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Brian L. Vattiat, Hanshin Lee, Taylor Chonis, Gary J. Hill, Christian Haubitz-Reinke, "Design, assembly, and performance of the low-resolution spectrograph 2 integral field unit," Proc. SPIE 9908, Ground-based and Airborne Instrumentation for Astronomy VI, 99083O (9 August 2016); doi: 10.1117/12.2231227

Event: SPIE Astronomical Telescopes + Instrumentation, 2016, Edinburgh, United Kingdom

Design and Assembly of the Low Resolution Spectrograph 2 Integral Field Unit

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ABSTRACT

The Low Resolution Spectrograph 2 (LRS2) was recently deployed on the Hobby-Eberly Telescope (HET). LRS2 consists of four spectrographic channels, each covering adjacent wavelength bands from 360-1050nm which are fed with a fiber optic integral field unit (IFU). The integral field unit developed for this instrument represents a transformative approach to expanding the wavelength coverage of integral field spectrographs. The unique input feed of the IFU serves two functions; combining the wavelength coverage of two spectrographic channels to one spatial field on sky, and expanding the field of view of each individual fiber to eliminate the interstitial space between fibers on sky. The spectral multiplexing is achieved with dichroic beam splitter and collimator, while the focal reduction is achieved with a pair of micro lens arrays. The optical components required micron scale alignment precision in a compact mechanical package to allow integration on the telescope focal surface. Here we report on the design, assembly, and performance of the IFU.

1. INTRODUCTION

The Hobby-Eberly Telescope (HET) [1] is an innovative 10m-class telescope that operates with a fixed altitude segmented spherical primary mirror while a tracker, located at the top of the telescope, moves the wide-field corrector (WFC) and focal plane assembly (FPA) in order to track the sidereal and non-sidereal motions of celestial objects. The two LRS2 IFUs are mounted to the HET focal plane assembly and the fiber cables carry light to the LRS2 spectrographs mounted on the telescope's side The LRS2 spectrographs were built from modified VIRUS platforms [2], using grism dispersers instead of volume phase holographic gratings and deep-depletion CCDs for the red channels.

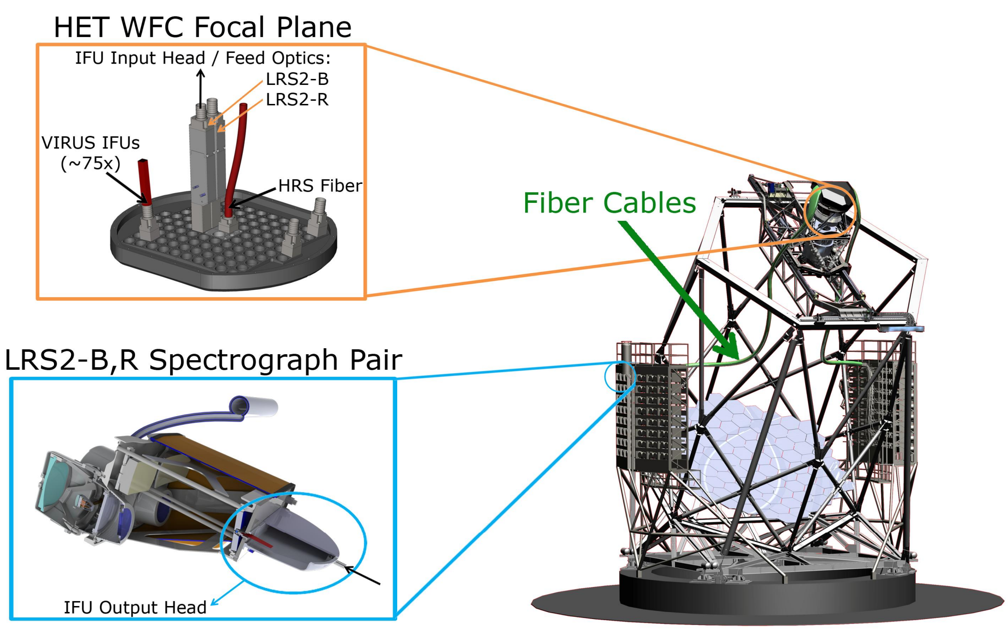


Figure 1 Illustration showing the Hobby Eberly Telescope along with the LRS2 spectrographs and IFU

