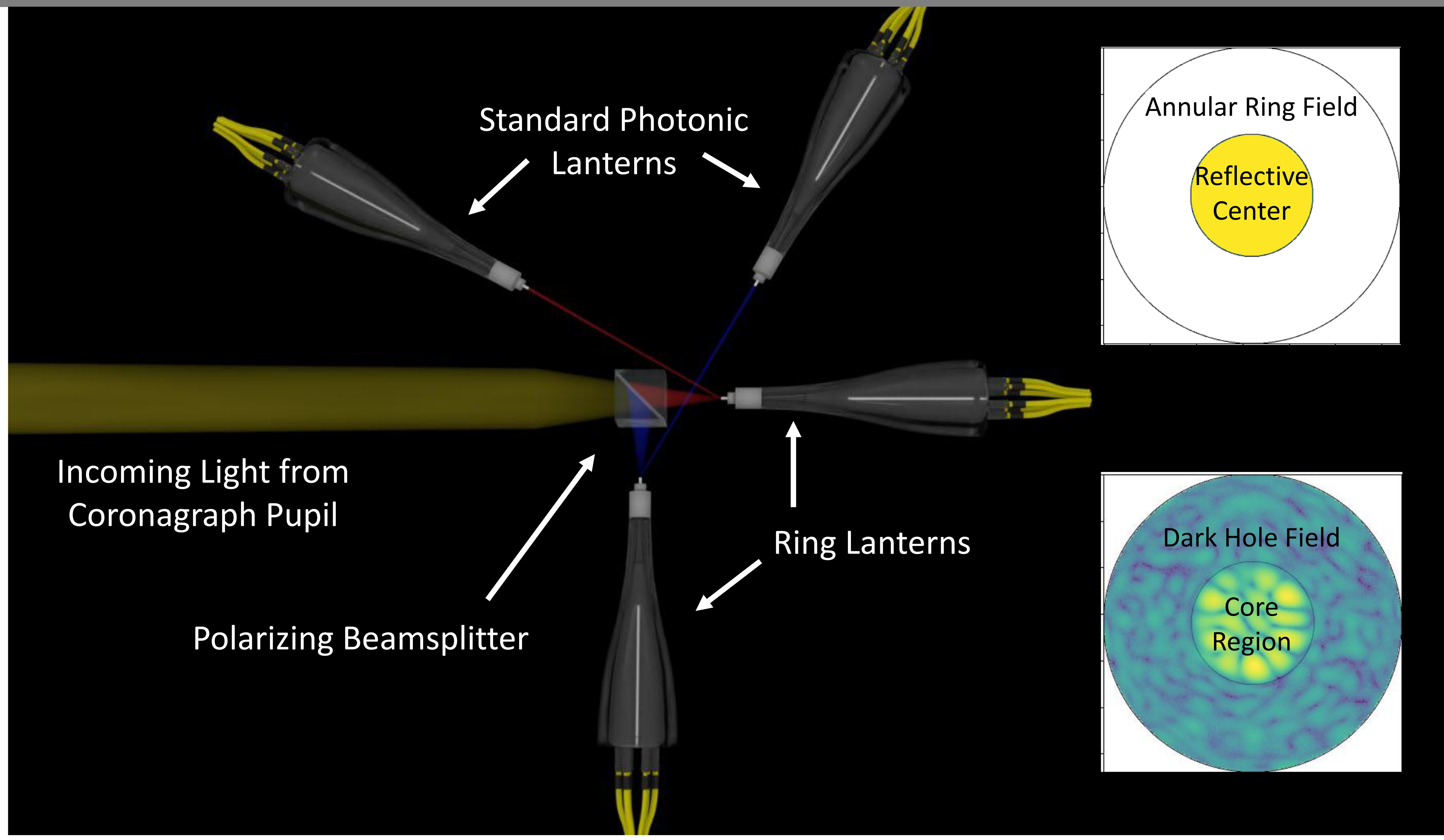

Fig. 2: Proposed PEEPSS schematic layout
The PEEPSS module will be placed at a coronagraph focal plane. Starting on the left, light from the coronagraph passes through focusing optics and a polarizing beamsplitter, before reaching the focus at the faces of the two ring lanterns. The dark hole couples to the ring lantern, while the central or "core" region reflects to another standard lantern. (Inset images) The top image shows a labelled representation of the face of the ring lanterns, while the bottom shows the same overlayed with a simulated coronagraph image.

