2.3.1 Composite and Fiber Arm

A fiber arm device was developed to be the extremity of the patrol device physically coupled at the COBRA motor device. The Figure 17 shows a sample of composite machined to form the “fiber arm” device for the “fiber positioner” system. The ideal condition requires a material with elasticity controlled so as not to cause stress or shift the positioning of the optical fiber under temperature gradients. Just for such purposes, we have developed a special composite formed from a mixture of EPO-TEK 301-2 and Zircon Oxide and others materials in nano-particle form, cured and submitted to a customized thermal treatment, Cesar et al. [01]. To avoid bubbles and points of stress, this mixture needs to be prepared in a separate receptacle inside a vacuum chamber. The resulting material is more resistant and harder than EPO-TEK 301-2 and it is found to be well suited to the fabrication of optical fiber arrays. An important secondary characteristic is the ease with which it can be polished. This feature is a result of the micro particles, which keep the polished surface very homogeneous during the final polishing procedure. The resulting composite combines the beneficial characteristics of both the epoxy and the zircon oxide. Its main property is the coefficient of thermal expansion, significantly lower than simple solidified epoxy; the exact value depends on the relative concentrations. While the characteristics of this particular composite still are under study, we have nevertheless deployed this material in the construction of devices for several fiber instruments. In order to slow down the F-ratio after the wide-field corrector by a factor of 1.28, microlens will be glued at the extremity of the fiber in the fiber arm, as shown in Figure 18. Accordingly, the F-ratio changes as follows: - Field center: F/2.18→F/2.79 - Field edge; F/2.01→F/2.57. Manufacturing viable alternatives are being investigated to produce this microlens, Figure 19 in a number of companies. At this moment, we are experimenting alternative techniques to align, assemble and glue the microlens at the fiber arm, Figure 20. The best option will be the most efficient and the faster.

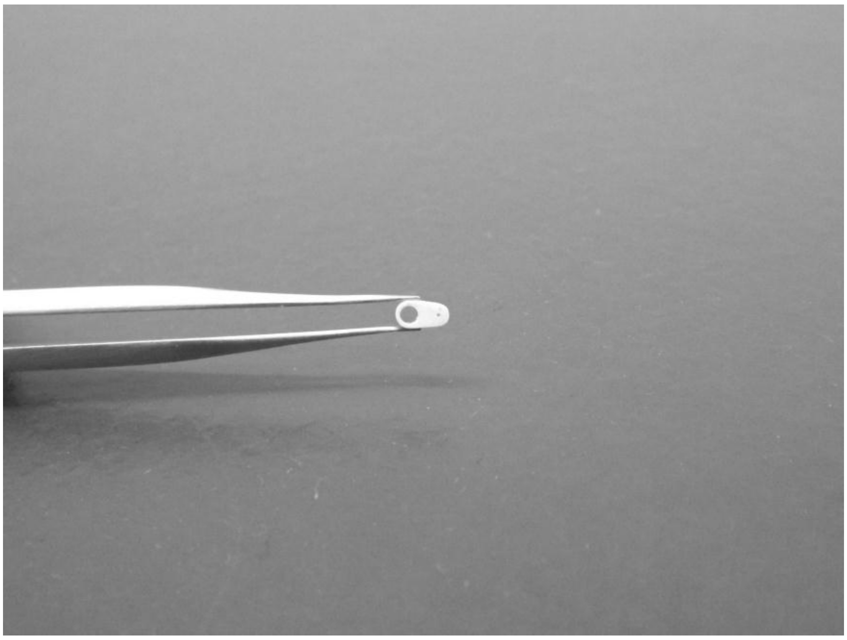

Figure 17: Fiber arm machined in composite. It shows a fiber arm device constructed with the composite to form the optical fiber ferrule of a fiber positioner system. This is a part of a complex patrol system that may be used as the positioner for WFMOS. The big advantage to the use of the composite is in the speed and quality of the polishing.