Ground-based and Airborne Instrumentation for Astronomy VI, edited by Christopher J. Evans, Luc Simard, Hideki Takami
Proc. of SPIE Vol. 9908, 99083O · © 2016 SPIE · CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2231227

Two IFUs were built for LRS2, with one IFU feeding two spectrographic channels. The "Blue" IFU feeds to spectrographic bands of 370nm to 700nm. The "Red" IFU feeds to spectrographic bands 650nm to 1050nm. Each IFU consists of four functional subassemblies: the focal extender, the dichroic beam splitter, the micro focal reducer, and the fiber bundle. The following sections address these subassemblies.

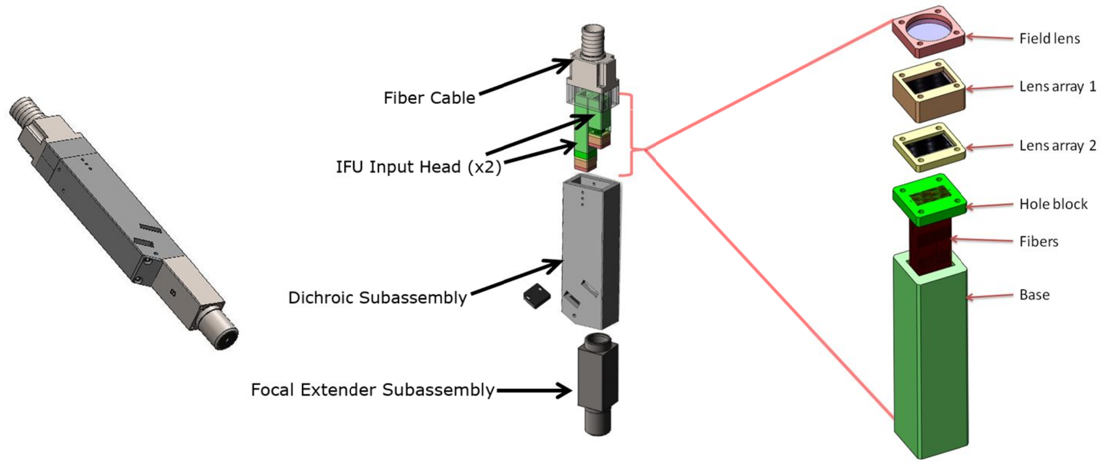


Figure 2 An overview of one LRS2 IFU mechanics

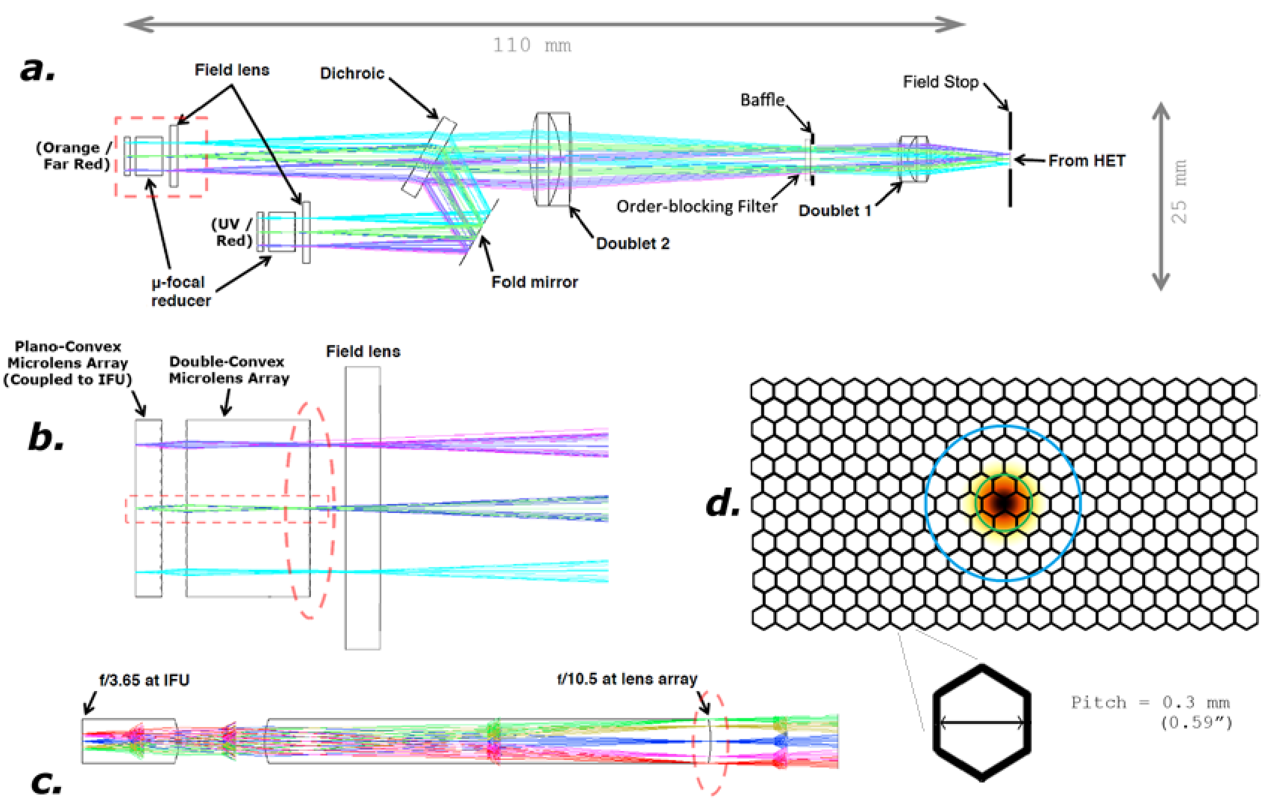


Figure 3 An overview of the LRS2 IFU optical design

2. FOCAL EXTENDER

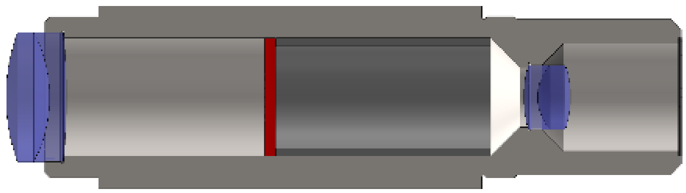


Figure 4 A sectional view of the focal extender

The purpose of the focal extender is convert the f/3.65 light delivered from the telescope to f/10.5. This conversion is needed in order for the microlens array focal reducer to map a contiguous space on sky to the non-contiguous fiber cores. The microlens array focal reducer is covered in subsequent sections.

The focal extender optics consist of two doublets and an order blocking filter. The doublets were custom fabricated from fused silica and LLF1 by Harold Johnson Optical Laboratories (now owned by JML Optical Industries). The doublets are 6 and 12mm in diameter and have a usable field of view of 14 arcseconds. The image quality of the dual-doublet relay is <0.25 arcseconds EE90 across the central 12 arcsecond field of view.

The mechanical housing for the focal extender optics was fabricated from steel grade 1.4305 (AISI 303) at Institut für Astrophysik Göttingen. The positional tolerance requirements required by the optical design were achievable with precision machining of a monolithic part. No adjustment mechanisms or compensators were necessary. The optical components were fixed to their mechanical seats with Henkel Tra-bond F112. This mechanical part also contains the features which interface to the telescope's Input Head Mount Plate (IHMP). Those features are identical to a VIRUS IFU input head.

