Design and Development of a 16-inch Telescope Receiver System for Atmospheric Lidar Application

Scope of the Work

- The scope of the work entails the end-to-end development of a 16-inch Telescope Receiver for Mie (Aerosol) Lidar Application, which includes the design and fabrication of the telescope along with 2-channel back-end optics assembly near the telescope focal plane, and the integration, installation, testing and commissioning of the complete system at the installation site (SPL facility at IPRC, Mahendragiri).
- The party has to demonstrate the performance of the system during the development phase (at the factory site) and during the installation and commissioning phase (at IPRC, Mahendragiri).
- During the installation, the party should perform and demonstrate precise optical alignment of the telescope FOV with the vertically transmitted laser beam (laser arranged by VSSC at the installation site), confirming the reception of backscattered laser signals from higher altitudes.
- The system will be accepted and commissioned only after the successful operation as the telescope receiver for an atmospheric Mie lidar system at the installation site.

System Description

- The envisaged Telescope Receiver consists of a 16-inch telescope and back-end optics assembly (near the telescope focal plane) with two independent optics channels. The telescope should have a clear aperture diameter of ~400 mm, f-number in the range 8-11, and FOV of ~1 mrad (full angle), with a suitable and compact telescope configuration for atmospheric Mie (aerosol) lidar application.
- The mirror surface finish (P-V) should be $\lambda/4$ @ 532 nm with an RMS error of $\lambda/25$ @ 532 nm, and the overall optical efficiency is to be >80% (weighted avg., including obscuration of primary mirror) over the spectral range 0.4 - 1.1 μm.
- The Telescope Receiver also consists of back-end optics with two independent channels (co- and cross-polarized channels for depolarization studies), including C/F optics, filters and PMT detectors.
- The telescope should be designed and realized as a zenith-looking system, pointing vertically upwards into the atmosphere.
- An elevation-azimuth steering mechanism should be incorporated in the mounting structure of the telescope, for precise alignment of the telescope FOV axis with the vertically transmitted laser beam up to an altitude ≥ 20 km.
- The primary function of the Telescope Receiver is radiation (photon) flux collection, i.e., the collection of backscattered laser photons from the atmosphere. It has to be noted that the telescope application is for radiation flux collection and not for imaging purpose.

Technical Specifications of Telescope Receiver

The Telescope Receiver consists of a zenith-looking ~16-inch (~400 mm) dia. telescope system with a narrow FOV of about 1 mrad (full angle), having two independent channels in the back-end optics assembly near the telescope focal plane. The purpose of the receiver is for flux collection, i.e., to

collect the backscattered laser photons scattered by atmospheric aerosols and molecules, in the region from near surface to ≥20 km altitude. The specifications of the Telescope and Back-end optics channels are detailed below.

1. Specifications of Telescope

The major technical specifications of the 16-inch Telescope are given in Table-1.

Table 1: Telescope Parameters for 16-inch Telescope

Parameter	Specification
Optical configuration	Suitable and compact telescope configuration for atmospheric lidar application
Telescope mirrors	Primary Mirror clear aperture of ~16 inch (~400 mm) diameter and Secondary Mirror of suitable diameter.
Obscuration of Primary Mirror	<10%
Telescope System f-number	Any value in the range f/8 to f/11
Field-of-view	~1 mrad (full angle)
Mirror material	Fused silica (quartz) OR Material with lower Coefficient of Thermal Expansion (CTE)
Spectral range	0.4-1.1 µm or wider
Mirror Surface Figure/ Surface Finish requirement	P-V: 133nm (λ/4 @ 532 nm & λ/4.7 @ 633 nm) or better RMS: 22 nm (λ/25 @532 nm & λ/28 @ 633 nm) or better
Overall Optical Efficiency of the Telescope (including obscuration of the primary mirror by secondary mirror and mounting arms/structures)	> 80% (weighted avg.) over 0.4-1.1 µm
Wavefront error (system level)	≤ 140 nm
Telescope performance stability	Telescope structure including mirrors shall be suitably designed to ensure optical performance over temperature variation of ± 5 deg C from room temperature (20°C to 30°C).
Protective Cover	Adequate protective cover for shielding the telescope from weather events (rain, dust, wind etc.) during non-operational period
Optical coating	Enhanced Aluminium coating Conforming to MIL-M-13508C with suitable protective coating. Minimum reflectance: > 90% over 0.4 - 1.1 µm Average reflectance: > 92% (weighted avg.) over 0.4- 1.1 µm
Alignment reference	Suitable alignment provisions to be kept for realignment during unmount and remount of mirrors for telescope recoating.
Calibration	Internal alignment reference for focusing/ calibration should be provided.
Mechanical finish	Parts blackened to avoid stray light
Mounting Structure	Telescope Receiver should be mounted in zenith-looking mode.

