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VERY LARGE TELESCOPE

Technical Specifications and statement of work for the Laser Assembly of the PRIMA Metrology System

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Table of Contents

1 Scope

This document defines the technical specifications and statement of work for the Design and Manufacturing of the Laser Assembly of the PRIMA metrology.

2 Applicable documents

AD 1 Technical Specifications for the PRIMA Metrology System, VLT-SPE-ESO-15730-2211, Issue 1, 16/10/00

AD 2 Feasibility study for the frequency stabilization of the PRIMA Metrology Laser, VLT-TRE-IMT-15731-2868, 24/7/02

AD 3 PRIMA Metrology Test Campaign 27/4/02 to 5/5/02, VLT-TRE-ESO-15730-2827, Issue 1.0, 4/7/02

AD 4 User Manual: Diode-pumped Fiber-coupled Non planar Ring laser, Model 125-1319-200, Lightwave Electronics.

AD 5 Technical Specifications for the Fiber Coupler Unit of the PRIMA Metrology, VLT-SPE-ESO-15731-2920, issue 1, 16/10/02.

AD 6 Interface Control Document between VLTI and its instruments, VLT-ICD-ESO-15000-1826, Issue 3, 15/2/02

AD 7 ESO's EMC Guidelines

3 Acronyms

- AIT: Assembly, Integration and Test
- AOM: Acousto-Optics Modulator
- AD: Applicable Document
- CPU: Central Processing Unit
- EOM: Electro-Optics Modulator
- EMC: Electromagnetic compatibility
- FDR: Final Design Review
- HW: Hardware
- ICD: Interface Control Document
- I/O: Input/Output
- KO: Kick Off
- LCU: Local Control Unit

- NPRO:Non-Planar Ring Oscillator
- PAE: Provisional Acceptance Europe
- PM: Polarization maintaining
- PRIMA:Phase Referenced Imaging and Micro-arcsec Astrometry
- RD:Reference Document
- SM: Single Mode
- SW: Software
- TBC:To Be Confirmed
- TBD:To Be Defined

4 System definition and implementation baseline

The Laser Assembly of the PRIMA Metrology is a sub-system of the PRIMA Metrology Light Source, AD 1. The role of this *Light Source* is to provide to the "PRIMA Metrology Beam Relay" four laser beams precisely defined in terms of wavelength[1], coherence length, frequency stability, optical power, and polarization state. These parameters are primarily defined by the Laser Assembly.

The Laser Assembly consists of a laser head associated with its frequency stabilization hardware, Fig. 1. This stabilization hardware generates an error signal proportional to the laser frequency shift with respect to a frequency reference. This error signal is acquired and processed by the Light Source Control HW/SW (under ESO's responsibility), which then sends a frequency correction command to the laser driver. Finally, the Laser Assembly feeds the "Heterodyne Assembly" with the frequency stabilized laser beam.

The implementation baseline for the Laser Assembly can be found in AD 2. The laser head has already been selected, AD 2, AD 3. It is the Nd-Yag Laser Model 125 from Lightwave electronics, AD 4. This laser emits at a wavelength of λ=1319nm a power of 200mW. The frequency of the laser can be controlled by adjusting the temperature of the laser resonator as well as by applying a voltage to a piezoelectric element bonded to the laser cavity. The interfaces to the laser head are described is section 5.3.3.

As sketched in Fig. 2, a portion of the laser power is focussed inside a frequency doubling crystal to generate a wavelength of $\lambda/2$=659.5nm. After modulation of its frequency using an E.O.M, the beam is transmitted through an Iodine cell, whose absorption line around
$\lambda/2$ defines a precise frequency reference. A detector measures the variation of intensity at the output of the iodine cell which, after demodulation, is directly related to the frequency shift of the laser with respect to the frequency reference provided by the Iodine absorption line.

1. or frequency, i.e including the necessary frequency shifts provided by Acousto optics modulators of the Heterodyne assembly

Considering that the bandwidth of the frequency stabilization loop should remain at the few Hz level, the control loop will be run by the Master CPU of the PRIMA metrology LCU. At this point, no additional CPU dedicated to the frequency stabilization appears necessary.

