



## NASA SBIR 2016 Phase I Solicitation

### S1.01 Lidar Remote Sensing Technologies

Lead Center: LaRC

Participating Center(s): GSFC, JPL

NASA recognizes the potential of lidar technology in meeting many of its science objectives by providing new capabilities or offering enhancements over current measurements of atmospheric and topographic parameters from ground, airborne, and space-based platforms. To meet NASA's requirements for remote sensing from space, advances are needed in state-of-the-art lidar technology with an emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar subsystem and component technologies that directly address the measurement of atmospheric constituents and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Compact, high-efficiency lidar instruments for deployment on unconventional platforms, such as balloon, small sat, and CubeSat are also considered and encouraged.

Proposals must show relevance to the development of lidar instruments that can be used for NASA science-focused measurements or to support current technology programs. Meeting science needs leads to four primary instrument types:

- *Backscatter* - Measures beam reflection from aerosols to retrieve the opacity of a gas.
- *Ranging* - Measures the return beam's time-of-flight to retrieve distance.
- *Doppler* - Measures wavelength changes in the return beam to retrieve relative velocity.
- *Differential absorption* - Measures attenuation of two different return beams (one centered on a spectral line of interest) to retrieve concentration of a trace gas.

Phase I research should demonstrate technical feasibility and show a path toward a Phase II prototype unit. Phase II prototypes should be capable of laboratory demonstration and preferably suitable for operation in the field from a ground-based station, an aircraft platform, or any science platform amply defended by the proposer. For the 2016 SBIR Program, NASA is soliciting the component and subsystem technologies described below.

- Compact and rugged single-frequency continuous-wave and pulsed lasers operating between 0.28- $\mu$ m and 2.05- $\mu$ m wavelengths suitable for lidar. Specific wavelengths are of interest to match absorption lines or atmospheric transmission: 0.28 to 0.32- $\mu$ m (ozone absorption), 0.45 to 0.49- $\mu$ m (transmission through ocean water), 0.532- $\mu$ m, 0.817 to 0.830- $\mu$ m (water lines), 1.0- $\mu$ m, 1.57- $\mu$ m (CO<sub>2</sub> line), 1.65- $\mu$ m (methane line), and 2.05- $\mu$ m (CO<sub>2</sub> line). For wavelengths associated with an absorption line, tunability on the order tens of nanometers is desired. Architectures involving new developments in diode laser, quantum cascade laser, and fiber laser technology are especially encouraged. For pulsed lasers two different regimes of repetition rate and pulse energies are desired: from 8-kHz to 10-kHz with pulse energy greater than 1-mJ and from 20-Hz to 100-Hz with pulse energy greater than 100-mJ.
- Optical amplifiers for increasing the energy of pulsed lasers in the wavelength range of 0.28- $\mu$ m to 2.05- $\mu$ m. Specific wavelengths of interest are listed above in the bullet above. Also, amplifier and modulator

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combinations for converting continuous-wave lasers to a pulsed format are encouraged. Amplifier designs must preserve the wavelength stability and spectral purity of the input laser.

- Ultra-low noise photoreceiver modules, operating at 1.6- $\mu\text{m}$  wavelength, consisting of the detection device, complete Dewar/cooling systems, and associated amplifiers. General requirements are: large single-element active detection diameter ( $>200$  micron), high quantum efficiency ( $>85\%$ ), noise equivalent power of the order of  $10\text{-}14$  W/sqrt(Hz), and bandwidth greater than 10 MHz.
- Novel, highly efficient approaches for High Spectral Resolution Lidar (HSRL) receivers. New approaches for high-efficiency measurement of HSRL aerosol properties at 1064, 532 and/or 355-nm. New or improved approaches are sought that substantially increase detection efficiency over current state of the art. Ideally, complete receiver subsystems will be proposed that can be evaluated and/or implemented in instrument concept designs.
- New space lidar technologies that use small and high-efficiency diode or fiber lasers to measure range and surface reflectance of asteroids and comets from  $>100$  km altitude during mapping to  $<1$  m during landing and sample return at a fraction of the power, mass, and cost of the Mercury Laser Altimeter (i.e., less than 7.4kg, 17W, and 28x28x26cm). The technologies can significantly extend the receiver dynamic range of the current space lidar without movable attenuators, providing sufficient link margin for the longest range but not saturating during landing. The output power of the laser transmitters should be continuously adjusted according to the spacecraft altitude. The receiver should have single photon sensitivity to achieve a near-quantum limited performance for long distance measurement. The receiver integration time can be continuously adjusted to allow trade-off between the maximum range and measurement rate. The lidar should have multiple beams so that it can measure not only the range but also surface slope and orientation.
- Narrow linewidth and frequency stable laser transmitter at 780-nm wavelength for development of low-cost, compact, and eye-safe high spectral resolution lidar (HSRL) for ground-based profile measurements of aerosol and cloud intensive and extensive properties. Desired specifications include pulse energy of 5 to 20-mJ, pulse repetition rate of 1 to 10-kHz, wavelength near 780-nm coincident with rubidium vapor line, linewidth  $< 10\text{-MHz}$ , spectral purity  $> 99.9\%$ , and wavelength tunability of at least 0.5-nm around central wavelength.