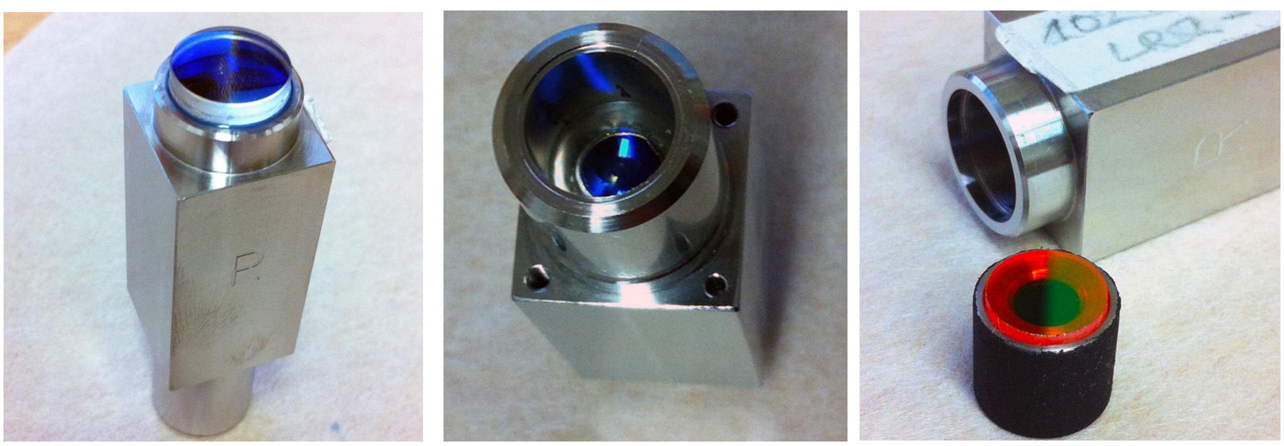


Figure 5. Photos of the focal extender during integration

3. DICHROIC BEAM SPLITTER

Light from the focal extender are then incident to a dichroic window at 30 degrees. The LRS2-B IFU has dichroic with crossover wavelength of 463.4nm. Light with longer wavelengths are transmitted through the dichroic to the "Orange" micro focal reducer assembly. Light with shorter wavelengths are reflected to a broadband mirror and then reflected again to the "UV" micro focal reducer. The LRS2-R IFU has a dichroic with crossover at 835nm. Longer wavelength light is transmitted to the "Far Red" micro focal reducer. Shorter wavelength light is reflected to the "Red" micro focal reducer. The dichroic windows and broadband mirrors were fabricated to JDS Uniphase.

The dichroic beam splitter mechanical housing is a monolithic part fabricated from steel 1.4305 (AISI 303) by Institut für Astrophysik Göttingen. The seats for the dichroic window and mirror were created with an EDM wire machine in order to produce planar surfaces that were accurately flat and parallel over the relatively large lengths. The optics are held in their respective slots with Tra-bond F112. The surface finish produced by EDM machining are well suited for epoxy adhesion.

The interior surfaces which interface with the fiber bundles were also created with an EDM wire machine. The seat for interfacing to the focal expander assembly was bored using traditional milling. No adjustment mechanisms were used in this assembly, although it did require three datum transfers for fabrication. In hindsight, this was unadvisable and would lead to problems discussed in subsequent sections.