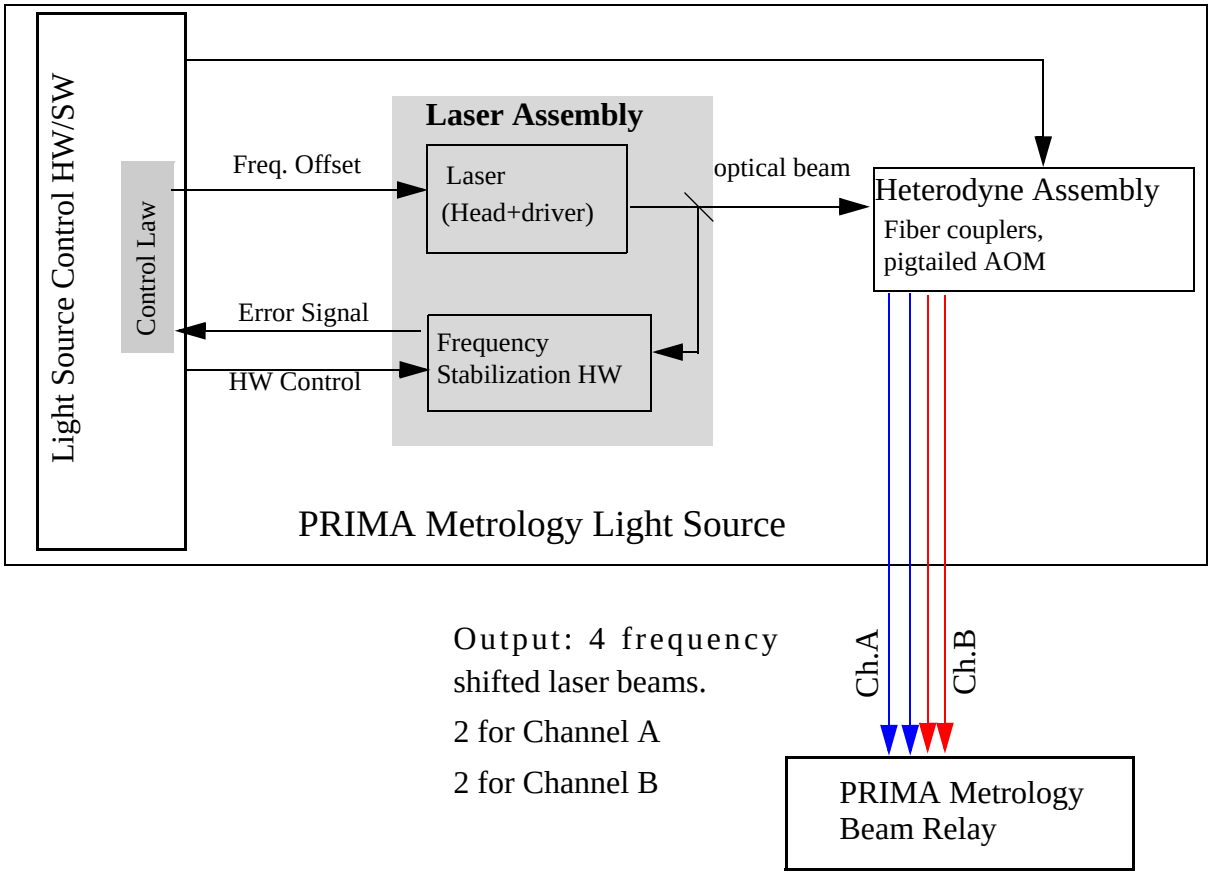

Figure 1 *Block diagram of the Light Source System of the PRIMA Metrology, including the Laser Assembly*

5 Technical Specifications

5.1 System Performance

The characteristics of the laser beam delivered by the Laser Assembly to the Heterodyne Assembly is specified in Table 1.

