Attachment Number C to the
Memorandum of Understanding (LIGO-M950060-A-M)
between the
Stanford Advanced Gravitational Wave Interferometry Group
and the
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory
August 15, 2002

This Attachment to the Memorandum of Understanding LIGO-M950060-A-M covers the role of the Stanford Advanced Gravitational Wave Interferometry Group (Stanford Group) as a Charter Member of the LIGO Scientific Collaboration (LSC) and a member of the Lasers/Optics Development Group (LODG). The period of performance for the activities in this Attachment is from **August 15, 2002 to February 15, 2003**. This period may be modified by agreement to a revision of this Attachment.

1. LIGO Scientific Collaboration - The LIGO Scientific Collaboration is organized as a separate organization from the LIGO Laboratory. It includes scientists from the LIGO Laboratory, and those from collaborating institutions, and has its own leadership and governance. The Collaboration will ensure equal scientific opportunity for individual participants and institutions. It will organize the research, publications, and all other scientific activities. The Collaboration will report to the Laboratory Directorate for final approval of its research program, technical work, observational physics publications, and talks announcing new observations and physics results. This will be done through regular reports to the Directorate and its PAC.

2. Charter Membership - An initial period for formation of the Charter group of institutions in the LIGO Scientific Collaboration commenced on March 1, 1997 and ended following the first full meeting of the Collaboration at which the Collaboration Council assumed its role.

   Following the charter period proposals will be evaluated through the Collaboration Council. With Collaboration approval, an MOU with the LIGO Laboratory, including Attachments defining specific work, will be required for any participating institutions.

3. This document is an agreement between the Stanford Group and the LIGO Laboratory concerning the activities of the Stanford Group as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the Lasers/Optics Development Group (LODG), and as indicated in Item No. 8 below.

4. Lasers/Optics Development Group - The Lasers/Optics Development Group (LODG) is the scientific collaboration for defining and developing future high power lasers and required improvements in optics for use in advanced subsystems for the initial LIGO interferometers

or in entirely new advanced interferometers. A specific Attachment will define the roles and responsibilities of groups in this development group. Members of this group will normally be authors in publications reporting the work of the group and will normally be eligible to participate in data runs and science beyond the LIGO I data run.

5. Report of Progress - The Stanford Group will provide a status report on its activities in support of LIGO every six months. The report will consist of: a) a summary status on research by topic as indicated item No. 8 below 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, b) updated List of Collaborators, and c) a plan of activities for the succeeding six-monthly period. The report will be due one month before the close of the period of performance under the Attachment in question.

6. Term of Membership - The membership will be renewed every six months upon evidence of satisfactory performance of agreed upon duties.

The Galileo group coordinates are included in Attachment Z to the Memorandum of Understanding LIGO-M950060-A-M.

7. Intellectual Property Rights - The rights to intellectual property developed under this Attachment will be subject to the National Science Foundation Grant Policy as indicated in Section 730, Intellectual Property.

8. During the period from **August 15, 2002 through February 15, 2003**: Professors Robert L. Byer, Martin M. Fejer; and James S. Harris; Senior Research Associate Roger Route; Part-time employees Alex Alexandrovski and Volodymyr Kondilenko; and Graduate Students David Jackrel, Shailendhar Saraf and Supriyo Sinha will work on high power optical amplifiers and their noise when saturated, adaptive optics for spatial mode control, a Gaussian to super Gaussian beam converter to improve the efficiency of the optical amplifier, optical absorption losses in sapphire and fused silica, and high power photodiodes. The Stanford group will:

   a) Demonstrate at least 100W output power from 2 MOPA stages using existing slabs in the high power laser lab;
   These slabs have Brewster windows and will be triple-passed to get around issues with input and output beam separation. Double passing and polarization separation cannot be used on these slabs due to the Brewster windows. Due to the severe thermal lensing that is appearing in the second stage, compensation using cylindrical lenses will be employed. If cylindrical lenses are insufficient to compensate for higher order thermal aberrations, dielectrically coated deformable mirrors will be used. Detailed beam characterization will be performed on the final output beam.

   b) Set up for the 200W experiment;
   This will involve small-signal gain measurements of the received YAG slabs which have undoped end caps sandwiching a 0.6% Nd doped core. Furthermore, as the pump intensity is extremely high, we will have to investigate if any parasitic oscillations are present. In

addition, the pump light will be tuned in wavelength for optimal amplifier gain. This will be accomplished at each output power by adjusting the temperature of the diode stacks.

c) Further develop phased array concepts;
Experiments involving super-mode generation from cold cavities for subsequent amplification in slabs will be continued. Phased gratings for this purpose will either be fabricated or purchased from an external vendor.

d) Implement superior control algorithms to increase the closed loop bandwidth of the adaptive optics system;
These algorithms may be required if adaptive optics are used in the 100 W edge-pumped design.

e) Test all-silicon deformable mirror architecture to permit scaling too much higher powers;

f) Continue to investigate the properties of a three layer deformable mirror with its lower crosstalk;
Specifically, we are interested in determining if a three-layer mirror is necessary or if the current two-layer structure has sufficient spatial resolution to adequately compensate for thermally induced aberrations in the slab lasers. Preliminary results indicate that two-layer structures may be sufficient but this has to be confirmed experimentally.

g) Continue making PCI measurements of absorption losses in sapphire optics;
Volodymyr Kondilenko will continue to study post-growth heat-treatment processing on the residual optical absorption in HEM-grown sapphire crystals. We will continue a series of high temperature heat-treatment studies (to 1600 C) under controlled atmospheres using high purity, high density alumina atmosphere control components.

h) Continue the measurement of optical absorption losses in coated fused silica optics produced at MLD Technologies in a collaborative study with LIGO aimed at optimizing MLD's coating deposition and subsequent heat-treatment parameters; and

j) Continue the development of high power photodiodes.
Photodiode development for the next six-month period will be focused on improving device efficiency and increasing the optical power levels at which the devices saturate. The major cause of the lower efficiencies in the InGaAs devices is the free-carrier absorption of roughly 30% of the incident light in the highly doped 450-micron thick substrate. Procedures are being developed to fabricate devices incorporating thinned substrates to reduce this parasitic absorption. Furthermore, GaInNAs devices will be grown with 2-micron thick absorbing layers, which will improve the efficiency of these devices substantially over the current devices that utilize 1-micron thick absorbing layers. The saturation power will be improved by increasing the breakdown voltage of the devices. The device junction will be passivated using an etching and polyamide-encapsulation procedure which will both decrease the leakage current and increase the device breakdown voltage. Studies using similar processes have shown that a substantial increase in breakdown voltage may be achievable, which will in turn increase the optical power the devices can detect before saturating.

9. As part of the research collaboration under this agreement the LIGO Laboratory will share, as requested and appropriate, LIGO data of relevance to the research focus in Item No. 8 above.

10. The research effort pursuant to this Attachment C will be coordinated by Roger Route and Gary Sanders on behalf of Stanford Group and the LIGO Laboratory, respectively.

11. 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. 8, as indicated below.

    a) Provide accommodations for Stanford Group investigators while on LIGO research assignment at Caltech, and/or LIGO sites.

    b) Provide on loan a 10W Laser to be used in conjunction with the Stanford edge pumped slab laser for testing optical components at high power.

Approved:

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Barry Barish LIGO Laboratory Director	Robert L. Byer Principal Investigator
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Date	Date