# FOCCoS for Subaru PFS

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## ABSTRACT

The Fiber Optical Cable and Connector System (FOCCoS), provides optical connection between 2400 positioners and a set of spectrographs by an optical fibers cable as part of Subaru PFS instrument. Each positioner retains one fiber entrance attached at a microlens, which is responsible for the F-ratio transformation into a larger one so that difficulties of spectrograph design are eased. The optical fibers cable will be segmented in 3 parts at long of the way, cable A, cable B and cable C, connected by a set of multi-fibers connectors. Cable B will be permanently attached at the Subaru telescope. The first set of multi-fibers connectors will connect the cable A to the cable C from the spectrograph system at the Nasmith platform. The cable A, is an extension of a pseudo-slit device obtained with the linear disposition of the extremities of the optical fibers and fixed by epoxy at a base of composite substrate. The second set of multi-fibers connectors will connect the other extremity of cable A to the cable B, which is part of the positioner's device structure. The optical fiber under study for this project is the Polymicro FBP120170190, which has shown very encouraging results. The kind of test involves FRD measurements caused by stress induced by rotation and twist of the fiber extremity, similar conditions to those produced by positioners of the PFS instrument. The multi-fibers connector under study is produced by *USCONEC* Company and may connect 32 optical fibers. The tests involve throughput of light and stability after many connections and disconnections. This paper will review the general design of the FOCCoS subsystem, methods used to fabricate the devices involved and the tests results necessary to evaluate the total efficiency of the set.

**Keywords:** Spectrograph, Optical Fibers, Multi-fibers connector

## 1. INTRODUCTION

FOCCOS subsystem, Figure 1, is defined by 4 interfaces:

1. Telescope (External Physical Interface):
• Cable route & Telescope
The route will be defined taking in account the telescope structure, the available places for the parts of the instrument and the movement of the telescope. (TBD)

2. Spectrograph (External Optical Interface):
• Pseudo slit & Spectrograph
For 4 spectrographs we need 4 pseudo slits. Each one should be 140mm long and holds 600 fibers, so the center-to-center fiber spacing is 230 microns. The fiber OD is 190 microns.

3. Cobra (External Optical Interface):
• Fiber arms & HSC
Each COBRA positioner unit will contain a fiber arm that holds one fiber whose positions, are articulated to be positioned over a small region of sky. This fiber needs to be polished and secured to the COBRA unit in a robust, but stress-free manner, which retains the intrinsic FRD of the fibers themselves. The fiber extremity requires a microlens glued to accept the fast (~f/2.3) beam input from the PF corrector with minimal throughput loss.

4. Connectors (Internal Optical Interface):
• Cable A & Cable B & Cable C
The modules of connectors are required to perform with optimal efficiency through a large number (TBD) of connect/disconnect cycles and are to be made so that there is no impairment to the surface quality of the fibers themselves. It will be necessary to have connection with all cables, cable A to cable B and cable B to cable C. The connector under study is from USCONEC, which was successfully used in the Apogee spectrograph for the SDSS.

