SPECIFICATION

THERMAL COMPENSATION SYSTEM LASER

APPROVALS	DATE	REV	DCN NO.	BY	CHECK	DCC	DATE
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DCC RELEASE							

1. Contents

2. Scope

The Advanced LIGO Thermal Compensation System (aLIGO TCS) projects a shaped, power stabilized intensity pattern on internal interferometer optics. This adaptively compensates thermal lensing induced by circulating interferometer power. The core of the projection system is a stable and reliable CW laser source emitting at least 50 W at a wavelength of 10.6 μm in a circular, well polarized and high quality mode. Total number of laser sources required is one (first article) plus eight production units.

This Specification defines requirements for the laser source only; ancillary external beam shaping, steering, magnification, polarization control, enclosure, cooling and modulation functions are not included except as reference information to support these specifications.

3. Requirements

Except as noted, all requirements apply over the full specified range of ambient and operational conditions and over the full specified service life of the furnished equipment.

Should any particular specification or requirement be found excessively costly or impractical to implement, LIGO encourages prospective vendors to submit with exceptions, and to provide a brief explanation of such exceptions. We also invite proposals for cost-effective and/or technically advantaged alternatives.

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3.1. Physical Description, Cooling and Power

3.1.1. Laser optics head envelope dimensions shall not exceed 200 x 30 x 30 cm with weight not to exceed 85 kg (excluding cooling and electrical power provisions and associated flexible connections).

3.1.2. Provision shall be afforded for safe lifting, installation, and replacement of each component or subassembly by no more than two people.

3.1.3. Performance and operational requirements, below, shall be achieved with a sealed gas device, rather than flowing gas.

3.1.4. Power shall be Buyer-supplied DC. The Seller may presume that furnished specifications will be consistent with the Seller's published power requirements.

3.1.5. Aqueous closed-cycle cooling will be provided by the Buyer at a flow rate not to exceed 8 liters/minute, and with nominal inlet temperature optionally adjustable from 15° C to 23° C with 0.1 °C resolution. Connection fitting type(s), coolant mix, and associated piping may be presumed to conform with Seller's published requirements. (Remote cooling unit may be located up to 50 m from laser head at Buyer's option).

3.1.6. Specified performance shall be maintained over coolant temperature variation of ±0.3° C about the coolant temperature set point, as measured at the laser head coolant inlet connection.

3.1.7. Specified performance shall be maintained over coolant flow rate variation of ± 10% with respect to nominal coolant flow rate, as measured at the laser head coolant inlet connection.

3.1.8. Total regulated liquid cooling capacity for all connected loads (including, for example, optics head and power supply) may not exceed 2.5 kW peak over all operating conditions.

3.1.9. Specified performance shall be maintained over ambient air temperatures between 18° C and 25° C.

3.1.10. Cooling fans are *not permitted* due to extreme environmental acoustic noise sensitivity.

3.1.11. A specified service life of 10,000 hours or greater is required. Periodic scheduled maintenance, if any, must be deferrable to at least 1,000 hour service intervals without compromising performance or service life. Required scheduled maintenance may not exceed 8 hours duration per service interruption.

3.2. Safety

3.2.1. Laser and power system shall comply with applicable CDRH/ANSI requirements for Class 4 research laser systems, installed in access- controlled laboratory environments, with or without user-supplied external enclosures.

3.2.2. A manually actuated physical shutter shall be provided to disable emission. Closure of the shutter shall be readily verified by inspection.

3.2.3. Remote wired interlock connection shall be provided to disable emission on external contact interruption. Emission shall be disabled if associated external wiring is inadvertently disconnected.

3.2.4. Remote electronic interlock shall be provided to disable emission on user-provided TTL-compatible external signal. Logic convention may be specified by the Seller; however, emission shall be forcibly disabled if external wiring is inadvertently disconnected.

