ARMY
STTR 09.A PROPOSAL SUBMISSION INSTRUCTIONS

The United States Army Research Office (ARO) manages the Army's Small Business Technology Transfer (STTR) Program. The following pages list topics that have been approved for the fiscal year 2009 STTR Program. Proposals addressing these areas will be accepted for consideration if they are received no later than the closing date and hour of this solicitation.

The Army anticipates funding sufficient to award one or two STTR Phase I contracts to small businesses with their partner research institutions in each topic area. Awards will be made on the basis of technical evaluations using the criteria contained in the solicitation, within the bounds of STTR funds available to the Army. If no proposals within a given area merit support relative to those in other areas, the Army will not award any contracts for that topic. Phase I contracts are limited to a maximum of $100,000 over a period not to exceed six months.

Only Government personnel will evaluate proposals with the exception of technical personnel from Azimuth, Inc. who will provide Advisory and Assistance Services to the Army, providing technical analysis in the evaluation of proposals submitted against Army topic number: A09A–T025 entitled "Non-invasive Assay to Discriminate Between Mild-Traumatic Brain Injury (TBI) and Post Traumatic Stress Disorder (PTSD)". Individuals from **Azimuth, Inc**. will be authorized access to only those portions of the proposal data and discussions that are necessary to enable them to perform their respective duties. This firm is expressly prohibited from competing for STTR awards and from scoring or ranking of proposals or recommending the selection of a source. In accomplishing their duties related to the source selection process, the aforementioned firm may require access to proprietary information contained in the offerors' proposals. Therefore, pursuant to FAR 9.505-4, these firms must execute an agreement that states that they will (1) protect the offerors' information from unauthorized use or disclosure for as long as it remains proprietary and (2) refrain from using the information for any purpose other than that for which it was furnished. These agreements will remain on file with the Army.

Please Note!

The Army requires that your entire proposal be submitted electronically through the DoD-wide SBIR/STTR Proposal Submission Web site (http://www.dodsbir.net/submission). A hardcopy is NOT required. Hand or electronic signature on the proposal is also NOT required.

The DoD-wide SBIR/STTR Proposal Submission system (available at http://www.dodsbir.net/submission) will lead you through the preparation and submission of your proposal. Refer to section 3.0 at the front of this solicitation for detailed instructions on Phase I proposal format. You must include a Company Commercialization Report as part of each proposal you submit; however, it does not count against the proposal page limit. If you have not updated your commercialization information in the past year, or need to review a copy of your report, visit the DoD SBIR/STTR Proposal Submission site. Please note that improper handling of the Commercialization Report may result in the proposal being substantially delayed and that information provided may have a direct impact on the review of the proposal. Refer to section 3.5d at the front of this solicitation for detailed instructions on the Company Commercialization Report.

If you collaborate with a university, please highlight the research that they are doing and verify that the work is FUNDAMENTAL RESEARCH.

Be reminded that if your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet. Therefore, do not include proprietary or classified information in these sections. DoD will not accept classified proposals for the STTR Program. Note also that the DoD web site contains data on all DoD SBIR/STTR Phase I and II awards going back several years. This information can be viewed on the DoD SBIR/STTR Awards Search Web site at www.dodsbir.net/awards.

Based upon progress achieved under a Phase I contract, utilizing the criteria in Section 4.3, a firm may be invited to submit a Phase II proposal (however, Fast Track Phase II proposals do not require invitation – see Section 4.5 of this solicitation). Phase II proposals should be structured as follows: the first 10-12 months (base effort) should be approximately $375,000; the second 10-12 months of funding should also be approximately $375,000. The entire Phase II effort should generally not exceed $750,000. Contract structure for the Phase II contract is at the discretion of the Army's Contracting Officer after negotiations with the small business.

The Army does not issue interim or option funding between STTR Phase I and II efforts, but will provide accelerated Phase II proposal evaluation and contracting for projects that qualify for fast-track status.

Army STTR Contracts may be fully funded or funded using options or incremental funding.

CONTRACTOR MANPOWER REPORTING (CMR) (Note: Applicable only to U.S. Army issued STTR contracts)

Accounting for Contract Services, otherwise known as Contractor Manpower Reporting (CMR), is a Department of Defense Business Initiative Council (BIC) sponsored program to obtain better visibility of the contractor service workforce. *This reporting requirement applies to all STTR contracts issued by an Army Contracting Office.*

Offerors are instructed to include an estimate for the cost of complying with CMR as part of the cost proposal for Phase I ($100,000 max) and Phase II ($750,000 max), under "CMR Compliance" in Other Direct Costs. This is an estimated total cost (if any) that would be incurred to comply with the CMR requirement. Only proposals that receive an award will be required to deliver CMR reporting, i.e. if the proposal is selected and an award is made, the contract will include a deliverable for CMR.

To date, there has been a wide range of estimated costs for CMR. While most final negotiated costs have been minimal, there appears to be some higher cost estimates that can often be attributed to misunderstanding the requirement. The STTR Program desires for the Government to pay a fair and reasonable price. This technical analysis is intended to help determine this fair and reasonable price for CMR as it applies to STTR contracts.

- The Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) operates and maintains the secure CMR System. The CMR Web site is located here: https://contractormanpower.army.pentagon.mil/.