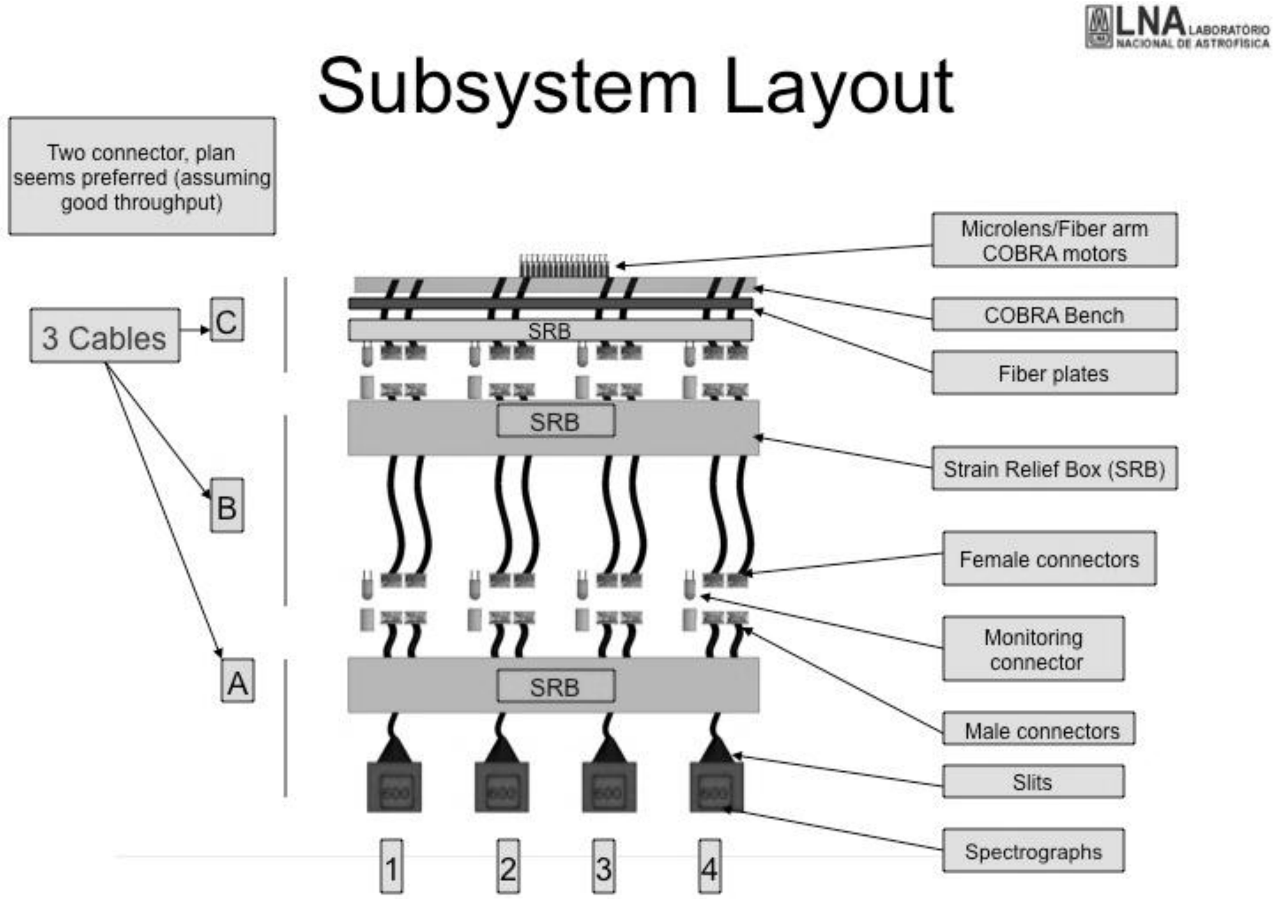


**Figure 1:** FOCCoS Layout subsystem showing the interfaces

All optical interfaces (OI), are involving a bundle of optical fibers divided in manageable groups. Physical interfaces (PI) refer to all other non-optical interfaces. Each group is encased by protective tubes and clamped along their route. The route starts at the COBRA positioner through a tower cell connectors (80 small unit Apogee) and then across the platform veins and down the telescope tube and through again the 8 Gang connectors to finish at the spectrograph.

## 2. CABLE SYSTEM

The cable system is sequentially divided in cable A, cable B and cable C, which are connected together by multifibers connectors. To protect the optical fibers from excessive strain or damage during operation and installation, a system of conduit tubes, furcation tubes, worm tubes and polyamide tubes will be used. The conduit tube is outer tube, which gives full protection to a group of furcation, or segmented tubes containing the optical fibers. In general they are constructed by steel rings covered by plastics or steel mesh as shown in the Figure 2. The furcation tube, Figure 3, is a set of double tubes constituting an external tube of plastic and an internal tube of PTFE within which several fibers are contained. Between the internal and external tubes there are Kevlar fibers. Furcations tubes are generally used to protect groups of optical fibers. The Kevlar and the external tube, of the Furcation tube are used to clamp a metallic termination. Segmented tubes, or worm tubes, Figure 4, are constructed of only one tube of PTFE plastic. However, the internal surface is extremely smooth, specially designed to accommodate optical fibers. The external surface is segmented, as shown. This kind of tube is good for allow the fibers to spin freely within the tube at the termination points. Polyamide tubes, Figure 5, are used as strain relief tube to prevent mechanical stress, and hence FRD, occurring at the point where the fiber enters the ferrule. The conduit contains the furcation tubes, each of which contain and protect approximately 30 optical fibers. The termination of each furcation tubes has a metallic termination point, which holds the furcation tube onto a plate. This plate is attached in the extremity of the protective conduit which itself is attached on the structure of the telescope.

