Characterization of Image Slicers

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Abstract

Image slicers have become essential equipment in the field of astronomy, particularly for Integral Field Spectroscopy (IFS). The design and manufacture of an Image Slicer presents many technical challenges and is complex to achieve. Thus, following its fabrication, characterization of the image slicer is necessary to ensure that it meets the established specifications. A series of metrological tests need to be developed to validate the optical performances.

Integral Field Unit

IFS is a technique to study extended objects such as distant galaxies and extra-solar planets in a single shot of the spectrum of a complete field of view. This is done by using an instrument called the Integral Field Unit (IFU). Figure 1 shows an example of an Image Slicer IFU that we are working on. (See table 1 for the image slicer specifications).

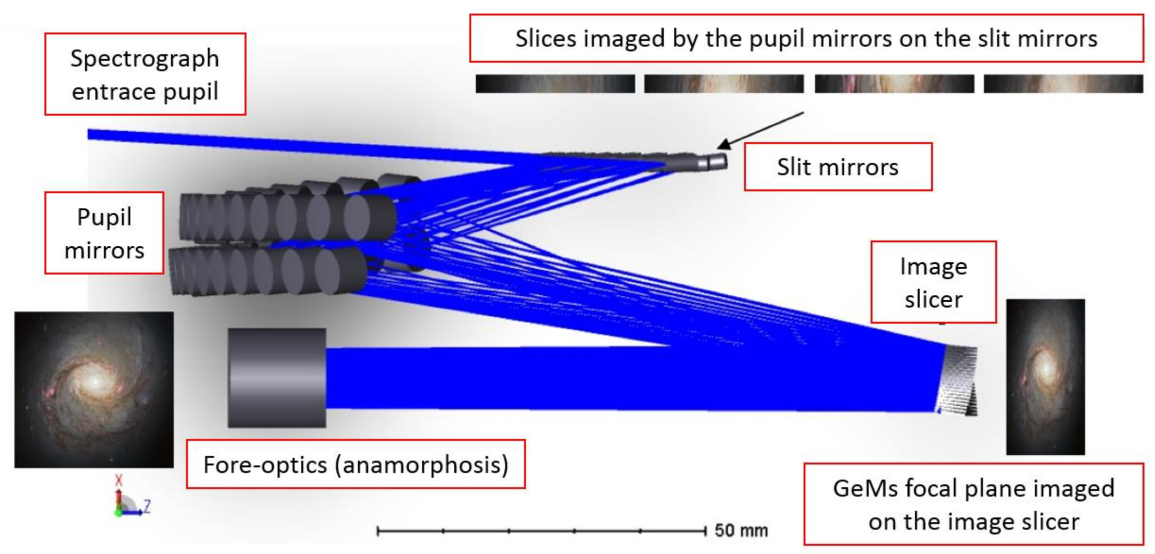

Figure 1 –Design of an Image Slicer IFU for GIRMOS instrument. [Credit: Tristan Chabot]

The working principle of this type of IFU is detailed in two conjugations: the pupil conjugation (Figure 2 – left) and the field conjugation (Figure 2 – right).

