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Characterization of micro lenses for Integral Field Spectrographs

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Abstract. Micro lens arrays in use for astronomical integral field spectroscopy have to fulfill several requirements: high filling factor, accurate lens pitch, consistent focal length within the array, good optical quality, low surface roughness, high absolute throughput. In this document we describe the workshop experiments devoted to measure the optical quality (PSF and Encircled Energy) and the geometrical characteristics (pitch and filling factor) of the micro - lens arrays. The characterization of the μ – lens array is necessary to choose the best lenslet array for a generic IFS. Only refractive μ – lenses are considered (neither diffractive nor graded – index lenslet arrays).

Key words. Methods:Differential photometry – Methods: Integral Field Spectroscopy

Micro lens arrays in use for astronomical integral field spectroscopy have to fulfill several requirements:

– high fill factor: this characteristics is the capacity to get light from the input field without light loss. Too large gaps between adjacent lenses will give a contribute to scattered light into the spectrograph.
– Constant lens pitch: the lens spacing and the distance between the PSFs should be the same through the whole array.
– Low scattered light: Light scattered by surface of the microlens is lost to the optical system.

We describe the workshop experiments and the measurement of the optical quality (PSF and Encircled Energy) and the definition of the geometrical characteristics (pitch and filling factor) of the micro - lens arrays. In order to test these micro–lens characteristics we set up two different experiment. In the first experiment we illuminate the lenslet array under test with a collimated beam while in the second experiment we repeat the measurement with a convergent beam. The tests have been performed on three new lenslet arrays purchased from two manufacturers. The μ–lenses have pitches ranging between 0.100 and 0.285 mm, with focal ratio in the range from F/9.1 to F/31.5. All μ–lenses are spherical in shape with different curvature radii ($0.8 \leq R_{Curvature} \leq 3.2$mm).

1. First Experiment

In the first experiment the microlens array was illuminated by a collimated beam coming from a pin hole of opportune size that is illuminated

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Table 1. Results of microlens Test. R_A indicates the radius of the first visible diffraction minimum.

	Pitch	**Filling Factor**	**PSF**					
			Th. R_A	M. R_A	Th. R_{80}	M. R_{80}	Ratio	
	(μm)	(%)	(μm)	(μm)	(μm)	(μm)	AIRY	EE.
AOA 285	289±2	96±1	6.9	7.5±1.1	5.18	6.2±0.9	1.1	1.2
AOA 200	204±2	93±2	24.3	21.3±0.9	17.88	21.2±0.9	0.9	1.2
Heptagon	101±1	87±1	12.3	18.9±0.6	9.08	58.0±2.0	1.5	5.9

by a light source (a diode laser) behind (see Figure 1). A selection of different microscope objectives were exploited to perform the different measurements. First of all we determine the pitch from the measurements of the distances between the lenslet foci on the detector. The measured pitch value results are in good agreement with the vendor specification within the measurement errors.

The filling factor was derived exploiting the higher magnification microscope objective (×10) coupled with a photographic camera. Sets of images of microlens surface were taken. Features on the lenses, periodical enclosures in the lenses and disuniformity in geometrical shape of the microlenses are clearly visible. The image of each lenslet is made of a clear zone and a surrounding opaque zone (the gap). The external limit of the gap is defined by the perimeter that is common with all neighbouring lenses. We note that the values of filling factor are lower than vendor specification (FF> 98%). The interlens gap is about 6 μm for each microlens array independently of its size.

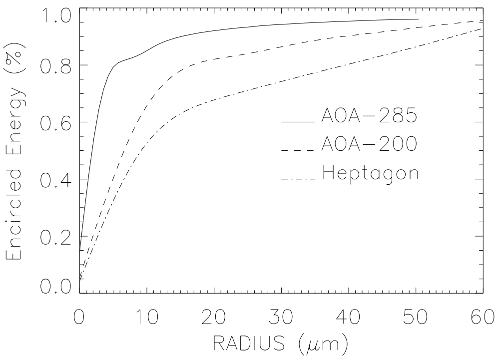

Fig. 2. EE versus radius for the three microlens arrays under test. The curves are normalized so that 100% EE is contained within the area of the lens.

