LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
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Use of Low Power YAG Lasers for LIGO Interferometer Integration

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Abstract

In the event of YAG lasers will be chosen for the initial LIGO interferometers, engineering the new lasers and modifying the CDS components which interface with them will extend beyond the currently planned PSL fab completion date, and into the time span when the lasers are needed for interferometer integration at the sites. The present note lays out the use of low power YAG lasers, commercially available today, for interferometer integration and shake-down at the sites (IIS), in order to keep the schedule for achieving initial interferometer target sensitivity.

Keywords: laser, YAG, PSL, operations, integration, schedule

1 INTRODUCTION

One of the major milestones in the LIGO Project Management Plan is commissioning the LIGO Detector by July, 2000.[1] A significant enabling event consists of the first prestabilized laser (PSL) becoming operational at the Hanford site in June, 1998. If a choice to use YAG lasers instead of Argon lasers in the initial LIGO interferometers is made, the 10 W YAG lasers will still be in the fabrication stage by June, 1998, thus one needs to find a way to integrate and debug the interferometers without the benefit of the PSL. Since the full 10W at 1064 nm are not needed during most of the commissioning process; a smaller, simpler laser should be adequate. Thus, we discuss the use of a 700 mW YAG laser which is commercially available today, in a configuration which ensures that the transition to the 10 W lasers will be literally quick and easy.

The document is laid out as follows: Section 2 lists the assumptions, and Section 3 describes the use of the low power laser for interferometer integration and shake-down (IIS). The draft specification of a possible 10 W YAG laser is given in Appendix 1.

1. Commissioning is marked by reaching a sensitivity of $h_{RMS} \leq 10^{-20}$

2 ASSUMPTIONS

1. The consequence of a decision to use YAG lasers will cause the PSL to miss the June, 1998 date by roughly **one and a half years**. This worst case estimate is built on the following ingredients:
    - A decision to use YAG lasers may be made at the end of 1996.
    - Current PSL activities, centered on the Argon laser, will continue until the decision to switch is made.
    - All the PSL work carried out until the decision to switch laser is made will have to be repeated, causing a **2 year** slip in PSL schedule.[1, 2]
    - There is a **4-moths** float in the PSL schedule in November 1996, and another **4-moths** float before June 1998.
    - Allow for **~2 months** delay for various unpredictable reasons.

Note: since this assumptions is the main driver for the need to use a low power laser for IIS, it is suggested that it be thoroughly scrutinized before the program suggested here is adopted. For example, one should analyze the possibility that the PSL fab schedule could be considerably shortened by ordering a 10 W YAG laser which is fully engineered for integration in the PSL subsystem. More schedule relief is likely to result from the CDS part of the PSL not having to be completely redesigned if it is decided to switch to YAG lasers.

2. IIS can be performed at power levels considerably lower than the nominal 10 W at 1064 nm.
3. The feedback control system interfaces for the 10 W YAG laser will be designed according to the specification of Appendix 1.
4. Besides the slow and the intermediate speed feedback control inputs listed in the Specification, the PSL will have a fast control input (~1 MHz actuation rate), implemented by using a Pockels cell(s).
5. Installation of IOO and COC subsystem will proceed according to the current schedule.
6. The nominal PSL team will not be available for installation and use of the low power laser at the sites, as they will be working on PSL fab. It is assumed that the necessary resources will be made available by the Project, in order to keep work at the sites on schedule.

3 USE OF LOW POWER YAG

3.1. Discussion of the Concept

The low power YAG laser to be used in the initial phase of IIS will be a nonplanar ring oscillator (NPRO), Model 126, available from Lightwave Electronics for $27k. This laser delivers 700 mW of single frequency light.

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1. PSL detector activities started in January 1995.
2. This is probably an excessively pessimistic assumption, as we know that some aspects of the PSL work, like user graphics interfaces, are almost entirely "color blind." Some parts of the feedback control system electronics, e. g. the front end and the phase correcting Pockels cell drive, will probably be adequate for the YAG with no modifications. Moreover, the experience currently being gained by the PSL team has not been factored into this assumption.