- The CMR requirement consists of the following 13 items, which are located within the contract document, the contractor's existing cost accounting system (i.e. estimated direct labor hours, estimated direct labor dollars), or obtained from the contracting officer representative:

  (1) Contracting Office, Contracting Officer, Contracting Officer's Technical Representative;

  (2) Contract number, including task and delivery order number;

  (3) Beginning and ending dates covered by reporting period;

  (4) Contractor name, address, phone number, e-mail address, identity of contractor employee entering data;

  (5) Estimated direct labor hours (including subcontractors);

  (6) Estimated direct labor dollars paid this reporting period (including subcontractors);

  (7) Total payments (including subcontractors);

  (8) Predominant Federal Service Code (FSC) reflecting services provided by contractor (and separate predominant FSC for each subcontractor if different);

  (9) Estimated data collection cost;

  (10) Organizational title associated with the Unit Identification Code (UIC) for the Army Requiring Activity (The Army Requiring Activity is responsible for providing the contractor with its UIC for the purposes of reporting this information);

(11) Locations where contractor and subcontractors perform the work (specified by zip code in the United States and nearest city, country, when in an overseas location, using standardized nomenclature provided on Web site);

(12) Presence of deployment or contingency contract language; and,

(13) Number of contractor and subcontractor employees deployed in theater this reporting period (by country).

- The reporting period will be the period of performance not to exceed 12 months ending September 30 of each government fiscal year and must be reported by 31 October of each calendar year.

- According to the required CMR contract language, the contractor may use a direct XML data transfer to the Contractor Manpower Reporting System database server or fill in the fields on the Government Web site. The CMR Web site also has a no-cost CMR XML Converter Tool.

- The CMR FAQ explains that a fair and reasonable price for CMR should not exceed 20 hours per contractor. Please note that this charge is PER CONTRACTOR not PER CONTRACT, for an optional one time set up of the XML schema to upload the data to the server from the contractor's payroll systems automatically. This is not a required technical approach for compliance with this requirement, nor is it likely the most economical for small businesses. If this is the chosen approach, the CMR FAQ goes on to explain that this is a ONE TIME CHARGE, and there should be no direct charge for recurring reporting. This would exclude charging for any future Government contract or to charge against the current STTR contract if the one time set up of XML was previously funded in a prior Government contract.

- Given the small size of our STTR contracts and companies, it is our opinion that the modification of contractor payroll systems for automatic XML data transfer is not in the best interest of the Government. CMR is an annual reporting requirement that can be achieved through multiple means to include manual entry, MS Excel spreadsheet development, or use of the free Government XML converter tool. The annual reporting should take less than a few hours annually by an administrative level employee. Depending on labor rates, we would expect the total annual cost for STTR companies to not exceed $500 annually, or to be included in overhead rates.

Army STTR 09A Topic Index

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A09A-T025	Non-invasive assay to discriminate between mild-Traumatic Brain Injury (TBI) and Post Traumatic Stress Disorder (PTSD)
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Army STTR 09A Topic Descriptions

A09A-T001 TITLE: Atmospheric propagation of terahertz radiation

TECHNOLOGY AREAS: Air Platform, Battlespace, Space Platforms

OBJECTIVE: Develop a modeling tool that can accurately and verifiably model the propagation of 0.1-1.0 THz radiation through the atmosphere for a variety of atmospheric conditions simultaneously: temperature, altitude/elevation, dew point, rain/sleet/snow, fog, dust/smoke, wind- and terrain-induced turbulence, and trace gas contaminants.

DESCRIPTION: The terahertz spectral region, located between the microwave and the infrared, has been comparatively neglected because of the combined challenges of poor sources and atmospheric attenuation. Source technology has improved recently, and a rebirth of interest in terahertz capabilities is underway as a result. However, the fundamental limitation imposed by atmospheric absorption of terahertz radiation, primarily caused by water vapor, is insurmountable. Scenarios that depend on the atmospheric propagation of terahertz radiation must therefore account for the strongly frequency-dependent attenuation. Surprisingly, there is disagreement about the amount of clear air atmospheric attenuation in the 0.1-1.0 THz region.[1-3] It is poorly understood how that attenuation is altered by aerosol scattering and trace gas absorption, or how attenuation varies temporally and spatially because of turbulence. The contribution of “continuum absorption” and how it depends on environmental factors is an area of active debate.

In order to assess the viability of terahertz technologies in scenarios of military interest, an experimentally verified model of terahertz atmospheric attenuation is needed for all these conditions. Ideally, the model would take as inputs a location (e.g. Washington, DC), a time of day and year (e.g. night, winter), and a weather report (e.g. overcast, snow flurries, light winds) and from them estimate salient environmental parameters required for the model (e.g. standard atmosphere, temperature 30°F, elevation 6 m MSL, dew point 27°F, wind speed 5 kts, 1000 ft ceiling, 1 km visibility from flurries, 100 µg/cubic meter dust/smoke, Cn2 ~ 10^-14 m^-2/3, typical urban trace gas contaminants and concentrations). After allowing the user to adjust these parameters as desired, the model then estimates the point-to-point attenuation through any user-designated slant path through the atmosphere, plotted graphically as a function of frequency from 0.1-1.0 THz. The effects of temporal (e.g. wind) and spatial (e.g. heterogeneous terrain) turbulence may be represented by broadening the plot width to represent the range of attenuation values.