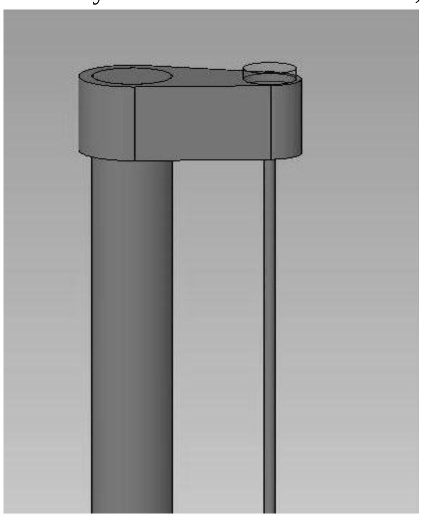

Figure 18: Fiber arm with optical fiber and lens

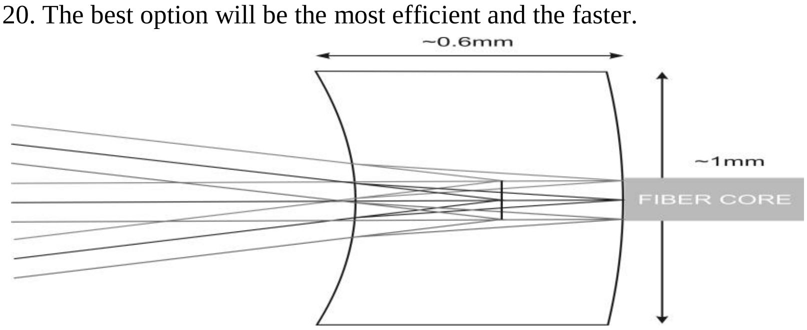

Figure 19: Lens design in evaluation

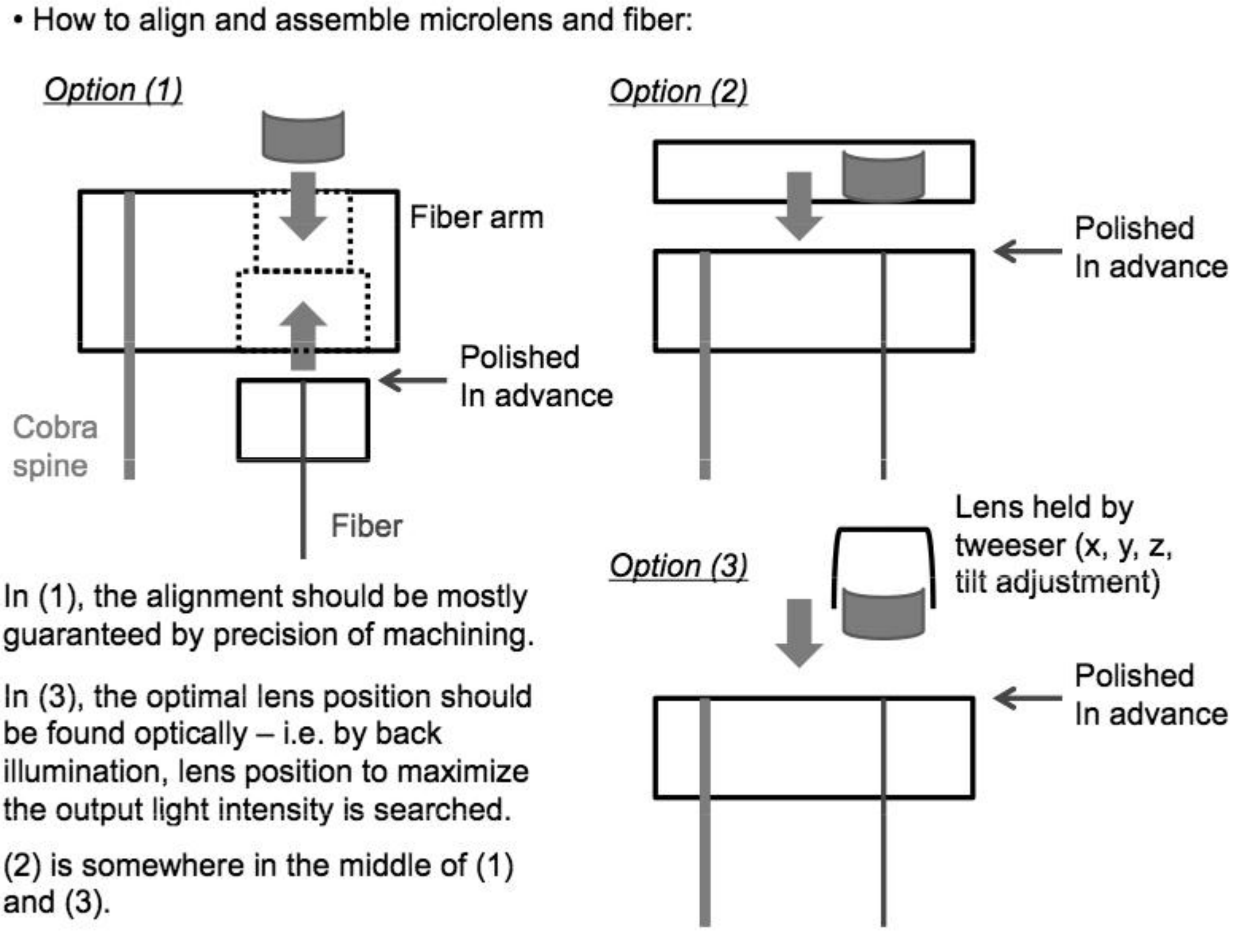

Figure 20: Three possible assemble process of the lens at the fiber arm

3. OPTICAL FIBERS IN TEST

The only fiber in test at this moment is the Polymicro FBP120170190. However, Fujikura Company is working with a possible different fiber that we may do tests in the near future. This will be a second option of optical fiber and all the tests described below will be repeated as soon as we have an available sample. We have prepared two samples with 6 and 50 meters length. Both extremities were encapsulated inside a composite ferrule and polished with high performance. We are avoiding measure small pieces like one or two meters because the effects of the annular degeneration.

3.1 Throughput & FRD Measurements

To measure the FRD properties of an optical fiber it is necessary to illuminate the fiber test with an input beam of known focal ratio. Then the output beam can be measured and compared with the input beam. We have adapted a method described by Barden, to measure absolute efficiencies.[02] In our experimental set-up; we can change the focal ratio of the input fiber in test. However, the most important was to feed the fibers around f/2.3 matched to the output focal ratio of Subaru's Hyper-Supreme corrector. The experimental apparatus used to achieve this is illustrated in Figure 21. A halogen lamp which light is diffused and condensed