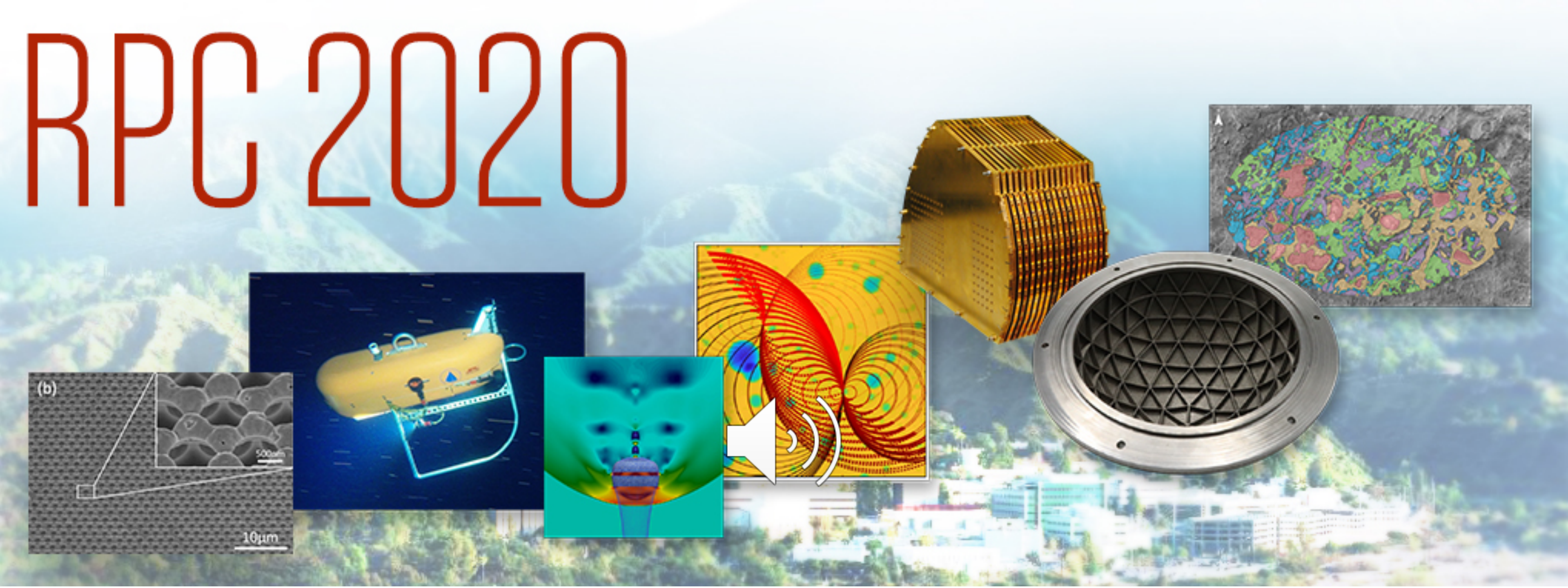

Virtual Research Presentation Conference

VORTEX FIBER NULLING FOR TARGETED EXOPLANET CHARACTERIZATION WITHIN THE DIFFRACTION LIMIT

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Program: Topical RTD

Assigned Presentation #032

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Introduction

Abstract

The objective of this project is to develop a new method for direct exoplanet observations known as vortex fiber nulling (VFN). By carrying out the first optical breadboard demonstrations of this concept and building a prototype system that may be deployed on current and future ground- and space-based telescopes, we will show the unique potential of the VFN technique for detecting exoplanets and studying their atmospheres. The advantage of VFN is that it allows for the detection and characterization of exoplanets that are orbiting too close to their star to be directly imaged; i.e. their angular separation is < ~lambda/D, where lambda is the wavelength and D is the telescope diameter. VFN combines a vortex phase mask and a single-mode fiber to reject light from the star whose noise contribution would otherwise inhibit spectral analysis of an exoplanet. Our aim is to demonstrate rejection, or “nulling,” of starlight by a factor of 1e-4 in the optical and infrared (IR) wavelength regimes. The IR prototype is designed to be compatible with the Keck Planet Imager and Characterizer (KPIC; PI: Mawet) instrument at W.M. Keck Observatory, where our device may be installed for on-sky use.