**Figure 2-** External conduit tube, segmented to receive the compensation box.

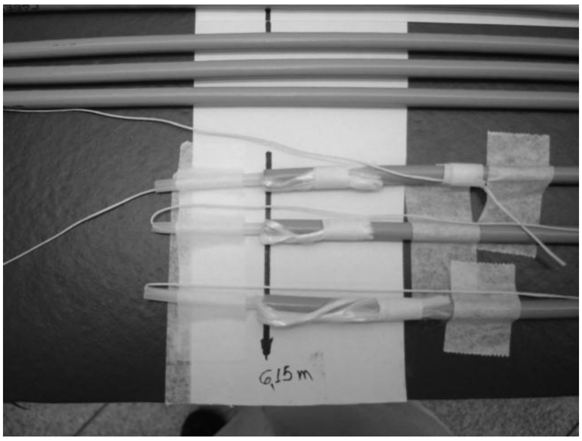


**Figure 3-** Arrangement of furcation tubes

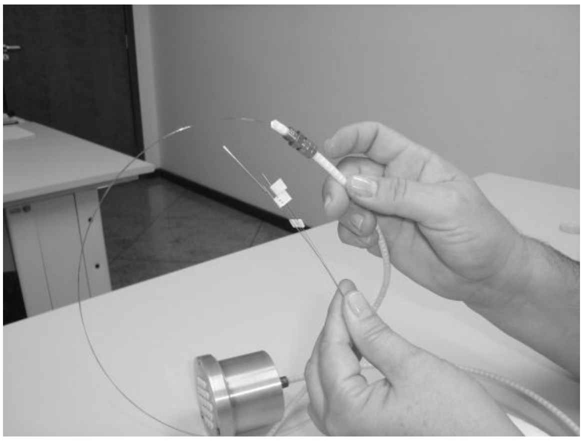

**Figure 4-** Worm (segmented) tubes

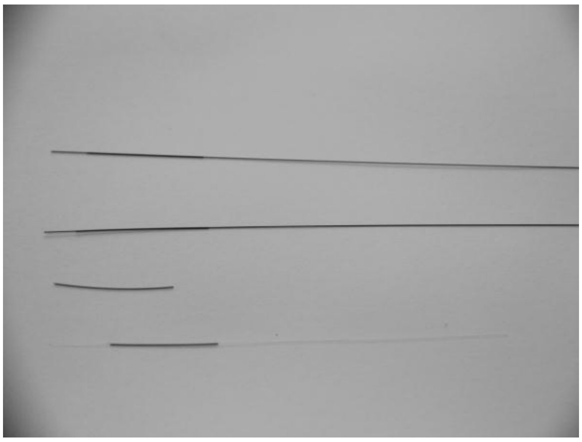

**Figure 5-** Polyamide tube

## 2.1 Cable A

Cable A, will be the cable installed at the spectrograph side, including the slit system. The composition of this cable is basically small conduit tubes, containing furcation tubes with groups of optical fibers to be distributed for 4 pseudo slits devices and to feed the spectrographs sets. Cable A is a set of parallels cables starting in the slit device, crossing a distribution box and finishing at the connectors system, Figure 6.

