Title	**Tender No. I-ITN21001 dated 26th April, 2021 for Design, Develop, Test & Delivery of Optical Fiber Bundle Assembly for CXRS-Pedestal Diagnostics**
Sub Title	**PART-A (II): Scope of Supply, Scope of Work and Technical Specifications**

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1. Objective and Scope

The ITER-Charge eXchange Recombination Spectroscopy (ITER-CXRS) pedestal diagnostic requires the optical fibers for the light transmission from interspace zone to the diagnostic area. In this document, the required optical fiber bundle assembly technical specifications are described. The scope of this tender is

- Design of fiber head terminations, bundle to bundle connector
- Submission of engineering drawings for fiber head terminations and connectors, assembly drawing for fiber bundle assembly to ITER-India for review
- Development of Optical Fiber Bundle Assembly including fiber head terminations and bundle to bundle connectors
- Factory Testing of Optical Fiber Bundle Assembly
- Supply and final acceptance at ITER-India site for Optical Fiber Bundle Assembly

The integrated fiber bundle assembly includes: the fiber bundle channels, the bundle to bundle coupling connections, the required terminations, and arrangement of the calibration fibers, test fiber along with light source and meter (power measuring device) for fiber bundle assembly testing.

2. Details of Fiber Bundle Assembly Terminations

The proposed optical fiber assembly is used to study the image coupling to the fiber head, transfer of the collected light (image coupling) from one bundle to another bundle and integrating the same with spectrometer entrance slit as well as calibration experiments. To meet these requirements an optical fiber assembly with five termination points (A, B, C, D, & E) is needed as per defined scheme shown in Figure 1.

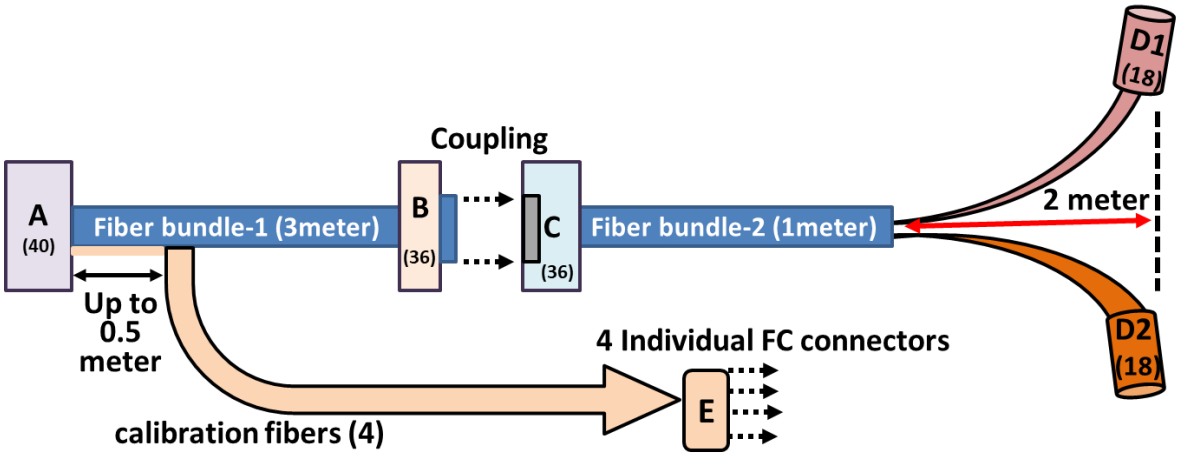

Figure 1: Schematic of the optical fiber bundle Assembly with all the required terminations.

2.1 Specification of fiber head A

At point **A,** the light is coupled to fibers and it is defined as fiber head. The detailed schematic of fiber head is shown in Figure 2. The fiber head has 10 × 4 matrix of fibers. Each column has 10 fibers and denoted as one channel in ITER-CXRS-pedestal diagnostics. In each channel, 9 fibers are for light collection and one is reserved for calibration (fiber #1, top of the nine) as shown in Figure 2 (a). All the four calibration fibers will be bundled out separately between A and B and terminated with the individual Ferrule connectors (FC) as represented by E termination in Figure 1. The detailed specifications of this fiber bundle assembly are given in Table 1 & Table 2.