3.3. Static Optical Requirements[1]

3.3.1. Laser emission wavelength shall be (10.6 ± 0.2) μm

3.3.2. Laser emission power shall be at least 50W CW, not to exceed 80W CW

3.3.3. Laser emission mode shall be non-astigmatic TEM_{00} with no more than 0.5% of total power appearing in spurious lobes or higher-order features.

3.3.4. Emitted beam shall be linearly polarized with extinction ratio of 100:1 or greater. Polarization axis shall be arranged either *parallel* OR *perpendicular* to the (nominally horizontal) head mounting interface plane[2], within a precision of ± 1 degree.

3.3.5. Emitted beam diameter (defined at $1/e^2$ of peak intensity) shall not exceed 8.0 mm at exit aperture.

3.3.6. Emitted beam full-width divergence (far-field) shall not exceed 10.0 mrad

3.3.7. After initial warm-up and selection of operating point, laser emission shall maintain a **single longitudinal mode** throughout specified ambient and coolant temperature fluctuation ranges, and throughout the specified coolant flow fluctuation range.

3.4. Dynamic Optical Requirements[3]

3.4.1. After initial warm-up and selection of operating point, laser emission shall maintain a single longitudinal mode over time, with not more than one mode hop per 24 hours, averaged over at least 100 hours. Power stability requirements given below must be maintained subsequent to any allowable mode hops.

3.4.2. Laser emission power shall be stable to ± 5% long-term (e.g., between scheduled maintenance periods if applicable)

3.4.3. Short-term emission fractional power stability shall be ± 2.5% or better for integration times up to 1000 seconds.

3.4.4. Narrowband power fluctuations at ambient electric power line or any harmonic frequency (n x 60 Hz, where n =1,2,3,…) may not exceed 0.1 % RMS.

3.4.5. Narrowband spurious power fluctuations at any other frequencies from 1 Hz to 10 kHz may not exceed 0.1 % RMS in total.

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[1] To apply after 30 minute warm up from cold start
[2] All units provided under this contract must employ the same polarization convention, whichever is chosen.
[3] To apply after 30 minute warm up from cold start

3.4.6. Laser beam direction shall be stable to ±5 % of the emitted beam divergence angle long-term (e.g., between scheduled maintenance periods if applicable)

3.4.7. Laser beam pointing angle jitter shall be less than ±0.5% RMS of the emitted beam divergence angle over measurement intervals up to 1,000 seconds.

3.5. Testing Requirements

3.5.1. Prior to shipment the Seller shall run each laser for 24 hours under simulated operating conditions (refer to Section 3.1.8) and then verify the following performance specifications:

3.5.2. Output power after 30 minute warm up

3.5.3. Long term power stability (one day)

3.5.4. Medium term power stability (one hour)

3.5.5. TEM_{00} content of emission mode (using beam scanner or thermal imager)

3.6. Required Documentation

3.6.1. Installation, operation and performance check/verification instructions

3.6.2. Pre-shipment test results (see section 3.5 above)

3.6.3. Engineering drawings of mechanical, electrical and optical interface(s)

3.6.4. Engineering & procurement specifications for required interface equipment (connectors, adapters, etc.)

3.6.5. Mass properties (including center of mass and mass moments of inertia)

3.6.6. Principal construction materials of housings and interfaces

3.6.7. Unique serial number for each device

3.6.8. Warranted lifetime of operation

3.7. Packaging, Storage and Shipping

3.7.1. Seller shall provide reusable shipping container with each unit delivered.

3.7.2. Units will be delivered to Caltech (Pasadena, CA), LIGO Hanford (Hanford, WA) and LIGO Livingston (Livingston, LA). Shipment destinations and dates will be provided upon award.

3.8. Delivery Schedule

Quantity	*Purpose*	*Early*	*Late*	*Location*
1	First article for evaluation & system integration test	4/15/10	5/31/10	Caltech
4	Production (on review: quoted option)	10/1/10	5/15/11	LIGO Hanford
4	Production (on review: quoted option)	10/1/10	5/15/11	LIGO Livingston

Table 1: Proposed delivery schedule