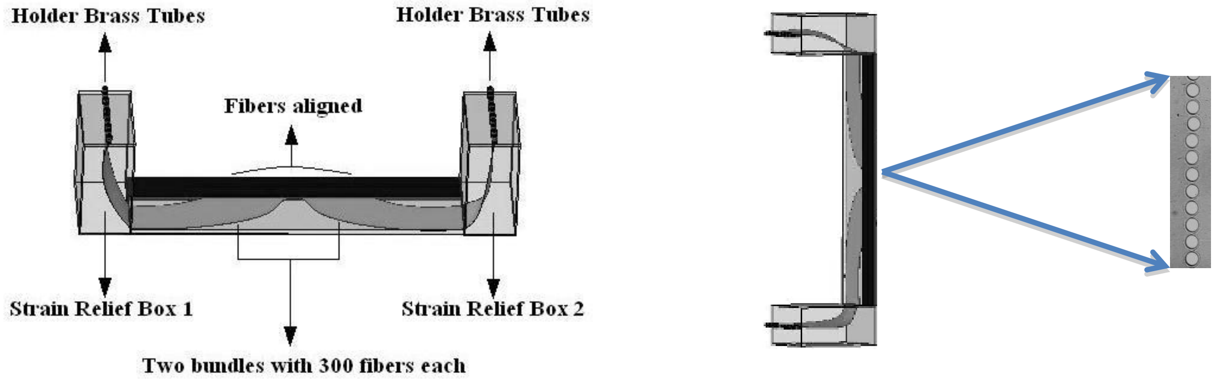


**Figure 6:** Fiber Device termination is one of the extremities of the cable A. Segmented tubes, starting in the holder brass, conduct the fibers at the other extremity of the cable A, called optical bench connectors.

### 2.1.1 Slit Device

The slit device is a monoblock, made and machined in composite, Figure 7, with all fibers disposed in a circular arrangement. Each one is 140 mm long and holds 600 fibers, so the center-to-center fiber spacing is 230 microns. The fiber OD is 190 microns. In this case, the best option is to use a mask of precision. The device assembled with the correct gap need to be made with two twin masks as a shown in Figure 8. This is a metal mask very thin obtained by a technique called electro formation. The mask obtained by this way can be configured to have holes with specifics diameters and pits, with errors around 1 micron in the diameter and in the position of the holes. This technique can produce a metal nickel plate with 200 microns of thickness and the procedure is very cheap. It is possible to obtain micro holes with the diameter exactly one or two microns larger than the diameter of the used fiber. Four slit devices will be constructed, each one containing 600 fibers aligned through holes of 190 microns in diameter with a pitch of 230 microns. The device is immersed in a container, with EPOTEK 301-2, constructed using plates of PTFE doped with graphite. After dry it is very easy to remove the frontal plate without offer any damage to the block or the fibers. The polishing process consists of: 1) to cut the end of the block and removal of the excess of glue with 2000 and 2500 grit emery paper; 2) initial lapping with 6 micron diamond slurry on a copper plate and 3) a second lapping with 1 micron diamond slurry on a tin-lead plate is used until the complete removal of the frontal mask of precision. The final polishing is made with colloidal silica solution on a chemical cloth with 0.01 micron. The Figure 9 shows the slit system during the assembly.

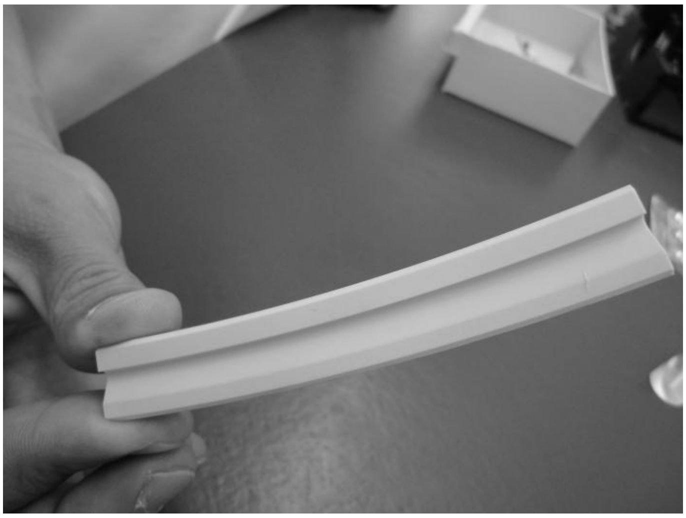

**Figure 7:** Monoblock made and machined to be the slit block

A meniscus lens whose inner radius R1 is the same as the radius of the fiber slit and whose outer radius R2, longer to make the lens negative, with AR coating in both sides may be glued against the slit block to protect the fibers extremities and avoid scratches or damages.