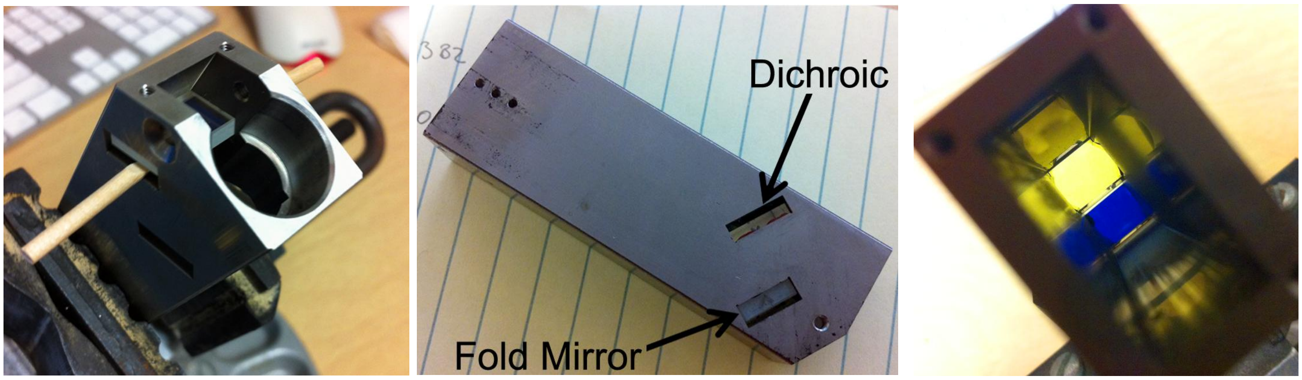


Figure 6. Photos of the dichroic beam splitter assembly during integration

4. MICRO FOCAL REDUCER

The micro focal reducer assemblies consist of a field lens and two microlens arrays. The assemblies are positioned at the focus of the image formed by the focal extender. The enlarged image is sliced by the first microlens array and the resulting sub-images are reduced to the match the fiber core diameter and optimal input focal ratio of f/3.65. The microlens arrays were fabricated by Advanced Microoptic Systems Gmbh.

The micro focal reducers require precise alignment of the two lens arrays to each other and to the fiber array. The spacing of the micro lens arrays to each other and to the field lens is set by fixing each optic in a cell. Each cell was made from stainless steel ground to the precise thickness needed to set the desired spacing to the next element. The rectangular holes needed in the cells to accommodate the micro lens arrays were also cut with an EDM wire machine. The corners of the rectangular holes were “undercut” to relief the sharp corners of the microlens arrays but also proved useful during integration. The undercuts also act as capillary channels for applying the epoxy used to fix optic in cell. After the optic is fitted in dry, epoxy was applied to the undercuts with a syringe. The undercuts acted as a reservoir and

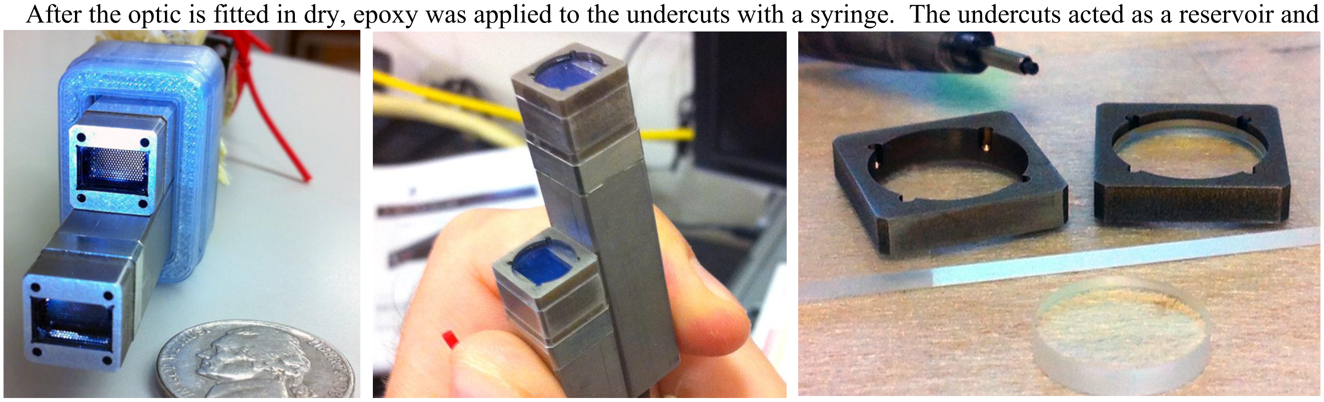


Figure 7. Photos of the micro focal reducers during integration

the epoxy was drawn into the space between optic and EDM-finished metal cell. The cells were fabricated by the UT-Austin Astronomy machine shop.