Every effort will be made to set up the NPRO such that, seen from across all interfaces, it looks as similar as possible to the 10 W laser it replaces, except for power. The design of the power stabilization arrangement (PS) does not depend on laser power, and is thus not included in this discussion. The PS is a relatively simple subsystem which is easy to insert in the beam paths if required by IIS.

It is suggested that the NPRO be used as shown in Fig. 1. The main features of the arrangement are:

- The NPRO is a smaller laser and thus fits inside the area designated for the 10 W laser on the PSL table.
- If the output light beam from the NPRO differs from the 10 W laser output, a group of matching lenses ensures that the beam outside the dotted outline has the same geometry (i. e. waist size and location) as the beam from the 10 W laser.

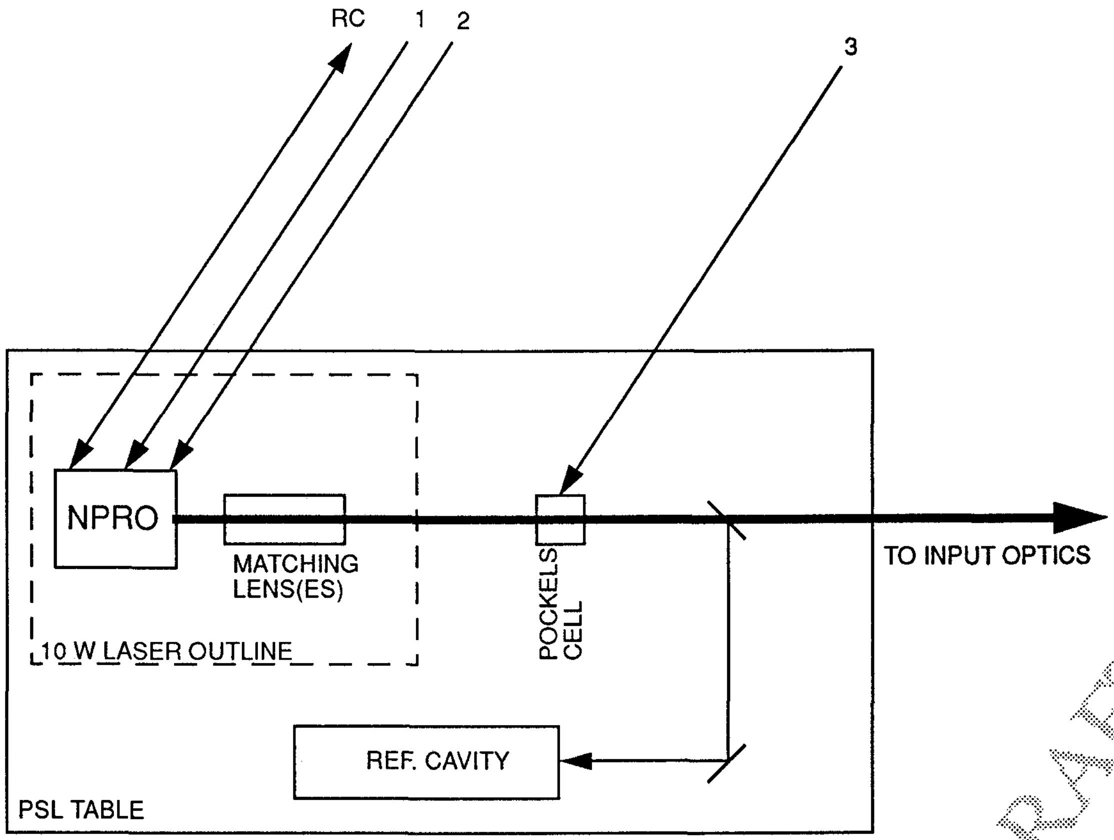

Fig. 1. Illustration of suggested use of a low power laser (NPRO) instead of the 10 W laser, for LIGO IIS. Slanted lines represent the relevant part of the interface with the CDS. RC: laser remote control and monitoring link; 1, 2, 3,: slow, intermediate, and fast feedback control signals for frequency stabilization.

- The Pockels cell, the two pick-offs and the reference cavity are part of the arrangement for the 10 W laser.
- Signal 3, the drive for the Pockels cell, is the same as for the 10 W laser.
- The slow and intermediate speed signals, labelled 2, 3, are the same as for the 10 W laser.[1]
- In all likelihood, the remote control and monitoring link will have to be custom designed and built for the NPRO.