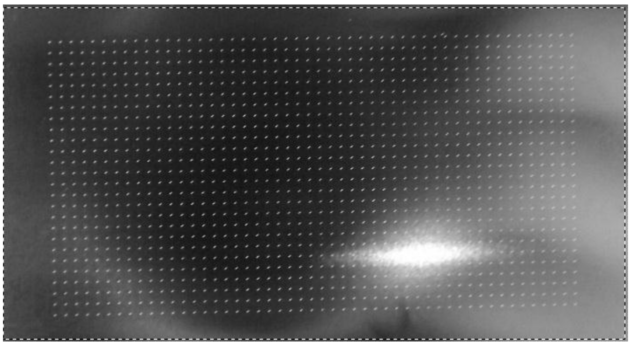

**Figure 8:** Photo of the mask of precision used to obtain the slit with correct distribution and gap between the optical fibers.

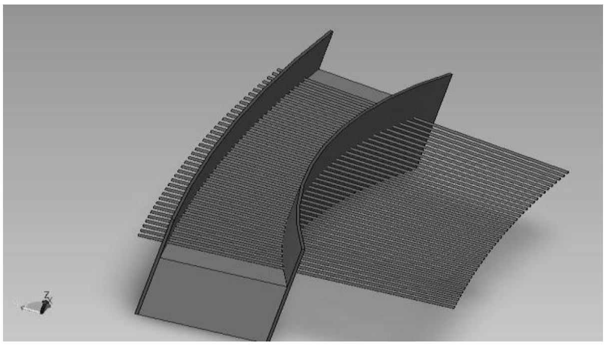

**Figure 9:** Schematic of the curved slit during the assembly. The fibers do not touch the base made with composite.

## 2.2 Cable B

Cable B will be the cable permanently installed at the telescope structure, composing the longest cable of the system, with around 40 meters. This cable is basically a conduit tube containing several plastic tubes inside (furcation tubes) through which the groups of optical fibers are protected, Figure 10. The routing of the cable is either looped across to the "Great Wall", within which the spectrographs are housed, or through the cable warp of the elevation axis. The cable will interface directly with the telescope and dome structure from the TES vanes to the Great Wall and it needs to define minimal stress on the fibers during telescope pointing and field rotation of the TES.

Changes in the length between local fiber securing points will be accommodated through the use of constant force springs. A set of strain relief boxes, Figure 11, will be located at the extremities of the cable B, close to the spectrograph system and close to the top end system. This defines enough free length of fibers out of the protection tubes to facilitate the manipulation of the fibers during the construction and the polishing procedures of the cable. The cable B, at the top end side, will be separated in two parts to conduct fibers only by the furcation's tubes, willing in combs on both laterals of the spider plate, Figure12.

