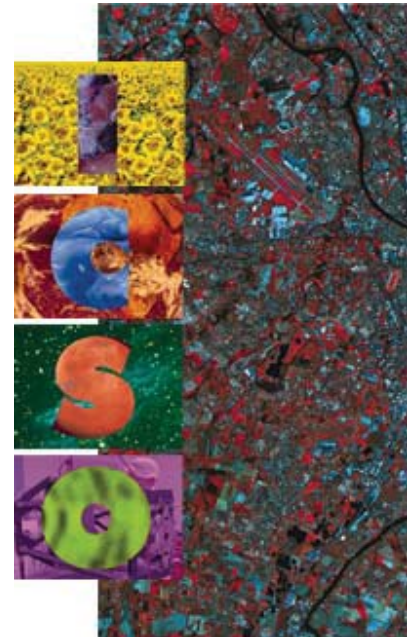# International Conference on Space Optics—ICSO 2000

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Spectral behavior of integrated optics asymmetric y-junction used for optimizing a planar optics telescope beam combiner

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SPECTRAL BEHAVIOR OF INTEGRATED OPTICS ASYMMETRIC Y-JUNCTION USED FOR OPTIMIZING A PLANAR OPTICS TELESCOPE BEAM COMBINER.

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ABSTRACT - Astronomical aperture synthesis requires to combine beams coming from telescopes, with constraints on mechanical and thermal stability, accuracy on the measurement of the interferences visibility. One adapted way for solving the problem is integrated planar optics. A first two telescope beam combiner made by ion exchange technique on glass substrate and build with symmetric Y-junction provides laboratory white light interferograms simultaneously with photometric calibration. In order to increase the interferometric signal without loss of photometric output, we propose to replace symmetric Y-junctions by asymmetric ones. In this paper, we report the conception, the manufacturing and the characterization of asymmetric Y-junction realized by ion exchange on glass substrate. The specific application of astronomical interferometry required the characterization of such component in term of spectral behavior, so we report the simulation and the measurement of asymmetric Y-junction response versus wavelength.

1. INTRODUCTION

Integrated optical components have now their own place in many applications especially optical communication systems. More recently, they have been successively used in astronomical applications [Coud 94], [Malb 99], [Berg 99], [Hagu 00]. In this matter, the integrated optical Y-junction can be efficiently used to perform the combination process over a wide range of wavelength. However, the Y-junction does not exactly replace the bulk beam splitter / combiner as it enables to combine in-phase beams only while out of phase beams (beams with 180° phase shift) are lost as radiation in the output. In order to increase the interferometric signal, two way are possible. One way consists in replacing the symmetrical Y-junction used for the combination by a multimode interference structure (MMI) [Elsa 99] which permits to keep all the interferometric signal. One other way consist in decreasing the photometric signal by using asymmetric Y-junction. The new application of integrated optics components for stellar interferometry implies their use throughout a typical spectral bandwidth of 0.3-0.4μm.

The first section present the design of the asymmetric Y-junction and the process of fabrication. The behavior of the structure simulated by BPM calculation is described in section 2. The optical set-up used for the characterization of the component - losses (coupling, propagation, intrinsic losses of the

optical functions), single mode behavior and ability to operate throughout a wide spectral bandwidth - and the results obtained are summarized in the section 3.