Photonic Lanterns for HWO

Photonic lanterns act as mode multiplexers, splitting an incoming multimode image into a set of single mode beams for wavefront sensing. They can simultaneously act as robust, high efficiency couplers between an integral field and a single mode spectrograph.

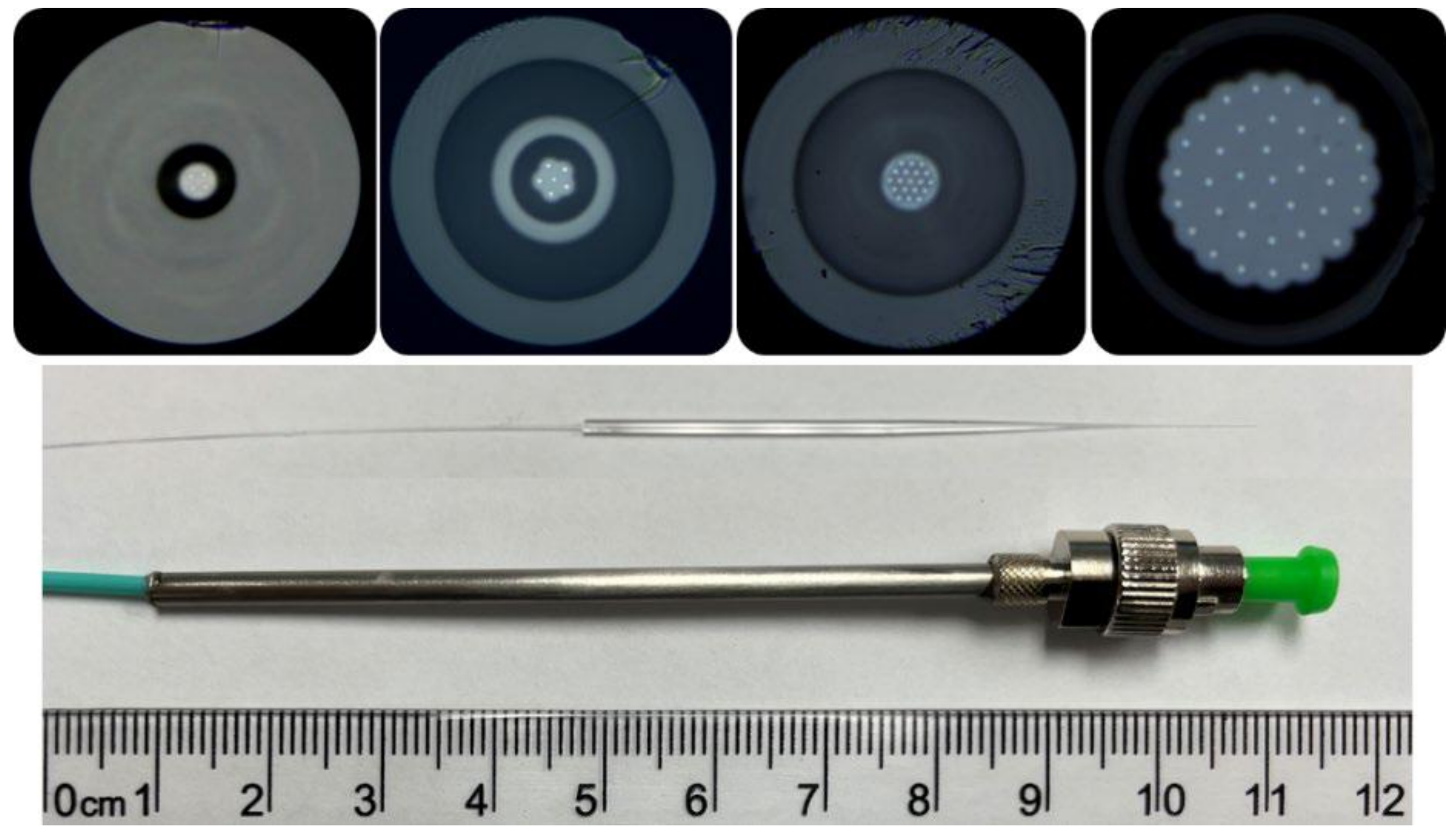

Fig. 3: CREOL-fabricated photonic lantern.
(top) Microscope cross-sections of various photonic lanterns fabricated at CREOL. (bottom) Sample bare photonic lantern, above a packaged and connectorized photonic lantern of the same type.