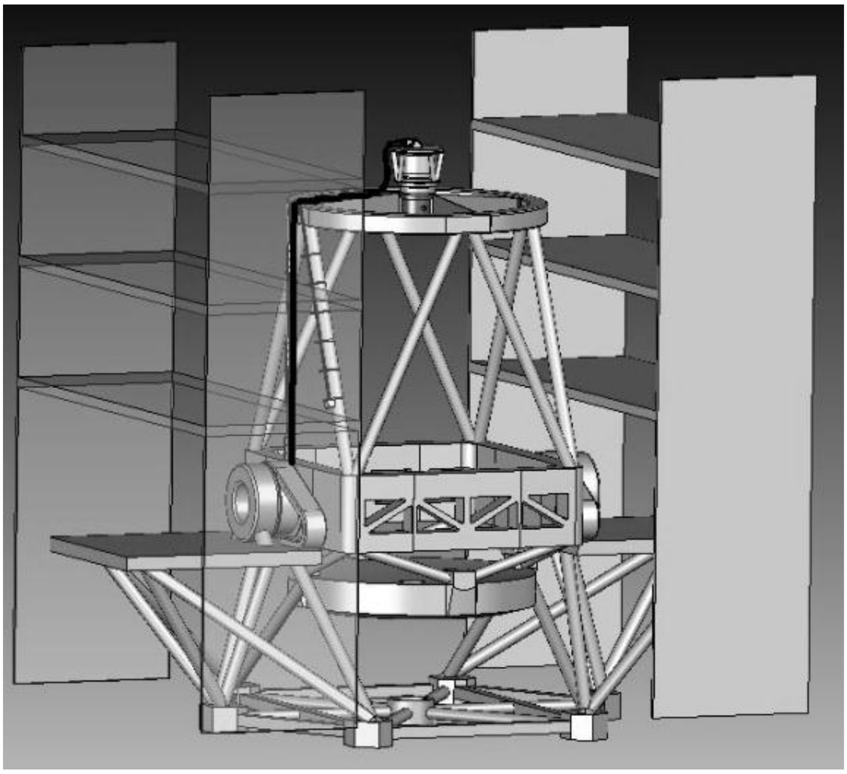

**Figure 10:** Possible disposition of the Cable B clamped at the telescope structure

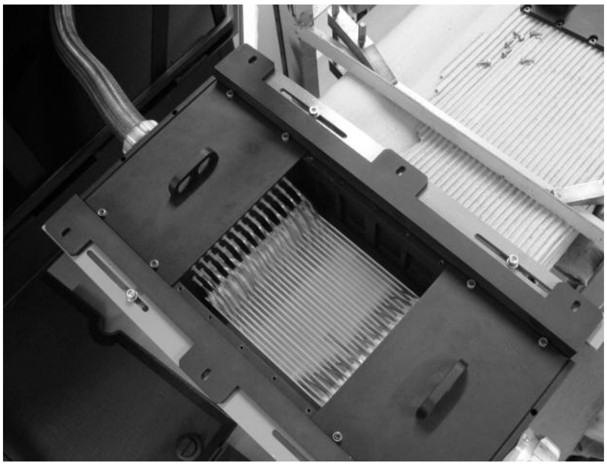

**Figure 11:** Strain relief box in study to be used in both extremities of the Cable B.

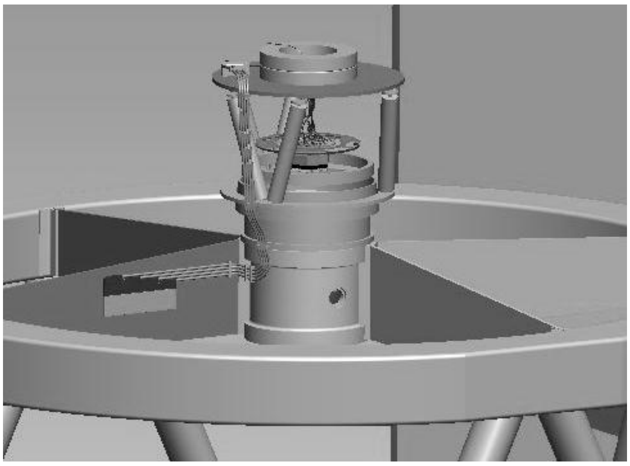

**Figure 12:** Combs of tubes containing optical fibers, in one of sides of the spider plate on the top end of the telescope.

## 2.3 Cable C

Cable C, will be the cable installed at the top end devices, the COBRA motors systems. It will be composed by a set of segmented tubes articulated inside of the PFI chamber, Figure 13. Cable C is a set of parallels cables that start in the fiber arm devices, crossing the COBRA plate, fiber plates, strain relief boxes and finishing at the connectors system, Figure 14.

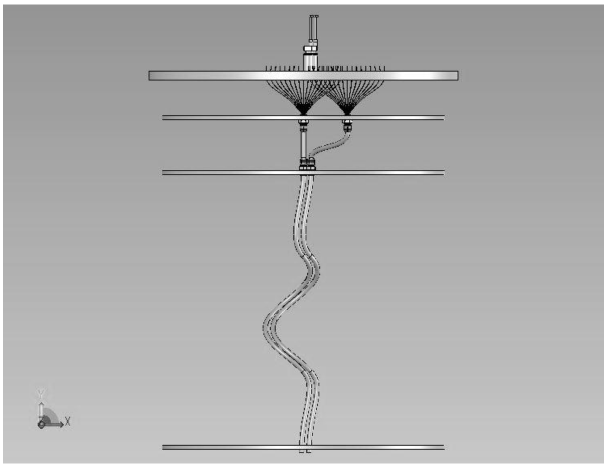

**Figure 13:** Concept for the plates system inside the chamber (PFS envelop) and the segmented tubes secured for the assembly plate by holders terminals.