PHASE I: Develop a THz atmospheric propagation model that graphically plots the frequency-dependent attenuation for a given scenario (temperature, source altitude/elevation, dew point, wind, rain/sleet/snow, fog, and dust/smoke) for user defined slant paths (angle and distance). Propose a plan for the detailed experimental validation of the model, the inclusion of wind and terrain turbulence, and the inclusion of a spectral library of common atmospheric trace gases.

PHASE II: Complete and experimentally validate the model developed in Phase I by measuring THz atmospheric propagation in a wide variety of conditions and frequencies, including the spatio-temporal effects of wind- and terrain-induced turbulence. Perform an error analysis to indicate how these measurements may be extrapolated to conditions and frequencies that were not measured. Add a database of trace gas molecular absorption spectra, and allow for the inclusion of these gases in the model at user-defined concentrations. Deliver the complete, validated model to AMRDEC.

PHASE III DUAL USE APPLICATIONS: Commercialization of a validated THz atmospheric propagation model will enable the informed development of THz technologies, such as detecting toxic industrial chemicals, imaging through obscurants, and interference-free wide bandwidth communications.

REFERENCES:
1. M.J. Rosker and H.B. Wallace, “Imaging through the atmosphere at terahertz frequencies”, Microwave Symposium 2007, IEEE/MTT-S International, p. 773 (2007).

2. H.J. Liebe, “MPM-An atmospheric millimeter-wave propagation model”, International J. of Infrared and Millimeter Waves, Vol. 10, p. 631 (Springer, 1989).

3. Liebe, H. J., Rosenkranz, P. W., G. A. Hufford, and M. G. Cotton. 1993. Propagation modeling of moist air and suspended water/ice particles below 1000 GHz. AGARD Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation, Electromagnetic Wave Propagation Panel Symposium, Palma de Mallorca, Spain, 17-21 May, 1993, p. 31. AGARDCP-542, NASA Center for Aerospace Information, 800 Elk Ridge Landing Road, Linthicum Heights, Maryland 21090-2934.

KEYWORDS: Terahertz radiation, atmospheric propagation, spectroscopy

A09A-T002 TITLE: Dynamically Tunable Metamaterials

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Impressive progress has been achieved in recent years in artificial materials or metamaterials. The ability to design metamaterials with a negative index of refraction, zero index of refraction, and a magnetic response has lead to impressive applications including cloaking, superresolution, perfect reflectors, and perfect absorbers, just to name a few. Negative index metamaterials are now available over a range spanning from microwave to optical frequencies. While progress in metamaterial design has advanced rapidly, little attention has been paid to the research and development of active metamaterials. The objective of the Phase I is to perform a feasibility study of a method to tune the electric and/or magnetic properties of metamaterials.

DESCRIPTION: To take full advantage of the designer properties of metamaterials requires a method to tune the electromagnetic response of the metamaterial, preferably over a broad frequency range in as short of time as possible. To date, nearly all demonstrations of actively tuned metamaterials have been achieved by varying the capacitance of a split ring resonator. This inherently limits the tuning to the magnetic response and to frequencies in the terahertz or lower. Examples of recently demonstrated active tuning of split ring resonators include voltage tuned capacitance with barium strontium titanate [1] , photocapacitance tuned semi-insulating gallium arsenide[2] and silicon[3], temperature tuning of vanadium dioxide[4], and nonlinear power tuning of a varactor[5]. While impressive, these results represent a tuning method for the magnetic component for a single type of metamaterial. Methods to actively tune the electric response are lacking. In addition, there are numerous other types of metamaterials based on totally different geometries with potential for active tuning. By way of example, a negative index material based on metal nanoclusters has recently been proposed[6]. It is known that metal particles have a large nonlinear response to incident radiation and can also generate large fields at their surface. This opens the way for nonlinear tuning or electro-optic tuning. The primary intent of this solicitation is to stimulate research and development in tunable metamaterials. The solicitation is not limited to a specific type of metamaterial or a specific frequency range.

PHASE I: Conduct a feasibility analysis of a dynamically tunable metamaterial. The tuning method can be applied to the electric or magnetic response of the metamaterial or both. Linear or nonlinear methods are acceptable. Consideration should also be given to the response time of the individual unit cell. The primary product of this solicitation is a tunable metamaterial and its' potential application to a realistic product.

PHASE II: Finalize the device and material parameters from the Phase I. Conduct basic experimental observation of the expected performance of the tunable metamaterial. Design and fabricate a prototype lattice consisting of several unit cells.

PHASE III DUAL USE APPLICATIONS: The ability to build artificial materials to nearly any specification of electric and magnetic response provides an unprecedented control of electromagnetic radiation. To this, add the ability to actively change the response and the potential opens for a wide array of applications in nonmechanical beam steering, communication networks, and switching devices.

REFERENCES:
1. T.H. Hand and S.A. Cummer, "Frequency tuning electromagnetic metamaterial using ferroelectric loaded split rings," J. Appl. Phys. 103, 066105 (2008).

2. K.A. Boulais, D.W. Rule, S. Simmons, F. Santiago, V. Gehman, K. Long, and A. Rayms-Keller, "Tunable split-ring resonator for metamaterials using photocapacitance of semi-insulating GaAs," Appl. Phys. Lett. 93, 043518 (2008).

