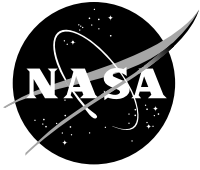


NASA/TM—2017-219459



An Overview of Communications Technology and Development Efforts for 2015 SBIR Phase I

*Hung D. Nguyen and Gynelle C. Steele
Glenn Research Center, Cleveland, Ohio*

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Abstract

Technological innovation is the overall focus of NASA's Small Business Innovation Research (SBIR) program. The program invests in the development of innovative concepts and technologies to help NASA's mission directorates address critical research and development needs for agency projects.

This report highlights innovative SBIR 2015 Phase I projects that specifically address areas in Communications Technology and Development, one of six core competencies at NASA Glenn Research Center. Each article describes an innovation, defines its technical objective, and highlights NASA applications as well as commercial and industrial applications.

Fifteen technologies are featured: novel solid state lasers for space-based water vapor DIAL; an optical system for monitoring net ocular blood flow; wide temperature, high voltage, high-energy-density capacitors for aerospace exploration; an instrument for airborne measurement of carbonyl sulfide; a high-power tunable seed laser for a methane lidar transmitter; a ROC-rib deployable Ka-band antenna for nanosatellites; a SiC-based microcontroller for high-temperature in situ instruments and systems; improved yield, performance, and reliability of high-actuator-count deformable mirrors; an embedded multifunctional optical sensor system; switching electronics for space-based telescopes with advanced AO systems; an integrated miniature DBR laser module for lidar instruments; a mobile passive MWIR gas imager; a multi-wavelength seed-derived laser for in situ validation of airborne remote sensing instruments; a compact wireless EVA communications system (CWECS); and a compact, rugged, and low-cost atmospheric ozone DIAL transmitter.

This report serves as an opportunity for NASA engineers, researchers, program managers, and other personnel to learn about innovations in this technology area as well as possibilities for collaboration with innovative small businesses that would benefit NASA programs and projects.

Novel Solid-State Lasers for Space-Based Water Vapor DIAL

Fibertek, Inc.

Fibertek, Inc. proposes to develop a novel laser source designed to meet the needs of planned space-based atmospheric water-vapor (WV) differential absorption lidar (DIAL) instruments. Our approach is based on frequency doubling the output wavelength of efficient near-infrared (NIR) solid-state laser materials doped with rare earth ions that can be efficiently pumped by high-brightness semiconductor laser diodes. We will also investigate novel resonators, designed to reduce the pulse width and increase the extraction efficiency on low-gain, three-level laser transitions. Our proposed innovation has the potential for improving the operating efficiency of water vapor DIAL laser transmitters by about a factor of two compared to current lasers.

Applications

NASA

The laser technology to be developed under this SBIR program lays the foundation for an affordable class of space-based remote sensing instruments that are compatible with Earth Venture or ISS-class missions. Because of the lower cost, we expect the frequency of these opportunities to be far greater than those of major missions such as ICESat-2 and those recommended in the decadal study: ACE, ASCENDS, and LIST. EV-class missions also serve as pathfinders for major space-based instruments and thus reduce the risk for the higher value missions. The technology developed under this SBIR has application for remote sensing of multiple atmospheric species linked to global climate change, including methane, water vapor, and potentially carbon dioxide.

Commercialization

In addition to NASA, NOAA has a long history of fielding water vapor remote sensing instruments—both terrestrial and airborne platforms. Many of these have been based on low-power (laser diode) sources and therefore have limited range capability. The proposed Er:YAG frequency-doubled laser can access the same WV lines but with orders of magnitude higher peak power, which enables measurements with higher precision and coverage rates. Upgrade of existing lidar systems with the new laser technology will also provide a viable market for high-performance laser systems.



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Proposal number: 15-1 S1.01-9914

Optical System for Monitoring Net Ocular Blood Flow

Physical Sciences Inc.

Physical Sciences Inc. (PSI) proposes to develop an advanced ocular imaging platform for comprehensive examination of the eye posterior segment (retina/choroid) based on non-invasive multimodal optical imaging techniques, including Optical Coherence Tomography (OCT) and PSI's proprietary confocal line-scanning ophthalmoscopy (LSO). Software control of scan patterns and data processing and display/segmentation algorithms will accommodate a variety of novel approaches within a single optical platform and enhance diagnostic capabilities to standard OCT- and LSO-based techniques. In addition to structural information such as retina and choroid thickness maps and volume, quantitative and scalable tools for wide dynamic range blood flow metrics will be designed in Phase I and demonstrated in human volunteers and animal models in Phase II.