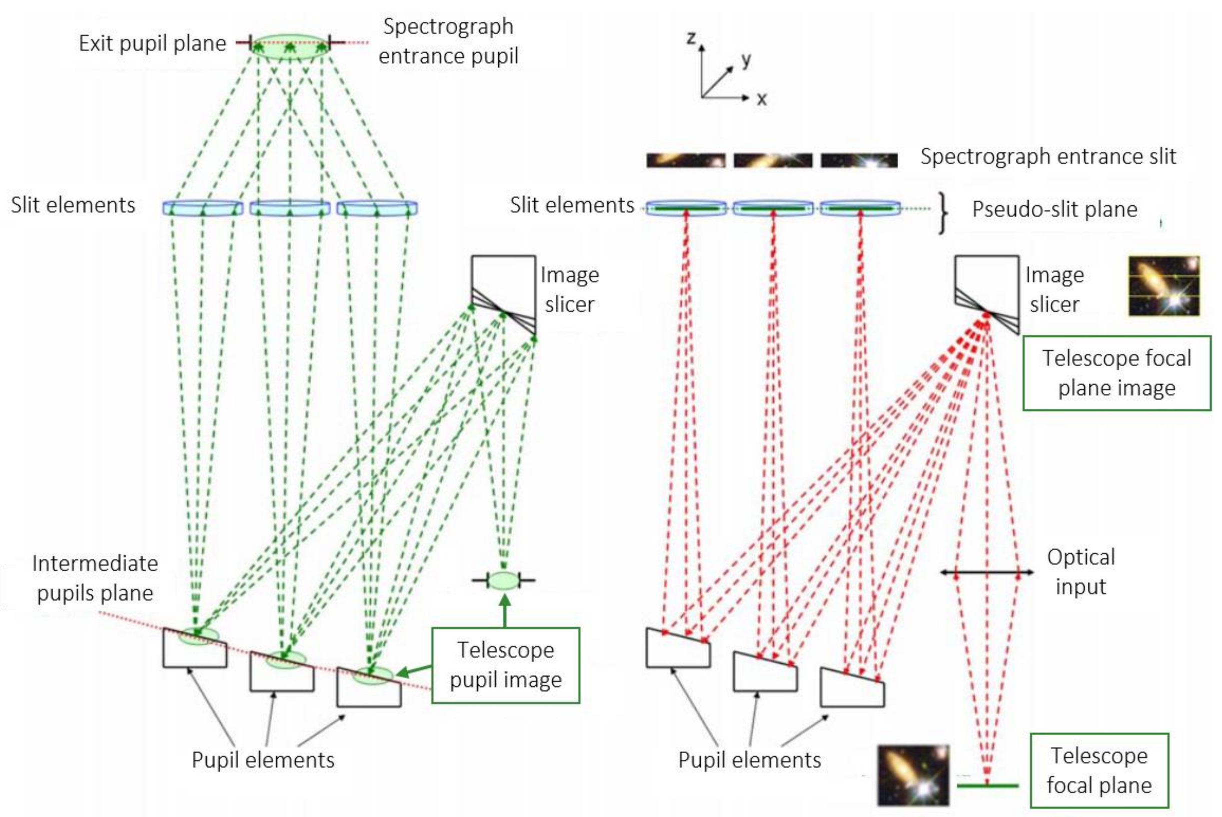

Figure 2 – Working principle of Image Slicer IFU. [1]

Image Slicer

The image slicer is the central element of the IFU. It consists of a stack of thin segments, each having a different angle precisely chosen in order to avoid the overlap of the spectra during the dispersion.

The series of metrological tests will be on a part of the image slicer (6 slices) manufactured by the team of the AOFI at Université Laval. (see Figure 3)

Table 1 – Image Slicer specifications

Number of slices	Width of slices	Length of slices	Radius	Material	Machining method
6	$1\ mm$	$21\ mm$	$800\ mm$	Aluminum	Diamond turning (Tip: $50\ \mu m$ Step-Size: $5\ \mu m$)
Tilt around x			Tilt around y		
$[-2.783, -1.866, -0.929, 0, 0.926, 1{,}864]$			$[-4.477, -6.453, -4.329, -6.304, -4.186, -6.163]$		

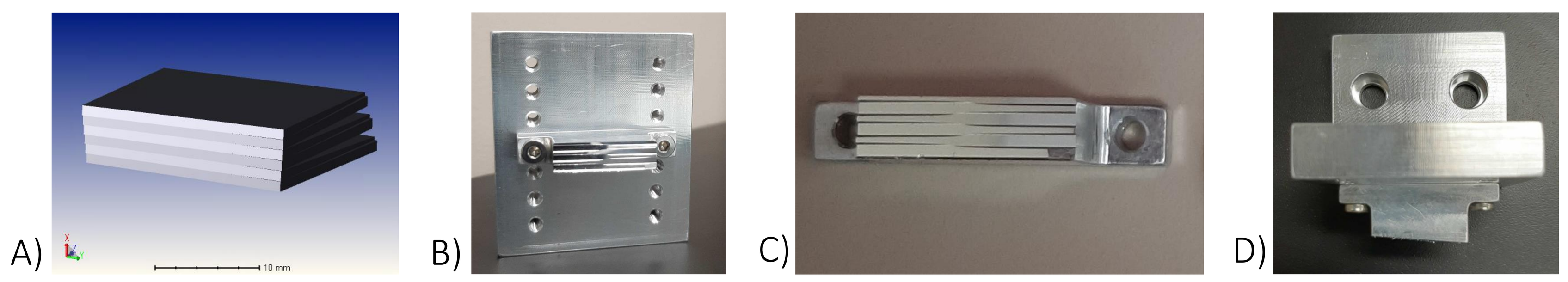

Figure 3 – Image Slicer. A) Design from Zemax, B) Slicer on is support, C) Top view, D) Side view.

Physical Control Tests

These are the preliminary results of the physical control tests. These tests are carried out with a Talysurf PGI Freeform Surface Profiler of the AOFI. It is a metrology instrument with a form repeatability of 100 nm and slope angles of up to 85 degrees.