3. A. Degiron, J.J. Mock, and D.R. Smith, "Modulating and tuning the response of metamaterials at the unit cell level," Optics Express 15, 1115 (2007).

4. T. Driscoll, et al., "Dynamic tuning of an infrared hybrid-metamaterial resonance using vanadium dioxide," Appl. Phys. Lett. 93, 024101 (2008).

5. I.V. Shadrivov, S.K. Morrison, and Y.S. Kivshar, "Tunable split-ring resonators for nonlinear negative-index metamaterials," Optics Express 14, 9344 (2006).

6. Q. Wu and W. Park, "Negative index materials based on metal nanoclusters," Appl. Phys Lett. 92, 153114 (2008).

KEYWORDS: metamaterial, tunable, split-ring resonator, negative index, zero index.

A09A-T003 TITLE: Simultaneous Particle Imaging Velocimetry and Thermometry (PIVT) in Reacting Flows

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Design, develop and demonstrate the feasibility of a flow imaging system which can simultaneously and accurately reveal the spatially correlated flow velocity and temperature fields in at least two dimensions of a reacting, high temperature system.

DESCRIPTION: Accurate determination of velocity and temperature fields in reacting (combusting) and non-reacting flows is critical for the design of future high performance propulsion systems and engines. Currently, it is not possible to simultaneously capture both of these fields with spatial correlation in a reacting flow with a single measurement system. This leads to several technical challenges in gaining accurate information about velocity and temperature in reacting flow systems. Recent studies (1-3) have demonstrated that it is possible to dope high temperature ceramic particles to achieve multi-phonon assisted upconversion of incoming laser light. These Lanthanide ion doped upconversion nanoparticles can upshift the incoming light by sequential multi-photon absorptoion or phonon assisted energy transfer. The latter can be shown to be a function of temperature, giving a process to measure the temperature of the flow. Use of such a material as particle in a seeded flow promises the ability to detect multi-dimensional, spatially correlated temperature and velocity fields simultaneously for high temperature reacting flows.

PHASE I: Design, develop and demonstrate the feasibility of simultaneously measuring temperature and velocity in non-reactive and reactive high temperature flows. Demonstrate temperature accuracy of at least 10K and velocity accuracy of at least 10% for flows up to 2200K and flows that range from .03-.3Ma. Deliver details of the planned Phase II system that quantify temperature and velocity sensitivity, resolution and dynamic range of the planned system.

PHASE II: Design, develop and demonstrate a system capable of determining spatially correlated and simultaneous multi-dimensional temperature and velocity fields in high temperature reacting (combusting) and non-reacting flows. The system shall have minimum velocity accuracy of 5% and minimum temperature accuracy of 5K for atmospheric or higher pressure flows up to 2500K over a range of .03-1Ma. Deliver one system to the Army for evaluation.

PHASE III DUAL USE: Development of diagnostics to allow spatially correlated simultaneous velocimetry and thermometry measurements within high temperature reacting flows will allow for better understanding in development of propulsion systems for both the civilian sector and DoD. Potential applications include, but are not limited to imaging velocity and temperature fields in gas turbine engines, afterburner sections, internal combustion engines and boilers.

REFERENCES:
1. J.F. Suyver, A. Aebischer, D. Biner, P. Gerner, J. Grimm, S. Heer,K.W. Kramer, C. Reinhard, H.U. Gudel, (2005) Optical Materials v27, pp 1111–1130.

2. F. Auzel, (2004) Chem. Rev. v104, pp139-173

3. Qin, X.; Yokomori, T.; Ju, Y. G., (2007), Applied Physics Letters v90.

KEYWORDS: velocimetry, thermometry, phonon assisted upconversion

A09A-T004 TITLE: <u>Innovative technologies to effectively treat multi-drug resistant and/or biofilm-embedded bacteria</u>

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective of this STTR topic is to develop a technology to effectively treat drug resistance and eliminate bacteria, including those embedded in biofilms during natural infections, and on implanted medical devices.

DESCRIPTION: Widespread use of antibiotics, and bacterial adaptation have combined to make antibiotic resistant pathogens prevalent. Especially troublesome are bacterial strains such as methicillin resistant Staphylococcus aureus (MRSA), which is resistant to multiple antibiotics and extremely difficult to eradicate. Until recently, vancomycin was the antibiotic of choice for MRSA, but now MRSA strains resistant to vancomycin are also becoming prevalent[1]. Another agent of special concern is Acinetobacter baumannii, a bacterial agent that has natural resistant to multiple antibiotics[2] and frequently infects wounds suffered by warfighters in Iraq and Afghanistan[3]. To complicate the problem further, bacteria can form biofilms during infection of a host; biofilms often develop and persist on medical implants. Once embedded in biofilms, bacteria that are normally sensitive to an antibiotic are protected and will be resistant to antibiotic concentrations several orders of magnitude higher than normally lethal levels[4].

An effective method is clearly needed to prevent or treat infections of wounds and medical implants such as catheters. The method should be broadly applicable, be effective against bacteria embedded in biofilms and also effective against multiple drug resistant (MDR) strains. Viable approaches to resolving this problem include using bacteriophage[5], bacterial conjugation of bactericidal proteins[6], antimicrobial peptides[7], or other as yet untested methods, in conjunction with a method for biofilm dispersal or other approaches that facilitate antibiotic interaction with biofilm embedded bacteria. Funding preference will be given to those methods that are effective against MDR strains AND biofilm embedded bacteria.