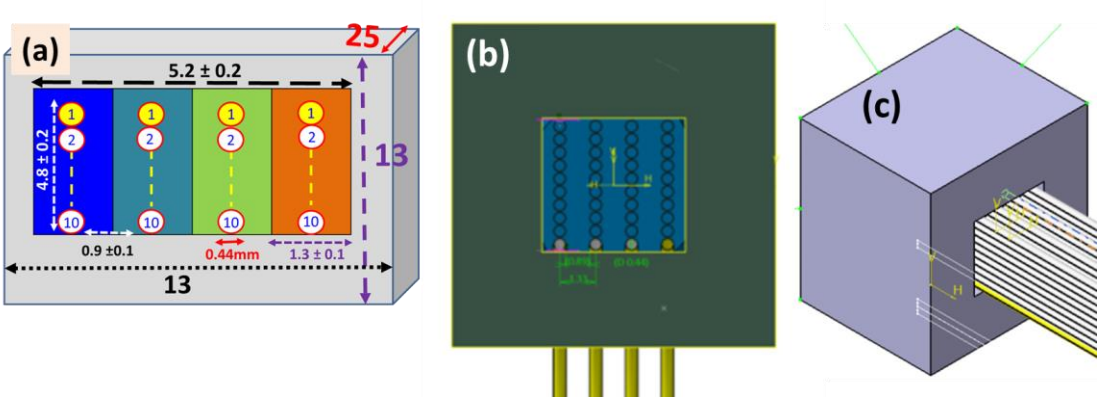

Figure 2: Schematic of Fiber head at termination A (a) required Fiber arrangements and gap in-between the Fibers channels, (b &c) and a 3D CAD models (front & back)

2.2 Specifications of Termination B & C

The termination B and C are required for fiber bundle to bundle coupling to couple the all 36 fibers (channel 1 fiber#1 of B to channel 1 fiber#1 of C and so on) and shown in Figure 3 (a). The connector can be any one of the available standard Commercial off-the-shelf (COTS) item. The proposed connection scheme is as shown in Figure 3 (b) & (c) or if the proposed scheme is not possible then an alternative arrangement can be quoted or discussed with us to meet the performance and dimensional requirements. Any suitable outer casing configuration (Threaded/ bayonet or any other suitable option) can be chosen for considering the quick coupling and decoupling of fiber bundle which can be achievable within the outer diameter of ≤35 mm.

A stable signal transmission is required, therefore the uncertainty in the measured transmission losses after each 5th connection/disconnection should be as minimum as possible. For the better reproducibility, the total losses should be within the range 10-20%. This specified losses also includes the losses incurred in connection/disconnections.

The fiber arrangement at B & C (shown in Figure 3 (c)) need to be chosen so as to meet the requirements of efficient coupling, minimum cross talk and most importantly by keeping (as per ITER requirements) the maximum allowable outer diameter of the casing up to ≤35mm at B & C terminations. Figure 3 (b) shows a typical scheme of the same.