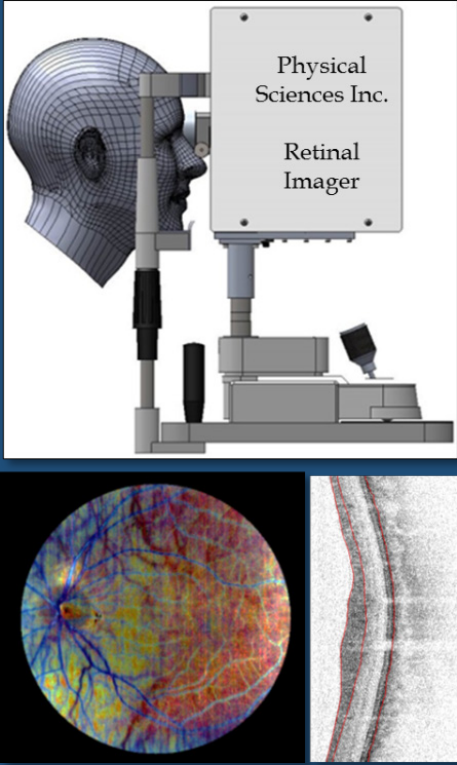
Applications

NASA

The auto-regulation of blood flow and fluid transport in the eye is exquisitely sensitive to many neurovascular and metabolic signaling systems. Though the effects of glucose, oxygen, and carbon dioxide (fuel, oxidizer, and waste) are the most commonly studied, there is also evidence that the fluid shifts and intraocular/intracranial pressure changes observed or inferred in the microgravity environment likewise produce responses with potential long-term consequences for ocular health. An advanced multimodal diagnostic imaging platform that can accurately track multiple anatomical and physiological changes in the eye over time is therefore fundamental to understanding and mitigating these effects. Such a flexible device may offer significant advantages to NASA research facilities that would otherwise need to adapt multiple single-purpose commercial clinical devices to NASA applications.

Commercialization

PSI has a long and successful history in developing advanced ophthalmic imaging instrumentation. The main objective of the proposed research is development of a multimodal platform that can non-invasively and non-mydratically characterize the posterior segment of the eye both structurally (thickness maps and volume of retina and choroid) and hemodynamically (blood flow in the retina and choroid). A novel imaging system combining Optical Coherence Tomography (OCT) with PSI's proprietary Line-scanning Doppler Flowmetry (LSDF) near 1050 nm will provide 3D structural information and local flow parameters while semi-quantitative LSDF flow visualizations will aid in characterizing global blood flow patterns. Such a unique platform capable of generating structural and functional maps of the eye will have immediate clinical applications for a broad range of eye diseases, including diabetic retinopathy, glaucoma age-related, macular degeneration, and other conditions.



Physical Sciences Inc.
Retinal Imager

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Proposal number: 15-1 H12.01-9633

Wide Temperature, High Voltage, High-Energy-Density Capacitors for Aerospace Exploration

Powdermet, Inc.

NASA requires advanced power electronic and energy storage devices that can work at various temperature (-100 °C to 400 °C) and high operating voltage with high energy and power density where traditional power and energy storage devices cannot be applied. Current state-of-the-art capacitors suffer from temperature reliability, especially at high temperature, as well as low energy density, making them bulky and costly. Power systems for NASA missions must be operated efficiently at high temperatures to eliminate the need for on-board cooling systems. The high performance capacitor (temperature reliability and high energy density) will save space, reduce weight, and improve reliability. The proposed Phase I SBIR program will demonstrate Powdermet, Inc.'s ability to produce an advanced nanocomposite capacitor that can be applied in harsh and extreme environments, as required by NASA aerospace exploration. This novel capacitor will feature a wide operating temperature (-100 °C to 400 °C), high operating voltage (>kilovolt), high energy density (>4 J/cc), and high power density (>MW/cc) as well as operating in high-radiation environments.

Applications

NASA

These advanced nanocomposite capacitors can be widely used in advanced power electronic and energy storage devices required by NASA for aerospace exploration, such as Titan missions, Lunar Quest, advanced aeronautic equipment, and so on. The proposed capacitors working under extreme environments for aerospace exploration will ultimately aid the NASA mission in the following functional areas: 1) high voltage, radiation hardened, high temperature and high power passive components and energy storage devices; 2) high power density/high efficiency power electronics and associated drivers for switching elements; 3) NASA systems ion thruster propulsion power supply system; 4) NASA solar power system backups; 5) vehicle power assists.

Commercialization

The proposed novel nanocomposite capacitor can provide direct benefit for future advanced pulsed-power electronic devices and electric power systems, such as lasers, radar, pacemakers, electromagnetic armors, defibrillators, and high power microwaves. The U.S. Air Force specifically has applications for high temperature capacitors to extend the temperature range of power electronics equipment. Downhole power electronics in the oil and gas industry need to work at high temperatures. Capacitors are also finding uses in the renewable energy generation market or in alternative energy sources, such as hybrid and plug-in electrical vehicles as well as solar power systems.

Hybracap Application

NASA/Military
Medicine
Transportation

Hybracap VALUE

- **WIDER**
 - Operating temperatures
 - Applications-high operating voltage
- **FASTER**
 - Sub microsecond discharge speed
- **SMALLER & LIGHTER**
 - Due to higher (10x) energy density
 - No requirement for active cooling system
- **HIGHER**
 - Power density (as high as MW/cc)

Firm Contact

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Proposal number: 15-1 S3.03-8858

Instrument for Airborne Measurement of Carbonyl Sulfide

Southwest Sciences, Inc.

Southwest Sciences is developing compact, low power instrumentation for the real-time direct measurement of carbonyl sulfide (OCS) in the atmosphere, especially targeting airborne measurements. The instrument will be based on a recently introduced room temperature interband cascade laser (ICL) operating in the 4830 nm region. This laser has a substantially reduced (by a factor of approximately 12) power requirement compared to quantum cascade lasers operating in the same region and should be better suited for use in atmospheric field instruments. The Phase I effort concentrated on characterizing the sensitivity and precision that can be achieved for OCS measurement, using this laser in a laboratory prototype. The Phase I work also included direct measurement of ambient carbonyl sulfide, at concentrations of approximately 500 parts-per-trillion in the local outside air. The follow-on Phase II project emphasizes development of an airborne-worthy prototype instrument that can be field tested.