Table 1 Specification for the laser beam delivered by the Laser Assembly

Parameters	**Specifications**
Wavelength	λ=1319nm (ν=2.27.10^{14} Hz)
Optical Power	P>150mW
Standard Deviation of the Power Intensity fluctuations	σ_P<0.05% rms (bandwidth 5Hz-10Mhz)
Linewidth/Coherence Length	$\delta\nu$< 5kHz over 1msec (L_c>>1000m)
Laser Frequency Stability	$d\nu/\nu<10^{-8}$ or $d\nu$<2.27 MHz over the time window [125µsec to 1 hour]
Accuracy on the knowledge of the emitted frequency (includes periodic re-calibration)	$d\nu/\nu<10^{-8}$ (lifetime)
Polarization state	Linear Extinction ratio: 20dB

It shall not be necessary to re-calibrate the laser frequency more often than once every year.

5.2 Hardware configuration

A preliminary hardware configuration of the Laser Assembly is sketched in Fig. 2, according to the implementation baseline described in section 4. This configuration shall be finalised during the Design Phase of the Laser Assembly.

Fig. 2 shows also the minimum set of functions to be accessible by the Light Source Control HW:

- *Set* the temperature set-point and *Read* the current temperature of the crystal and of the Iodine cell
- *Set* the modulation function of the E.O.M and *Read* the current modulation characteristics.
- *Switch ON/OFF* all electronic equipment of the Laser Assembly

The temperature of the doubling crystal and of the Iodine cell shall be controlled using the ESO standard temperature controller CN77000 from Newport-Omega. This controller must be

configured for analog control (its 0-10V ouput must be amplified to generate sufficient current to the heater). PT100 sensors shall be conneted to the controller to monitor the temperatures. The temperature set-point and temperature reading will be accessible to the LCU through its transition module (RS485 protocol).

The *set-up* of the laser head as well as the reading of the laser head *status* will de done using the RS-232 interface available on the laser driver, AD 4. Interfaces to the Light Source Control HW are defined in section 5.3.

The beam splitter necessary to redirect a portion of the laser beam towards the frequency stabilization hardware shall be preferably fiber pigtailed.