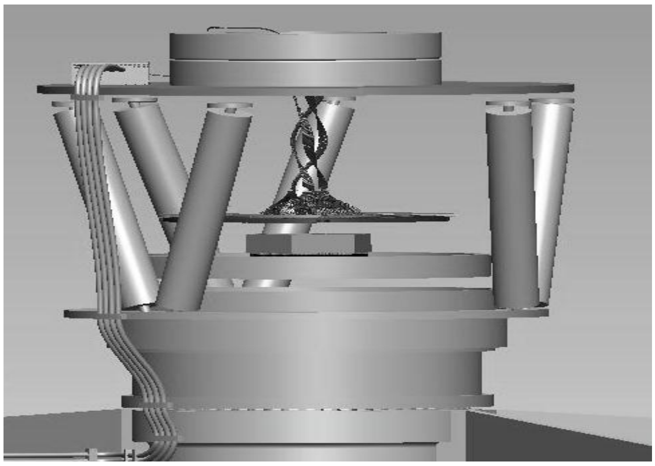

**Figure 14:** PFI Chamber drawing with internal details of the segmented tubes incasing the optical fibers. The structure will be projected to have the cable wrap on the top.

The Cable C needs to be integrated with the COBRA system, which is a set of devices including COBRA motors that are responsible for the patrol of the fiber. The plan for the construction of this cable has 2 parts: the first one will be at LNA and, the second one, at JPL. The first part, Figure 15, includes: cutting the fibers, populate the arms with optical fibers, to glue the fibers, polish the fiber arms and to glue the microlens at the fiber extremity. The second part, Figure 16, includes: passing the optical fibers through the COBRA motors, populate the segmented tubes, passing the fibers through the connectors, and polishing of the connectors.

