

The Image Slicers for the Subaru Telescope High Dispersion Spectrograph

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The High Dispersion Spectrograph (HDS) on Subaru Telescope can achieve a very high resolving power, up to 150000, by applying a very narrow slit. When a slit of $0''.3$ ($150\ \mu\text{m}$) width is applied, the resolving power is 115000. The throughput at the slit is, however, as low as 45 % for the typical seeing size of the telescope at Mauna Kea in Hawaii ($\sim 0''.6$). In order to improve the efficiency of the spectrograph for observations with very high resolution, we installed a Bowen-Walraven type image slicer [1]. This type of image slicer traps incident light in a thin plate by total internal reflection, and slices the image by sending the light at every second reflection to a glass prism inclined with an appropriate angle (see figure 1). After designing the instrument in late 2008, it was constructed in 2009 and installed in 2010. The instrument was opened for common use of HDS from 2011 August.

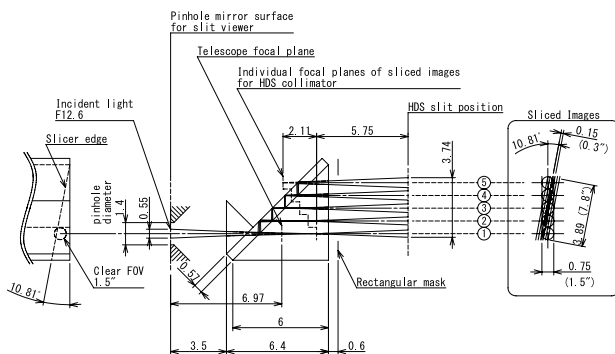


Figure 1: Optical design of IS#1.

The Bowen-Walraven type image slicer that we installed is optimized for the two following prime requirements. The first requirement is to maximize the energy from point sources under the typical seeing of $0''.6$ on Mauna Kea. Therefore, the clear aperture should be up to $1''.5$ (corresponding to $0.75\ \text{mm}$ on the focal plane of Subaru Telescope). The second requirement is a spectral resolving power as high as $R \sim 110000$. Therefore, the width of the sliced images should be $0''.3$ ($0.15\ \text{mm}$). In order to fill these two requirements, the image slicer is designed to transform a $1''.5 \times 1''.5$ field of view into five sliced images of $0''.3$ width, as shown in figure 1. The five sliced images (hereafter “slices”) are numbered from 1 to 5 along the optical path, as shown in the figure. We note that since observing targets of this instrument are assumed to be bright stars, no slice is dedicated to obtain a background-sky spectrum.

The gain of photons expected by using the image slicer, that is, the ratio of the fraction of light entering the

spectrograph with the image slicer to that with the $0''.3$ slit, is higher than unity for a seeing size larger than $0''.3$, and reaches two at $0''.8$ (see black lines in figure 2). Hence, to obtain spectra with resolution as high as $R = 110000$, a higher S/N is expected by using the image slicer under any seeing condition at Mauna Kea. Science results using this instrument on, e.g., metal-poor binary stars and an extrasolar planet have been published [2,3].

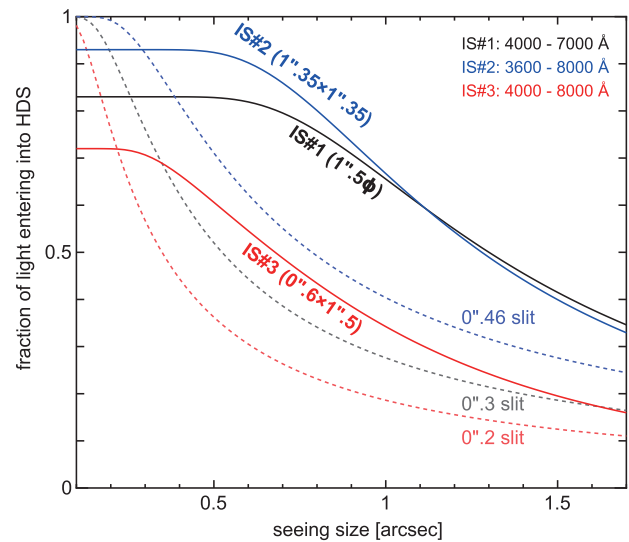


Figure 2: Efficiencies of image slicers and corresponding slits.

In addition to this first image slicer (IS#1), we developed two more similar ones. The second one (IS#2), which achieves $R = 85000$ with the $0''.46 \times 3$ format, was opened for common use of HDS from 2012 August. Its spectral resolution is adjusted to the one used the most frequently in HDS observations. The third one (IS#3) has the highest spectral resolution $R = 165000$ with the $0''.2 \times 3$ format. Among the 8–10 meters telescopes in the world, HDS with the IS#3 must be the unique instrument to realize efficient observations with such highest spectral resolution. This IS#3 is also going to be opened for common use in 2013.

References

- [1] Tajitsu, A., Aoki, W., Yamamuro, T.: 2012, *PASJ*, **64**, 77.
- [2] Aoki, W., Ito, H., Tajitsu, A.: 2012, *ApJ*, **751**, L6.
- [3] Hirano, T., et al.: 2012, *ApJ*, **759**, L36.