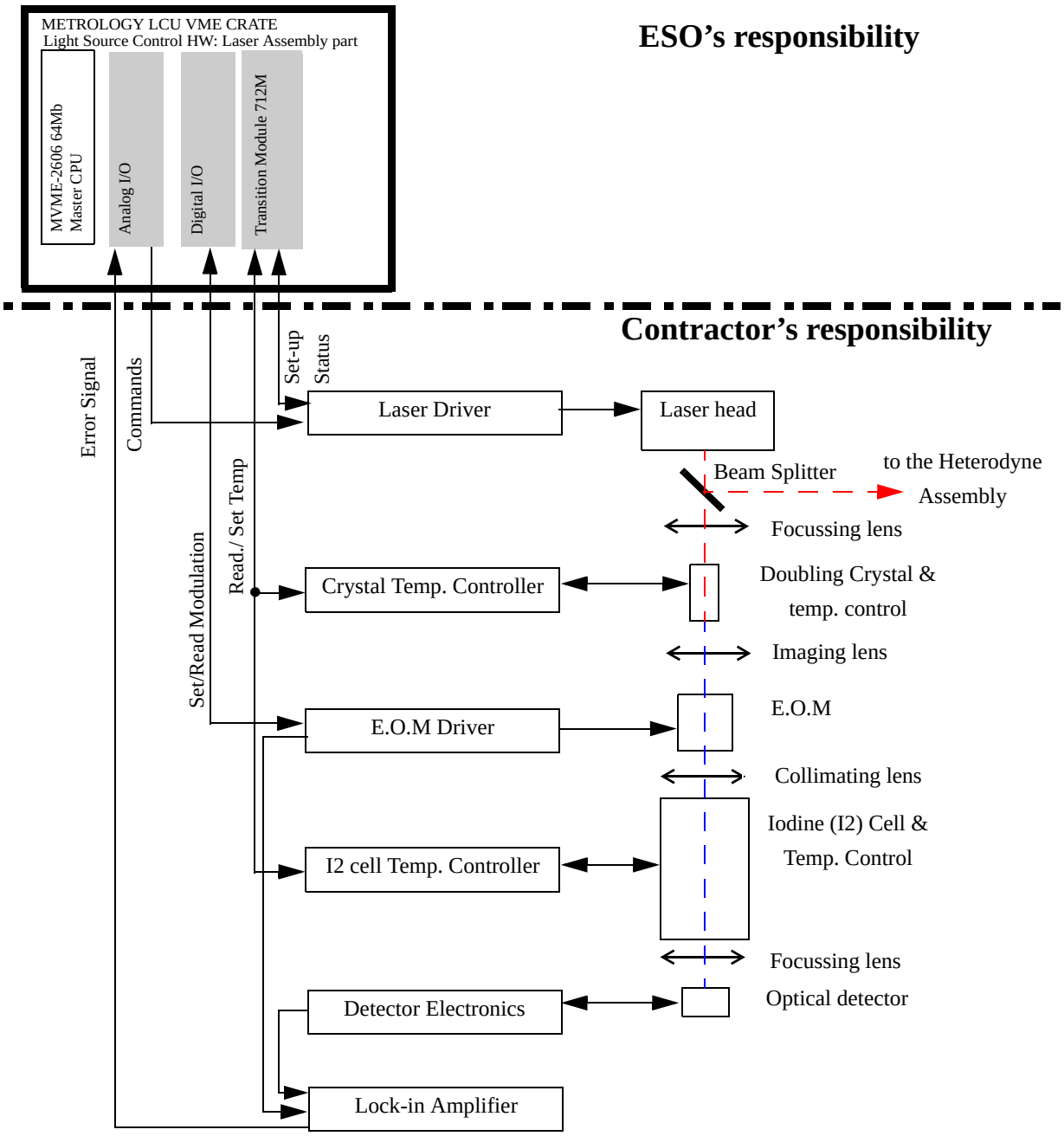

Figure 2 *Hardware configuration (To be confirmed and defined in detail during the design phase of the Laser Assembly). The dash lines represent the optical path.*

5.3 Interface definition and requirements

5.3.1 Allocated space

A surface of 800x800 mm2 is allocated to the Laser Assembly. The Laser Assembly shall be mounted on a breadboard table. This breadboard table will then be fixed on the 800x1500mm^2 *Newport* optical table installed inside the VLTI storage room (see Fig. 3). The volume required for the Electronic equipment of the Laser Assembly shall be defined during the Design Phase. This equipment shall be mounted inside the electronic cabinet reserved for the PRIMA Metrology system (800x800mm^2 footprint area).

Figure 3 *Optical table available at Paranal inside the storage room for the PRIMA Metrology Light source (800x1500mm^2)*

5.3.2 Electrical Power and cabling

All electrical connections will be provided inside the Electronic Cabinet of the PRIMA Metrology System, located close to the optical table of the light source, AD 6. During the Design Phase, all required power connections shall be identified to enable an appropriate design of the Electronic cabinet.

Any cables and/or hoses required from the electronic cabinet and the Laser Assembly Breadboard shall be carefully routed and protected to avoid any hazards to personnel and equipment.

5.3.3 Interface to the Laser Head

The technical characteristics of the laser head are described in AD 4. The laser beam is available at the output of a SM-PM fiber terminated by a FC/PC connector. The frequency of the laser can be tuned by applying a voltage on two inputs of the laser driver (standard BNC female connectors). The first input controls the temperature of the laser resonator with the following characteristics:

- Tuning coefficient: 3.8 GHz/V (Typical between mode hops)
- Range: 10GHz (continuous range between mode hops); 30GHz (total tuning range)
- maximum input voltage: ±10V
- Bandwidth: 1Hz

The second inputs generates a frequency shift by applying a stress on laser crystal using a piezo. The characteristics of this input are;

- Tuning coefficient: 1.9 MHz/V (Typical)
- Range: 30MHz (for a voltage input range of ±15V)
- Bandwidth: 30kHz

5.3.4 Interface to the Heterodyne Assembly

The frequency stabilized laser beam shall feed the Fiber Coupler Array of the Heterodyne Assembly, AD 5, using a SM-PM optical fiber. This fiber shall be terminated by a FC/APC connector HPC-S8.6-PM/K (2mm key) from *Diamond*[2].The key shall be actively aligned along the slow axis of the SM-PM fiber with a precision ±0.8º. The input of the Fiber Coupler Array is a FC/APC adaptor MPC-S8.22-PM/6Kt.X (2mm key) from *Diamond*.