	Adequate elevation-azimuth steering mechanism should be incorporated in the mounting structure of the telescope, for coarse and fine adjustment of the FOV axis (within ± 5°) Adjustment range: ± 5 deg Coarse resolution: 0.1 deg or better Fine resolution: 0.005 deg or better
Range of operating conditions (air-conditioned)	Room temperature: 20°C to 30°C; Room Relative humidity: 50-65%
Storage conditions (non-operating conditions in the room)	Room temperature: 20°C to 40°C; Room Relative humidity: 70-80% Designed and constructed to withstand hazards associated with transit and storage at the installation site.

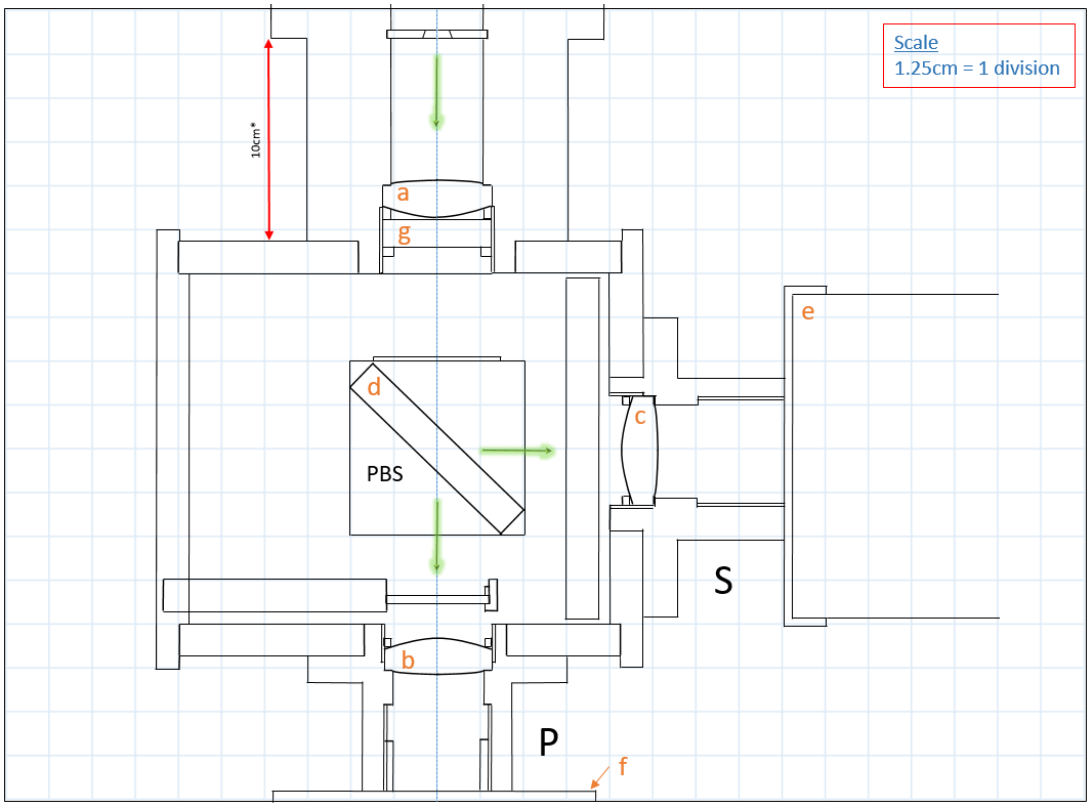

Figure 1: Nominal optical design layout of the telescope back-end optics and detector assembly for the Telescope Receiver. Legend: (a) Plano-convex lens [size=25 ± 1 mm, f=80 ± 1 mm (nominal)]; (b, c) Plano convex lens [size=25 ± 1 mm, f= 40 ± 1 mm (nominal)]; (d) Polarized Beam Splitter Cube, 532.0 nm; (e,f) PMTs; (g) Narrowband IF filter, 532.0 nm. Provisions for mounting ND filters for P and S channels should be included in the design.

2. Specifications of Back-end Optics Assembly with 2 independent channels

The back-end optics of the Telescope Receiver consists of variable iris at the telescope focal plane, fine focal plane adjustment mechanism, collimating and focusing (C/F) optics, polarizing beam splitter cube for splitting the beam into two independent channels, appropriate mounting mechanism for interference filters (IF), filter wheel mechanisms for mounting and selecting desired ND filters in the two channels, and provision for mounting PMT detectors. The entire optics are aligned to the Telescope Receiver beam axis. The polarizing beam splitter cube splits the collected backscattered signal/flux into two independent channels, namely P and S, to get Co-polarization and

Cross-polarization components, with each channel again having independent optics, ND filters and detectors. Party has to provide appropriate mechanisms for fine focal plane adjustments and filter selection (for ND and interference filters). Figure 1 shows the nominal optical design layout of the back-end optics and detector assembly for the Telescope Receiver (Note: detectors and IF/ND filters will be provided by VSSC).

