New Folder Name Conceptual Lay-out for a 10W single Frequency, Prestabilized Nd:YAG laser

CALIFORNIA INSTITUTE OF TECHNOLOGY

Laser Interferometer Gravitational Wave Observatory (LIGO) Project

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Subject: Conceptual lay-out for a 10 W single frequency, prestabilized Nd:YAG laser

Goals: Establishment of a baseline concept for the 10 W single frequency Nd:YAG laser needed for initial LIGO interferometer operation. Establishment of a baseline concept for the prestabilization (in frequency and amplitude) of the laser.

We assume that once the concept presented here has been adopted, the systems analysis will start at once. We expect that the baseline will have to be iterated as more detailed quantitative knowledge becomes available through analysis.

Scope: The level of detail in the conceptual lay-out should be sufficient for guiding the systems analysis for the laser and the associated frequency and intensity stabilization servos.

The development of a prototype prestabilized laser is divided into two tasks: development of a single frequency laser of moderate power (~10 W); development of the frequency and amplitude prestabilization of the laser.

Implementation Guidelines for the single frequency laser

1. To the furthest extent possible, the components of the laser system should be coming from well-established companies in the laser and optics industry.
2. The concept should ensure speedy development of a low power, ~500 mW laser, to cover the immediate needs of the LIGO project: implementation of a new laser in the prototype interferometers; implementation of the new laser in the OTF for testing of optics at the new wavelength.
3. Increasing the output power to the nominal level of 10 W and possibly higher power level should have the character of an add-on, i. e. the power upgrade should be possible with minimum change to the optics and to the control systems developed for the low power laser.
4. The implementation of the commercially supplied 10 W laser should require minimal, or at best no redesign of the resonator.

Implementation guidelines for the (pre)stabilization

1. The design of the frequency prestabilization should be done with the goal of improving the performance beyond that typically achieved with our current prestabilized lasers (i.e., design changes which have relatively clear advantages over the present system and are relatively simple to implement should be made, but we do not endeavor to undertake a research program to improve the frequency prestabilization).
2. The optics external to the laser should be kept at a minimum, in order to preserve the quality of the light beam.

Candidate conceptual designs

Three possible conceptual designs for the 10 W single frequency laser system have arisen; in each case the 10 W laser and low power master oscillator (if applicable) would come from a commercial laser company:

1. A master oscillator (hundreds of mW), injection locked slave laser (~10 W) system. The master oscillator provides the means for making the slave laser oscillate in a single frequency, and for frequency control of the output beam.
2. A 10 W laser alone, rebuilt for single frequency operation (most likely in a ring with intracavity elements to enforce single direction operation) and fast control of the frequency (via fast and slow pzts). This is similar to the current rebuilding of the Ar+, with the additional task of producing a single frequency output (as the commercial vendor would probably not provide this option).
3. A master oscillator (hundreds of mW) and power amplifier (power gain of around 20). Frequency control would be done on the master oscillator; the amplifier stage would most likely involve several passes through the gain medium.

Design	Advantages	Disadvantages
master/ slave	- satisfies laser guidelines 2,3 - some filtering of frequency and amplitude noise by slave resonator	- requires additional control loop for injection locking
solo 10W laser	- no additional control associated with injection locking - some filtering of frequency and amplitude noise by resonator	- not consistent with laser guidelines 2,3 - requires modification of resonator (in conflict with guideline 4 - poorer raw frequency stability than injection locked laser
MOPA	- no additional control associated with injection locking - satisfies laser guidelines 2,3	- no experience with this design in laboratory research - no cavity filtering of: spatial mode; high frequency amplitude and frequency noise - requires mode matching to gain medium (in conflict with the spirit of guideline 4)

Design selected: Considering the above advantages and disadvantages in conjunction with the guidelines, we propose to pursue the first design: master oscillator, injection locked slave laser.

The desired situation is where the 10 W slave laser is supplied by the vendor with a ring cavity geometry and with one mirror mounted on a pzt (it would then be ready for injection locking).

Description of Concept

The baseline concept is illustrated in the figure below, and includes the following features:

1. The 10 W laser will be based on a high quality commercially available laser diode pumped laser head (ideally in a ring geometry), injection locked by a low power monolithic laser, e. g. Model 126-700 made by Lightwave Electronics.
2. The initial implementation will be based on the low power laser alone.
3. Frequency stabilization will rely on the temperature control and on the fast PZT built into the low power laser, and on a traditional phase correcting Pockels cell.
4. In order to obtain improved frequency stabilization, the reference cavity will be of a rugged and compact design, possibly consisting of a low thermal expansion spacer and optically contacted mirrors, with no PZT tuning provided.
5. Frequency tuning of the laser output, in order to keep it resonant with the mode cleaner, will be achieved by using an acousto-optic modulator, similar to the arrangement employed in Glasgow.
6. Power stabilization will be implemented by controlling the current driving the laser diodes.

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PROPOSED CONFIGURATION FOR 10 W, SINGLE FREQUENCY, STABILIZED 1064 nm Nd:YAG LASER