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Development and Characterization of an Ultra Stable Single Mode Fiber Fed Spectrograph in the Infrared

To deliver a radial velocity instrument capable of extreme precision requires careful design with attention to the interplay of optical, mechanical and thermal design choices. Ideally, an instrument starts with a spectrograph of sufficient resolution and an intrinsic stability that leads to optimal precision over months or years. For a demonstrator instrument developed at Macquarie University, we trade off optical and mechanical design choices, and use advances in photonic technologies as enablers to satisfy science cases requiring extreme precision. We start at the fiber injection with single mode fibers to feed the spectrograph, thus eliminating issues with modal noise in the beam. Our design also allows for the use of a diffraction-limited integral field unit to take spatially resolved spectra of stellar surfaces. In this case, microlens arrays on seven single mode fiber cores are arranged in a hexagonal patterned multicore fiber. The spectrograph itself is a white pupil design utilizing a monolithic 152 mm primary mirror with 550 mm focal length. The dispersive element is a 60 mm x 150 mm silver coated Zerodur R6 grating from Richardson Grating Labs. The groove count is sufficiently low at 13.33 lines/mm to keep the orders narrow, allowing for the use of an InGaAs detector with limited pixel count. We design mounts for all the elements on the bench, analyse the stresses and displacements with finite element analysis and machine them from Al-6061. With the spectrograph taking shape in the lab, we measured the grating efficiency and spot qualities to verify our design and as-built specifications. We use a volume phase holographic grating as a cross disperser and custom camera optics to feed the InGaAs detector. The detector comes from Princeton Infrared Technologies, and has a peak quantum efficiency >80 % at 1200 to 1600 nm, covering the near infrared part of the design spectral range of 650 to 1500 nm. The detector has 12 micron pixels and at 1280x1024 offers us a comparatively large format for the cost. We also evaluate the detector, measure it's noise levels, and write control software to make it suitable for astronomical observations.

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