Table 2: Technical Requirements of back-end optics assembly for the Telescope Receiver:

Component	Requirements/Specifications
Description *[See Figure 1 for a nominal optical design layout of the telescope back-end optics and detector assembly for the Telescope Receiver]*	- The Back-end Optics Assembly is to be a modular unit attached to the telescope cylinder, near the telescope focal plane, at the appropriate location considering the telescope configuration. Nominal optics design for the back-end optics assembly is provided in Figure 1. The party can provide the design for back-end optics as per the requirement, and is responsible for selecting the appropriate optical components for the same. - The back-end optics consists of variable iris at the focal plane, collimating and focusing (C/F) optics, polarized beam splitter cube, appropriate mechanisms for mounting and selecting desired narrow-band interference filters (IF) and ND filters, and provision for mounting two independent Photomultiplier Tube (PMT) detectors for two channels. - **List of back-end optics components to be provided by VSSC:** *(Price of these components should not be included in the bid)* i. Interference Filters ii. ND filters iii. PMT detectors *(Detailed specifications of these items will be provided to the party during design finalization after the placement of PO)* - **List of back-end optics components to be provided by the party:** i. Variable Iris ii. All C/F optics components (plano-convex lenses/collimators) iii. Polarizing Beam Splitter cube iv. Mounting mechanism for Interference Filters v. Filter wheel mechanism for mounting and selecting ND filters for P channel vi. Filter wheel mechanism for mounting and selecting ND filters for S channel vii. Focal plane adjustment mechanism viii. Any other essential optical components ix. All other mounts and fixtures for mounting the components - Variable iris at the focal plane is for limiting the FOV of the telescope receiver system (envisaged full-angle FOV is ~1 mrad). In order to enable fine corrections/adjustments in the FOV, a variable iris is required. The iris should have markings and indicators. - The beam collected by the telescope is taken out through a suitable opening, further reaching the collimating C/F optics and polarizing beam