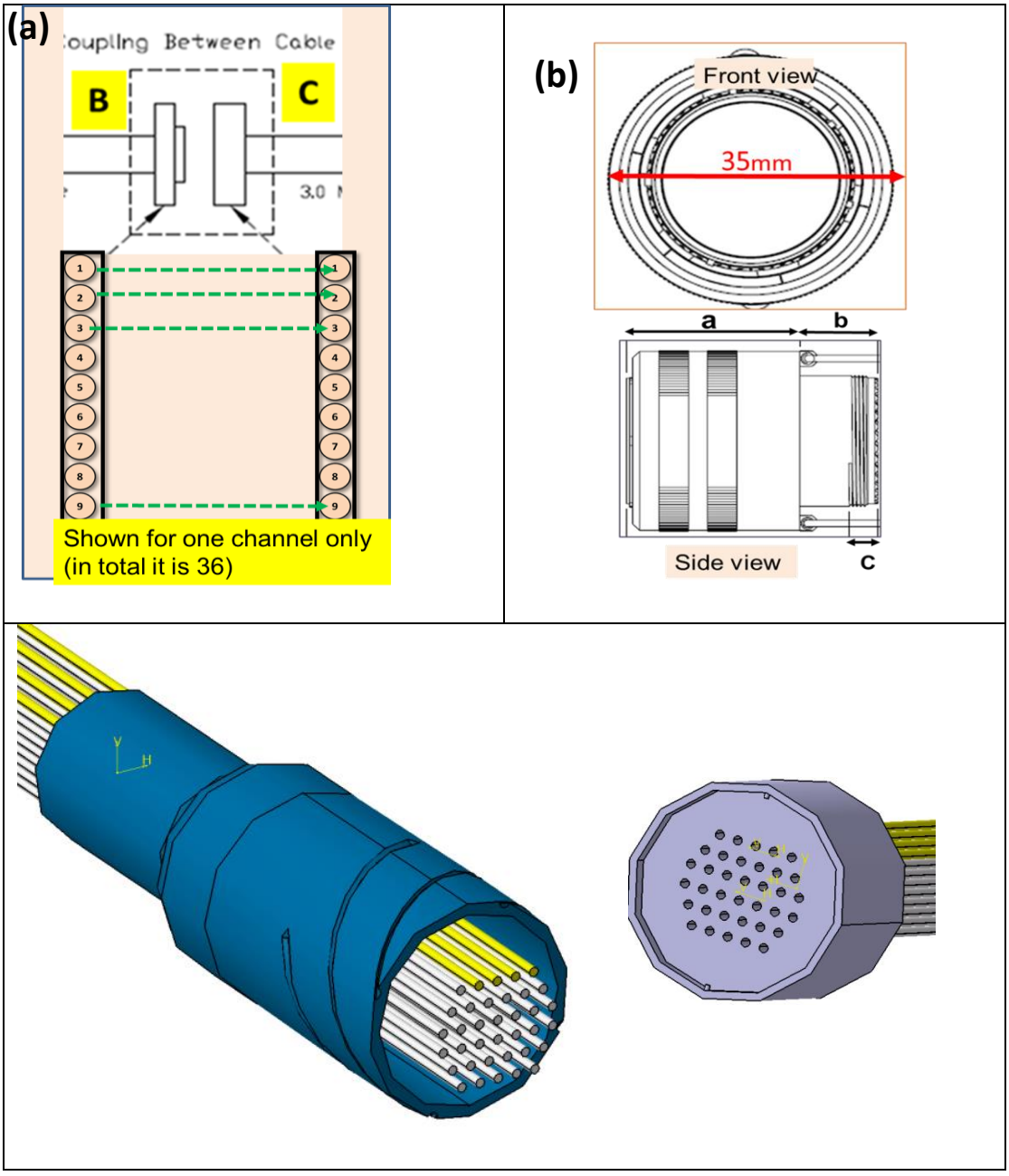

Figure 3: Schematic of fiber bundle to bundle connection and possible arrangement of fibers

2.3 Specifications of Termination D

The fiber head termination at D point is integrated with the entrance slit of the Spectrometer using a fiber adapter as shown in Figure 4. Actually, to accommodate the 36 fibers, the termination is divided into two bundles having 18 fibers each, they are denoted as D1 and D2. The dimensions of fiber head i.e termination D1or D2 has to be compatible with the universal fiber adaptor (from

Princeton Teledyne instruments) provided at the entrance of the Spectrometer: Part no: Model FC-446-021-U with a compatible 10mm diameter fiber bundle. If required the adaptor details can be provided. In connector D1 a set of 9 fibers represent a single channel. Hence the connectors D1 and D2 will represent four channel and both these connecters should be as identical as possible. The outer diameter of D1 is 10 mm as shown in of Figure 5 (a) and the 3D CAD model is shown in Figure 5 (b). The required spacing between channel 1 & 2 is 0.44mm which is equivalent to one fiber.

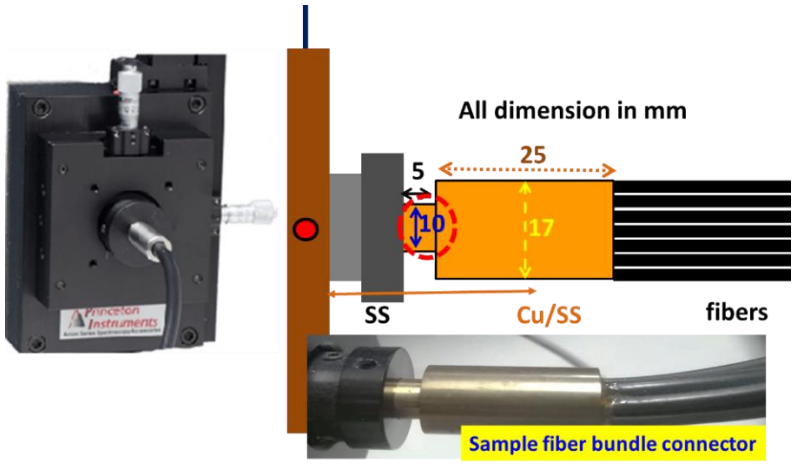

Figure 4: Schematic of fiber head termination at D point for coupling with spectrometer

