

**Attachment LAS to the
Memorandum of Understanding (LIGO-M050297-00-M)
between the
Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group and
the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005**

This Attachment LAS to the Memorandum of Understanding LIGO-M050297-00-M defines the role of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWI) as a Member of the LIGO Scientific Collaboration (LSC) and a member of the Lasers Development Group (LDG). The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Lasers Development Group - The Lasers Development Group (LDG) is the scientific collaboration for defining and developing future high power lasers for use in advanced subsystems for the initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachments define the roles and responsibilities of groups in this development group.
2. During the period August 15, 2005 to August 15, 2006, the members of SAGWI Group will participate in the LAS (Lasers and Detectors Development Group) in the following areas:

Power-scaling of MOPA laser systems

(R. Byer, K. Urbanek, P. Lu)

- a) Scale the Nd:YAG slab MOPA laser system to higher powers; We have increased the reliability of our system in this period at the expense of output power. In the coming period, we will attempt to scale to the 200 W level by optimizing the alignment of the second slab, and investigate the possible use of Gaussian to super-Gaussian convertors to improve extraction efficiencies from the end-pumped slab. We will determine the fidelity to which we can convert the super-Gaussian from the output back into a TEM₀₀ Gaussian beam. We will investigate the use of silicate bonding to bond dielectric coated YAG pieces for use in parasitic mode suppression to improve the small signal gain of the end-pumped slab.

Development of fiber laser systems

(R.L. Byer, S. Sinha)

- b) Scale fiber MOPA to 160 W;

We will work to scale the fiber MOPA output to the 160 W level with a single stage of amplification with good beam quality and acceptable polarization extinction ratio. We hope to demonstrate over 50% optical-to-optical efficiency with respect to incident pump power. We will continue to modify the design of our fiber fixtures to increase the

reliability of the system. We will order a more reliable 400 W fiber-coupled pump diode stack that will allow us to scale the output power to the 200 W level.

c) Characterize fiber MOPA output;

We will characterize the intensity noise, phase noise and pointing stability of this system at the maximum operating power. We will measure the TEM₀₀ mode content by locking the output to a mode cleaner and we will characterize mode content fluctuations over time. We also plan to characterize the reliability of the system by running the system continuously for a week to determine if either catastrophic failure or a gradual reduction in performance is observed (for example from fiber photo-darkening).

d) Investigate phosphate fibers for possible applications in Advanced LIGO;

Using primarily ARO (Army Research Office) support, we are planning to build a single frequency fiber MOPA in highly doped phosphate fibers. Phosphate fibers promise a lower noise contribution from spontaneous Brillouin scattering noise (compared to silicates) due to shorter fiber lengths. We plan to obtain double-clad Yb:phosphate fibers through a collaboration with NP Photonics that will be suitable for generating output powers > 10 W. We will characterize this system to determine if these fibers can be used for creating extremely compact LIGO pre-amplifiers and/or scaled to over 100 W for use as power amplifiers.

Development of high-power photodiodes

(D. Jackrel, Z Rao, J. Harris, M. Fejer)

e) Continue the development of high power photodiodes.

Photodiode development for the next twelve month period will be focused on fabricating both InGaAs and GaInNAs(Sb) rear-illuminated devices with higher efficiencies, lower dark currents and high temperature packages compatible with other Advanced LIGO research activities. In addition, segmented detectors which have the ability to handle higher power levels and provide pointing and spatial mode information, may be investigated. In order to reach external quantum efficiencies approaching 90%, the substrate must be thinned to less than 10 μm . Attempts to achieve these ultra-thin structures, where the substrate is completely removed, have failed, however, due to an ineffective etch-stop layer (the function of which is to protect the device layers from the etchant used for substrate removal). In the future, the epitaxial growth procedure will be redesigned to accommodate a more effective etch-stop layer, which will in turn enable the fabrication of 80% to 90% efficient devices. The dilute nitride and nitride-antimonide materials will continue to be developed in the hopes that a high efficiency, low dark current device will be the result. Materials characterization of these structures is critical in the determination of the causes of device deficiencies. The epitaxial structures will therefore be characterized using x-ray diffraction, photoluminescence (PL), deep-level transient spectroscopy (DLTS), spectral cathodoluminescence (CL) imaging and other techniques. Finally, devices will be wire-bonded and packaged in high temperature packages and sent to MIT and GEO 600 to be characterized for properties such as electronic noise and spatial uniformity. They may potentially become integrated into Advanced LIGO test systems such as the high-power laser intensity stabilization system under development at GEO 600.

3. Resource Sharing: The LIGO Laboratory will contribute resources including allocation of appropriate scientific and engineering personnel, research facilities and funding in support of the effort in Item No. 2, as indicated below.
 - a) Research accommodations for SAGWI group members while on LIGO research assignment at any LIGO Laboratory site,
 - b) Access to LIGO data through established LSC channels in support of this work.
4. Coordination and Reporting – SAGWI Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2 will be carried out within the Lasers Development Working Group of the LSC. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, including progress against the milestones if any, significant accomplishments such as new insights/discoveries or publications, issues of concern if any, and an indication of invested time. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

Approved:

Barry Barish
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Robert L. Byer
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Peter Saulson
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