Problem Description

a) Context (Why this problem and why now)
Exoplanet detection and characterization requires the smallest possible inner working angle. Current and future facilities using traditional coronagraph techniques have inner working angle (IWA) beyond the diffraction limit, preventing the direct detection and characterization of a large fraction of exoplanet population (e.g. HZ around M-type star, giant exoplanets on Solar system scales in star forming regions, etc.). Moreover since the IWA scales with wavelength, spectroscopic characterization of planets detected at short wavelengths is prevented.

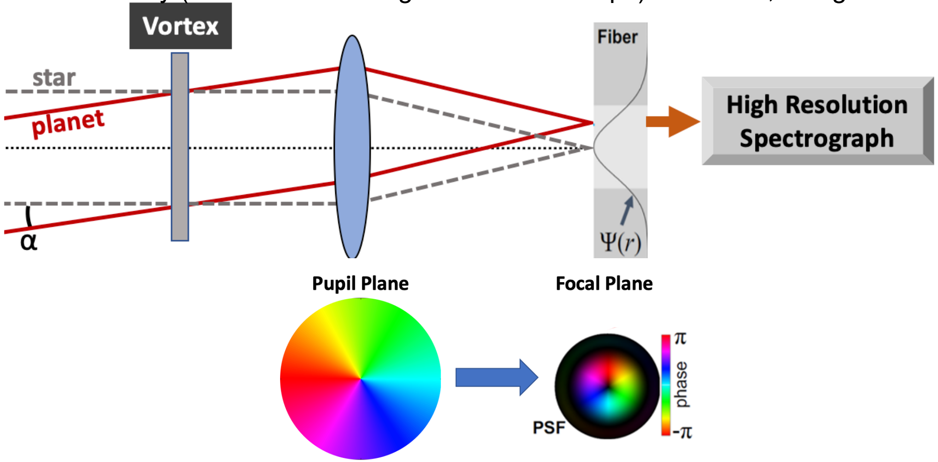
b) SOA (Comparison or advancement over current state-of-the-art)
The current state of the art in coronagraphy, as far as IWA is concerned is the vortex coronagraph. But even the VC can only provide an IWA around 2-3 l/D.

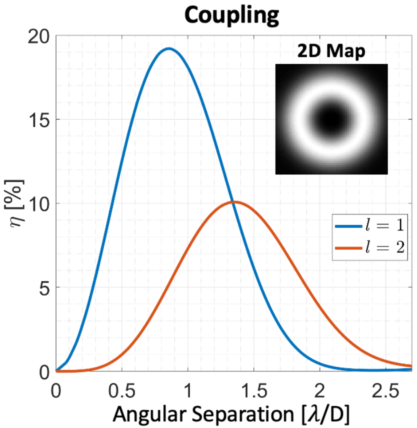
c) Relevance to NASA and JPL (Impact on current or future programs)
A primary goal of future space telescopes in the optical and near IR is to directly image exoplanets and study their atmospheres. VFN probes exoplanets that are otherwise inaccessible with high-contrast imaging instruments due to their relatively small angular separation from their host star. Since the inner working angle (~0.5 lambda/D) increases with wavelength, VFN also allows for a planet’s spectrum to be analyzed further into the IR. Thus, VFN has the potential to significantly improve the scientific yield of future NASA flagship astrophysics missions. VFN is compatible with a large range of telescope designs, including segmented and centrally- obscured telescopes, which are generally not favored for high-contrast applications.

Methodology

a) Formulation, theory or experiment description
The Vortex Fiber Nuller is a new concept reminiscent of the Bracewell Nulling Interferometer and related Fiber Nulling concept. It uses a Vortex Phase Mask of charge 1 or 2 in the pupil plane followed by a single mode fiber (SMF). The Vortex phase ramp induces a E-field distribution orthogonal to the fundamental propagation mode of single mode fiber, which nulls the on-axis coherent starlight. An off-axis planet PSF partially couples into the SMF, with its light propagated to a spectrograph for detection and spectroscopic characterization.

b) Innovation, advancement
The VFN, although based on nulling interferometry, is a new concept. The VFN architecture supersedes the Bracewell concept in that it does not require to define two rotating subapertures, thus making use of an entire telescope pupil. It is mostly insensitive to aperture geometry (contrary to traditional coronagraphs), and defines a centro-symmetrical transmission map around the central star. Any off-axis signal falling in this symmetrical transmission map is propagated to the spectrograph, and thus prior knowledge of the position angle of a planet is not necessary (immense advantage for RV follow-ups). The VFN, being an interferometer, provides a IWA within the diffraction limit.