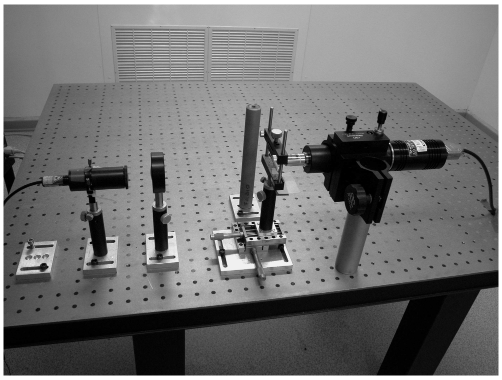

Fig. 1. The set–up of the parallel beam experiment

The measurements of PSF and Encircled Energy allow a comparison between different kinds of lenslet arrays. The main requirement in intensity measurements is the ability to measure both the central peak and the wings of the diffraction figure with the same accuracy. This requirement can be translated into a high dynamic range requested to the detector. A second concern is related to the data reduction, or how to define the limit of the area where the total intensity is integrated. The micro lenses are illuminated with their convex surface facing the laser illuminating beam in order to reduce the amount of spherical aberration. The microscope (×10) is then adjusted in order to bring in focus on the detector several lenslet PSF.

Results of the experiment are summarized in Table1. Theoretically predicted values of radius of the first diffraction minima are given

Fig. 3. The set–up of the convergent beam experiment

The EE (see Figure 2) is evaluated integrating the PSF within a circle having an area equal to that of the micro lenses. As it is possible to see, the low filling factor of Heptagon lenses coupled with the poor machining of that surfaces cause a large amount of scattered light. A poor result is given also for AOA 200, while AOA 285 seems to have a much better behaviour.

2. Second Experiment

With the second experiment (see Figure 3) we would like to test the first experiment results using an experimental set up which reproduces the operative condition for the IFS. This has been obtained illuminating the microlens array with a converging beam. The optics was calculated in order to obtain a diffraction image onto the microlens. We used a Diode Laser to illuminate an opal screen behind a 100 μm pinhole. The light is collimated by a 300 mm focal length lens and in order to have a magnification of 5 onto the image plane we use a second lens with a focal length of 1500 mm. We placed a variable aperture iris diaphragm at the pupil formed by the collimating Lens. First we verify that we have a correct diffraction figure on the focal plane of second lens. The Airy diameter of the diffraction pattern is of about 700 μm (slightly larger than two microlens diameters) yelding a beam speed of F/422 and a clear aperture of the diaphragm of 3.5 mm. We then placed the microlens array on the 2^{nd} lens focal plane and we gathered the light from the array with a $\times 10$ microscope objective obtainig the diffraction images made by microlenses. Using this setup we used the microscope to reimage the micropupils formed by the lenslets onto the detector focal plane. This is the same optical configuration foreseen in the case of CHEOPS IFS.

3. Conclusion

All AOA lenslet arrays tested were found to have accurate pitches with filling factor slightly different from vendor characteristics. All lenses had a PSF with a clearly observable diffraction pattern indicating the absence of significant aberrations. The EE performance seems slightly degraded (especially for AOA-200) by the presence of scattered light caused by surface roughness or the interlens gaps. From PSF analyses it results that the hexagonal shaped lenses (F/9.12) concentrate more light in the first anulus than the squared lenses (F/31.5). On the contrary really cheap Heptagon microlenses do not show a pronunced Airy minimum and are of poor quality showing a larger amount of scattered light and a low filling factor. The measured quality of the AOA Hexagonal microlenses permits us to consider AOA microlenses as a possible choice for the IFU once the right size and optical characteristics are defined by the optimization of the final IFS optical design. Moreover, in the final design the use of silica lenses should be as well considered. The second experiment made in convergent beam reproduce the same results obtained in the first.