PHASE I: Produce data demonstrating the efficacy of the antimicrobial with activity against MRSA, A. baumannii or other MDR strains at a concentrations that have low toxicity for mammalian cells and/or develop techniques, methods or procedures that will expose biofilm embedded bacteria to therapeutic interventions.

PHASE II: The investigators will demonstrate the feasibility of eliminating MDR bacteria and provide an understanding of the mechanism(s) OR using established biofilms on the surface of materials commonly used for medical implants and catheters, show that the bacteria can be effectively killed with a treatment that is predicted to be non-toxic to humans. Demonstration of effectiveness in an animal model will not be required for biofilms at this time.

DUAL USE APPLICATIONS:
An effective treatment to eliminate MDR bacterial infections in people and on medical implants will find widespread use in civilian and military hospitals and managed care facilities.

REFERENCES:
1. Apelbaum PC. The emergence of vancomycin-intermediate and vancomycin-resistant strains of Staphylococcus aureus. Clin Microbiol Infect 2006;12 Suppl 1:16-23.

2. Adams-Haduch JM, et al. Genetic basis of multidrug resistance in Acinetobacter baumannii clinical isolates at a tertiary medical center in Pennsylvania. Antimicrob Agents Chemother 2008; Aug 25 [epub ahead of print].

3. Peleg AY, Seifert H, Paterson DL. Acinetobacter baumannii: emergence of a successful pathogen. Clin Microbiol Rev 2008;21:538-582.

4. Lewis K. Multidrug tolerance of biofilms and persister cells. Curr Top Microbiol Immunol 2008;322:107-31.

5. Soothill JS. Treatment of experimental infections of mice with bacteriophages. J Med Microbiol 1992;37:258–261.

6. Shanki R, et al. A novel antibacterial gene transfer treatment for multidrug resistant Acinetobacter baumannii-induced burn sepsis. J. Burn Care Res. 2007;28:6-12.

7. Liu Z, Young AW, Hu P, Rice AJ, Zhou C, Zhang Y, Kallenbach NR.Tuning the membrane selectivity of antimicrobial peptides by using multivalent design. Chembiochem. 2007, 23, 2063-2065.

KEYWORDS: antibiotic resistance, biofilms, medical treatment

A09A-T005 TITLE: Minority carrier lifetime measurements in Strained Layer Superlattices (SLS)

TECHNOLOGY AREAS: Materials/Processes, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: The goal of this research and development is to develop a quantitative measurement of the minority carrier lifetime in strained layer superlattice (SLS) pn diodes.

DESCRIPTION: Conventional technology for infrared detectors makes use of cooled HgCdTe diodes and uncooled VOx bolometers. HgCdTe suffers from the availability of large substrates and it has been the desire of the IR community to find an alternative to the expensive CZT substrates needed for the MBE growth of HgCdTe. One potential substitute is the type II SLS system because it can be grown onGaSb which is available in 3 and 4" diameter substrates. The SLS system presently however, is not without its own problems.

Conventional diode technology for IR technology is of a mesa or a lateral design. As the pixel pitch is reduced, the issues of sidegating and lateral diffusion become important. For the mesa design, passivation issues for the sidewalls become important. The issue for the SLS is more complicated. The transport of the carriers is vertical, along the growth direction. A simple Hall measurement of the carrier mobility will only measure the horizontal velocities of majority carriers. A quantitative measurement of the minority carrier lifetime is critical in order to better understand the excess dark currents which affect SLS technology. Knowing the lifetime will allow materials people to better address issues of growth, processing, and /or fabrication that may be affecting minority carrier transport.

PHASE I: The offerer will design a technique capable of measuring minority carrier lifetimes on the timescale of 35 nanoseconds. The technique may be based on optical or electrical excitation.

PHASE II: The offerer will construct, test and evaluate the performance of an apparatus for measuring minority carrier lifetime. Apparatus must demonstrate its capability to measure the minority carrier lifetime for SLS and conventional IR sensors. The apparatus must have a dynamic range capable of measuring lifetimes between 10 nanosecs and 25 microseconds, approximately 3 orders of magnitude.

PHASE III DUAL USE APPLICATIONS: Infrared sensors are uses in both DoD and civilian applications. The apparatus will be useful for measurement of lifetimes for either application. Civilian users are police and firefighters as well as remote sensing applications in meteorology and climatology.

REFERENCES:
1. D. Hoffman, A. Gin, Y. Wei, A. Hood, F. Fuchs, and M. Razeghi, IEEE J. Quantum Electron. 41, 1474, 2005.

2. F. Fuchs, U. Weimer, W. Pletschen, J. Schmitz, E. Ahlswede, M. Walther, J. Wagner, and P. Koidl, Appl. Phys. Lett. 71, 3251, 1997.

3. H. B. Bepp and E. W. Williams, in Semiconductors and Semimetals, edited by R. K. Willardson and A. C. Beer, Academic, New York, 1972, Vol. 8, p. 181.