3.2. Resources

1. Hardware:
    - NPRO: 3 units,[2] $81k.[3]
    - Reference cavities with accompanying vacuum equipment: 3 units. Building this hardware is part of the PSL fab subtask. The latter will have to be scheduled so that the reference cavities can be delivered in time for the IIS.
    - Laser remote control and monitoring link design& prototyping: 1 man-months (MM), Engineering, $1k.
    - Laser remote control and monitoring link: 3 units, $3k.

2. Installation of NPRO at the sites (3 units): 3 MM, Engineering

Bottom line:

- Cost: <$100k
- Engineering manpower: 4 MM

1. This is no accident. The draft specification has been written in the assumption that the 10 W laser it will be a master/slave combination, with the master either a Model 126, or a very similar NPRO.
2. NPRO's are needed for IIS of all three interferometers, which starts before the end of 1999, when the PSL's become available.
3. at 1995 prices. At the time when they are needed, NPRO price may be lower, due to falling pump diode laser prices, or higher, driven by demand.

APPENDIX 1 Nd:YAG Laser Specifications

Document **LIGO-E950081-00-I,** A. Abramovici, D. H. Shoemaker

A1.1 LIGHT

A1.1.1 General

1. Wavelength: 1064 nm, single frequency
2. Beam quality: $M^2<1.1$
3. Output power: >10W in TEM_{00} mode

A1.1.2 Stability

1. Power
    1. Long term variation < 5%
    2. Relaxation oscillation less than 10 times the shot noise corresponding to 10 mW
    3. Minimum stretch of continuous operation: 500 hours
4. Frequency drift $<10^{-6}/^{o}C$, free running
5. Pointing drift $<10^{-5}rad/^{o}C$ p.t.p., free running

A1.1.3 Noise

1. Relative power fluctuations $<10^{-6}/Hz^{1/2}$, above 100 Hz
2. Frequency: consistent with performance of NPRO[1]
3. Pointing: TBD

A1.2 OUTPUT CONTROL

1. Power: TBD[2]
2. Frequency:
    1. Slow tuning over >1 GHz, over time spans corresponding to room temperature changes
    2. Fast tuning over >100 MHz, at rates up to 100 kHz

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1. This spec needs to be studied in the context of the interferometer subsystem, including effect of low noise on control systems, in particular the possibility to relax some gain requirements on the latter.
2. The choice between a fixed power design (power adjustment via external attenuator) and a design based on variable pump power should be based on a trade study by the vendor

A1.3 INTERFACES

A1.3.1 Electrical

1. Mains: 110V-60Hz, single phase
2. Controls
    1. Local and remote (TTL) ON/OFF switches
    2. Local LOCAL/REMOTE switch selector

3. Inputs
    1. Connectors: items which are commercially available from multiple sources are strongly preferred. To be selected by vendor, subject to consultation with and approval by LIGO.
    2. Inputs for frequency control signals 2.2.1 and 2.2.2 above
    3. POWER SELECT signal if applicable (see Footnote 2)
    4. Remote LOCAL/REMOTE SELECT

4. Outputs
    1. ON/OFF status
    2. Output shutter status
    3. Power level
    4. Head temperature

A1.3.2 Mechanical

1.The laser beam will be 14 cm above the plane defined by the support points.
2.The laser will be supported on three legs, attached to the rigid resonator frame.
3.The rigid resonator frame will extend 10 cm outside laser enclosure, 10 cm below the output beam, parallel to the beam and horizontally centered on it. This extension will be provided with 1/4-20 threaded utility holes, number and pattern TBD.
4. Support points for lifting and other handling will be provided.

A1.3.3 Cooling

1. Cooling capacity and type (air, water) to be set by interaction with vendor.
2. The laser cooling unit will be separate from the laser head.

A1.4 MISCELLANEOUS

Laser subsystems that need periodic maintenance will be designed as modules, kinematically attached to the frame whenever needed, and easy to remove and replace.

A1.5 SAFETY

The laser will be provided with all safety arrangements required by applicable regulations.