Abstract. A number of design options for image slicers for NGST and Gemini are being investigated. These image slicers are all of the focussing type and both refractive and reflective solutions are being explored. One such device, an image slicer that focuses 10 slices on a spectrograph slit is now in operation at the McMath Solar telescope. It consists of three lenslet arrays, and additionally acts as a focal reducer and provides correction for astigmatism of the telescope. A combined refractive and reflective slicer designed for use on NGST delivers near-diffraction limited images for up to 40 slices.

1. Introduction

Image slicers were initially designed and used to reformat the seeing disk of stars into a shape that could efficiently be introduced into the slit of a spectrograph. The first of these, designed by Bowen (1938), reflected nearly-focussed starlight parallel to the slit and then reflected slices of it into the slit using thin mirror facets whose width equalled the slit width. An inherent disadvantage of this type of slicer is that only one slice is in focus at the slit, although it, and the more elegant Walraven image slicer design, were still useful for their original purpose. In practice, the non-uniform illumination of the spectrograph collimator frequently led to substantial problems and they were not extensively used. The superpositioning image slicers (Richardson, 1968) were designed for use with a single-slit spectrograph in which photographic plates were used as detectors. Each slice of the blurry star is elongated and then superimposed on the slit providing deliberate scrambling (for more accurate radial velocities and more uniform illumination along the slit). In this way, the image slicer increased slit transmission and improved the spectrophotometric accuracy, especially with
non-linear detectors such as photographic emulsions. A more detailed discussion of these image slicers is given by Richardson, Fletcher & Grundmann (1984).

Now that superb spatial resolution can be achieved through use of adaptive optics or by telescopes in space, image slicers are being considered to reformat the more-or-less circular images of resolved targets such as galaxies into long slit-shaped apertures in order to obtain 2-D spectral information or to study kinematics of the whole object at once. Of course, to preserve the spatial information, these new designs (e.g., Diego 1994; Content 1997) must ensure that the slices are in proper focus. We are examining both all-reflective and all-refractive types of these focussing image slicers. In the following sections we describe two specific examples of these Richardson Focussing Image Slicers (RFIS).

2. RFIS 2.1: McMath Focussing Image Slicer

As mentioned above, a disadvantage of the Bowen-Walraven type of image slicer is that only one slice is in perfect focus on the slit, the others being out of focus because the light travels a larger (or smaller) distance before reaching the slit. In 1994, one of us (EHR) designed a stacking type image slicer for Drew Potter of Lockheed/NASA, Houston for use on the McMath solar telescope spectrograph. The basic goal was to slice the planet Mercury into 10 slices and then stack these along the 20 mm long slit, demagnified by a factor of 2, with each slice in focus in order to preserve the spatial resolution of planetary features along the slit.

The detailed specifications were:

- slice the 10'' disk of the planet Mercury into ten 4mm × 0.4mm slices
- demagnify the slices by a factor of 2 (from f/54 to f/27)
- correct for astigmatism of telescope
- maintain focus of slices along the slit
- conform to mechanical constraints of the existing Bowen/Walraven image slicer

The optical design, by EHR Optical Systems, comprises 3 sets of lenslet arrays, 30 lenslets total, all BK7 glass. The lens fabrication was carried out by Lumonics (formerly Interoptics) Ottawa, and the mechanical assembly was designed by A. Moore. An overall layout and a photograph of the completed slicer are shown in Figure [Fig]. The components were successfully aligned and installed in 1996. Performance tests are ongoing, but it apparently works as expected.

3. Richardson Focussing Image Slicers designed for NGST

3.1. RFIS 3.1

An all-refractive image slicer, similar to McMath design described above, was designed for NGST. In this case, however, the design is considerably simpler since it doesn’t have to incorporate focal reduction nor to compensate for telescope
Figure 1. Left: The overall mechanical layout of RFIS 2.1. Three sets of lenslets arrays are used to slice up the image and refocus the slices into the slit. A beam splitter above the entrance to the device is used to deflect some light to the guide camera. Right: A schematic diagram of RFIS 3.2. Light from the telescope enters the glass block from the upper left, reflects off the first mirrorlet array, returns to the top and reflects off another (long) array, and then is redirected by two nearly right angle prisms. It then passes through an array of field lenses just before the slit and into the spectrograph. The longest dimension is 126mm.

aberration. A ten-slice image slicer with an entrance aperture of 3\(\prime\) × 1\(\prime\) (ten 0\(\prime\).1 slices) is straightforward and larger ones appear possible.

3.2. RFIS 3.2

A combined refractive and reflective design appears to offer more advantages. This design, shown on the right in Figure 1, uses concave back-surface mirrors (the incident and reflected light beams are inside glass) and has only two air-glass surfaces (one at the 2\(\prime\)0 × 3\(\prime\)0 aperture, the other at the 65\(\prime\) long slit). The powered optics consist of the first mirrorlet array, the reimaging mirrorlet array and the field lenslet array located at the exit slit. Two near-right angle internally reflecting prisms redirect light to the fixed slit location. All of the optical surfaces are spherical or flat.

Features of the prototype design:

- Slices a 2\(\prime\) × 3\(\prime\) object at NGST focus into 20 0\(\prime\).1 slices

- Slices form a slit 65\(\prime\)(68mm) long times 0\(\prime\).1 wide. Each slice is offset from the next by 0\(\prime\).12 along the slit to preserve spatial information at the ends of the slices.
• Input is offset laterally from output by 43″, but location of the telescope focus/spectrograph input focus is preserved

• RMS image diameters are typically 46 microns (0.08) i.e., nearly diffraction-limited. The worst image (outermost) is 57 microns or 0.06″

• Very stable alignment since mirrors and lenses are bonded to a block of glass of the same material. For the NGST core wavelength range (1 – 5 µm), CaF$_2$ would be used.

• Good focus maintained over entire (1 - 5 µm) wavelength range

• Very high throughput, very low light loss and very low scattered light since there are only two air/glass surfaces and since all other reflective surfaces are internal.

• Design compensates for non-telecentricity of NGST telescope design.

• Very compact (126mm by about 12mm wide)

This design can be extended to provide either longer slices or to provide more slices of the same length. If one wished to sample the diffraction-limited images at 2µm with two pixels, then the nominal 4K detector would allow a total slit length equivalent to 100″. Hence a slightly larger format is possible with the strawman detector. Obviously, if one chose to accept lower spatial resolution then the field could be substantially enlarged. Another option to increase the field size (while retaining the superb resolution) would be to increase the length of the detector mosaic.

The McMath image slicer demonstrates that such an image slicer could be easily achieved in practice. The lenslets for the McMath device were made by fabricating two lenses for each stage which were then cut up (every second lenslet was destroyed by the saw cuts, so two lenses were required) to produce the lenslets. Subsequent alignment of the lenslets and of the image slicer posed no difficulties. Hence, the RFIS 3.2 design concept appears to provide an excellent image slicer for NGST scientific applications.

We are grateful to Murray Fletcher for assistance with the diagram of RFIS 3.2 which is shown in Figure 1.

References

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