KEYWORDS: Strained layer superlattice, infrared detector, minority lifetime

A09A-T006 TITLE: Real Time Analysis and Fusion of Data from Imagers for Passive Characterization of Stress, Anxiety, Uncertainty and Fatigue

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: To develop and demonstrate methods and tools for real time fusion of information from thermal and visual videos of the face for passive characterization of stress, anxiety, uncertainty and fatigue for man-machine interface applications

DESCRIPTION: Detection of stress, anxiety, uncertainty and fatigue (SAUF) has a number of applications of military importance including soldier stress monitoring, human-machine interface design, and automated training applications. Approaches to understanding the observables related to SAUF have been investigated and require real-time computer vision algorithms for pattern recognition and feature level fusion. Included in the observables would be respiration rate, heart rate, head turning, eye movements, and facial expression, [e.g., 2-5,7]. Recent research has demonstrated that there is a need to include more complex cues such as count of open pores and other heat patterns in high resolution thermal video [5]. The main challenges are (1) to find reliable features for automatically determining that a person is experiencing SAUF with the immediate task and (2) to develop robust pattern recognition methods for automatically mapping features to SAUF state [e.g., 1,8] when a human operator is looking at a computer screen or watching a TV. The focus of this effort is the development of innovative, rigorous methods and tools for feature characterization from thermal and visual facial video and for reliably mapping those features and their activities to a particular aspect of SAUF. The effort should also establish quantitative characterization of the degree and type of SAUF. Data in the form of captured videos in visible and thermal wavebands collected simultaneously will be furnished by the government and should be included in the proposed effort during both Phase I and II.

PHASE I: Effort in Phase I should be directed toward feasibility study, which should include the identification and fusion of reliable features for the components of SAUF in video imagery of human faces. Work will include the use of video of the face in appropriate wavebands: thermal (either midwave or longwave infrared), visible spectrum, and other electro-magnetic spectrum video as appropriate. The approach should consider only passive, non-contact methods. Once features in the videos are identified, methods and algorithms should be developed for detecting and characterizing the degree of SAUF components. The baseline condition for each human face trial needs to be automatically calibrated as part of Phase I since this condition will vary between and within human faces at different times. Performance metrics should be established for evaluating and validating the proposed methods or algorithms.

PHASE II: Effort should be focused on further refinements and real-time execution of the algorithms under realistic conditions of a person sitting at a computer either receiving training or making decisions. Methods/algorithms developed in Phase I should be optimized to improve performance. A prototype system demonstrating the methods and capabilities should be developed. Minimal manual calibration or adjustment should be required for real-time operation. A capability should be developed for fusing the significant information from videos collected simultaneously to provide real-time analysis of the state of the subject.

PHASE III DUAL-USE APPLICATIONS: Phase III will further develop and refine the prototype for commercialization. The technology should be ready for transition to the military and the defense industry for applications such as human-machine interfaces for training or decision aids. The capability will provide critical information for monitoring soldiers' SAUF state needed for adaptive human-machine interfaces. This capability has potential impact on human-machine interface design for a wide range of commercial applications including automobile, aviation, and computer industries.

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KEYWORDS: passive monitoring, stress, anxiety, uncertainty, fatigue, thermal imagery, man-machine interface, automated training

A09A-T007 TITLE: High Performance Quantum Cascade Lasers

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop robust, high-efficiency mid-infrared lasers based on quantum cascade of electrons. Power outputs for room temperature continuous wave operation of over 1 W are sought in the 3-5 micron band for IRCM (Infrared Countermeasures) and other appropriate military needs.

DESCRIPTION: DARPA MTO has recently funded a program on quantum cascade lasers (QCLs) in the 4-5 micron band for IRCM. However, new approaches to the development of such lasers are possible which enhance the thermal management and wavelength capability. Mid-infrared lasers are of high importance to the U. S. military for multiple applications which include IRCM, free-space optical communications, imaging laser radar, and chemical sensing. The Army Research Laboratory currently has programs in external cavity QCLs for chemical sensors which can also benefit from improved QCLs developed here; whereby, that program is more focused on the microsystem and not the fundamental laser technology for the QCL (which are purchased from a few suppliers).

PHASE I: Demonstrate design of high performance QCLs which show potential improvements in state-of-the-art output power, wall-plug efficiency and wavelength span from around 3 microns to 5 microns and into the LWIR regime as well. (LWIR is defined as 8-12 microns and has been used for photoacoustic spectroscopy for chemical detection)

PHASE II: Develop room temperature high efficiency (wall-plug efficiency > 15%) QCLs for numerous military applications. MOCVD (Metal Orgsaaic Chemical Vapor Deposition) or other manufacturable laser process should be used in order to produce low-cost lasers at high volume (relative to current prices for state-of-the-art lasers)

PHASE III: Commercialize QCLs and develop full manufacturing process for various wavelengths and packages to meet military needs. High-speed modulation of the QCLs may be another emphasis of the work for ladar and FSOCs. Dual use (civilian) applications include chemical sensing for breath analysisi, gas monitoring and biohazard monitoring.

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1. L. Diehl, D. Bour, S. Corzine, J. Zhu, G. Hofler, M. Loncar, M. Troccoli, F. Capasso, "High-temperature continuous wave operation of strain-balanced quantum cascade lasers grown by metal organic vapor-phase epitaxy" Applied Physics Letters, 89, 081101 (2006).

