Integrated optics beam combiner at 2.2µm for astronomical interferometers

Laurent Jocou (2), Pierre Labeye (1), Axelle Nolot (2), Sébastien Lardenois (3), Steve Oliver (3), Karine Perraut (2), Jean-Philippe Berger (4), Frank Eisenhauer (5), Valérie Lapras (1), and the Gravity Consortium

This paper presents the design, technological realization, and characterization of a four telescopes combiner in silica on silicon integrated optics for Gravity, a second generation interferometric instrument that will combine four telescopes at the VLTI (European Southern Observatory) in the spectral band 2µm to 2.4µm. The instrument is developed to study general relativity effects around our galactic center black hole. Its concept is based on two equivalent beam combiner instruments, one for scientific target, the other for freezing the atmospheric effects on the fringe patterns. This work was performed through collaboration between CEA-LETI, IPAG, and CIP Technologies.

**The IO Beam Combiners:** The fringe coding is a pairwise simultaneous ABCD sampling of the six baselines. The principle of the circuit (designed with our partner CEA/LETI) is the following: two successive couplers with theoretical coupling ratios of 66/33 and 50/50 respectively allow the light to be split in three beams that feed the beam combination cell. This cell embeds an achromatic π/2 phase shifter to create four outputs in phase quadrature. Each combiner has therefore 24 outputs (6 baselines × 4 A,B,C,D samples).

Amongst the possible silica on silicon technologies, Flame Hydrolysis Deposition (FHD) was chosen for the waveguide sandwich structure of Ge-doped silica between pure silica buffer layers to provide the highest material transparency in the K-band. Waveguide geometry was defined by contact photolithography.

**Results:** We show below the photometric and interferometric performances measured in lab on the 4 telescope ABCD combiner prototypes. The interferometric results obtained on 4T beam combiners show that all the contrasts are high and that all the ABCD phase shifters are very close to the specifications, confirming that i/ the current design is the good one and ii/ the CIP technology is able to comply with the Gravity interferometric requirements. We are now in an optimization process on the technological parameters. All our works (measurements coupled with numerical simulations) allow us defining the next steps for the Gravity beam combiners. We have to increase the index difference (from about 0.012 to 0.015) and to slightly enlarge the waveguide.

<table>
<thead>
<tr>
<th>Best for 4T beam combiner</th>
<th>Transmission (%)</th>
<th>Contrast (%)</th>
<th>Phase shift (°)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>49</td>
<td>&gt; 92</td>
<td>90 +/− 5</td>
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**Status:** The “preliminary design phase” has been completed in September 2010. The “Final Design Phase” should be completed by end 2011. The Gravity first light is planned in 2014.

Contact: laurent.jocou@obs.ujf-grenoble.fr