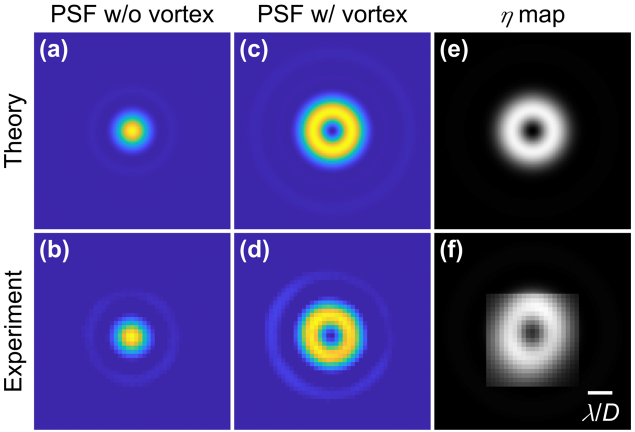


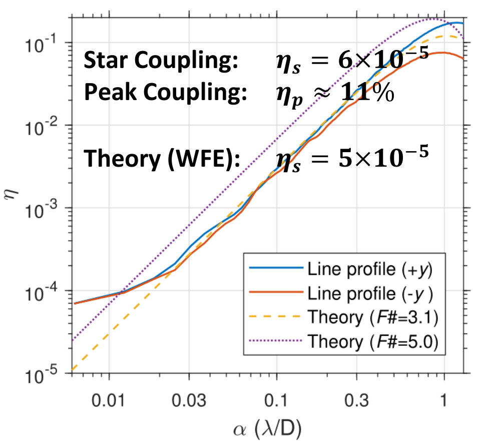
Results

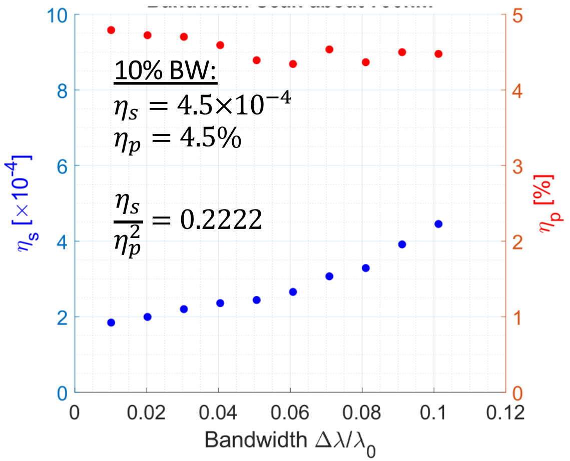
a) Accomplishments versus goals
Goal 1: demonstrate the VFN concept in the laboratory in monochromatic light
Goal 2: demonstrate the VFN in broadband light
Goal 3: procure a K-band Vortex mask and characterize it for inclusion into the Keck Planet Imager and Chararcterizer
All goals have been achieved.

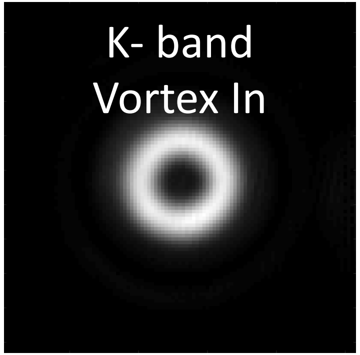
b) Significance
The VFN concept is demonstrated at a level sufficient for on-sky testing and science demonstration. The VFN is now baselined for KPIC and future Keck and TMT instrumentation.

c) Next steps
Integrate the K-band Vortex into the Keck Planet Imager and Characterizer at Keck Observatory for a science demonstration, and if successful a survey of nearby association and star forming regions.









Publications and References

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