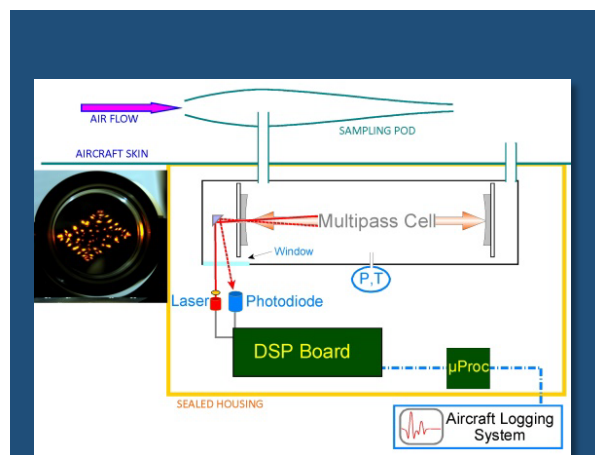
Applications

NASA

Phase I and Phase II will result in an instrument for measurement of carbonyl sulfide that could be used by NASA to measure this important sulfur species from airborne platforms or in ground-based studies. The instrument platform could be adapted for measurement of other atmospheric species (including carbon monoxide, hydrocarbon gases, water vapor, carbon dioxide, and other sulfur species). The technology also could be applied to in situ measurement of carbonyl sulfide in the 55 km cloud layers of the Venus atmosphere, where higher OCS concentrations are expected compared to terrestrial atmospheric concentrations.

Commercialization

This type of instrumentation is of interest to other government agencies involved in atmospheric research, including NOAA, the Department of Energy, and NSF-supported institutions such as NCAR. The instrumentation, if adapted for measurement of pollutant gases, could be of interest to EPA and industrial customers concerned with pollutant monitoring and control. Southwest Sciences intends to manufacture and sell instrumentation based on the project technology to NASA, other government agencies, and the general atmospheric research and environmental monitoring communities.



Conceptual layout of airborne instrument for measurement of carbonyl sulfide

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Proposal number: 15-1 S1.07-9285

High-Power Tunable Seed Laser for Methane LIDAR Transmitter

Princeton Lightwave, Inc.

Growing interest in precise measurements of methane concentration and distribution in the Earth's atmosphere is stimulating efforts to develop LIDAR systems in the spectral region of 1.65 μm utilizing Path Differential Absorption techniques. The key element of such systems is a high-energy optical source with good beam properties operating in the vicinity of a methane absorption line. A number of very promising architectures for designing high-energy lasers at 1651 nm have been described recently, but the performance of the lasers developed in these earlier efforts has been limited by the lack of a sufficiently high-power tunable seed laser. For this SBIR Phase I program, we propose to develop a robust seed laser that is fiber-coupled, narrow linewidth, tunable, highly reliable, and compact, and which ultimately will allow the realization of much higher performance high-energy laser sources designed for methane detection.

Applications

NASA

Development of a new high-power seed laser at 1651 nm will push the performance of LIDAR systems for methane detection to levels not currently possible, and it will allow for the deployment of significantly longer-range systems with higher precision measurements of methane concentration and distribution in the Earth's atmosphere. This laser technology to be developed will also potentially provide new capabilities for measurements of other atmospheric constituents and the surface topography of the Earth and other planetary bodies anticipated for numerous NASA mission programs. A significant increase in laser seed power will lead to dramatic enhancements in the stability of operation for methane detection laser transmitters, with consequent improvements in overall LIDAR system reliability.

Commercialization

There are a number of potential non-NASA commercial applications that will benefit from the development of a high-power tunable laser as proposed for this program. The detection of methane and other hydrocarbon gases is of critical importance in the energy industry, and laser sources developed for NASA systems will have direct relevance for related commercial requirements. As with NASA remote sensing applications, there are commercial applications for improved high-power lasers in various types of LIDAR systems for measuring atmospheric properties such as wind and weather patterns, air pollution, and general trace gas analysis. High-power laser sources are key elements of all range-finding and lidar systems and critically impact end system performance. The development of the proposed laser technology will serve broad applications in the biomedical arena, with examples such as nerve and fertility stimulation.

Coarse spectral position tuning of high-power seed laser (top) and methane absorption line: blue line—low-power DFB laser; red line—170 mW high-power seed laser (bottom).

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Proposal number: 15-1 S1.01-9021

ROC-Rib Deployable Ka-Band Antenna for Nanosatellites

Tendeg LLC

In these days of tight budgets and limited funding, NASA is constantly looking for new ways to reduce development time and costs of future spacecraft. This is the driving spirit behind NASA’s increasing interest in the CubeSat platform, and the vision that is guiding development and demonstration of higher-risk technologies that can eventually lead to low-cost atmospheric science from CubeSats. For example, a tantalizing next-generation CubeSat system would combine a high-gain deployable antenna with a high-frequency Ka-band transponder to support very high bandwidth communications and/or very high-resolution radiometric remote sensing of Earth’s surface and atmospheric phenomena.

To address this need, Tendeg proposes to develop a Ka-band deployable mesh antenna that can package within a 2U to 3U CubeSat volume and deploy to diameters of 0.75m to 1m. The antenna employs a backing structure that is a hybrid wrap-rib/perimeter-truss design. A net supports a reflective mesh while the entire assembly provides the structural depth and surface accuracy needed for Ka-band operation.