	splitter. The entire optics is to be aligned to the Telescope Receiver beam axis. - **The polarizing beam splitter cube splits the incoming backscattered signal into two independent channels, namely co-polarized (P) and cross-polarized (S) channels, each with an independent PMT, for depolarization studies.** - Adequate additional mechanical support is to be provided for the back-end C/F optics and detector assembly for P and S channels, ensuring the structural stability.
Material	Black Anodized Aluminum material is to be used for the back-end C/F opto-mechanical block of P and S channels
C/F optics components such as plano-convex lens/ collimators	Appropriate C/F optics components such as plano-convex lenses/collimators should be provided by the party (Please refer the nominal design of back-end optics given in Figure 1). Nominal specifications of the C/F components are: Plano-convex lens with Focal length 80 ± 1 mm and Size: 25 ± 1 mm (1 No.); Plano-convex lens with Focal length 40 ± 1 mm and Size: 25 ± 1 mm (2 Nos.). The C/F components should be designed for 532 nm Design Wavelength (DWL), ensuring minimal optical aberrations.
Polarizing Beam Splitter Cube	Appropriate polarizing beam splitter cube has to be provided by the party. This is required to split the received backscattered signals at 532 nm into two beams: co-polarized (P) and cross-polarized (S) components. Required specifications are: Transmittance of P polarized light > 97%; Reflectance of S polarized light > 98%; Incident angle: 0 deg. Size of the beam splitter cube should be greater than the size of the lenses of the C/F optics.
Mounting Mechanism for Interference Filters (IF)	Party has to provide appropriate mechanism to mount and select the desired interference filters (filter size: 25 ± 1 mm, nominal). The interference filters will be provided by VSSC.
Mounting Mechanism ND Filters for P and S channels (2 Nos.)	Party has to provide appropriate filter wheel mechanisms having multiple slots (4-6 slots) for mounting and selecting the desired ND filters (filter size: 25 ± 1 mm, nominal), for P and S channels. Party can provide the number of filter slots that can be accommodated in the filter wheel mechanisms for a compact design. ND filters will be provided by VSSC.
Detector mounting provisions for P & S channels (2 Nos.)	Party should provide appropriate modular provisions for mounting PMT detectors in the P and S channels of the back-end optics assembly. PMTs will be provided by VSSC. Specifications of the PMTs will be provided at the time of design finalization after the placement of PO.
Focal Plane Adjustment Mechanism	The party has to suggest appropriate mechanism for making fine focal plane adjustments, to enable possible defocusing corrections (of about ± 20 mm or better).
Spot Size	The achievable spot size of the image formed at the focal plane should be less than the PMT detector active area having diameter 7-8 mm. The achievable spot size should be clearly stated in the Techno-commercial Bid (Part-I).

Other Specifications/Requirements

(i) The party should undertake the complete optical & opto-mechanical design and realization of the Telescope Receiver, and deliver the integrated telescope system with two independent back-end optics channels.

(ii) The conformity of all technical specifications given in Table-1 and Table-2 should be explicitly stated in the Techno-Commercial Bid (Part-I).

(iii) The telescope cylinder should be made of material having opaque mechanical finish to block out all external stray light.

(iv) Appropriate opto-mechanical mirror mounts have to be incorporated, ensuring least obscuration of Primary Mirror (<10%).

(v) **Alignment corrections**: Suitable provision to be provided for handling and adjusting the mirrors for alignment corrections. This should include alignment references on the rear surface of the mirrors. Details of telescope alignment method are to be provided in the Techno-Commercial Bid (Part-I).

(vi) The mechanisms suggested for fine focal plane adjustments and the filter wheel mechanism for selection of desired IF/ND filters should also be detailed in the Techno-Commercial Bid (Part-I).

(vii) The party has to provide adequate Telescope Protective Cover to protect the system from weather events during non-operational period.

(viii) The design must include a safe method of mounting and removing the mirrors for recoating. Details of recoating method are to be provided.

(ix) The party shall provide a dedicated package of infrastructure along with the equipment: (i) Standard tools, tool holders and fixtures that form part of the telescope system, and other related systems; (ii) Fixture for removal and assembly of mirror for coating shall be provided.

(x) The party should provide detailed technical manuals for the handling, operation and maintenance of the system, including layout diagrams, components for systematic fault diagnostics, procedure for removal/recoating/re-fixing of mirrors, etc. Electronic versions of documentation shall also be provided.