5.3.5 Interface to the Light Source Control Hardware.

All communications between the Light source control HW and both the Laser head and the Frequency stabilization hardware shall be take place through the following ESO standard boards:

- Analog I/O board, VMI-VME-3123 (associated with the MPV-955 board). This board offers 16 Inputs/Outputs lines (16 bits).
- Digital I/O Board: Achromag AVME 9481 (64 I/O lines, 0-30V)
- Transition Module MVME-712M for RS232 communications
- Temperature controller CN77000 (Newport-Omega).

The range of the error signal generated by the frequency stabilization hardware shall be ± 5V (Analog Input).

Based on this error signal, two frequency offset commands will be sent to the Laser Driver by the Light Source Control HW using two Analog Outputs (control of the temperature and of the piezo Voltage of the laser head). The definition of the control law (i.e the generation of the commands

2. see http://www.diamond-fo.com

from the error signal) is under the contractor's responsibility. The implementation of this control law within the Light Source control HW/SW is under ESO's responsibility.

5.3.6 Interface to the Light Source Control Software

There is no direct software interface applicable to the Laser Assembly.

5.3.7 Environmental conditions inside the storage room and Thermal dissipation requirements

The Laser Assembly will operate in a temperature controlled environment (17 ºC ± 2 ºC). According to AD 1, the power dissipated by the overall PRIMA Metrology equipment shall be less than 1kW. During the Design phase, a thermal budget shall be elaborated for the Laser Assembly. It will be used as an input to the PRIMA Metrology thermal budget.

5.4 Design and Construction requirements

During the Design phase, the power spectral density of the laser frequency fluctuation shall be modelled using the function given by Eq. (5.4-1):

$$PSD_{dv}=10^{10} \times f^{-2} \text{ (in Hz}^2 \text{ per Hz, for f <10 kHz)} \quad (5.4\text{-}1)$$

The design of the Laser Assembly shall comply with the EMC guidelines of AD 7 and include all means necessary to preclude or limit hazards to personnel and equipment during assembly, disassembly, maintenance, test and operation. All path followed by the laser beam in free space shall be covered to avoid any eye damage and properly marked with stickers indicating laser radiation.

All main parts of the Laser Assembly as well as the exchangeable units shall be equipped with nameplates containing the following information:

- Part (or unit) name and reference number (including the product code 15731)
- Drawing number (if applicable)
- Date of manufacturing
- Name of manufacturer

5.5 Reliability and Maintainability

The reliability and maintainability requirements specified in AD 1 are applicable to the Laser Assembly. The Laser Assembly shall be designed to minimize maintenance work at Paranal.

5.6 Transport and assembly requirements

The Laser Assembly shall be packed in a re-useable container insuring protection against mechanical shock and electrical Hazards. The containers shall include shock indicators. A Packing List shall be provided for each box/container including its content, dimension and weight.

5.7 Product Assurance requirements

The product assurance strategy described in AD 1 shall be applied to the Laser Assembly. In particular, this includes the definition of a verification plan based on Table 2. Test procedures shall be defined and the corresponding tests conducted through the different phases of the project. This includes the acceptance tests, which shall provide evidence that all functional and performance requirements are met.

For the purpose of the acceptance testing, the contractor shall define and procure its own “Light Source Control HW”. This control hardware shall fulfil the same functions as the ESO VME based “Light Source Control HW” (see Fig. 2), but can be based on a PC platform if necessary (e.g. Labview acquisition boards & software running on a PC). The “Light Source Control HW” developed by the contractor is not part of the deliverable items (see section 6.6).