Applications

NASA

The primary NASA target application for the proposed deployable antenna technology is future NASA CubeSat and SmallSat spacecraft for which communications up/downlink or active and passive RF remote sensing measurement resolution is a major bottleneck in the system design. In particular, the proposed technology will enable very high bandwidth communications on the order of 1 to 2 Gbps from LEO to Earth and 10s of Mbps from Mars to Earth. As part of a sensor system, the antenna can be used for active radar applications (SAR, weather) and as a radiometer sensing ocean surface waves and winds. The antenna aperture is scalable to 2m to 3m.

Commercialization

Beyond NASA applications, the proposed deployable antenna technology could see use in other military and commercial applications where data up/downlink or RF sensing is also a considerable need. The focused narrow beam width provides the signal security needed for these applications. Terrestrial-based applications might include portable military and commercial communication networks that desire Ka-band operations and can benefit from lightweight, man-portable and deployable high-gain apertures.



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Proposal number: 15-1 S1.02-9216

A SiC-Based Microcontroller for High-Temperature In-Situ Instruments and Systems

Ozark Integrated Circuits, Inc.

NASA has a need for electronics that can support proposed flagship missions, such as probes, surface landers, and rovers for Venus. Devices that can operate at temperatures of up to 500 °C are needed. Ozark IC has built upon a large collection of key building blocks developed in complementary MOS silicon carbide (SiC-CMOS). Ozark IC has demonstrated that its SiC-CMOS integrated circuits can operate for 80 hours or more at the Venus surface temperatures—16x longer than the benchmark set by previous Venera missions. From extensive test and characterization, models and improved gates have been developed that are optimized for Venus surface conditions. Using these models, a general-purpose 16-bit SiC microcontroller with a 1KB SRAM has been designed and simulated, based upon the rugged MSP430 architecture. This component will provide real-time programmability for existing SiC and GaN support circuits in future missions.

Ozark IC and its partner, the University of Arkansas, have created the world’s largest known library of CMOS silicon-carbide (SiC) analog and mixed-signal circuits, intellectual property (IP) and packages that can operate at very high temperatures. Microcontroller-scale integration is now possible in this extremely dense SiC technology and, when combined with data converters, gate drivers, and other analog/mixed-signal circuitry, can serve in any number of high-temperature sample acquisition and analysis instruments.

Applications

NASA

NASA has demonstrated a resolve for a flagship mission in the coming years to revisit Venus and land instruments on the surface. Venus has a corrosive, high-pressure (~100 bar), high-temperature (up to 500 °C) environment. NASA experts have stated that the single greatest challenge to providing devices operable at the Venusian surface is the availability of high-temperature digital, analog, and mixed-signal electronics. The SiC integrated circuit technology that Ozark IC is actively commercializing can easily exceed NASA targets of 24 hours at 500 °C with proper packaging. By demonstrating the world’s first SiC microcontroller, this proposal represents a major step in creating a general-purpose chipset that will support a majority of functions required by a Venus lander.

Commercialization

Other non-NASA applications are relatively obvious—they include any market that needs a programmable microcontroller that will operate over a wide temperature range. These markets (with some applications) include, but are not limited to, Industrial Control (ovens), Power Generation (pipes in reactors, turbines and chemical plants), Scientific Observations (volcanos, geothermal and science laboratories), Military Aerospace (jet engines, missile tracking, high-altitude drones), Commercial Aviation (equipment monitoring), and Oil Exploration (intelligent drill bits), among others.

8-bit SiC-CMOS memory operated for over 95 hr at 470 °C

Designed and simulated 16-bit microcontroller

Part of a chip-set solution for high-temperature data acquisition and imaging

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Proposal number: 15-1 S1.06-9561

Improved Yield, Performance, and Reliability of High-Actuator-Count Deformable Mirrors

Boston Micromachines Corporation

The project team conducted processing and design research aimed at improving the yield, performance, and reliability of high-actuator-count micro-electro-mechanical deformable mirrors (MEMS DMs), which are essential for space-based coronagraph instruments. The primary objectives of this Phase I proposal were to develop and demonstrate solutions to manufacturing issues that arise when scaling MEMS DMs up to array sizes of 4000 actuators or more. The technical approach involved changes in DM processing technology and actuator geometry, which were successfully validated in an abbreviated fabrication run at a MEMS foundry. This work has led to a Phase II SBIR contract.

Applications

NASA

The main potential NASA commercial applications which are in need of deformable mirrors with improved yield, performance, and reliability over the current state of the art are space-based astronomical imaging systems, such as those doing direct imaging of exoplanets with coronagraphic telescopes. As more, larger telescopes are constructed, they will require control of light using adaptive optics over a large aperture. By utilizing DMs with improved actuator yield, these NASA systems will be able to better compensate for optical aberrations, increase overall throughput resulting from reduced diffractive losses, and simplify instrument design by eliminating the need for spatial filters in the optical path to mitigate diffractive effects.

Commercialization

Small-stroke, high-precision deformable mirrors have numerous commercial applications. The following applications apply to high-resolution devices as well as other BMC products, all of which benefit from new manufacturing processes developed which increase yield, performance, and reliability.

Space surveillance: BMC has success developing arrays up to 4096 elements for astronomy which can be used for space-based systems. These programs are funded by Department of Defense administrations with classified agendas.

