

Attachment Number 1 to the
Memorandum of Understanding (LIGO-M970056-00-M)
between the
Shanghai Institute of Optics and Fine Mechanics (SIOM)
of the Chinese Academy of Sciences, Shanghai, China
and the
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory
January 1, 1999

This Attachment to the Memorandum of Understanding LIGO-M970056-00-M describes the activities of the Shanghai Institute of Optics and Fine Mechanics (SIOM) of the Chinese Academy of Sciences, Shanghai, China in developing high quality, large Sapphire crystals for LIGO. The period of performance for the activities in this Attachment is from January 1, 1999 to December 31, 2000. This period may be modified by agreement to a revision of this Attachment.

1. The goal of this work is to produce high quality, large Sapphire crystal blanks, as specified, for test masses required by LIGO. The ultimate specification of LIGO test masses would require Sapphire crystal blanks of:
 - a. Diameter 25 cm and length 10 cm with Sapphire's c-axis along the cylinder axis with an alignment of $< 100 \mu\text{rad}$, and
 - b. Absorption of $< 5 \text{ ppm/cm}$ and homogeneity of $< 5 \times 10^{-7}$ at wavelength of 1064 nm within the central 8 cm.
2. This task will be led by Peizhen Deng and Jun Xu for SIOM and by Ren-yuan Zhu for LIGO.
3. Phase I Work Plan and Deliverables- The tasks to be carried out and the methods for so doing are:
 - a. SIOM will deliver three Sapphire crystal blank samples of diameter 11 cm and length 8 cm with the c-axis along the cylinder axis, low absorption ($< 10 \text{ ppm/cm}$) and good homogeneity ($< 5 \times 10^{-6}$) at a wavelength of 1064 nm within the central 5 cm. Sample delivery will start around the end of 1997 and will be complete by June 1998.
 - b. SIOM will provide a feasibility study of Sapphire test masses required by LIGO.
 - c. LIGO will provide technical evaluation of Sapphire samples.
4. The SIOM LIGO group will at times send their scientists to Caltech to work on LIGO experiments and coordinate activities with SIOM. The number will be flexible according to needs,

subject to approval by the LIGO Project. Financial support of these scientists will be determined by mutual agreement.

5. Technical, Schedule and Cost Reporting - The status of the work will be reviewed in a monthly teleconference involving all interested parties from SIOM and LIGO. The emphasis of these meetings will be on technical and schedule issues. In addition, the progress of Phase I Sapphire R&D (Phase I) will be reviewed on a bi-annual basis. A final evaluation of the Phase I results will take place two months after the receipt of all three Sapphire crystals on order, and a written Phase I report will be submitted to the LIGO Laboratory a month later. The preliminary plans for Phase II R&D, to be included in the Phase I report, will be finalized after the submission of Phase I report to the LIGO Laboratory.
6. Cost - The LIGO Laboratory provided US\$50,000 in advance funds to SIOM for the Phase I Sapphire R&D under a California Institute of Technology (Caltech) Purchase Order.
7. Intellectual Property Rights - The rights to intellectual property developed under this Attachment will be subject to the US National Science Foundation Grant Policy as indicated in Section 730, Intellectual Property.
8. The growth technology of Sapphire crystals is the property of SIOM. During the course of this project, information related to Sapphire crystal growth may be disclosed to LIGO scientists with an understanding that they will not pursue Sapphire crystal growth and that they will treat this information with due care and discretion.

Approved:

Barry Barish
Barry Barish
LIGO Principal Investigator

Dec 7, 1999
Date

Ren-yuan Zhu
Ren-yuan Zhu
LIGO Representative

Nov. 30, 1999
Date

Bill Kells
Bill Kells
LIGO Representative
Nov 29 1999
Date

Hu Qiguan
Qiguan Hu
SIOM Deputy Director

Dec. 27, 1999
Date

Jun Xu
Jun Xu
SIOM Sapphire Development Group

Dec. 27, 1999
Date

Deng Peizhen
Peizhen Deng
SIOM Sapphire Development Group

Dec. 27, 1999.
Date