2. INTEGRATED OPTICS ASYMMETRIC Y-JUNCTION

2.1- Design of the asymmetric Y-junction

The 10 mm $\times$ 36 mm component is schematically depicted in Fig.1. 18 asymmetric Y-junctions and 4 single mode straight waveguides are realized on the same substrate. The parameter of the junction is the angle α which varies between 0.5 and 4.5° . The curvature radius has been chosen in order to minimize the curvature losses (R> 20 mm).
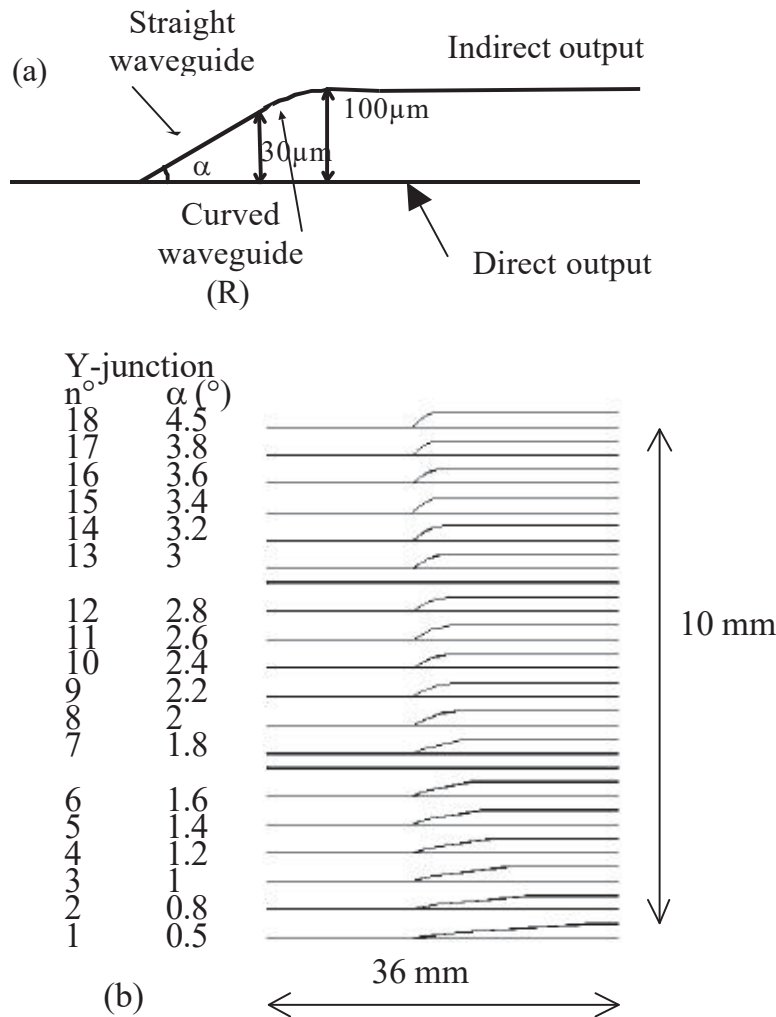

Fig. 1 : (a) Design of the asymmetric Y-junction.
(b) Scheme of the mask including 18 asymmetric Y-junctions

2.2- Simulation results

The behavior of the devices have been simulated using 2D BPM calculation (Prometheus BBV software). The diffused index profile was approximated by a step index with an index substrate of 1.505, an increase of index of 0.006 and a waveguide width of 5µm. In those conditions, we have calculated the variation of the power fraction in the direct and the indirect output versus the angle of the asymmetric Y-junction (fig. 2).
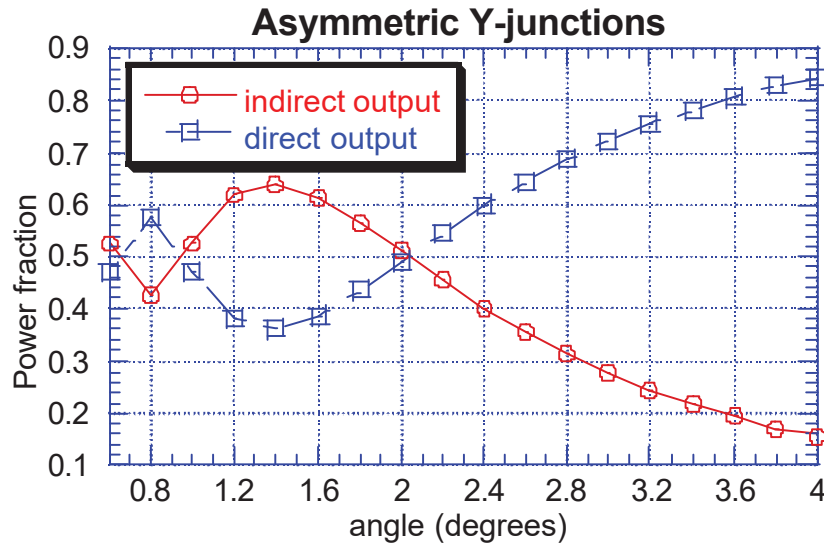
Asymmetric Y-junctions

Fig. 2 : Variation of the power fraction at the outputs of the asymmetric Y-junction versus the angle.