Optical communication: Lasercomm systems would benefit from this new process for long-range secure communication. Also, fiber optic communications can take advantage of our devices in an optical switching capacity.



This Phase I project sought to improve the manufacturability of high-actuator-count MEMS deformable mirrors like the one pictured above (shown next to a quarter for scale).

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Proposal number: 15-1 S2.01-9488

Embedded Multifunctional Optical Sensor System

Physical Optics Corporation

Physical Optics Corporation (POC) proposes to continue the development of a novel Embedded Multifunctional Optical Sensor (EMOS) System. The EMOS addresses NASA’s need for in situ sensor systems for use on rigid and/or flexible ablative thermal protection system (TPS) materials to measure multiple TPS structural, aerothermal, and aerodynamic response parameters including temperature, heat flux, and pressure. EMOS is based on use of novel materials for high-temperature operation and uniquely designed fiber optic microsensors. The EMOS system is capable of simultaneously measuring multiple TPS response parameters (e.g., pressure, temperature, and heat flux) using a suite of miniature (diameter <400 μm) fiber optic sensors. The outcome of the Phase I EMOS program was the successful feasibility demonstration of the proposed EMOS technology, capable of operating at temperatures at >1500 °C. At the end of Phase II, POC will perform a technology readiness level (TRL)-6 demonstration of the EMOS at POC or at NASA facilities and will deliver to NASA a fully operational EMOS system prototype.

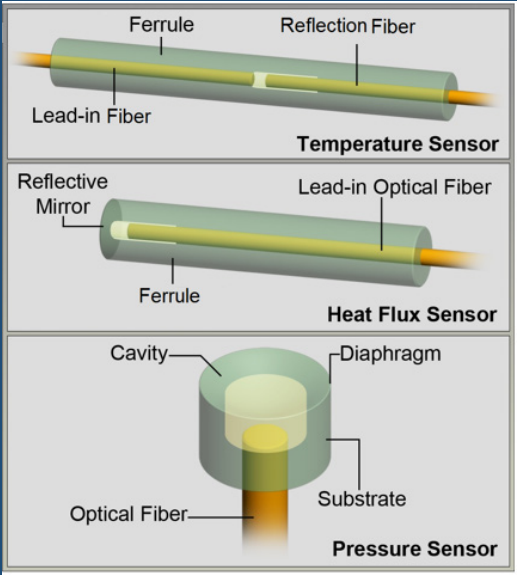
Applications

NASA

The proposed EMOS system will provide for NASA a distributed and embedded in situ system for measurement of TPS response in aerothermal and aerodynamic environments. It will provide better traceability from the modeling and design tools to actual performance, because the resultant EMOS data can lead to higher-fidelity design tools, improved risk quantification, decreased heat shield mass, and increases in direct payload. For specific NASA applications, these microsensors can be applied to different types of ablative materials used for TPSs, including, but not limited to, PICA, PICA-X, SIRCA, Superlight Ablator (SLA), and Avcoat, and those under development for planetary aerocapture and entry as well as return to Earth.

Commercialization

Military applications of the EMOS system will include health monitoring of military aircraft components. The military will benefit from this technology by incorporating EMOS into the engine and drivetrain components of rotorcraft to monitor, in situ and in real time, potential component failure, to reduce the amount of inspection and testing required, and to increase reliability and mission availability. Commercial applications include health monitoring of industrial control and heavy equipment used in construction and mining operations, commercial aircraft engines, drivetrain systems, and utility systems. An immediate application of the EMOS system will be monitoring coal-fired power plants, natural-gas-based power plants, and geothermal plants, as well as other power-generation facilities throughout the nation. This sensor suite can be used directly in critical high-temperature power plant components, including superheater and reheater pendants for in situ real-time condition monitoring.



The image contains three diagrams of fiber optic sensors:

- Temperature Sensor:** A cylindrical sensor with a green ferrule. A yellow lead-in fiber enters from the left, and a reflection fiber exits from the right.
- Heat Flux Sensor:** A cylindrical sensor with a green ferrule. A yellow lead-in optical fiber enters from the right, and a reflective mirror is located at the left end of the sensor.
- Pressure Sensor:** A cylindrical sensor with a green ferrule. It features a cavity at the top, a diaphragm in the middle, and an optical fiber entering from the bottom. The entire sensor is mounted on a substrate.

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Proposal number: 15-2 H7.01-9025

Switching Electronics for Space-Based Telescopes With Advanced AO Systems

Sunlite Science & Technology, Inc.

One preferred approach to directly image an exoplanet is to build a space-based telescope instrumented with advanced internal coronagraphs, where deformable mirrors (DMs) with high actuator counts are essential for achieving very high contrast detection. When actuator quantities are in the thousands, the electrical drivers pose a fascinating challenge for space-based applications, where power and mass are limited, and reliability is extremely important for the mission lifetime in space. What is proposed is a monolithic multiplexed driver, which can deliver voltages to 64x64 actuators at different time slots. Thus the required operation power is greatly reduced. By vertically integrating the application specific integrated circuit (ASIC) driver with a DM, the potential wiring failure will be eliminated. Furthermore, radiation resistance will be emphasized during ASIC design.