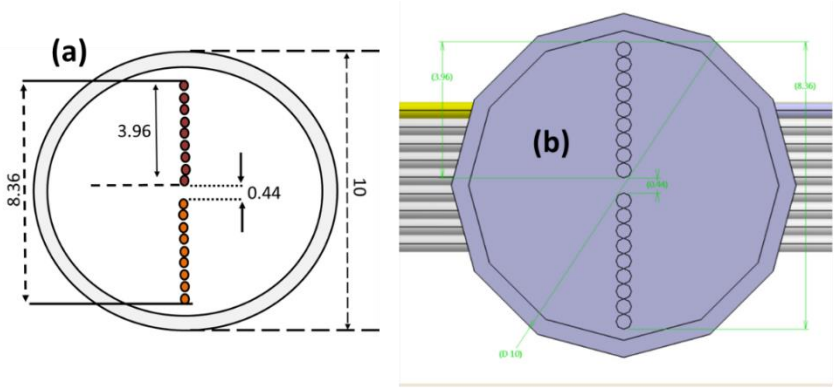

Figure 5: Schematic of the fiber arrangement for each channel in vertical array according to the spectrometer entrance slit & image plane requirement, and outer diameter of 10 mm (3.96×2 (Fiber)+0.44(gap between channels)+1.3 (Ferrule Thickness)+0.2(Tolerance)) in circular shape.

2.4 Specifications of Termination E

The termination head E is dedicated for calibration fibers. The calibration fibers are bundled and bifurcated from the main fiber bundle head A as shown in Figure 6. The combined length can be up to 0.5 m (according to the manufacturability of separate bundle formation for calibration (4) and

light collection (36) fibers) and after which the bifurcation begins. The length of bifurcated calibration fibers is around ~5.5 meter length and terminated with individual standard Ferrule Connector (FC) that will result the total calibration fiber length of 6 meter (Equivalent to other 36 fibers and test fiber i.e. also 6 meter) as shown in Figure 6.

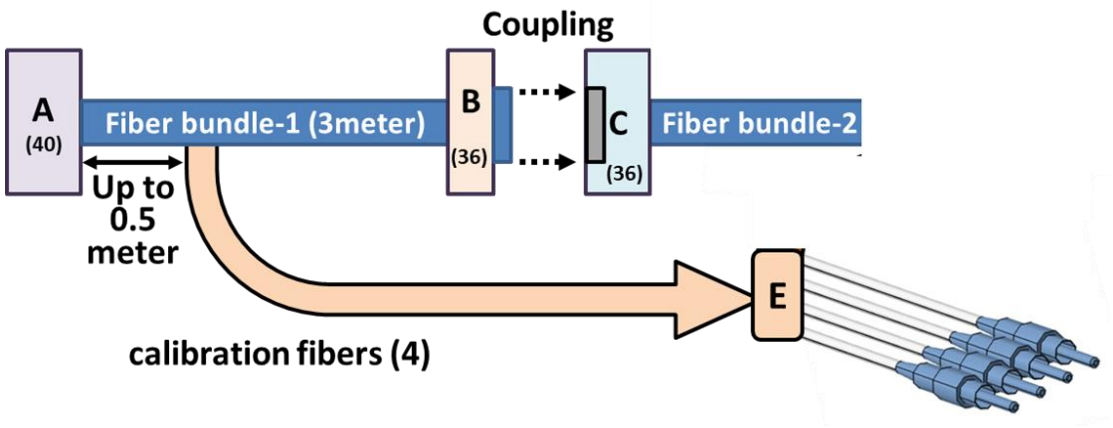

Figure 6: Schematic of calibration fiber termination (E) separated from the bundle each end with FC connectors

2.5 Test Fiber

The fiber bundle assembly is to be tested for its required transmission efficiency. Therefore, it is required to have a test fiber with identical material and length of six meter with same type of termination D (10 mm outer diameter as shown in figure 5 (a)) for spectrometer coupling at one end and another end will be the FC connector. This will be used for comparing the transmission efficiency of the fiber to fiber connector.

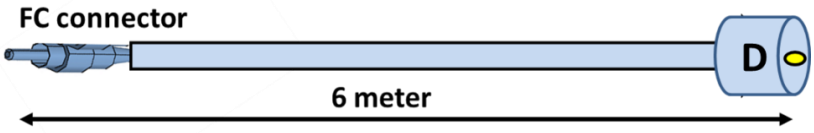

Figure 7. Schematic of test fiber for transmission efficiency estimation without connector.