(xi) Details of health monitoring and procedures for speedy trouble shooting (e.g., related to optical alignment issues, dust contamination, etc.) should be explicitly stated.

(xii) Among the optical components of the back-end optics assembly, VSSC will provide the interference filters, ND filters and PMT detectors, the cost of which should not be included in the bid. Other optical components such as polarizing beam splitters, C/F optics, and mounting fixtures for all optical components and detectors should be provided by the party.

General Terms and Conditions

(i) The party should have heritage in the design and development of optical telescopes. The party has to provide details of proven track-record (such as previous POs to reputed institutions) along with the Techno-Commercial Bid (Part-I).

(ii) The Techno-Commercial Bid (Part-I) should contain the following:

a) Optics design layout and detailed engineering drawings of the Telescope Receiver

b) Results and figures of ray-tracing simulation studies, including achievable spot size at focal plane

c) Telescope specifications including dimensions, configuration, optical material used, surface finish, reflective coating, reflectivity etc. for the mirrors

d) Telescope cylinder structure specifications

e) Detailed optical design layout and specifications of the back-end optics assembly

f) Opto-mechanical mounting structures of the telescope including back-end optics assembly

g) Details of telescope protective cover for non-operational period

h) Method to be adopted for optical alignment between receiver optical FOV axis and transmitted laser beam at the installation site

i) Details of telescope mounting systems, optical benches and mechanical fixtures

j) Specifications and quantity of all essential spares and consumables for system operation

k) Any additional features that can enhance the system capability or performance should be clearly described

l) Party shall exclusively list out spares/consumables, tools and fixtures, which will be provided along with the system

m) Technical specifications related to trouble shooting/self-diagnostic tools should be clearly stated (like, alignment issues, dust contamination, etc.)

n) List of equipment/tools required for routine operation and maintenance, post installation

o) Make and model details of the sub-components/items (if applicable)

p) Schedule breakup and timeline of the system development during different phases should be clearly stated. This should include the time required for the design and review, fabrication of the system at factory, assembly/integration of the system at factory site, testing at the factory site, disassembly of the system at the factory site, delivery, installation, testing, and commissioning of the system at IPRC, Mahendragiri.

q) Tests to be conducted during the development phase at the factory site and the parameters that are to be evaluated should be outlined. Tests that are to be performed at the installation site should also be outlined.

r) Duly filled compliance sheet, as per the format attached in Table-4 should be submitted as part of Techno-Commercial Bid (Part-I).

s) List of deliverables that will be given by the party as per the design and requirements.

t) Material to be used in the telescope cylinder and PM/FM mounts.

(iii) **Engineering Design Document:**

a) The final detailed engineering design document of the Telescope Receiver should be submitted by the party within one month of acceptance of the purchase order.

b) Detailed design drawings, ray-tracing and simulated results/figures should be included in the detailed design document.

c) Report on the detailed simulations for accepted telescope design /configuration/specifications, and the optimized receiver configuration arrived at should be included as part of the detailed design document.

d) The document should also contain details of (i) reflectance/transmittance of optical components; (ii) overall optical efficiency of the system; (iii) achievable spot size at focal plane based on the optimized design parameters.

e) The design document will be reviewed by VSSC, and any modifications suggested are to be incorporated in the final design upon mutual agreement. Any deviations in the design from party side due to any reason, has to be approved by VSSC.

(iv) Parties submitting quotations may be called for meetings at VSSC for technical clarifications, if required. If called, parties can attend the meetings directly at VSSC or through video mode, to provide technical clarifications.

(v) The party should provide monthly (or whenever requested) updates during the development phase of the system. Procurement/development of major subsystems/items, integration of subcomponents of the receiver system, factory verification and testing, disassembly and shipment should be informed to VSSC appropriately.