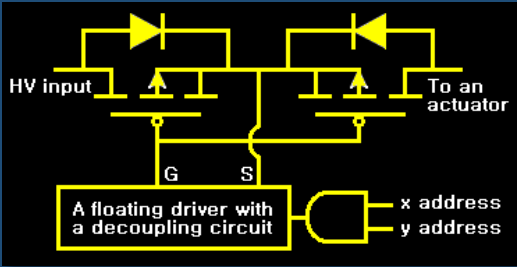
Applications

NASA

The proposed ASIC driver is specifically designed to drive the stacked DMs that NASA has qualified in ground. It will provide a reliable, low power, monolithic DM driver that can be used by an exoplanet-imaging coronagraph. Thus it will be found valuable in applications on those missions, such as WFIRST and ATLAST, where coronagraphic instruments are required.

Commercialization

The first beneficiaries of the ASIC driver are the DM manufacturers. With a vertically integrated ASIC driver, the fabrication of a DM will be dramatically simplified since thousands of wires will no longer be required. Thus, the yield and reliability will be greatly improved. Furthermore, with a simplified architecture, DMs with tens of thousands of actuators will become possible at affordable prices, which could attract more AO applications such as retinal imaging, fidelity microscopy imaging, and laser drilling.



The proposed unit driver is an HV analog bidirectional switch, featuring feedthrough free, configured by a pair of any type HV transistors.

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Proposal number: 15-1 S2.01-9534

Integrated Miniature DBR Laser Module for Lidar Instruments

Photodigm, Inc.

We propose to demonstrate a compact integrated laser module structure that addresses the requirements of the laser source in a water vapor differential absorption Lidar (DIAL) system. Our approach, with the development of the high performance DBR laser diode and the engineering of miniature integration technology, will provide narrow line-width and high power laser modules for numerous Lidar applications with the advantages of reduced size, weight, and power (SWaP). Under this Phase I SBIR program, we would demonstrate the operation of the compact integration laser modules, both on an optical bench and in a miniature housing, with output line-width and power at desired levels. In the Phase II program, Photodigm will continue to build the laser modules into compact, hermetic packages to achieve high reliability and manufacturability. The laser modules will be further integrated with monolith or discrete master oscillator (MO) power amplifier (PA) designs suitable for the next-generation Lidar instruments.


Applications

NASA

NASA's primary application for the proposed compact integration laser module would be deployment in the autonomous field DIAL sensor networks to map atmospheric water vapor with high spatial and temporal resolution. This application is well aligned with the Science Mission Directorate (SMD) instrument development program objective through the implement of smaller and more affordable DIAL transmitters. The compact integration technology applies to the full spectrum of GaAs material based DBR lasers that Photodigm offers, leading to potential applications in sensing of ozone and other trace gases. Follow-on development of the laser systems through rugged packaging and further integration of monolithic or discrete MOPA design will enable the deployment of DBR laser transmitters in numerous airborne and space-based platforms.

Commercialization

The miniature integrated laser module proposed would be the most compact and high power DBR laser with embedded optics available in the market. In addition to NASA's use in a number of LIDAR systems, a narrow line-width and high power laser module finds applications in various areas of spectroscopy, atomic physics, non-linear optics, and fiber amplifiers. The high spectral stability is desirable in applications resolving hyper-fine structures and applications demanding long coherent length. The size and weight reduction and fiber connection is suitable for handheld instrumentation. Photodigm recognizes the fastest commercial growth lies in gas sensing, aerospace metrology, and medical tomography.



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Mobile Passive MWIR Gas Imager

Boston Applied Technologies, Inc.

In this SBIR project, Boston Applied Technologies, Inc. (BATi) developed a unique optical imager for remote gas sensing. Tunable filters based on electro-optic effect have shown great potential in detecting gas concentration by obtaining its absorption spectrum. The core of the imager is a high speed electro-optic tunable filter based on patented OptoCeramic® material developed by BATi. This compact passive imager covers a large portion of mid-wave infrared. An innovative technical approach is employed to achieve narrow bandwidth at the same time. The successful combination of a wide tuning range and sharp passing bands gives the image an excellent ability to detect critical gas species such as carbon dioxide, carbon monoxide, methane, and water vapor simultaneously at high precision. A detection resolution of 5PPM has been achieved in bench-top tests with carbon dioxide. The imager also features high speed, a big aperture, and a large angle of view, and it is robust, lightweight, and low cost.