Lateral alignment of the field lens, microlens arrays, and fibers required a means to manipulate each element and a method to measure their relative alignments. Manipulation of each element was achieved with a purpose-built slip plate stage with 8 differential linear adjusters. Each microlens array and cell was placed in a larger slip plate adjustment cell. Each adjustment cell was held with a spring preload to three linear adjusters to control X and Y position and clocking. The field lens was positioned with two linear adjusters since clocking adjustment was not needed. Measuring the relative alignment was done by creating visual references on each element and using a video microscope to measure the position of those references. The microlens array vendor was able to produce chromate crosshair reference features on the planar border surfaces of the lens arrays. Those reference marks were precisely registered to the microlens surfaces and readily imaged by the video microscope. The fiber hole block, which is discussed in a subsequent section has additional holes not populated by fibers to act as reference marks. When properly aligned these extra holes are concentric with the reference marks on the microlens arrays.

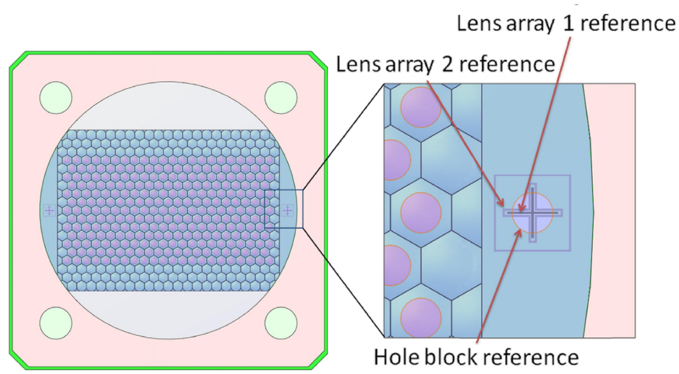


Figure 8. Illustration of the alignment features on the micro focal reducer

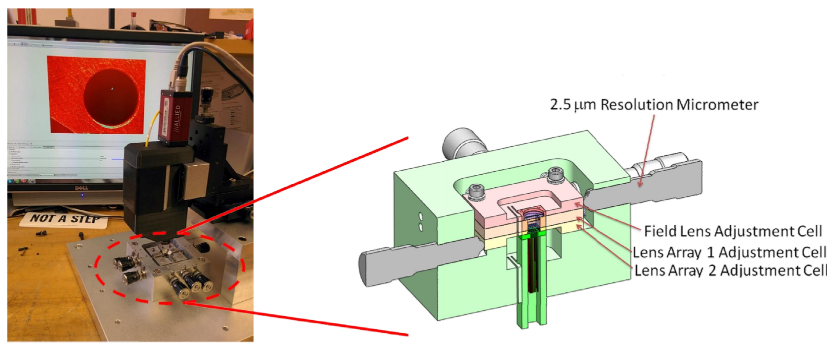


Figure 8. Photo and illustration of the adjustment stage built for alignment of the micro focal reducer