The figure 3 gives the variation of the power fraction in the direct and indirect outputs versus the wavelength (between 1.43 and 1.77μm, the near-infrared H atmospheric band) for asymmetric Y junctions with an angle between 0.6° and 4°. The waveguide defined for the simulation is single mode for a wavelength superior to 1.32 μm, so for the whole H band. The power fraction in the direct output of the Y-junction varies from 38.6% to 38%. It corresponds to a standard deviation of 0.19. In the indirect output, the power fraction varies between 60.8 and 61.1%, which correspond to a standard deviation of 0.08. Those results are similar for the other asymmetric Y-junctions.
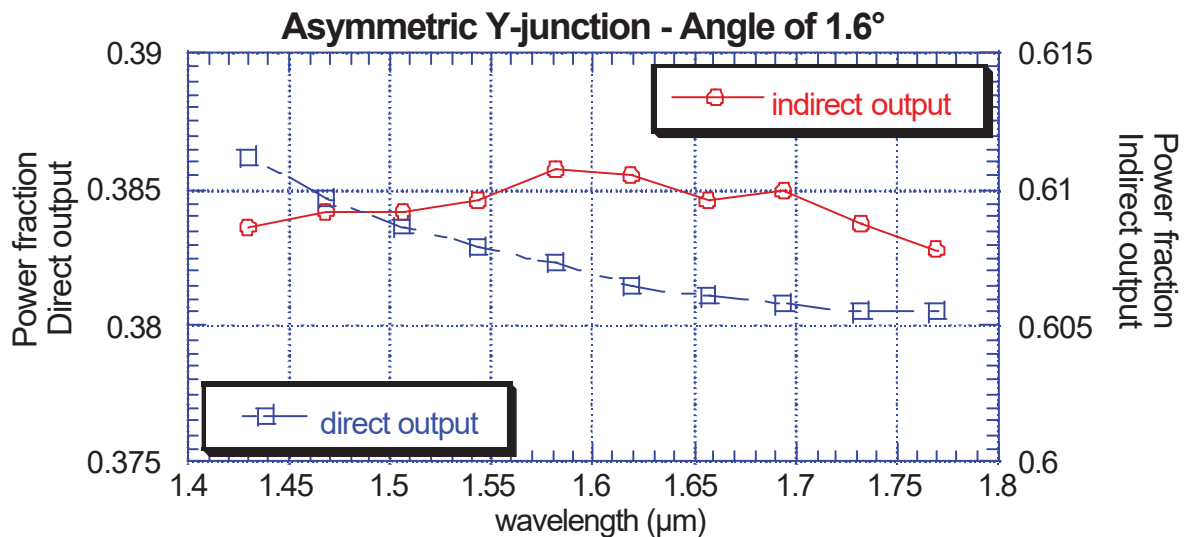
Asymmetric Y-junction - Angle of 1.6°

Fig. 3 : Variation of the power fraction in the two outputs of the asymmetric Y-junction (angle of 1.6°) versus the wavelength.

In conclusion, the designed structure are compatible with a wide band application. The chromatic dependence of the asymmetric Y-junction is less than 1.6% for the H band.

2.3- Ion exchange on glass technology

The method used to build integrated optics waveguide on glass substrate is the ion exchange [Rama 1988]; [Ross 1989] : the Na^+ ions of a glass substrate are exchanged by diffusion process with ions (K^+, Tl^+, Ag^+) of molten salts. The local modification of the glass chemical composition increases

the refractive index at the glass surface and the optical planar waveguide is created. By standard photo-masking techniques, the ion exchange can be limited and a channel waveguide is thus created. Since ion exchange only occurs at the surface of the glass, the last step of the process consists in embedding the guide by forcing the ions to migrate inside the substrate with an electric field.