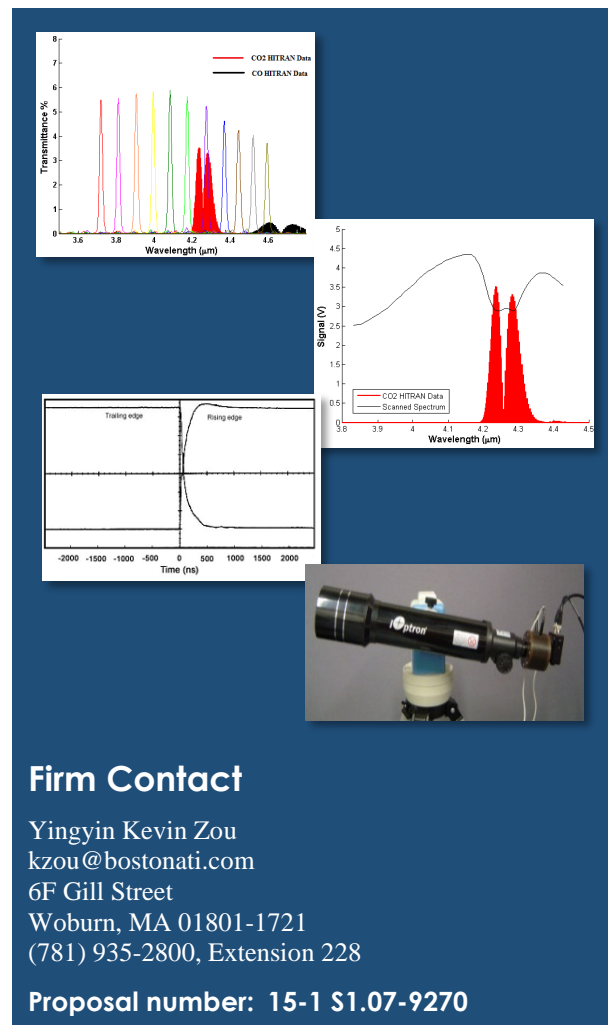
Applications

NASA

The goal of this SBIR project is to provide NASA with a mobile/airborne imaging system for remote high accuracy detection of gas emission sources. The core of the imager is a high speed tunable filter with both wide tuning range and narrow bandwidth in MWIR. First of all, it is a great candidate for general airborne multispectral/hyperspectral imaging. Besides remote gas sensing, due to its outstanding ability of acquiring spectral information, it will find many NASA applications in the fields of engineering, natural resource exploration, environmental monitoring, etc. For example, it can be applied to combustion research for jet engine diagnosis. By capturing the emission spectrum and using a multi-wavelength algorithm, the 2D measurement of flame temperature is realized immediately. The technical approach used for gas detection in this project can also be applied to measurement of species concentration in flame.

Commercialization

Multispectral/hyperspectral imaging technologies have found broad applications in homeland security, military surveillance, biomedical science, agriculture, chemical industry, forestry, emergency response/disaster management, insurance, and oil/gas exploration. The proposed core technology, a novel hyperspectral imaging approach, holds great potential in all these non-NASA applications where x-y-λ cube data is required. Commercialization in any of these areas can be highly profitable.



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A Multi-Wavelength Seed Derived Laser for In-Situ Validation of Airborne Remote Sensing Instruments

ADVR, Inc.

This Phase I SBIR will establish the feasibility of developing a collinear three-wavelength source for an in-situ, 180°, backscatter nephelometer. The three-wavelength source is being developed to facilitate on-board validation measurements of airborne remote backscatter lidar. Currently, commercial nephelometers utilized for in-situ validation measurements employ wavelengths that are both not matched to the operational wavelengths and not at the 180° angle used in near nadir remote sensing backscatter lidar systems. Uncertainties in the wavelength and angle dependence of the return signal make in-situ validation of the remote measurement difficult. The performance of remotely operated lidar systems will be greatly improved by the successful demonstration of an in-situ backscatter measurement with the proposed collinear three-wavelength source.

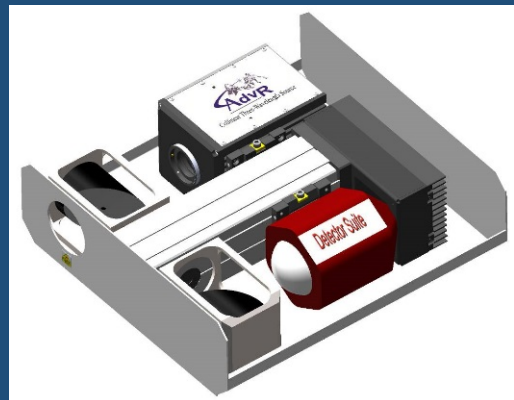
Applications

NASA

The primary beneficiary of the proposed module development is NASA's in-situ and remote sensing programs. Periodically poled materials offer a wider array of functionality, including robust, multi-element platforms for combining tasks like frequency conversion and modulation without adding insertion loss due to additional components. Several other missions that require seed derived, fiber coupled, frequency tripled lasers for calibration and locking, such as NASA's 3D WINDS, will also benefit. AdvR will maintain communications with these NASA groups during this Phase I effort to stay current with the present needs and remain flexible toward meeting specific application needs as technology progresses.

Commercialization

Nonlinear poled materials play an increasingly important role in photonics applications that may be in non-standard wavelength regions, some of which include microwave photonics, up conversion, infrared detection, IR generation, and biophotonics. In addition to its use with NASA's nonlinear optical material based photonic applications, the technology will be of use for military applications, sensing and environmental monitoring, and basic research. Additional markets that can utilize compact, rugged, highly efficient wavelength conversion modules are free space telecommunications, remote sensing, precision spectroscopy, interferometry, and frequency metrology.



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Compact Wireless EVA Communications System (CWECS)

Innoflight, Inc.

Extravehicular Activity (EVA) systems are critical to every foreseeable human exploration mission for in-space microgravity EVA and for planetary surface exploration. Innoflight proposes developing a Compact Wireless EVA Communications System (CWECS) as a replacement and advancement of the Space-to-Space EVA Mobility Unit (EMU) Radio (SSER).

The CWECS goals are (a) to provide backward compatibility with the existing SSCS network and SSER; (b) to provide enhanced communication between the EMU and the space vehicle (or ISS or future space habitat) via 802.11n, including high-speed telemetry from the EMU to the spacecraft; and (c) to provide personal area network (PAN) coverage for wireless biomed devices and sensors within the EMU.