5. FIBER BUNDLE

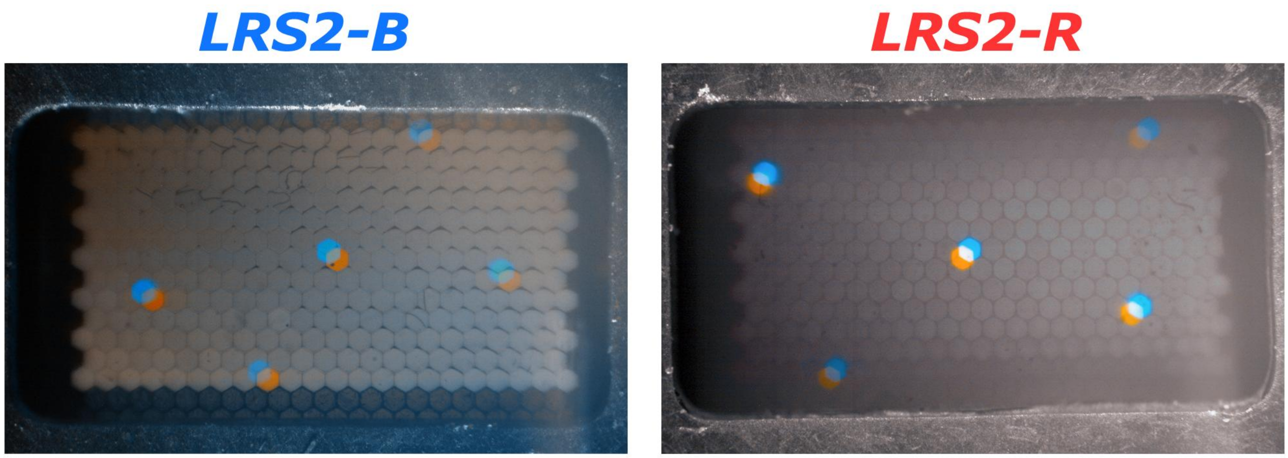
Four fiber bundles were produced for LRS2. Each bundle is ~18 meters long and has 280 optical fibers. The fibers have 170micron diameter fused silica cores made by Polymicro technologies. The input ends of the fibers are inserted into a block with an array of precision holes and fixed with Epotek 301-2 epoxy. The hole blocks were made by Euromicron Fiberoptic Gmbh. The output end of each fiber was placed on a block with precision grooves. The output groove block was fabricated by the UT-Austin Astronomy machine shop with a CNC end mill and engraving bits. The fiber bundles are inserted into a protective sleeve of woven Kevlar and then into a flexible metal conduit with PVC jacket. The Kevlar sleeve was obtained from Soller Composites and the metal conduit from Hagitec Co. The fiber bundles were integrated and their ends polished at the Leibniz-Institut für Astrophysik Potsdam in conjunction with Berlin-Fibre.

6. RESULTS

Once the alignment of the micro focal reducers was finished and the focal extender and dichroic assemblies were integrated, a series of lab tests were carried out. One such test was to illuminate corresponding fibers at the fiber bundle output slits in order to measure the spatial registration error between adjacent channels. For example, with the LRS2-B IFU, corresponding fibers were illuminated on the "UV" output slit and the "Orange" output slit. As can be seen from the figure below, the illuminated spots are not coincident. This indicates a misalignment between the two channels.

There could be several explanations for the misalignment. One possible cause is the parallelism and spacing between the dichroic beam splitter and fold mirror. Another possible cause is the spacing between the micro focal reducers and the attached fiber bundles. While this result is disappointing, it did not affect the intendent science usage and therefore a fix to the error was not pursued. The LRS2 instrument is now operational [3][4] on the HET telescope and available to the community for observations.

Figure 9. Photos of the micro focal reducers with individual fibers illuminated from the output slit



ACKNOWLEDGEMENTS

HETDEX is run by the University of Texas at Austin McDonald Observatory and Department of Astronomy with participation from the Ludwig-Maximilians-Universität München, Max-Planck-Institut für Extraterrestriche-Physik, Leibniz-Institut für Astrophysik Potsdam (AIP), Texas A&M University, Pennsylvania State University, Institut für Astrophysik Göttingen, University of Oxford, Max-Planck-Institut für Astrophysik and The University of Tokyo. In addition to Institutional support, HETDEX is funded by the National Science Foundation (grant AST-0926815), the State of Texas, the US Air Force (AFRL FA9451-04-2-0355), by the Texas Norman Hackerman Advanced Research Program under grants 003658-0005-2006 and 003658-0295-2007, and by generous support from private individuals and foundations.

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