

Dark fringe interferometry: Multi-beam configuration of the Alcatel nulling interferometer MAII and recent results

Christophe Buisset^{1,2†}, Xavier Rejeunier²,
Yves Rabbia¹, Cyril Ruilier², Marc Barillot², and Anders Karlsson³

¹O.C.A., Dpt GEMINI, UMR CNRS 6203, Av. Copernic, 06130 Grasse, FRANCE
email: Christophe.Buisset@obs-azur.fr

²Alcatel Alenia Space, Cannes, FRANCE

³ESA, Estec, Noordwijk, The NETHERLAND

Abstract. Direct detection and spectroscopic characterization of earth-like exoplanets require to eliminate the starlight in the recorded signal at a rejection level (collected flux / residual flux) around 10^6 in the thermal infrared domain. Another need is to reach angular resolution in the range 0.1 to 0.01 arcsec. In this context, nulling interferometry is recognized as the preferred instrumental approach. In the framework of the ESA-Darwin mission, preliminary studies for nulling systems have been initiated, the prime goal to achieve being mastering nulling process. In this purpose, Alcatel Space has developed a nulling test-bench, operating in near infrared ($1.55 \mu\text{m}$), not only to demonstrate capability of obtaining an appropriate rejection level but also to study and characterize the use of emerging techniques. The Darwin system will ultimately benefit from these results. In this paper, we report the most recent configuration of the Alcatel Space nulling breadboard which uses the multi-beam recombination technique, current baseline for Darwin. The results obtained with this version shows rejection performance at nearly 10^5 (stable level) with a polychromatic source ($\lambda = 1.55 \mu\text{m}$, $\Delta\lambda = 80 \text{ nm}$).

Keywords. Exoplanets, Direct detection, Nulling interferometry, Multi-beam recombination, ESA-Darwin

1. Introduction

In the framework of the DARWIN ESA mission (direct detection and spectral characterization of earth like exo-planets)(ESA(2000)), Alcatel Alenia Space has developed the test bench MAII which first intended to demonstrate the ability of obtaining high and stable rejection ratio $\rho \approx 10^6$. It also serves for testing emerging technologies via ESA contract and acquiring an experience in the field of nulling interferometry so as to develop a cryogenic version of the bench, operating at $\lambda \approx 10 \mu\text{m}$.

The MAII test bench currently operates at $\lambda \approx 1.55 \mu\text{m}$ (telecom spectral domain), fiber and integrated optic technologies being well developed in this wavelength domain. This test bench has already demonstrated the ability of obtaining rejection ratio $\rho \approx 10^5$ (monochromatic) and $\rho \approx 10^4$ (polychromatic) using an integrated optic combiner (Weber *et al.* (2004)).

We present a new configuration of the MAII bread board in which the modal filtering and recombination are made using one single-mode fiber. In a first part, we describe the breadboard global architecture. In a second part, we focus on main MAII subsystems

† Present address: Observatoire de la Côte d'Azur, Avenue Copernic, 06130 Grasse, FRANCE

and their functionality and in a third part, we present the nulling results obtained in February 2005.

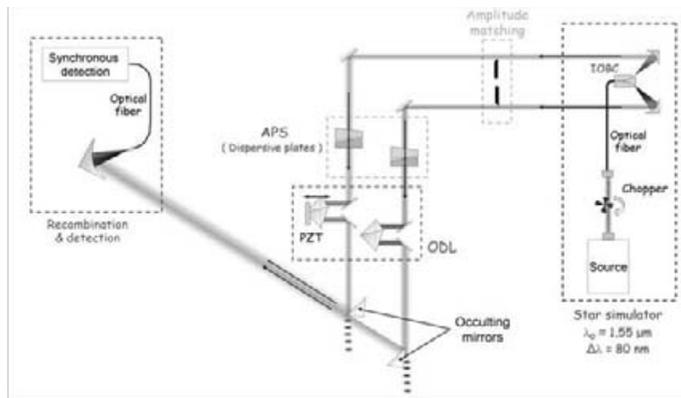


Figure 1. MAII breadboard.

2. The breadboard

The MAII breadboard is represented on Figure 1. It consists of a 2-arm interferometer in which an achromatic π -phase shifting between the fields that will interfere. High contrast interferometry needs for a fully symmetric design (Serabyn (2000)), implying that same optical elements must be present along each arm of the interferometer.

The breadboard is composed of three parts : the star simulator, the central part of the interferometer and the recombination and detection part. The central part of the interferometer contains the elements needed for introducing the achromatic π -phase shifting and matching the amplitude and phase of the fields that will interfere. The polarization matching is achieved by an accurate alignment of the optics what leads to a differential rotation angle of polarization of about 0.1 degree. In the following part, we describe the functionality of each subsystem of the breadboard.

2.1. Star Simulator, amplitude matching and OPD matching

The light emitted by the source enters the integrated optic component (IOBC) via a single mode optical fiber. The IOBC delivers two beams collimated by off axis parabolas. These beams stand for the output beams of two telescopes. Because of the birefringent behaviour of the IOBC, only simple polarization measurement can be done.

Knife edges are translated inside the beams to reach the amplitude matching. With the use of high precision translation stage, relative flux difference between the beams is less than 10^{-3} .

Two identical Optical Delay Lines (ODL) are installed along each arm of the interferometer. These ODL are equipped with a corner cube instead of the classical rooftop. The OPD matching is reached by translating the corner cube along one arm of the interferometer. On the other arm, the similar but static delay line maintains the symmetry of the interferometer. The OPD is manually and real-time adjusted.

2.2. π phase shifting and chromatic correction (APS)

The Achromatic Phase Shifter (APS) is composed of 2 wedged dispersive plates of different materials installed along each arm of the interferometer. A convenient combination

of the plates thickness and the use of the ODL yields the achromatic π phase shifting between the arms of the interferometer.

2.3. recombination and detection

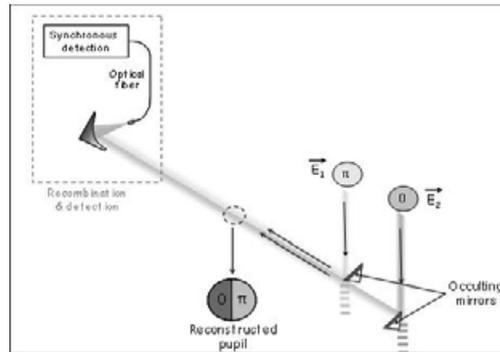


Figure 2. MAII breadboard.

Multibeam mode for recombination consists of:

- Synthesizing a “reconstructed pupil” from 2 half-pupils. Each half-pupil is taken from each arm of the interferometer by occulting mirrors. Consequently, a π phase shifting remains between each part of the reconstructed pupil.

- Recombining and filtering the fields with unique single-mode fiber. An off-axis parabola makes the beams focused at the entry of the fiber.

3. Results

In February 2005, we obtained $\rho = 6.7 \times 10^4$ as the best single polarization nulling performance for a polychromatic source with 5% of spectral bandwidth. Values higher than $5 \cdot 10^4$ appear on several time intervals of typically 5 seconds.

4. Conclusion

We have presented the latest version of the MAII breadboard used for demonstrating the feasibility of the multibeam-recombination. The results we obtained demonstrate the feasibility of this kind of recombination for obtaining high rejection ratio, compatible with the ESA-DARWIN performance requirement. To go further, replacement of the IOBC by a non birefringent source and automatic control of the OPD should improve the null performance and its stability.

References

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All photographs: Laurent Thareau [l.thareau@free.fr].