Applications

NASA

The current SSER is provided by NASA as GFE. To provide backward compatibility to EMU/EVA spacesuit efforts that use the GFE SSER, Innoflight proposes building an SSER-compliant variant of CWECS. This will enable consideration in upcoming EMU block upgrades for ISS operations, and using the ISS and the Asteroid Redirect Mission (ARM) as enabling capabilities for a Mars surface mission. Furthermore, for advanced EVA concepts, including the Exploration EVA, the CWECS will be repackaged into smaller form factor and weight. Deep-space high-speed wireless capabilities will be of interest to the Jet Propulsion Laboratory (JPL) and their robotics efforts.

The NASA SBIR program is an ideal vehicle to provide cost savings and/or cost avoidance for an EMU program overdue for innovation but with budget constraints that prohibit a large-scale program to advance the spacesuit design.

Commercialization

Innoflight will work with JSC to understand and pursue opportunities to offer EVA technologies to commercial spaceflight companies such as Virgin Galactic and international space agencies such as ESA and JAXA.

Furthermore, deep-space high-speed wireless capabilities will be of interest for autonomous spacecraft. Innoflight has experience with the Air Force Research Laboratory's Space Vehicles Directorate (AFRL/RV), the Space and Missile Systems Center (SMC), the Defense Advanced Research Projects Agency (DARPA), and the National Reconnaissance Office (NRO), and Innoflight will pursue these customers interested in wireless network capabilities for fractionated and swarming spacecraft concepts.



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Compact, Rugged, and Low-Cost Atmospheric Ozone DIAL Transmitter

Bridger Photonics, Inc.

Bridger Photonics, Inc. (Bridger) proposes developing the most efficient, compact, rugged, low-power-consumption and cost-effective UV ozone differential absorption lidar (DIAL) transmitter available. Bridger will demonstrate pulse energies above 0.5 mJ with a goal of 1 mJ/pulse with a pulse repetition frequency of 1 kHz. The proposed transmitter will enable widespread deployment of ozone DIAL systems capable of continuous range-resolved atmospheric ozone measurements from ground-based and airborne platforms to advance NASA's Earth science mission.

Applications

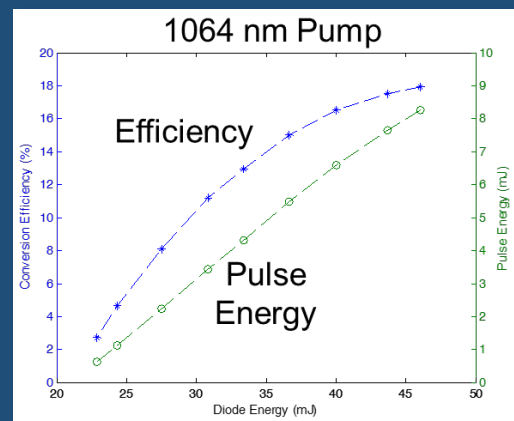
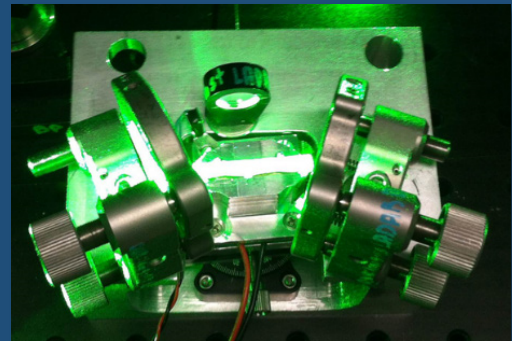
NASA

NASA's primary application for the proposed transmitter would be for widespread deployment of ground-based and airborne sensors to map ozone concentrations with high spatial and temporal resolution. This will allow NASA to carry out its Earth Science missions with smaller and/or more affordable DIAL transmitters, enabling NASA programs to meet multiple mission needs and make the best use of limited resources. Our system will be highly useful for both integrated column and range-resolved measurements due to its short pulse durations and scalable high energies.

Additionally, our base pump laser can be frequency down-converted into the SWIR spectral band rather than frequency up-converted to the ultra-violet band. This will enable compact single-mode, high-energy pulses for profiling other important greenhouse gases and pollutants such as CH₄, CO₂, H₂O, CO, NO₂, and many others.

Commercialization

The pump laser for the proposed design would be the most compact and high energy kilohertz-rate air-cooled Nd:YAG laser on the market. Bridger envisions a wide variety of applications for this laser, including gas sensing lidar, hard-target ranging, ablation applications including mass spectrometry, nonlinear spectroscopy, and as a general purpose OPO pump. Within the lidar market, both NOAA and the EPA would be potential customers for the complete UV transmitter to advance their ozone monitoring initiatives. Other commercial markets include detection of illicit methamphetamine labs, onsite pollution detection, verification of carbon sequestration sites, methane pipeline monitoring, and chemical weapons detection. The proposed transmitter could easily be adapted to detect a host of other gases, most of which are detected in the short wave infrared and mid-infrared spectral regions and are well suited to a seeded version of Bridger's existing OPO. The global market for sensors was estimated at \$62.8 billion in 2011 and was expected to increase to \$67.7 billion in 2012 and then to nearly \$91.5 billion by 2016, at a compound annual growth rate (CAGR) of 7.8%. The market for biosensors and chemical sensors was expected to experience the highest growth at a compound annual growth rate (CAGR) of 9.6% during the 4-year period from 2012 to 2016. These estimates indicate that chemical sensing is a profitable market for this product line for some time.



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