Integrated optics components designed for microsensor or telecommunication applications operate at wavelength that correspond to atmospheric transmission bands (0.8µm for the I band, 1.2µm for the J band, 1.5µm for the H band, 2.2µm for the K band). The assymmetric Y-junction are made by silver-ion exchange upon a special silicate glass substrate. The technological parameters are chosen to provide single mode waveguides throughout the entire near-infrared H atmospheric band (1.43-1.77µm). The results report herein describe a component made by the GeeO Consortium (Grenoble, France).

3.   MEASUREMENT RESULTS

3.1- Experimental measurement of optical losses

- *Coupling losses*

To estimate the coupling efficiency at the fiber-waveguide interface, we measure the radius of the fundamental mode by near-field imaging (fig. 4). The waveguide are quasi-circular with a width at 1/e equal to 5.5×6.5µm compared to the optical fibre 8.5×8.5µm. These dimensions lead to a coupling efficiency of 87.6% (coupling losses of 0.57dB).
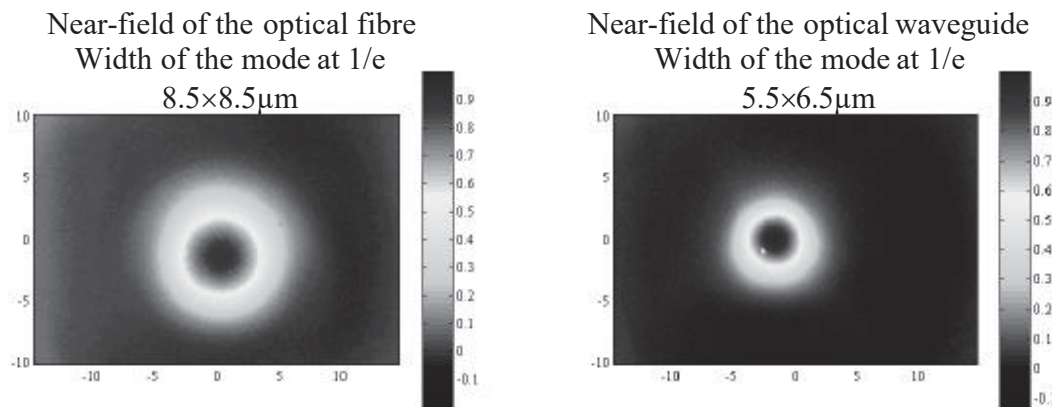

Fig. 4 : Near-field of the optical fibre compared with thus of the optical waveguide at the wavelength of 1.55µm

- *Propagation losses*

With ion-exchange technology, propagation losses depend on the diffused ions and the conditions of diffusion. For Ag^+ ions, these losses remain less than 0.1 dB/cm.

- *Intrinsic losses from the optical function*

Depending on the design of the integrated optics asymmetric Y-junction, light can be lost because of uncontrolled radiated modes. The junctions includes additional losses estimated at 0.8 ± 0.2dB, which corresponds to a transmission of $83 \pm 4.5\%$ compared to a the straight waveguide. The measurements have been made on three different samples.

3.2- Power division of the asymmetric Y-junctions

The measurement are performed as follows : the flux of a laser diode at 1.55µm is coupled into a single mode fiber that excites the input waveguide of the component. The near-field of the two outputs (direct and indirect) of the asymmetric Y-junction and of a straight waveguide are then imaged on a CCD detector and the measured powers are compared. The power division in the two