Table 2 Verification matrix of the Laser Assembly

Requirements	**Verification by**		
	Design	**Analysis**	**Test**
System Performance	X	X	X
Hardware configuration	X	X	X
Interface definition and requirements	X	X	X
Design and Construction requirements	X	X	X (TBC for EMC)
Reliability and Maintainability	X	X	
Reliability and Maintainability	X		

6 Statement of Work

6.1 Introduction

The contractor shall perform all tasks necessary for the delivery to ESO of the Laser Assembly in accordance with the present document. This include packing and transport of the Laser Assembly to ESO-Garching.

All tasks shall be defined and distributed among two workpackages according to PRIMA Metrology Project Plan.

- WP3211: Design of the Laser Assembly
- WP3311: Laser Assembly procurement&Manufacturing / Testing in Europe

A preliminary Workpackage definition is given in Table 3 and Table 4.

6.2 Project Phases and Reviews

The project shall follow the standard phases applied to ESO projects, i.e:

- A Design Phase concluded by a Final Design Review.
- A Manufacturing, Assembly, Integration and Test Phase concluded by a Provisional acceptance

6.3 Project Milestones Summary

Table 3 Milestones

Milestones	Acronym	Schedule	Location of meeting
Kick Off Meeting	KO	T0	Contractor’s premises
Final Design Review	FDR	T0+ 4 months	ESO Garching
Provisional Acceptance in Europe	PAE	T0+12 months	Contractor’s premises

6.4 Reporting and meetings

The project reporting shall be based on the following types of reports and meetings:

- Monthly Progress Report prepared by the contractor including an update of the project’s schedule and of the status of the tasks defined in the Workpackages.

- Bi-Monthly Progress Meeting held at the contractor's premises or at ESO Garching.
- Project Review Reports

Problems shall be reported in the form of Red Flag reports, Request for Waiver or Change Request.

6.5 Documentation

The following numbering scheme shall be used by the Contractor for all documents related to the Phase Meter project.

VLT-BBB-CCC-15731-GGGG

where:

· BBB identifies the type of document (see list below)

· CCC is the code for the Firm or Organization issuing the document (given by ESO)

· 15731 is the product code number of the Laser Assembly

· GGGG is a sequential identification number (including preceding zeros)

The document type codes (BBB) are defined as follows:

· CRE:Change Request

· DWG:Drawings

· ICD:Interface Control Document

· LIS:List

· MAN:Manual

· MIN:Minutes of Meeting

· PLA:Plan

· RFW:Request for Waiver

· TRE:Technical Report

6.6 Deliverable

The contractor shall deliver one Laser Assembly fulfilling all requirements described in this document. This includes:

- One Laser Head
- The HW for frequency doubling and frequency stabilization (see Fig. 2).
- The control law for the frequency stabilization. This law will be implemented on the Light source control HW under ESO's responsibility.
- All necessary spare parts and documents listed in the Workpackage definition.
- The data packages of the FDR and PAE

Table 4 Definition of WP 3211

Project: Prima Metrology **WP 3211 Laser Assembly** **WP Manager: TBD** **Contractor: TBD** **Start: KO** **End: FDR**
Inputs PRIMA Metrology Technical specifications (VLT-SPE-ESO-15730-2211) Technical Specifications and statement of work for the Laser Assembly of the PRIMA Metrology System (VLT-SPE-ESO-15731-2852)
Task Description Design of the Laser Assembly based on the technical specification and on the results of the frequency stabilization study performed in 2002 by the Institute of Microtechnology of Neuchâtel (VLT-TRE-IMT-15731-2868) Preparation of the FDR data package.
Outputs FDR data package (design and analysis reports, thermal dissipation budget,Interface control document, manufacturing drawings, test and verification plan, spare part list; preliminary installation and operation manuals)
Resources To be completed by the contractor

Table 5 Definition of WP 3311

Project: Prima Metrology **WP 3311: Laser Assembly procurement&Manufacturing / Testing in Europe** **WP Manager: TBD** **Contractor: TBD** **Start: FDR** **End: PVA**
Inputs Phase Meter FDR data Package (WP3211)
Task Description Procurement, Manufacturing and Testing of the Laser Assembly
Outputs Acceptance Data Package (as built drawings, updated Interface Control Document, verification and test report, spare part list; installation and operation manuals, Packing list).
Resources To be completed by the contractor