NASA SBIR 2004 Phase I Solicitation

S2.06 Technologies for Gravity Wave Detection

Lead Center: JPL

Participating Center(s): GSFC

Instruments that detect low frequency gravity waves offer a new window on the universe, its origin, evolution and structure. Complementing ground-based experiments such as the Laser Interferometer Gravitational Wave Observatory (LIGO), the Laser Interferometer Space Antenna (LISA), and the follow on vision mission, Big Bang Observer, will implement ambitious systems to detect and characterize gravity waves associated with the Big Bang, mergers of black holes, and other significant astrophysical phenomena. The success of such investigations will largely depend on the technology building blocks that are needed to implement multiple spacecraft constellations with extremely precise laser interferometers and test masses which are actively decoupled from systematic and random disturbances.

The technology areas are organized into two subsystems, one dealing with the disturbance rejection subsystem, which houses the proof mass with active sensors and thrusters to cancel non-gravity wave disturbances, and the other implementing the network of laser interferometers with nanometer-level resolution of relative range between the test masses. Because the systems will be deployed in space, the technologies to be considered must be, or have, credible paths toward full space flight qualification, including thermal and radiation considerations. Background information on LISA, along with preliminary technology discussions, can be found in the proceedings of the 4th International LISA Symposium, Penn State University, 19–24 July 2002, published in the Classical and Quantum Gravity Journal, Volume 20, Number 10, 21 May 2003.

Disturbance Reduction System (DRS)

- Vacuum system – non-magnetic vacuum pump for reaching pressures of \(-6\) Pa with a pumping volume of 1 liter; with associated valves and electronics
- Vacuum gauge – read pressure down to \(10^{-6}\) Pa on orbit, must be non-magnetic
- Caging actuator – hold 2 kg mass \(~4\) cm\(^3\) against launch loads of \(~25\) g rms, with the capability for moving caged test mass over \(~10\) micron range with \(~1\) nm precision during ground testing
- Test mass, \(~4\) cm\(^3\), mass \(~1–2\) kg, magnetic susceptibility \(-6\) (e.g., 73% gold/27% platinum)
Laser Interferometer

- Laser with exceptional power, frequency noise, amplitude noise, lifetime characteristics.
  - Fiber coupled output power (1 W) CW
  - A combination of a lower power master oscillator with suitable amplifier to yield 1 W of total fiber coupled output power may be acceptable
  - Frequency and amplitude noise characteristics: Frequency stability to \(30 \text{ Hz}/\text{vHz at 1mHz}\), and power stability to \(2 \times 10^{-4}/\text{vHz at 1 mHz}\)
  - Lifetime of 10 years or more.
  - Wavelength is nominally 1.064 micron, but +/- 20% of that value is acceptable.
  - Semiconductor diode pump laser with outstanding reliability to operate with a suitable solid-state laser (e.g., non-planar ring oscillator laser) is required.

- Electro-optical modulator – produce phase modulation of continuous laser beam with 10% (power) modulation depth at frequencies from 1.9–2.1 GHz with fiber coupled input and output. Baseline operation will be at 1.064 microns. In addition to the space qualification requirements, the modulator must be able to handle optical power levels at \(\sim 1 \text{ W}\).

Research and technology development should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit to a participating NASA Center for testing at the completion of the Phase II contract.