outputs was measured for three different samples versus the angle of the asymmetric Y-junction (fig. 5). The measurements are reproductible and are in good agreement with the simulation results.
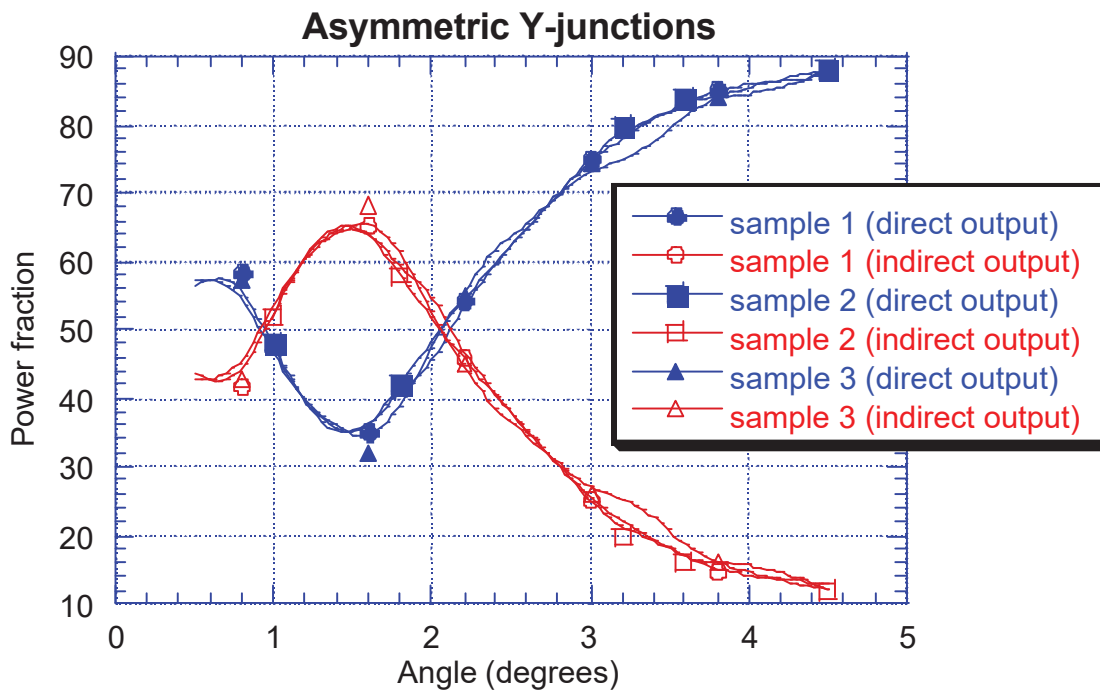

Fig. 5 : Power division measurements versus the angle of the asymmetric Y-junction.

3.3- Spectroscopic measurements and single mode behaviour

The measurement are performed as follows : the flux of a broadband white-light source is coupled into a multimode fiber that excites all waveguide mode at all wavelengths. Another multimode fiber carries the output signal to the spectrometer, whose wavelength range is 0.6-1.65µm with a 5nm spectral resolution. The spectra are calibrated with the spectral response of the source directly measured at the output of the multimode injection fibre. The spectral response of the junction is also calibrated with the spectrum of a straight waveguide obtained under the same technological conditions. We can thus separate spectral effects of the waveguide and the junction.

