NASA SBIR 2005 Phase I Solicitation

S4.04 Optics and Optical Telescopes (including X-ray, UV, Visual, IR)

Lead Center: GSFC

Participating Center(s): JPL, MSFC

With the reorganization of NASA activities into the Exploration Mission Directorate (EMD) and the Space Mission Directorate (SMD), there is a renewed call for novel optical technologies that extend the state-of-the-art across wavelength bands from far-IR to Gamma-ray. Missions to study the Earth and Sun, the other solar system planets and objects, and the origins and fate of the universe are proposed to operate from low Earth orbit to L2 or drift-away trajectories depending on their system of study and environmental requirements.

Among other areas of study, future planet finder missions will require lightweight optical apertures of tens of square meters with sub-nanometer surface figure errors. Infrared versions will require cooling optics to cryogenic temperatures (to 4 K). Telescopes studying the Sun and its environment in the UV and EUV (20-300 nm wavelength) require novel optical coatings and filters, high precision aspheric optics, and high-density uniform and variable line density diffraction gratings. And high-energy X-ray telescopes will study the origins and fate of the universe with

For all missions, low-mass optics and deployment structures are extremely important. Also, wavefront sensing and control systems are sought that may alleviate the stringent mass and stiffness requirements of such large optics. Finally, advanced, low-cost manufacturing, metrology, and modeling techniques will be required to make these missions possible.

The previous year's Optical Technologies (S2.04) and UV and EUV Optics (S1.06) have been merged to form this year's Optics and Optical Telescopes subtopic. All previously relevant areas of research are invited in this new subtopic including:

**Optics**

- Ultra-smooth (2-3 Angstroms rms) replicated optics that are rigid and lightweight;
- Lightweight, high modulus (e.g., silicon carbide) optics and structures;
• Ultra-stable optics over time periods from minutes to hours;

• Cryogenic optics, structures, and mechanisms for space telescopes and interferometers;

• High-performance, diamond turned optics (including freeform optical surfaces);

• Large, thin, ultra-lightweight grazing incidence optics for X-ray mirrors with angular resolutions less than 5 arcsec. (>100 cm\(^2\), 2 areal density);

• Wide field-of-view optics using square pore slumped microchannel plates or equivalent;

• Large, ultra-lightweight optical mirrors (2 at near-IR through visible), including membrane optics for very large aperture space telescopes and interferometers;

• UV and EUV Imaging mirrors with simultaneously large aperture (1-4 m diameter), low mass (5-20 kg/m\(^2\)), accurate figure (~0.01 wave rms or better at 632 nm), and low micro-roughness (Smooth sub-mm scale image slicer and microlens array component technologies to allow fabrication of integral field spectrographs in the UV and visible, for simultaneous spectroscopy of two spatial dimensions and one spectral dimension.

**Filters**

• Large area, thin blocking filters with high efficiency at low energy X-ray energies (Ultraviolet filters with deep blocking (5) of longer and shorter wavelengths, including "solar blind" performance; novel near- to far-IR filters with increased bandwidth, stability, and out-of-band blocking performance;

• FUV and EUV coatings (filters) with improved reflectivity (transmission) and selectivity (narrow bands, broad bands, or edges). Technologies include multilayers, transmission gratings, and Fabry-Perot etalons, among others; and

• Improved X-ray and Gamma-ray modulation optics and coded aperture masks (sub-arcsecond resolution at 10 keV to 10 arcsecond resolution at 1 MeV).

**Gratings**

• Fabrication techniques for ultra-thin-flat silicon (or like material) for grating substrates for X-ray energies

• High resolving power diffraction gratings (>4000 lines/mm) at acceptable focal lengths and pixel sizes; and

• Improvements in grating manufacturing technologies, such as high efficiency/low scatter gratings, variable line spacing, improved echelle gratings, active grating surfaces (gratings replicated onto deformable substrates), and gratings ruled onto concave, aspheric surfaces.

**Metrology**

• Low-cost, high quality, large optics fabrication processes and test methods including active metrology feedback systems during fabrication, and artificial intelligence controlled systems;

• Portable and miniaturized state-of-the-art optical characterization instrumentation and rapid, large-area surface-roughness characterization techniques are needed. 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; and

- 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 for testing the figure of large, convex, aspheric surfaces to fractional wave tolerances in the visible.

Wavefront Sensing and Control

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

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

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

Optical Design

- 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.