NASA SBIR 2004 Phase I Solicitation

S2.04 Optical Technologies

Lead Center: GSFC

Participating Center(s): JPL

The NASA Space Science Enterprise is studying future missions to explore the Structure and Evolution of the Universe (SEU). To understand the structure and evolution of the universe, a variety of large space-based observatories are necessary to observe cosmic phenomena from radio waves to the highest energy cosmic rays. It will be necessary to operate some of these observatories at cryogenic temperatures (to 4 K) beyond geosynchronous orbits. Apertures for normal incidence telescope optics are required up to 40 m in diameter, while grazing incidence optics are required to support apertures up to 10 m in diameter. For some missions, these apertures will form a constellation of telescopes operating as interferometers. These interferometric observatories may have effective apertures up to 1000 m diameter. Low mass of critical components such as the primary mirror, its support and/or deployment structure, is extremely important. In order to meet the stringent optical alignment and tolerances necessary for a high quality telescope and to provide a robust design, there are significant benefits possible from employing systems that can adaptively correct for image degrading sources from inside and outside the spacecraft. This includes correction systems for large aperture space telescopes that require control across the entire wavefront, typically at low temporal bandwidth. The following technologies are sought:

- Grazing incidence focusing mirrors with response up to 150 keV.
- Large, ultra-lightweight grazing incidence optics for x-ray mirrors with angular resolutions less than 5 arcsec.
- Wide field-of-view optics using square pore slumped microchannel plates or equivalent.
- Develop fabrication techniques for ultra-thin-flat silicon (or like material) for grating substrates for x-ray energies
- Large area thin blocking filters with high efficiency at low energy x-ray energies
- Ultraviolet filters with deep blocking
- Develop novel materials and fabrication techniques for producing ultra-lightweight mirrors, high-performance diamond turned optics (including freeform optical surfaces), and ultra-smooth (2–3 angstroms rms) replicated optics that are both rigid and lightweight. Lightweight high modulus (e.g., silicon carbide) optics and structures are also desired.
- High-performance (e.g., high modulus, low density, high thermal conductivity) materials and fabrication processes for ultra-lightweight, high precision (e.g., subarcsecond resolution or
- Advanced, low-cost, high quality large optics fabrication processes and test methods including active
metrology feedback systems during fabrication, and artificial intelligence controlled systems.

- Large, ultra-lightweight optical mirrors including membrane optics for very large aperture space telescopes and interferometers.

- Cryogenic optics, structures, and mechanisms for space telescopes and interferometers.

- Ultra-precise, low mass deployable structures to reduce launch volume for large-aperture space telescopes and interferometers.

- Segmented optical systems with high-precision controls; active and/or adaptive mirrors; shape control of deformable telescope mirrors; and image stabilization systems.

- Advanced, wavefront sensing and control systems including image based wavefront sensors.

- Wavefront correction techniques and optics for large aperture membrane mirrors and refractors (curved lenses, Fresnel lenses, diffractive lenses).

- Nanometer to sub-picometer metrology for space telescopes and interferometers.

- Develop ultra-stable optics over time periods from minutes to hours.

- Advanced analytical models, simulations, and evaluation techniques, and new integrations of suites of existing software tools allowing a broader and more in-depth evaluation of design alternatives and identification of optimum system parameters including optical, thermal, structural, and dynamic performance of large space telescopes and interferometers.

- Develop portable and miniaturized state-of-the-art optical characterization instrumentation and rapid, large-area surface-roughness characterization techniques are needed. In addition, develop calibrated processes for determination of surface roughness using replicas made from the actual surface. Traceable surface roughness standards suitable for calibrating profilometers over sub-micron to millimeter wavelength ranges are needed.

- Develop instruments capable of rapidly determining the approximate surface roughness of an optical surface, allowing modification of process parameters to improve finish, without the need to remove the optics from the polishing machine. Techniques are needed for testing the figure of large, convex aspheric surfaces to fractional wave tolerances in the visible.