to illuminate a pinhole device is the primary light source. A filter centered at 550 nm defines the wavelength in which we are working on. The pinhole is the secondary light source and it projects light to be collimated using an achromatic collimator lens device. The collimated beam is then coupled into the test fiber by a scientific grabber CCD (Andor Solis DL-604 M-OEM). An iris diaphragm, placed in the collimated beam, can be used to select the input focal ratio. A CCD for alignment is fed by a beam splitter and allows the image of the source fiber to be accurately positioned with respect to the test fiber by means of observation on a TV monitor. A displacement device, defines the alignment of the optical axis of the CCD detector with either the output fiber with either the output of the collimated beam before at the test fiber entrance. In another words this tip-tilt translation stage allows obtain image from the output of the test fiber and image from the collimator focus. In fact, a defocus of 7 mm ± 0.01 mm was then applied to the CCD detector in both positions to avoid the saturation of the pixels. The Figure 22 shows the experiment assembled on the optical bench. The optical fibers can then be examined over a range of focal ratios. Background exposures were also taken for subtraction from the test exposures to remove the effects of hot pixels, stray light, etc. In general, the technique to measure FRD uses **a science-grade** CCD (with frame grabber) and employs the IRAF routines QPHOT and PPOFILE (Tody, 1993) for data reduction.[03]