3. Technical Specifications of Fiber Bundle Assembly

The technical specifications of 40 numbers step index multimode fibers of 6-meter length and a separate test fiber with FC terminations are described in Table **1** (Main Technical specification) & Table **2** (General Technical specification).

Table 1: Optical Fiber bundle Assembly: Main Technical specification

S. No.	Parameters	ITER-India Specifications
1	No of different types of terminations for bundle to bundle, image, and Spectrometer entrance slit couplings	5 (A,B,C,D,E as defined in termination requirement section (dimensions in mm), fiber head A-See figure 2(a) B&C- See figure 3 (b) D- See Figure 4 & 5 (a)
2	Core diameter	400±20 μm
3	Cladding diameter	~440 μm
4	Operation Wavelength range	450-700 nm
5	Numerical Aperture (N.A.)	0.22± 0.02
6	Fiber Transmission Attenuation (for wavelength range 450-700 nm)	30-50 dB/km
7	Expected Overall transmission efficiency including bundle to bundle coupling (Connecting efficiency) losses	80-90% or better
8	Length of each Fiber	6 meters (in two part 3+3 meter as per termination)
9	Fiber Type	Multimode single core Fiber

Table 2*: *Optical Fiber bundle Assembly: General Technical specification

S. No.	Parameters	ITER-India Specifications*
1	Quantity of fibers bundle assembly	One (fiber bundle assembly that includes 40 fibers + 1 separate test fiber)
2	Coating over cladding	Polyamide coating Or any suitable material (Please specify)
3	Protective sleeve over coating	Has to provide for sufficient protection (For example : Flexible metallic jacketing/Tube
4	Operation Temperature	Up to 50^{o}C
5	Core Material	Pure Silica
6	Minimum Bend Radius	Short Term: 100 × Clad Diameter Long Term: 200 × Clad Diameter
7	Cure epoxy	According to the transmission and dimension tolerances

*Documentary evidence/Certificate should be provided for above mentioned general technical specification of Optical Fiber bundle Assembly

Light Source & Power Meter

Technical specification of the Suitable light source to test the optical fiber bundle assembly transmission performance for three wavelength regions blue (~450nm), Green (~525nm) & red (~650nm) defined in Table 3.

The required power meter should be compatible with the light source (Table 3) along with the fiber bundle assembly transmission performance measurement requirements. Technical specification of the power meter to measure the transmission losses in the desired wavelength region with the suitable power rating defined in Table 4.

Table 3: Light source specifications

Sl. No	Parameters	ITER-India Specifications
1	Quantity	01
2	Power Output	Suitable for fiber bundle assembly testing (Please specify)
3	Fiber coupling	Ferrule connector (FC) compatible with light source
4	Wavelength (nm)	Blue (~450nm), Green (~525nm) & Red (~650nm)
5	Type	LED or other compact light sources with known power output

Table 4: Power meter specifications

Sl. No	Parameters	ITER-India Specifications
1	Quantity	01
2	Fiber coupling	Ferrule connector (FC) compatible with power meter
3	Sensor size (Aperture)	≥10 mm
4	Spectral Range	450-700 nm
5	Power range	compatible with the light source and fiber bundle assembly performance measurement requirement

4. Transmission Efficiency Test for Acceptance of Optical Fiber Bundle Assembly (Factory Acceptance Test)

The fiber bundle assembly performance shall be tested at factory by measuring the transmission loss. The test can be conducted by placing a source signal (example an Light (optical) source) through fiber head A and then detecting the signal at connector D using a detector (example: optical power meter) as shown in Figure 8. The transmission loss is the power lost during the signal transmission in the path from A to D.

This can be performed using the light source (**Table 3**) in the required working wavelength range and optical power meter (**Table 4**) which is generally used in optical fiber light transmission attenuation testing. The performance test schematic is shown in Figure 8, only for one fiber, the similar test needs to be performed for all 36 fibers (Fiber bundle) and the test report for the same

needs to be submitted for evaluation. This test has to be conducted at factory before dispatch. After approval of this test report, dispatch clearance will be given.