(vi) **Test and Evaluation of the System at the Factory Site:**

a) Test results of the system should be recorded and provided to VSSC during the developmental phase at the factory site.

b) The possible acceptance tests at the factory site include component level tests, spot size tests and star imaging tests using CCD / array detectors.

c) The party has to provide the details of the test results pertaining to the optics alignment, optical efficiency, etc.

d) The party has to explicitly provide the actual spot size achieved at the focal plane during factory testing, prior to delivery of the item.

e) Pre-delivery test/measurement results of the system are mandatorily required for performance evaluations. Shipment of the system will be approved only after the test results are evaluated and certified as satisfactory by VSSC.

f) VSSC reserves the right to witness the tests and review the progress of work at various milestones of the project at any reasonable point of time during the developmental phase at the factory site of the party.

(vii) **Supply, Installation, Testing and Commissioning at the Installation Site:**

a) The system including all the sub-components and accessories are to be delivered at IPRC, Mahendragiri, Tirunelveli district, Tamil Nadu (hereafter referred IPRC site or installation site).

b) Supply of the complete system at the installation site at IPRC should not exceed **6 months** from the date of design approval by VSSC.

c) Integration, Installation, Testing and Commissioning of the Telescope Receiver system at the IPRC site should be completed within **2 weeks**, from the date of delivery of the complete system at the installation site.

d) Test runs of the system should be carried out at the installation site in the presence of experts appointed by VSSC as per the mutually agreeable acceptance test procedure.

e) Possible acceptance tests include component level tests, spot size tests, and star imaging tests using CCD / array detectors. During the installation of the system, the party has to perform the optical alignment tests and demonstrate the achieved spot size at the focal plane.

f) The party should mandatorily perform and demonstrate precise optical alignment of the telescope FOV with the vertically transmitted laser beam, confirming the reception of backscattered lidar signal up to an altitude ≥ 20 km. The laser transmitter system for this purpose will be provided by VSSC at the installation site.

g) Successful tests and demonstration of the system at the installation site is required for the commissioning of the system. The system will be accepted only after integrating with the complete lidar system operating in Mie (aerosol) mode, and obtaining successful test results that meet all the scientific/technical requirements.

h) All necessary tools/equipment/accessories required for installation, optical alignment, testing, commissioning and operation of the receiver system should be brought by the party.

(viii) **Training**: Adequate technical training on handling, operating and maintaining the optics of the receiver system (including the optical alignment) should be imparted to the identified VSSC personnel at IPRC site during the installation period. Training should cover all the technical details of the system, including the handling and replacement of sub-components, consumables and spares, whenever required.

(ix) **Quality Standards:**

a) All the sub-systems and components used in the Telescope Receiver should be of high quality and reliability to support long-term and continuous operation of the system.

b) International standard shall be followed while selecting materials, components, equipment used in realizing the system. The manufacturer may mention the standards followed (e.g. MIL std., Industry std. etc.). The mirror material certificate of compliance (COC) is to be provided.

(x) **Warranty:** A minimum 1-year Warranty should be provided for the system/sub-components (from the date of acceptance of the system after commissioning).

a) List of spares (including their quantity) covered under the warranty period should be explicitly stated in the Techno-Commercial Bid (Part-I).

b) This includes workmanship, breakdown maintenance visits and replacement of defected subsystems/sub-components/spares in case of system failure at no extra cost *(maximum shut down period: less than 30 days).*

c) Party should explicitly state the terms and conditions of the warranty.

(xi) **Major Milestones**:

Following are the major milestones and timeline for the realization of the system after the placement of PO:

Milestone	**Timeline**
Submission of Final Design and Engineering Drawings to VSSC for review	Within **30 days** of PO placement
System development begins	T0 (i.e., from the date of design approval)
Delivery of System at installation site	T1 = T0 + 6 Months
Installation, Testing & Commissioning, including Training	T2 = T1 + 2 weeks

Commercial Terms and Conditions

(i) Supplier has to quote for the complete system and partial offers will not be considered.

(ii) **Local Content:** Only Class-I and Class-II Local Suppliers as per Make in India policy are eligible to participate. The percentage of local content and location of value addition should be explicitly stated in the Techno-Commercial Bid (Part-I).

