NASA SBIR 2022 Phase I Solicitation

S11.01  Lidar Remote-Sensing Technologies

Lead Center: LaRC

Participating Center(s): GSFC

Scope Title

Lidar Remote-Sensing Technologies

Scope Description

NASA recognizes the potential of lidar technology to meet many of its science objectives by providing new capabilities or offering enhancements over current measurements of atmospheric, geophysical, 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 features 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 unmanned aerial vehicles, SmallSats, and CubeSats 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 and clouds to retrieve the optical and microphysical properties of suspended particulates.
- Laser spectral absorption: Measures laser absorption by trace gases from atmospheric or surface backscatter and volatiles on surfaces of airless planetary bodies at multiple laser wavelengths to retrieve concentration of gas within measurement volume.
- Ranging: Measures the return beam's time of flight to retrieve distance.
- Doppler: Measures wavelength changes in the return beam to retrieve relative velocity.

Expected TRL or TRL Range at completion of the Project

3 to 6

Primary Technology Taxonomy
Desired Deliverables of Phase I and Phase II

- Prototype
- Hardware
- Software

Desired Deliverables Description

Phase I research should demonstrate technical feasibility and show a path toward a Phase II prototype unit. A typical Phase I deliverable could be a technical report demonstrating the feasibility of the technology and a design that is to be built under a Phase II program. In some instances where a small subsystem is under investigation, a prototype deliverable under the Phase I is acceptable.

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. Higher fidelity Phase II prototypes that are fielded in harsh environments such as aircraft often require follow-on programs such as Phase III SBIR to evaluate and optimize performance in relevant environment.

As seen in the section below on “State of the Art and Critical Gaps,” desired deliverables are oriented toward subsystem or system-level lidar technology solutions, as opposed to a stand-alone component. That is, desired technologies should be toward a lidar system, rather than a component such as a laser or photodetector of unspecified applicability to a measurement goal.

State of the Art and Critical Gaps

- Transformative technologies and architectures are sought to vastly reduce the cost, size, and complexity of lidar instruments from a system perspective. Advances are sought for high-efficiency high-pulse energy (>>1 mJ) and high power (>>1 W) transmitters for operation on a wide range of compact (SmallSat, CubeSat, or Unmanned Aerial Vehicle size) packages. Reduction in the complexity of laser architectures is sought, while still meeting performance metrics for the measured geophysical observable. Hybrid diode/fiber/crystal architectures are sought as affordable sensor solutions to help reduce complexity and sensitivity to environmental effects (vibration, thermal variations, and pressure variations). Laser thermal management often poses an engineering challenge that drives lidar systems to deploy on large and costly platforms. Hence, novel thermal management systems for laser, optical, and electronic subsystems are sought to increase efficiency, decrease physical footprint, and transition laser systems to more compact platforms. New materials concepts could be of interest for the reduction of weight for lidar-specific telescopes, optical benches, and subcomponents. Integrated subsystems combining laser, optical, fiber, and/or photodetector components are of interest for reducing the size, weight, and power of lidar instruments.
- Compact, efficient, and rugged narrow-linewidth pulsed lasers operating between ultraviolet and infrared wavelengths suitable for lidar are sought. Specific wavelengths are of interest to match absorption lines or atmospheric transmission are: 290 to 320 nm (ozone absorption), 450 to 490 nm (ocean sensing), 532 nm (aerosols), 820 nm (water vapor line), 935 nm (water vapor line), 1064 nm (aerosols), 1550 nm (Doppler
wind), 1645 to 1650 nm (high pulse energy (>10 mJ) for methane line, Doppler wind, and orbital debris tracking), 2050 nm (Doppler wind), 3000 to 4000 nm (hydrocarbon lines and ice measurement), and 6000 nm (nonterrestrial ice and water measurement). Architectures involving new developments in high-efficiency diode laser, quantum cascade laser, and fiber laser technologies are especially encouraged. For pulsed lasers two different regimes of repetition rate and pulse energies are desired: from 1 to 10 kHz with pulse energy greater than 1 mJ and from 20 to 100 Hz with pulse energy greater than 100 mJ. For laser spectral absorption applications, such as differential absorption lidar, a single frequency (pulse transform limited) and frequency-agile source is required to tune >100 pm on a shot-by-shot basis while maintaining high spectral purity of >1,000:1. Laser sources of wavelength at or around 780 nm are not sought this year. Laser sources for lidar measurements of carbon dioxide are not sought this year.

- Novel approaches and components for lidar receivers are sought, matching one or more of the wavelengths listed in the bullet above. Such receiver technology could include integrated optical/photonic circuitry, freeform telescopes and/or aft optics, frequency-agile ultra-narrow-band solar blocking filters for water vapor differential absorption lidar (DIAL) (<10 pm FWHM (full width at half maximum), >80% transmission and phase locked to the transmit wavelength), and phased-array or electro-optical beam scanners for large (>10 cm) apertures (especially those preserving transmission of circular polarization). Integrated receivers for Doppler wind measurement at 1550, 1650, or 2050 nm wavelength are sought for coherent heterodyne detection at bandwidths of 1 GHz or higher, combining local oscillator laser, photodetector, and/or fiber mixing. Development of telescopes should be submitted to a different subtopic (S12.03), unless the design is specifically a lidar component, such as a telescope integrated with other optics. Receivers for direct-detection wind lidar are not sought this year.

- New three-dimensional (3D) mapping and hazard detection lidar with compact and high-efficiency diode and fiber lasers to measure range and surface reflectance of planets or asteroids from >100 km altitude during mapping to <1 m during landing or sample collection, within size, weight, and power to fit into a CubeSat or smaller. New lidar technologies are sought that allow system reconfiguration in orbit, single-photon sensitivities and single beam for long-distance measurement, and variable dynamic range and multiple beams for near-range measurements. High-speed 2D scanners are also sought for single-beam lidars that enable wide scan angles with high repeatability and accuracy.

**Relevance / Science Traceability**

The proposed subtopic addresses missions, programs, and projects identified by the Science Mission Directorate (SMD), including:

- Atmospheric water vapor: Profiling of tropospheric water vapor supports studies in weather and dynamics, radiation budget, clouds, and aerosol processes.
- Aerosols: Profiling of atmospheric aerosols and how aerosols relate to clouds and precipitation.
- Atmospheric winds: Profiling of wind fields to support studies in weather and atmospheric dynamics on Earth and atmospheric structure of planets.
- Topography: Altimetry to support studies of vegetation and the cryosphere of Earth, as well as the surface of planets and solar system bodies.
- Greenhouse gases: Column measurements of atmospheric gases, such as methane, that affect climate variability.
- Hydrocarbons: Measurements of planetary atmospheres.
- Gases related to air quality: Sensing of tropospheric ozone, nitrogen dioxide, or formaldehyde to support NASA projects in atmospheric chemistry and health effects.
- Automated landing, hazard avoidance, and docking: Technologies to aid spacecraft and lander maneuvering and safe operations.

**References**

- NASA missions are aligned with the National Research Council's decadal surveys, with the latest survey on earth science published in 2018 under the title "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space": [http://sites.nationalacademies.org/DEPS/esas2017/index.htm](http://sites.nationalacademies.org/DEPS/esas2017/index.htm)
survey-2023-2032

- Description of NASA lidar instruments and applications can be found at:
  - https://science.larc.nasa.gov/lidar/
  - https://science.gsfc.nasa.gov/sci/