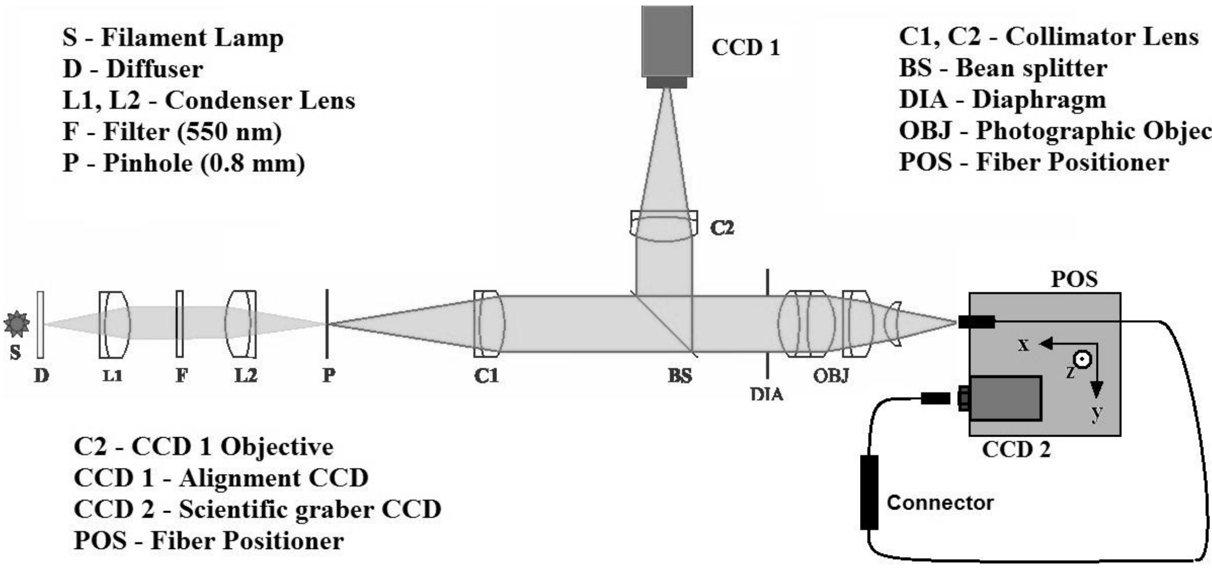

Figure 21: Schematic diagram used to measure absolute transmission

Figure 22: Optical bench to measure FRD Experimentation

Characteristics of the experimentation:

• Five Input F-ratios: F/2.2 – F/2.4 – F/2.6 – F/2.8 – F3.0
• Output graph curves between F/2 and F/4
• Two samples length: 6m and 50m
• Spotlight projected on the fiber from a “far field” source covering 90% of the core disc
• Software for data reduction Calculation *Flat Field and Dark Field
• Experimental error less than 1 %

3.2 Analysis Software

We have developed a custom software package (DEGFOC 3.0) to reduce the fiber images and to obtain throughput energy curves. This software works in a Windows© environment. We found it to be an effective solution for use in the optical laboratory environment allowing for ease of analysis. The DEGFOC 3.0 package gives curves of Enclosed Energy and Absolute Transmission as is shown in the Figure 23 with the option to save the result in ASCII format to be used in any graphic software. Fiber throughputs are automatically determined as a function of output focal ratio.

The first step of a measurement is an estimation of the background level to be subtracted from the test exposures to remove the effects of hot pixels and stray light. The software then finds the image center by calculating the weighted average of all pixels. It associates a radius with each pixel and calculates the eccentricity that, in the ideal case, should be zero. Our target here is to obtain the absolute transmission of the fiber at a particular Input Focal Ratio. After establishing the distance between the fiber test and the CCD detector, the software defines concentric annulus centered on the fiber image. These are ~~then~~ used to define the efficiency over a range of f-numbers at the exit of the fiber, where each f-number value contains the summation of partial energy emergent from the fiber. Each energy value is calculated by the number of counts within each annulus divided by total number of counts from the lens camera images with some small defocus. The limiting focal ratio that can propagate in the tested fiber is approximately F/2.2 taking in account the numerical aperture of this fiber to be 0.22 ± 0.02. Therefore we have defined F/2.2 to be the outer limit of the external annulus within which all of the light from the test fiber will be collected. The corresponding diameters of the annulus are converted to output focal ratios, multiplying them by the appropriate constant given by the distance between the fiber output end and the detector.