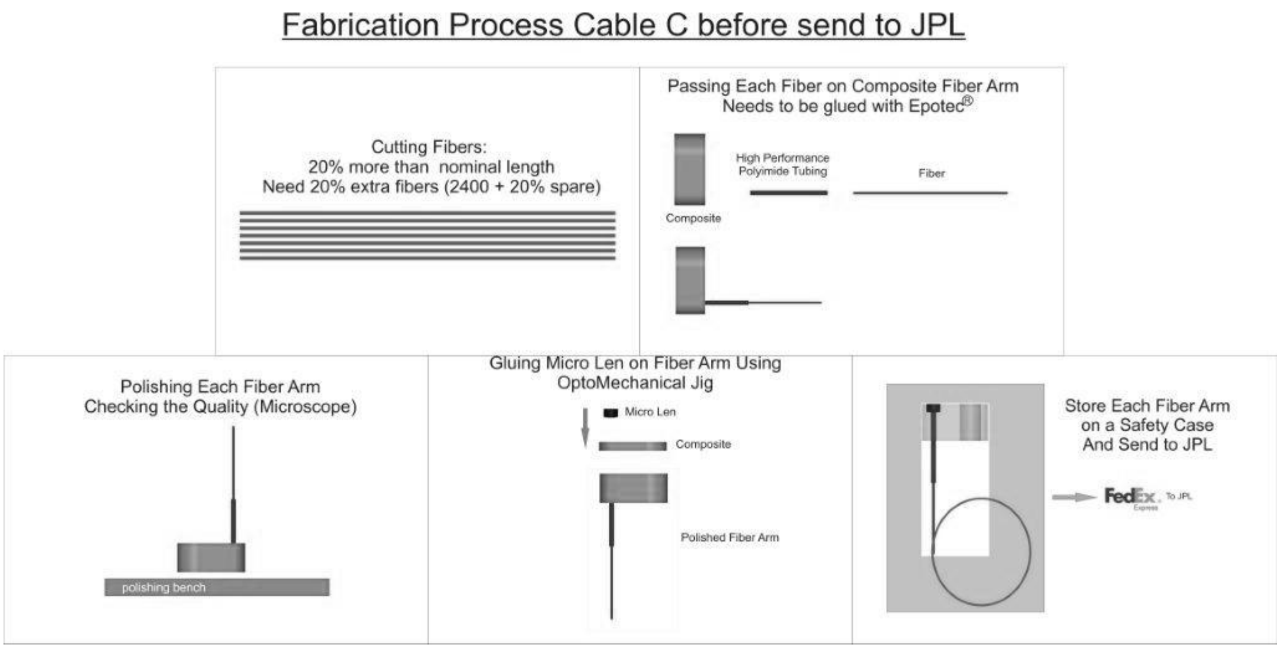


Figure 15: Fabrication process of the cable C before sends it to JPL

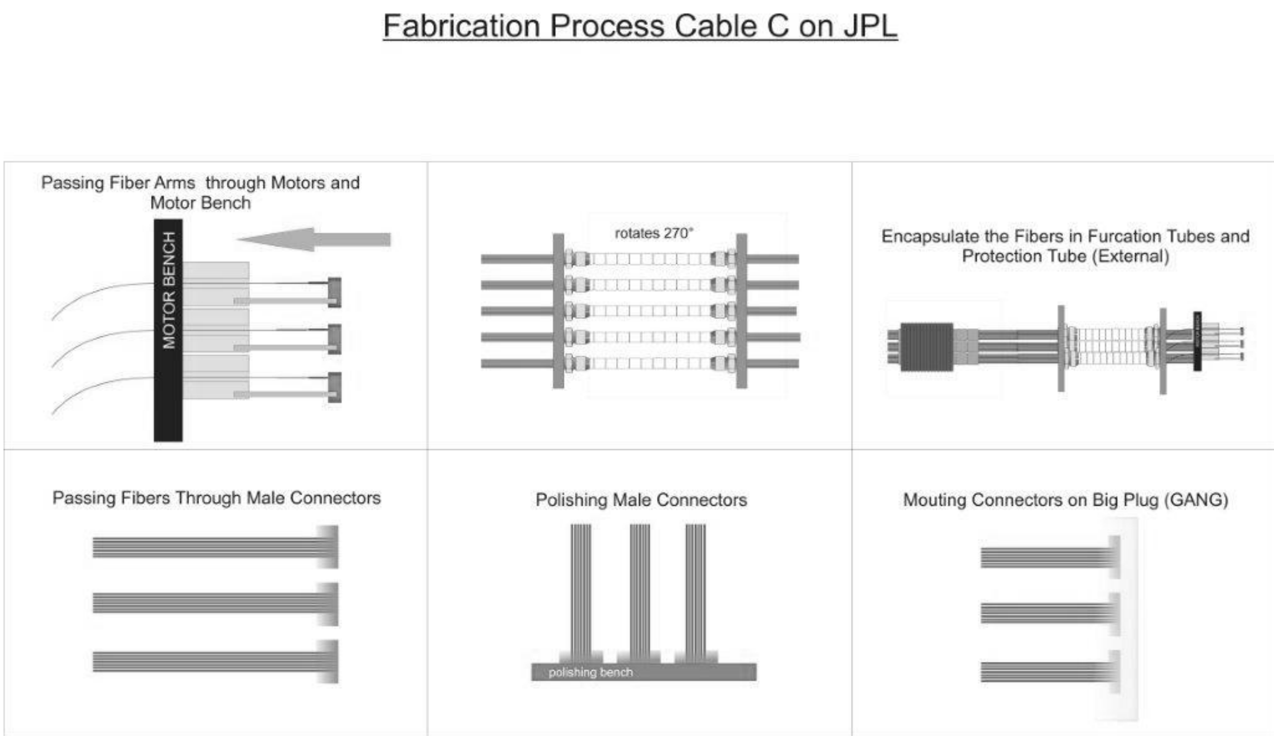


**Figure 16:** Fabrication process of the cable C at JPL