Master thesis and internship[BR]- Master's thesis : Achromatic phase shifter in nulling interferometry for exoplanet detection[BR]- Integration internship

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Abstract

"Achromatic Phase Shifter (APS) in nulling interferometry for exoplanet detection" by Casimir Fayt. University of Liège (ULiège), Master's degree in aerospace engineering with a focus on space engineering, 2020-2021.

Nulling interferometry is a recent technology in exoplanet detection and has enormous potential for future discoveries. Only achieved in terrestrial telescopes, its implementation in space could give rise to a new momentum in exoplanet science. The main figure of merit of the nulling interferometer is the nulling ratio, which describes the intensity ratio between the bright and dark fringes.. Clear measurements imply a ratio greater than the radiance ratio between the star and the planet (typically in the order of 10^4).

The nulling ratio is deeply impacted by the phase shifter. In the context of implementing this technique within a new observation satellite, the different phase shifter concepts must be updated and carefully selected. This work is part of this approach.

Various existing concepts are compared before selecting the most promising candidates: dispersive prisms, Fresnel rhombs, and integrated optics. These three systems are investigated and simulated to obtain their performance. Several constraints such as size, scientific requirements, or manufacturing considerations are taken into account. The different mission sizes considered define four spectral bands across which the phase shifter must be tested: [0.3 - 0.7], [0.9 - 2.1], [1.5 - 3.5], [2.6 - 6.4] microns.

For the smallest mission sizes, wedge prisms and Fresnel rhombs seemed unsuitable for the size requirement. For larger missions, the wider spectral band implies long propagation in a medium such that the intrinsic material dispersion seems to become problematic. Those two concepts were, therefore, quickly discarded because of room considerations and spectral bandwidth, and considering the advantages offered by integrated optics.

Considering the integrated optics, an algorithm based on a mode solver for dielectric rectangular waveguide was computed. A polynomial fit of the effective index difference between waveguides of different widths allowed to define a matrix system. Solving this system provides the length of the elements resulting in the desired phase shift as achromatic as possible. Integrated phase shifters in silica of fewer than four centimetres could provide the required rejection ratio for the two first spectral bands. For the two larger bands, the integrated optics do not meet the requirement within a technically acceptable size. The mirror approach seems the most promising concept for those spectral bands because of the intrinsic achromaticity of metallic reflections.

Keywords

Achromatic phase shifter, integrated optics, satellite, nulling interferometry, exoplanet, astronomy.