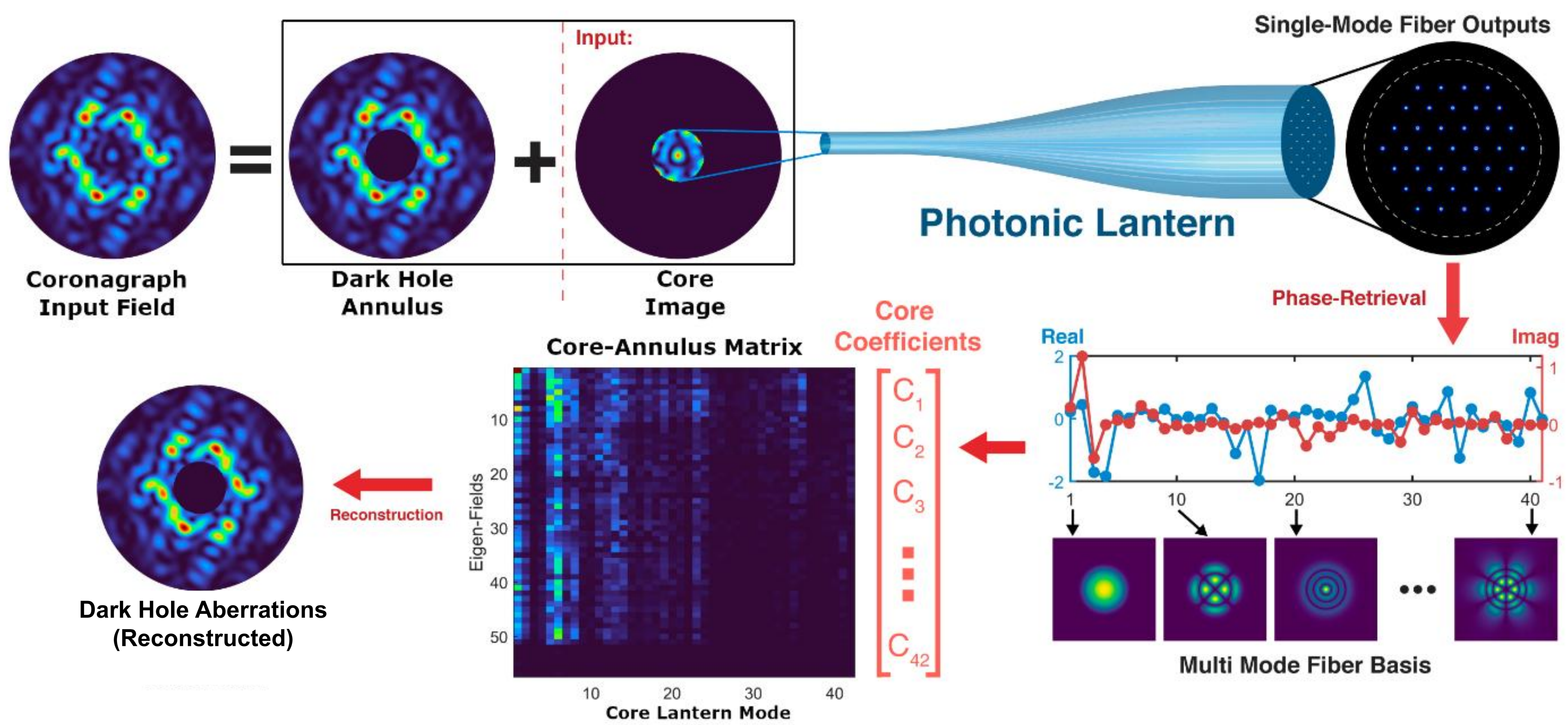

Fig. 4: PEEPSS wavefront sensing
The core region with residual light from the host star can provide sufficient information to reconstruct the dark hole, allowing simultaneous wavefront sensing (with the center region) and science observations (in the annulus). A conventional photonic lantern splits the core region into spatial mode outputs, giving us the phase and amplitude for each spatial mode via phase retrieval. Using a previously calculated transfer matrix to relate the core and the "eigenfields" (which describe the dark hole modes), we reconstruct the wavefront aberrations in the dark hole based solely on the light in the core.

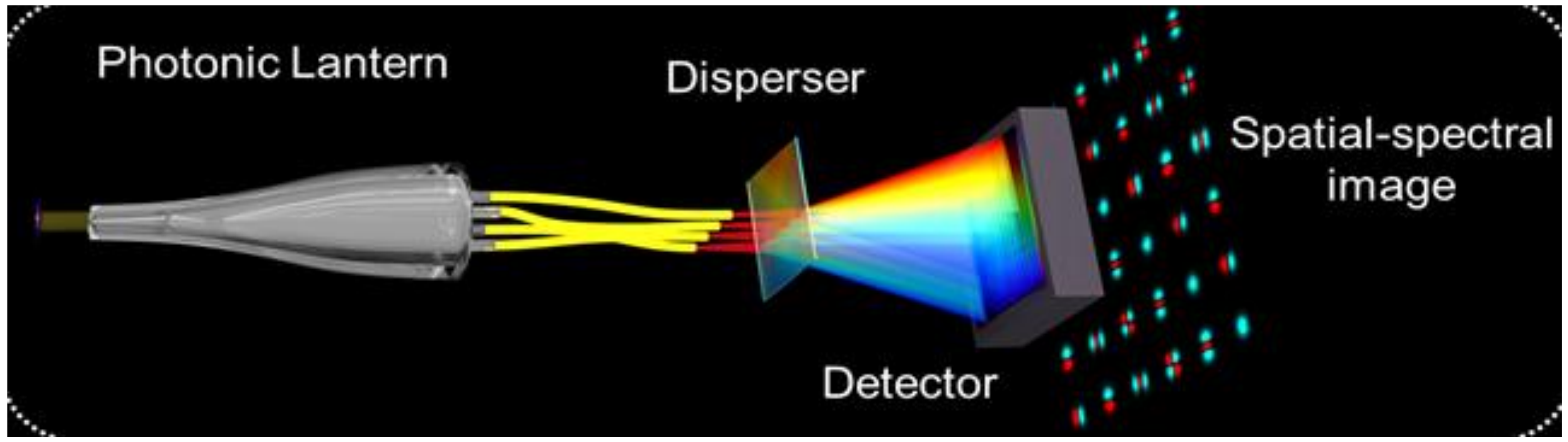

Fig. 5: Spectroscopy of the dark hole
Each of the individual outputs from each photonic lantern will pass through a spectrograph. For the dark hole spatial modes, we will be able to a) recombine them to create a complete image of the dark hole, and b) identify the modes relevant to any observed planets, providing their spectra as well.

Conclusions and takeaways

- Using a multi-lantern system for capturing and splitting the light from a coronagraph, PEEPSS will allow simultaneous science observations in the dark hole and wavefront sensing in the image core.
- PEEPSS will give HWO the capability to perform simultaneous **focal plane wavefront sensing**, and **imaging/spectroscopy** of exoplanets.

Acknowledgements

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