A. Surface Roughness

The analysis, over 6 slices, of the roughness profile (see Figure 4) is based on ISO 4287 with a Gaussian filter:

The RMS roughness : $Rq = 23.35\ nm$

The Step-Size: $\Delta L = 5.03 \pm 0.89\ \mu m$

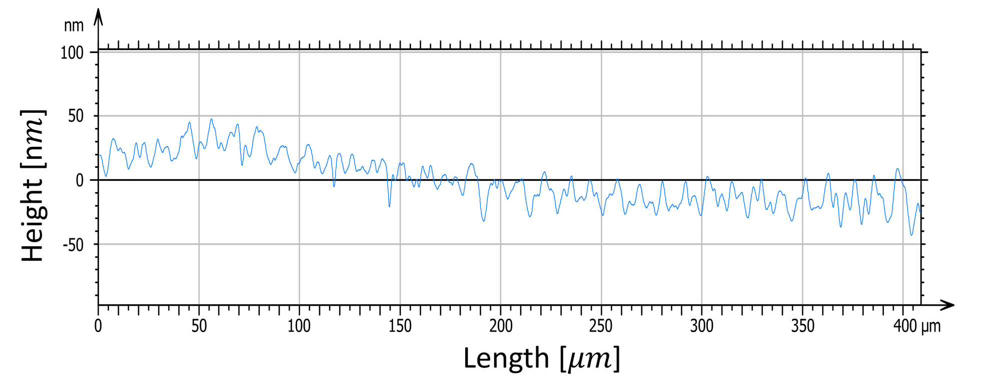

Figure 4 – Extract of surface roughness profile on one slice.

B. Tilt and Geometry

- The tilt is measured by extracting the linear component of the analyzed surface. The slice 3 tilt is taken as a reference for other slices. The literature shows that the angular errors are $< 2'$ $(0.0333°)$ [4] (See Figure 5).
- The active width of the slice is not constant along its length. The higher the jump between two slices at a given position, the more the active surface of the above slice decreases. On the area evaluated (+/- 5 mm around the centre), the active surface of the slice decreases by approximately 30% (See Figure 7).

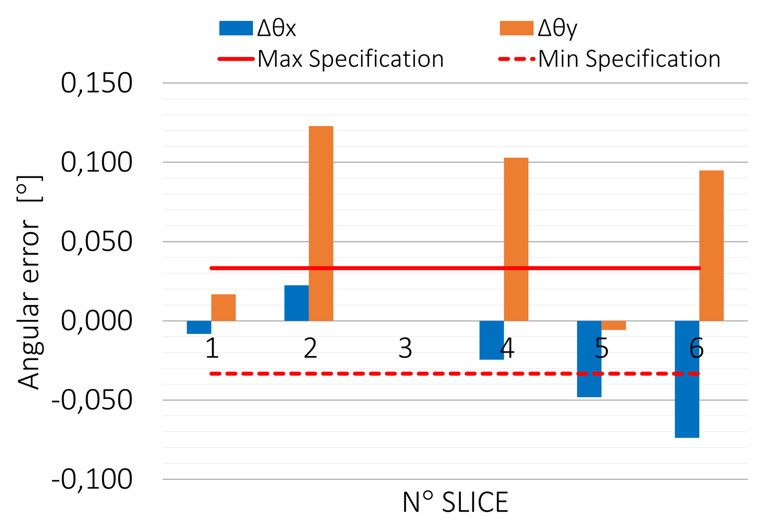

Figure 5 – Angular errors on the slices.

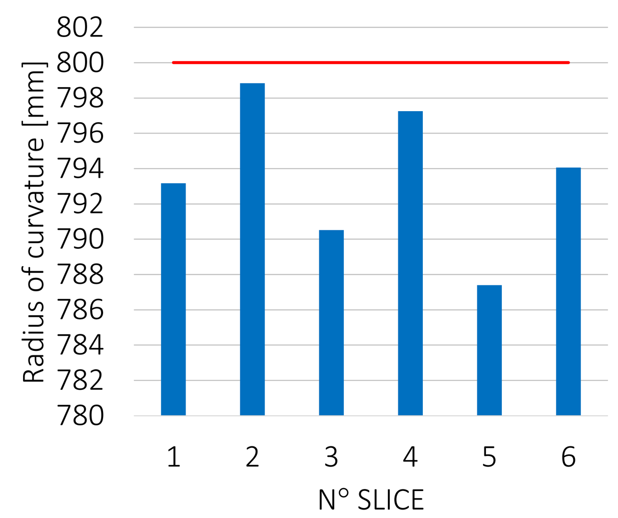

Figure 6 – Radius of curvature.