KEYWORDS: mid-wave infrared, semiconductor lasers, quantum cascade lasers

A09A-T008 TITLE: Ultraviolet and blue compact laser sources for scalable quantum computing

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Design and development of innovative compact ultraviolet (UV) and blue light continuous wavelength (CW) laser sources that would enable quantum computing and broader sensor technology.

DESCRIPTION: Many trapped ion systems used for qubits require UV or blue laser sources for their operation. Trapped ions represent one of the very promising avenues for scalable quantum computing. Typical wavelengths needed for photo-ionization, cooling, optical pumping, and qubit operations are in the 200-450 nm range. CW power requirements are hundreds of microwatts for photoionization and one to a few milliwatts for laser cooling and state readout of tens of ions. Sources must be narrow band (~1 MHz or less) and continuously tunable over several GHz about the central frequency. Output modes should be close to TEM00, with good pointing stability and low power fluctuations (a few percent). Currently, complicated frequency doubled or quadrupled systems are used, requiring expensive and complex lasers. Lenses and mirrors outside the vacuum chamber are used to steer the laser beams. These techniques are satisfactory for the early experiments involving a few ions (qubits) but are too complicated to scale to larger systems. Compact solid-state sources that can be coupled to single-mode optical fibers are highly desirable. Such sources are not readily available and this topic seeks to develop and commercialize the technology utilizing the existing research base. The developed technology is anticipated to have wider commercial applications in sensors for chemical and biological agent detection. The technology is also anticipated to impact other physical implementations of quantum computing.

PHASE I: Research and development areas include: (1) Simple high efficiency direct techniques to generate UV and blue lasers; (2) Up-conversion techniques using periodically poled devices; (3) Improving up-conversion efficiency using waveguides; (4) Optical materials (for e.g. fibers) with low degradation and improved lifetime. Proposed solutions must consider needs and constraints of anticipated qubit experiments. Collaboration or consultation with experimental ion trapping groups is highly encouraged. During Phase I the following must be completed: conception and design of the source, estimates of performance, and assessments of feasibility. Depending on the intended application, initial prototypes must be capable of photoionization loading up to ten ions per second, or laser-cooling, optical pumping and state readout of several qubits. The proposed technology must be scalable to larger numbers of qubits.

PHASE II: Finalize design and build prototypes of the source. Provide a demonstration deployment that validates the technology at a laboratory that does suitable ion trapping experiments. The Phase-II program shall provide a plan to transition the technology to commercial development and deployment.

PHASE III DUAL USE APPLICATIONS: The technology developed here has impact on the successful demonstration of quantum computing. In addition to critical national security applications, quantum computing is anticipated to have an impact on commercial applications involving hard computational problems such as optimization, routing, planning and scheduling. The technology developed here is also anticipated to have broader impact, such as on the development of compact sensors for chemical and biological agent detection.

REFERENCES:
1. See www.iontrap.umd.edu/research_info/ioncatalog/ for a list of relevant wavelengths for various ions in use for quantum computing.

KEYWORDS: UV laser sources, blue laser sources, periodically poled crystals, waveguides.

A09A-T009 TITLE: Snapshot Raman Imager

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The design of a snapshot Raman imager in the short-wave infrared (SWIR) with moderate spectral and coarse spatial resolutions. Snapshot operation with no scanning elements will require the implementation of innovative optical system technologies such as micro-optical systems and/or compressive sampling.

DESCRIPTION: Hyperspectral imaging allows for a wealth of information to be extracted from a scene of interest.[1,2] In a conventional color (RGB) camera, only three spectral bands are acquired, which limits the ability of the system to provide spectral discrimination of objects. A hyperspectral imager will allow sufficient spectral information to gather chemical composition. For example, Raman spectroscopy provides spectra with sharp peaks allowing for sensor systems with a high chemical specificity. In order to provide the number of spectral channels needed for Raman spectroscopy with imaging capabilities, a high-performance hyperspectral imager is required.

Airborne instruments have been very successful at performing detailed analysis for the remote sensing communities[3]. This increased information has typically come at a steep cost, however, with bulky, expensive instruments. Much of this cost goes into the large imaging optics and the high bandwidth data collection and storage subsystems that are required. New designs are needed to miniaturize the form factor of hyperspectral imagers.

The data acquired from a hyperspectral imager is frequently thought of as a cube of data, with two spatial dimensions (x,y) and one spectral dimension (ë). Since most detectors are not spectrally sensitive, the light is either separated spatially by a dispersive element such as a prism or a grating or is interfered with itself to take advantage of the wavelength dependence of the interference fringes that result. Both approaches require scanning and acquiring of temporal series of data. While for many applications scanning is acceptable, there are advantages in a snapshot approach---the ability to measure dynamic events, less complicated spatial-spectral registration, a more compact form factor, and enhanced reliability due to no moving parts.

This solicitation calls for a snapshot Raman imager (full spatial-spectral datacube information from one data acquisition) in the short-wave infrared (1-2 microns) with coarse spatial resolution (at least 64x64 spatial resolution elements) and moderate spectral resolution (at least 32 spectral channels over the 1-2 micron range).

PHASE I: During Phase I the instrument will be designed and simulated to show the feasibility of achieving the required specifications.