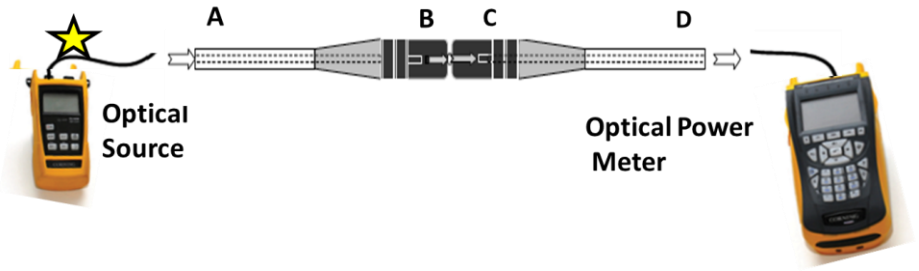

Figure 8. Schematic for the optical fiber to fiber connector efficiency test.

Expected test results:

a. The transmission loss is within the range of 10-20% or less than this.
b. A stable transmission is expected through this assembly therefore the uncertainty in the measured transmission losses after each 5th connection/disconnection should be minimized for the better reproducibility. The total losses should be within the allowable range i.e. 10-20%.even after a repeated connection and disconnection.
c. The connections and disconnections time should be as minimum as possible (few tens of secs), to meet this, locking system without usage of screws shall be desirable or the bayonet type connector can also be used.

The above mentioned tests are ITER-India proposed tests, but the Supplier may also propose any alternative suitable test procedure/proposal which can be mutually agreed, to be performed successfully at factory before dispatch.

5. Quality Requirements

The supplier shall submit the MIP (Manufacturing and Inspection Plan) detailing the steps to be followed during the manufacturing for approval prior to start the manufacturing process.
The Quality plan and MIP will be reviewed by ITER-India before starting of Manufacturing. The procedure for performance testing at supplier site should be submitted by the supplier to ITER-India for approval.

6. General Information & Instruction to Supplier

The supplier should provide the following information along with bid

1. The Roadmap for development of optical fiber bundle to bundle connector. Clearly mention if this is considered with customized solution or with combination of COTS component.
2. 2D drawing of all the termination

3. Fiber bundle to bundle coupling scheme details

Duly filled and signed Compliance sheet (Table-5,6 and 7) as per section no. 7 below For Dispatch Clearance

Before delivering the optical fiber bundle to ITER-India

1. Updated 2D drawing of all the termination
2. Engineering details of developed or COTS connectors (specifications & drawings)
3. The test results of the transmission efficiency test.

2) Certificate of compliance (COC) of the items according to the required specifications. Vendor has to dispatch the materials only after getting the dispatch clearance certificate from ITER-India.

At ITER-India, site acceptance test shall be performed which may be repeat of the factory acceptance test.

7. Compliance sheet

Table 5: Compliance sheet for Optical Fiber bundle Assembly: Main technical specification

S. No.	Parameters	ITER-India Specifications	Supplier Specification
1	No of different types of terminations for bundle to bundle, image, and Spectrometer entrance slit couplings	5 (A,B,C,D,E as defined in termination requirement section (dimensions in mm), fiber head A-See figure 2(a) B&C- See figure 3 (b) D- See Figure 4 & 5 (a)	
2	Core diameter	400±20 μm	
3	Cladding diameter	~440 μm	
4	Operation Wavelength range	450-700 nm	
5	Numerical Aperture (N.A.)	0.22± 0.02	
6	Fiber Transmission Attenuation (for wavelength range 450-700 nm)	30-50 dB/km	
7	Expected Overall transmission efficiency including bundle to bundle coupling (Connecting efficiency) losses	80-90% or better	
8	Length of each Fiber	6 meters (in two part 3+3 meter as per termination)	

9	Fiber Type	Multimode single core Fiber	

Table 6: Compliance Sheet of Light source specifications

Sl. No	Parameters	ITER-India Specifications	Supplier Specification
1	Power Output	Suitable for fiber bundle assembly testing (Please specify)	
2	Fiber coupling	Ferrule connector (FC) compatible with light source	
3	Wavelength (nm)	Blue (~450nm), Green (~525nm) & Red (~650nm)	
4	Type	LED or other compact light sources with known power output	

Table 7: Compliance Sheet of power meter specifications

Sl. No	Parameters	ITER-India Specifications	Supplier Specification
1	Fiber coupling	Ferrule connector (FC) compatible with power meter	
2	Sensor size (Aperture)	≥10 mm	
3	Spectral Range	450-700 nm	
4	Power range	compatible with the light source and fiber bundle assembly performance measurement requirement	

Bidder's representative name and Designation

Representative's sign:

Bidder's official stamp/seal:

Date