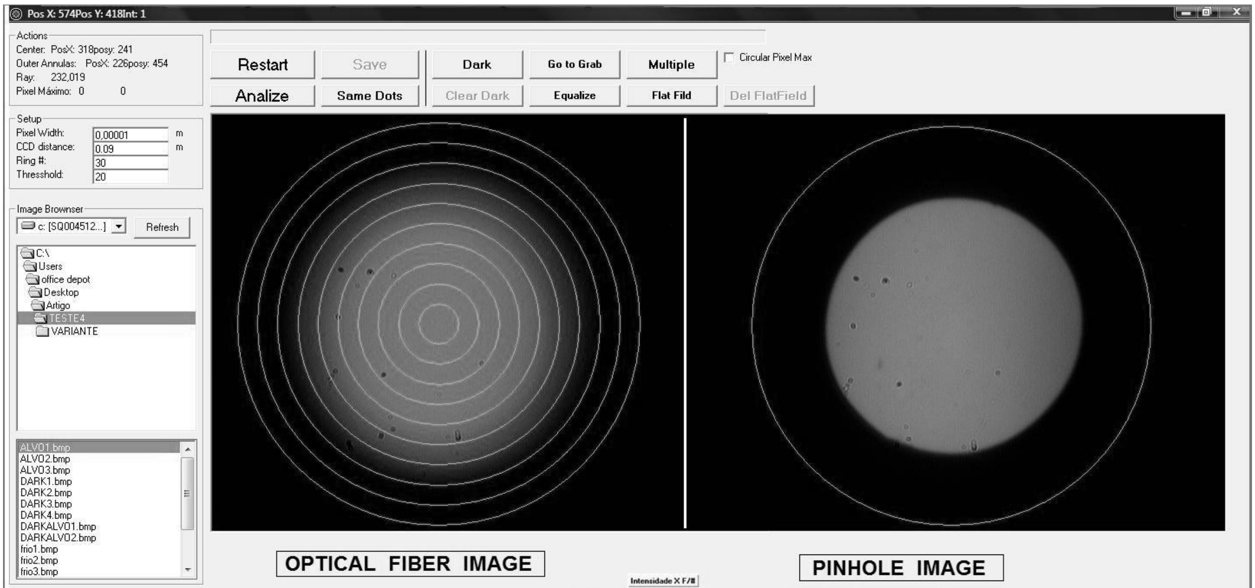

Figure 23: Print screen of the windows to the DEGFOC software. The software is user-friendly and has all the tools to produce the curve of enclosed energy as shown at the right. The center of the fiber spot, at left, is calculated from the weighted average of all pixels. Parameters such as distance between CCD and fiber, size of pixel and annulus number may be changed in the configuration box to optimize the calculation.

3.3 Results

Plots of absolute transmission versus output focal ratio for a sample with 6 meters Polymicro (FBP are presented in the Figure 24. For this sample we have obtained 6 graphs (Absolut Transmission & Output Focal Ratio), with 6 different Input Focal ratio; F/2.2, F/2.4, F/2.6, F/2.8 and F/3.0. The analysis has shown us that there is a box with 3 regions to be explored in operational conditions. A gray code, Bad, Good and Nice, despite to be arbitrary, may facilitate the analysis of the general throughput of the instrument. For example, if we intend to feed the fibers in Cable C around 6 meters length with F/2.6 would be reasonable expect obtain efficiency around 80%.