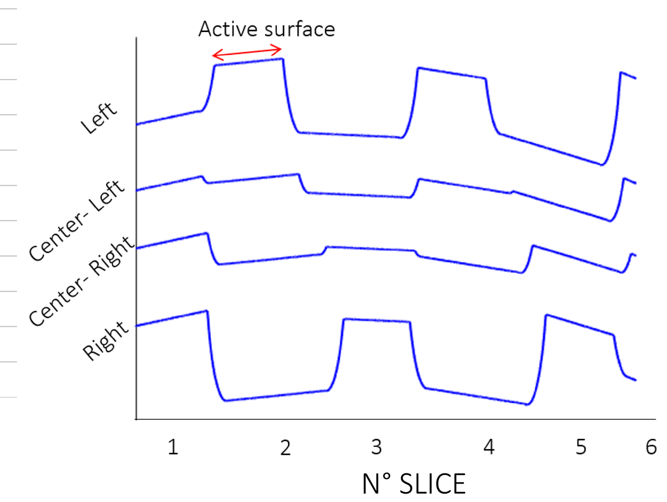

Figure 7 – Slicer cross sections.

Intermediate Pupils Characterization Bench

The objective of this test bench (see Figure 8) is to

- Evaluate the tilt of the slices
- Determine the positions, dimensions and shapes of intermediate pupils (see Figure 9)

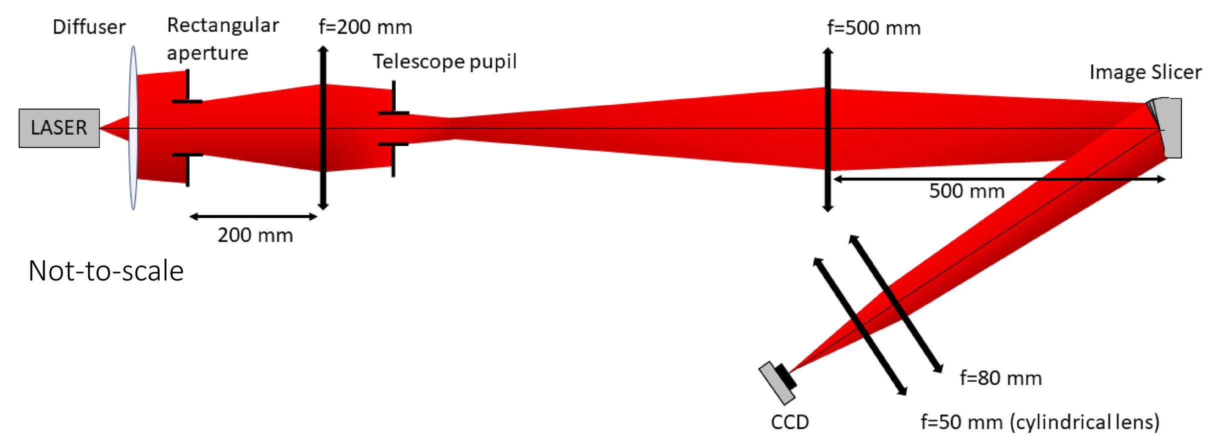

Figure 8 – Intermediate pupils characterization bench.

The rectangular aperture is imaged on the Image Slicer. The telescope pupil is imaged on the CCD. For each slice there is an intermediate pupil.

The Image Slicer having a radius of curvature in a single axis, a cylindrical lens is used so the intermediate pupil is formed in the same focal plane.

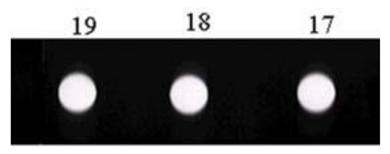

Figure 9 – Intermediate pupils. [1]

Future Tests

To complete the characterization and to conclude on the validation of the optical performances some other tests are needed.

Physical control tests:

- Edge quality
- 3D surface roughness

Optical control tests:

- Pseudo-slits analysis
- Image quality (PSF)
- Image reconstruction

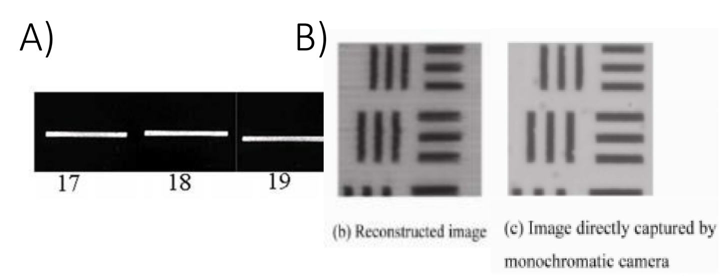

Figure 10 – Optical control tests. A) Pseudo-slits [1] , B) Image reconstruction. [3]

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