The maximum of the flux after λ= 1µm in figure 6 is characteristic of the transition between bimodal and single mode behavior. This proves the existence of single mode behavior of the waveguide beyond 1µm and therefore over the whole H band.
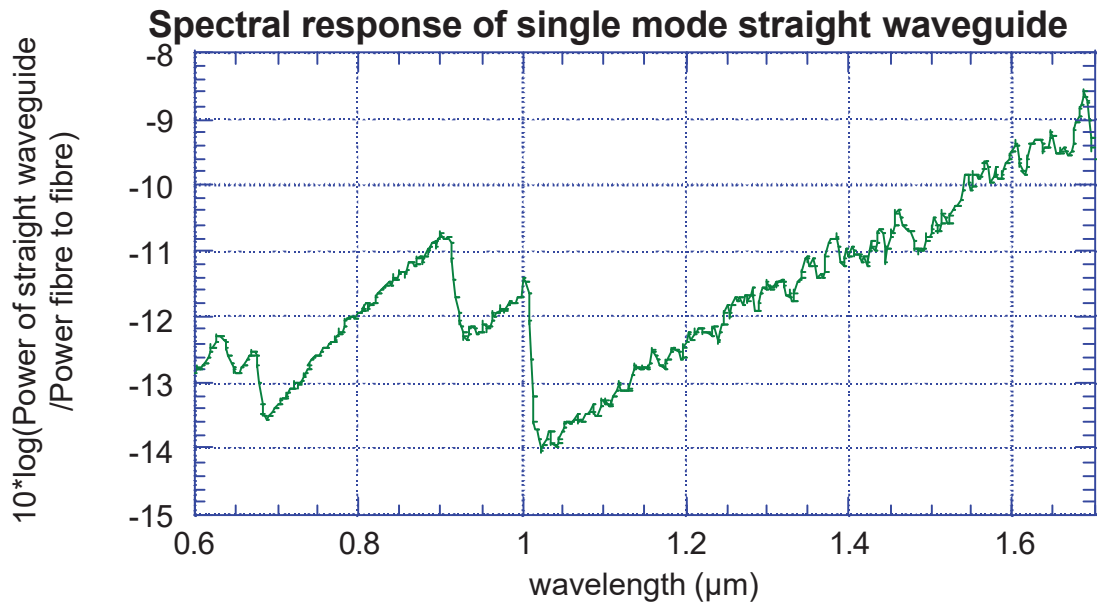
Spectral response of single mode straight waveguide

Fig. 6 : Spectrum of the straight waveguide (see text for details).

Figures 7 and 8 shows the ratio between the asymmetric Y-junction spectra (direct and indirect output) and a straight waveguide for a given illumination. For $\lambda \geq 1.05$ µm this ratio is constant near 0.6 for the indirect output and 0.3 for the direct output, showing the quasi achromatic response of the asymmetric Y-junction from 1.05 to 1.65 µm.
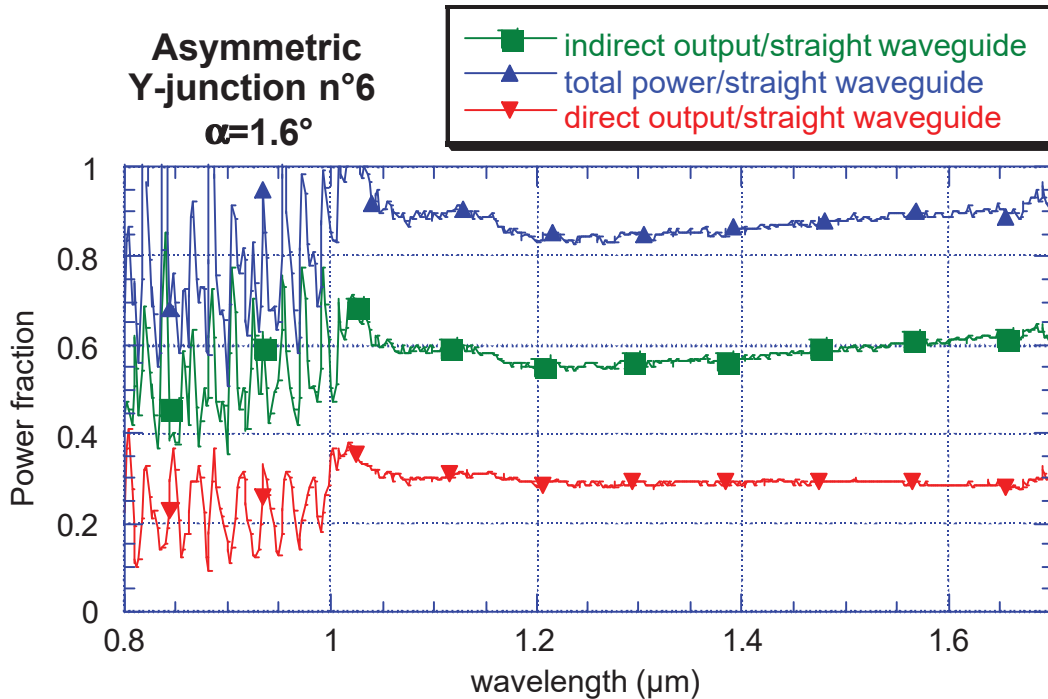