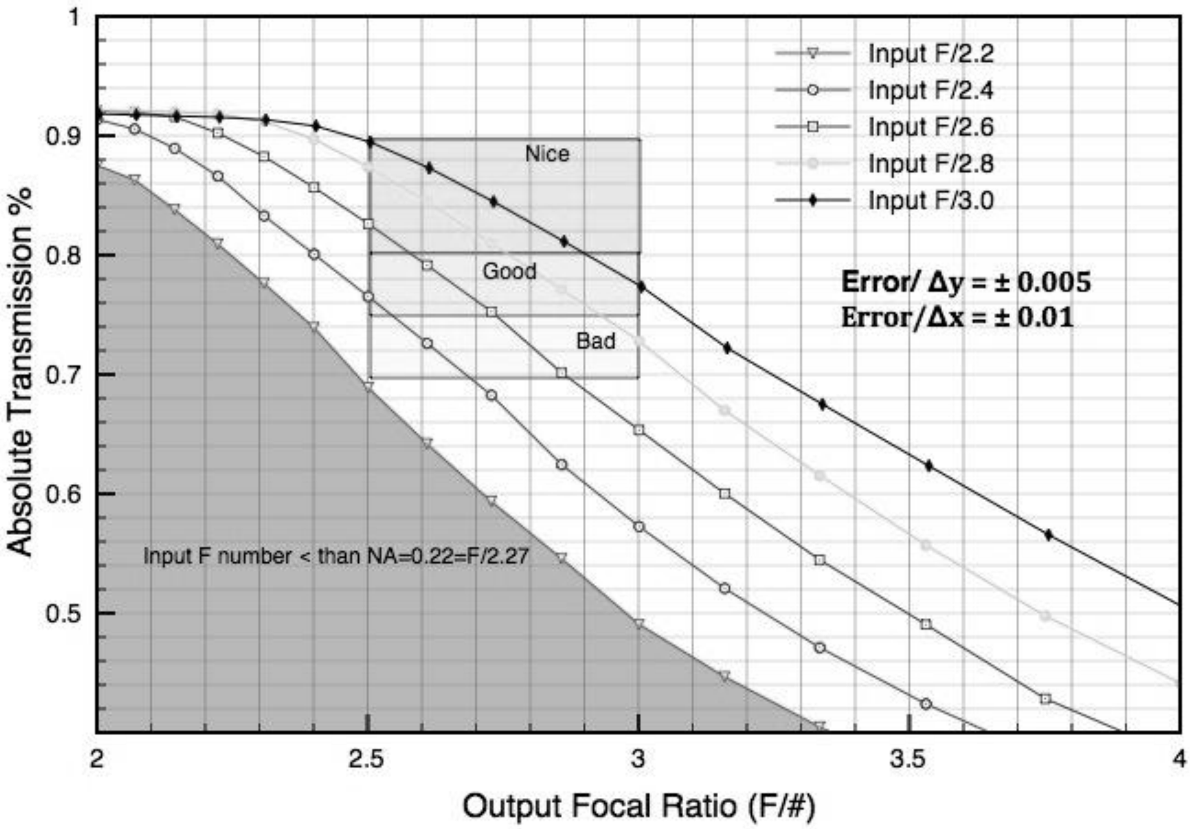

Figure 24: Optical Fibers Investigation FRD in Absolute Transmission Curves - 6 meters

4. MULTI-FIBERS CONNECTORS SYSTEM

The multi-fibers connector under study, shown in Figure 25, is produced by USCONEC Company. The called Apogee connector can connect 32 optical fibers in a single ferrule. The material of this ferrules are manufactures durable, composite, Polyphenylene Sulfide (PPS) based thermoplastic ferrules. The connections are held in place by a push-on/pull-off latch, and the connector can also be distinguished by a pair of metal guide pins that protrude from the front of the connector. Two fibers per connector will be used to monitoring the connection procedure. Lifetime and throughput are being investigated at this moment, but was found to be easy to polish and it is small enough to be mounted in groups. Moreover, its use in the spectrograph Apogee (SDSS) has produced excellent results.[04]