(iii) **Liquidated Damages:** LD Clause @ 0.5% per week subject to a maximum 10% of order value is applicable beyond the promised schedule for supply, installation, testing, training and commissioning of the system.

(iv) **Security Deposit (SD) & Performance Bank Guarantee (PBG)**: SD & PBG can be in the form of Bank Guarantee, DD, FDR etc. Combined Bank Guarantee for Security Deposit and Performance (equivalent to 3% of the total contract value) shall be submitted on receipt of PO/contract and valid till completion of standard warranty. BG shall be submitted along with order acceptance.

(v) **Delivery Terms:** All items/subsystems should be delivered at IPRC, Mahendragiri, Tamil Nadu. Delivery terms should be clearly stated in the Techno-Commercial Bid (Part-I).

(vi) **Payment Terms:** Payment terms for supply and payment terms for installation, testing, and commissioning of the system should be indicated separately.

(vii) **Authorization from OEM/Principal & Licence:** In case of imported parts/items, valid Authorization Letter from the OEM/Principal should be provided along with valid licence while submitting the quote and this shall be attached with the Techno-Commercial Bid (Part-I). The licence and authorization should be valid for an extended period, at least up to the end of warranty period. Communication should be only with OEM or Indian agent.

(viii) **Quote Validity:** The Bid should be valid for a minimum of 180 days from the date of opening of the Part-I. The party should clearly confirm the validity of their quote in the Techno-Commercial Bid (Part-I).

(ix) Note: All the above details should be provided in the Techno-Commercial Bid (Part-I).

Prescribed format for submitting Price Bid

The party should provide the split-up price of the items/subsystems and the total cost of the Telescope Receiver along with the Price Bid (Part-II) as given in the prescribed format in Table-3.

Table-3

To be submitted along with the Price Bid (Part-II) in the prescribed format given below.

Sl No.	Particulars	Price
1	Subsystems/components and other items of Telescope Receiver:	
	(a) Telescope Receiver: Telescope system with opto-mechanical mounting structures & fixtures and telescope protective cover, including 2-channel back-end optics assembly (excluding IF/ND Filters and detectors). Split-up cost of primary and secondary mirrors, back-end optics and protective cover shall be provided.	
	(b) Any others , please specify	
2	Integration, Installation, Testing, Alignment with vertically transmitted laser beam, and Commissioning of the system	
3	Essential spares (items that are not covered under warranty) and consumables for the system operation for a period of 1 year. List of items, quantity and cost should be provided.	
	Total Cost of Telescope Receiver (Aggregate of Sl. No. 1-3)	

No.	Particulars	Price
7	Freight (From _____ to _____)	
8	GST applicable	

Compliance Table for Telescope Receiver system

The party should submit the duly filled compliance sheet, as per the format given in Table-4 along with the **Techno-Commercial Bid (Part-I)**.

Table-4
To be submitted along with the Techno-Commercial Bid [Part-I]

Sl. No.	Description	Compliance	List of Supporting Documents added	Remarks
1	Design and development of the proposed Telescope Receiver should meet all the technical specifications and requirements stated in Tables 1 and 2.			
2	The Techno-Commercial Bid (Part-I) should contain the following:			
	a) The preliminary optics design, opto-mechanical design, overall configuration, schematic diagrams, and all the technical details of all sub-systems and major components of the Telescope Receiver.			
	b) Detailed technical specifications (including make and model, if applicable) of the mirrors, mirror mounting structures, telescope cylinder, variable iris, collimating and focusing optics, polarizing beam-splitter, and all other optical/opto-mechanical components.			
	c) Detailed results of the ray-tracing simulation studies and the design parameters optimized therein, including the achievable spot size at the focal plane.			
	d) Suggested methodology for optical alignment of the telescope and for maintaining the parallelism between the transmitted laser beam and receiver optical axis.			
	e) List of deliverables that will be given by the party as per the design and requirements.			
	f) Outline of acceptance tests that are to be performed at the factory site and installation site.			
	g) Any other details to be specified			