Fig. 7 : Spectral response of the asymmetric Y-junction compared with a straight waveguide.
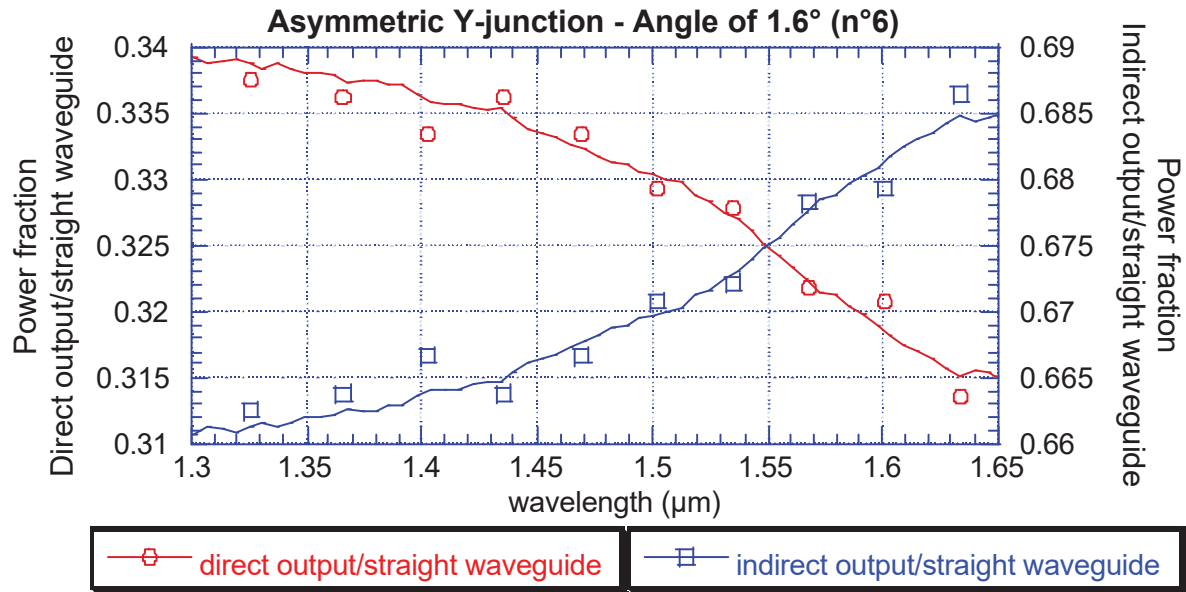
Asymmetric Y-junction - Angle of 1.6° (n°6)

Legend: direct output/straight waveguide — indirect output/straight waveguide

Fig. 8 : Quasi achromatic spectral response of the asymmetric Y-junction compared with a straight waveguide.

4. CONCLUSION AND PERSPECTIVES

Table 1 : Summ up of theoretical and measurement results.

Asymmetric Y-junction	Number 6	Number 18
Angle	1.6°	4.5°
Theoretical results		
Power fraction in direct output	38.5	88.2
Power fraction in indirect output	61.5	11.8
Standard deviation of the power fraction versus wavelength (H band)		
Direct output	0.19	0.7
Indirect output	0.08	0.6
Measurements at 1.55µm		
Power fraction in direct output	33.5±1.5	87.5±1.5
Power fraction in indirect output	66.5±1.5	12.5±1.5
Standard deviation of the power fraction versus wavelength (1.3 to 1.65µm)		
Direct output	0.3	0.6
Indirect output	1.9	0.4

The table 1 resumes and compares the results obtained for two different asymmetric Y-junctions. We see a very good agreement between the results obtained for a large angle asymmetric Y-junction. The quasi achromatic response of the junction (standard deviation minor than 0.6) is verified and we can now use these devices in order to optimize the design of the integrated optics astronomical combiners.

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