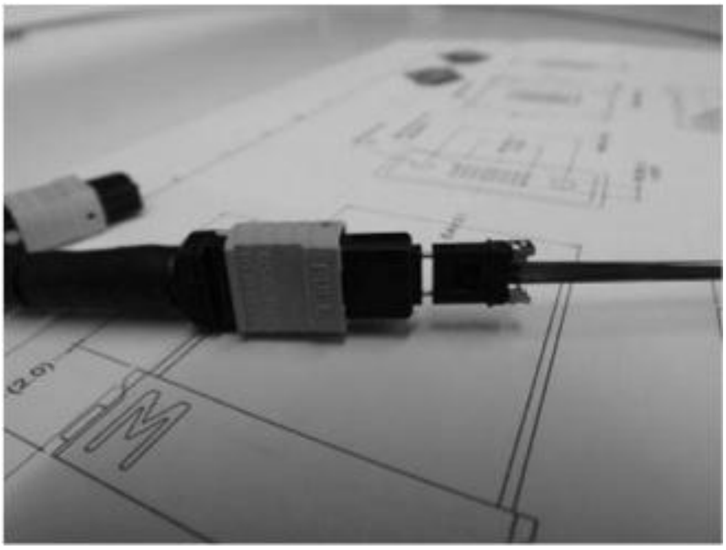

Figure 25: 32 optical fibers multi-connector produced by USCONEC Company in test phase.

It will be necessary to use two different types of structures to organize the connectors: Tower Connector system, with 80 connectors will be a group of connector's cells, TBD, to connect cable B (Telescope Structure) with cable C (Positioners Plate), Figure 26. Gang Connector system, is a group of 8 gang connectors, each one with 10 Apogee connectors to connect cable B (Telescope Structure) with cable A (Spectrograph), Figure 27. The bench tests with the Apogee connector and the chosen fibers should measure the throughput of light and the stability after many connections and disconnections. The test proceeding to evaluate the throughput is in developing at this moment. The lifetime of the ferrules should also be studied in the next few months.

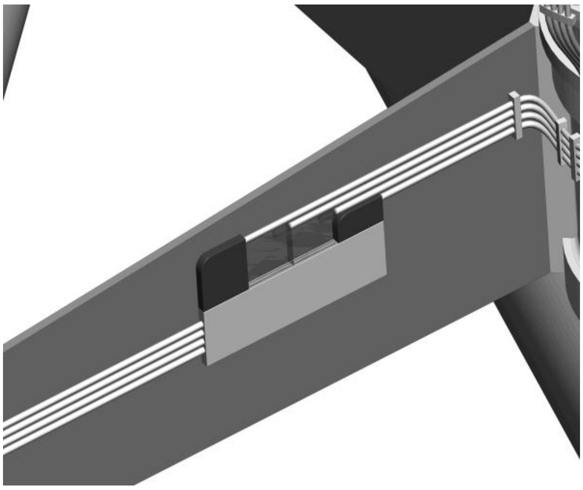

Figure 26: Tower Connector System, to be used at the telescope top end side. The Tower Connector system will be a group with 80 USCONEC multi-connectors

Figure 27: Gang Connector System, to be used at spectrograph side. Ten multifibers connectors inside 30 x 10 = 300 ➔ 2 Gang Connector per pseudo-slit

5. SUMMARY AND CONCLUSIONS

We described here the conceptual design for FOCCoS, (Fiber Optical Cable and Connectors System) to be a subsystem of SuMIRe- PFS, (SUBARU Measurement of Images and Redshifts- Prime Focus Spectrograph). A set of 4 pseudo-slits will comprise one of the extremities of the cable system. The other extremity will direct the fibers for fiber arms devices as the part of a patrol system. Each fiber arm will have one end of optical fiber polished and coupled at a microlens. FOCCoS is being projected for work with 2400 optical fibers segmented in 3 cables connected by sets of multi-fibers connectors. The multi-fibers connector under study is produced by USCONEC Company and Polymicro Company produces the optical fiber actually in test. It is expected to experiment with other types of optical fiber produced by Fujikura Company. A new composite material with optimized characteristics will be used as part of the substrate of the pseudo-slits and the fiber arms device.

6. ACKNOWLEDGMENTS

We gratefully acknowledge support from: The Funding Program for World-Leading Innovative R&D on Science and Technology. SUBARU Measurements of Images and Redshifts (SuMIRE), CSTP, Japan. Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP), Brasil. Laboratório Nacional de Astrofísica, (LNA) e Ministério da Ciência Tecnologia e Inovação, (MCTI), Brasil. We would like also to gratefully acknowledge Youichi Ohyama and Hung-Hsu Ling, PO members.

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