PHASE II: Build, test, and integrate a state-of-the-art optical brassboard realization of the snapshot Raman imager. Design the software needed to perform the signal processing required to implement snapshot operation.

PHASE III DUAL USE COMMERCIALIZATION: Civilian applications include remote sensing, industrial process control, and law enforcement.

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3. W. Smith, D. Zhou, F. Harrison, H. Revercomb, A. Larar, A. Huang, and B. Huang, “Hyperspectral remote sensing of atmospheric profiles from satellites and aircraft,” in Proc. SPIE, 4151, pp. 94-102, 2001.

KEYWORDS: Hyperspectral imager, Raman.

A09A-T010 TITLE: <u>Multi-layered lightweight alloy development for improved blast and penetration resistance</u>

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: This project seeks to develop multi-layered, lightweight armor alloys systems that offer improved fragmentation and armor piercing performance as compared to aluminum alloy 2519-T87 in thicknesses from 1” to 4” and the rupture resistance of 5083-H131 when subjected to a mine blast event. This project should use advanced computational techniques to assist in the development of complimentary alloys that provide an optimal combination of hardness, strength, and ductility. In addition to blast and penetration resistance, corrosion and stress corrosion resistance, and manufacturability should be considered. The resulting multilayered alloy systems should be fully metallurgically bonded and should be weldable using existing welding technologies. The solution space may consider topology optimization and functional grading. Experiments and computational tools should be used to determine the strengthening mechanisms and failure response of these systems under dynamic loading conditions for the development of reliable design guidelines for lightweight, hybridized armor configurations.

DESCRIPTION: Laminated armor configurations have been developed and used for many years. Configurations of ceramic, composite and metal provide improved mass efficiency for a range of threats when compared to monolithic armor alloys. A number of these systems, such as ceramic based systems, use an adhesive bond which can be a weakness under blast loading conditions. Systems that use metallurgical bonding, such as dual hard armor, provide a high mass efficiency against armor piercing threats, but are challenging to produce. Eastern Europe has developed a high performing aluminum based laminated armor solution (ref 1. PAS) but the US has no comparable system. Following the dual hard analogy, systems using combinations of lightweight alloys that have improved blast and ballistic performance are sought. These systems should provide a 20% improvement in armor piercing performance and fragmentation protection, and better blast resistance as compared to aluminum alloy 2519-T87. They should also have the ability to be readily produced, have a high corrosion resistance, and the ability to be easily joined.

PHASE I: Use modeling and simulation, to identify combinations of lightweight alloy systems with microsctructures that exhibit optimal inelastic mechanisms and material properties under dynamic loading conditions. Assess candidate material systems for corrosion resistance and weldability using empirical methods. Develop pilot processing technology including ingot metallurgy, rapid solidification processes and metallurgical bonding processes. Conceive a plan to scale-up these processes that accounts for manufacturing cost. Fabricate small scale prototype designs and perform dynamic experiments to quantify their high rate response and conduct limited ballistic testing for proof of principle.

PHASE II: Prototype designs from Phase I should be scaled up for the application to mine blast protection. Experiments and computational tools should be used to assess and evaluate the durability and performance of these designs to realistic threats, dynamic loading conditions, and corrosive environments. Reliable guidelines should then be developed for the design, processing, and fabrication of these prototypes for batch production.

PHASE III COMMERCIALIZATION: There are a large number of vehicle applications. Improved lightweight armor alloys can be used as an appliqué armor for current tactical wheeled vehicles and for civilian armored sedans or as an integrated armor for future ground combat designs.

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3. Gandhi, S.J., “BFV Improved Armor Development Armor Systems Screening Test,” in the Proceedings of the Second TACOM Armor Coordination Conference for Light Combat Vehicles, Columbus, OH, 5-7 November 1985.

4. de Weert, A., “Novelis Fusion – The New Aluminum” in the Proceedings of the 13th International Arab Aluminum Conference, Dubai, 9-12 November 2008.

KEYWORDS: lightweight armor alloy, hybridized armor, blast resistant, penetration resistance, computational modeling, high strain rate

A09A-T011 TITLE: Windable Lithium-ion Conducting Ceramic Electrolytes

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop the materials and processes to produce a windable lithium-ion conducting ceramic electrolyte that is incorporated into a cylindrical lithium-air battery.

DESCRIPTION: Lithium-air batteries have inherently high-energy density in comparison to other battery chemistries and are a possible solution to the portable power needs of the dismounted warrior. The development of lithium-ion conducting ceramic electrolytes of the type LiM2PO4 and related compositions have enabled metallic lithium to be used as an anode with aqueous electrolytes, as well as with more common organic electrolyte systems (1,2). Air-cathodes can be coupled with a lithium anode and provide a battery with a practical energy density of 600 Wh/kg or greater (1). More conventional cathode reactions may also be employed. Although these batteries have high-energy densities, their power density is low and is restricted by the inherent material properties of presently available ceramic electrolytes. The ionic conductivity at room temperature of present electrolytes is 0.1 to 1 mS/cm, which limits the current density that can be drawn from a cell. Furthermore, the available ceramic electrolytes can not be wound into a cylindrical format (such as found in spiral-wound lithium-ion batteries), which limits their volumetric packing density. The focus of this project is to develop windable lithium-ion conducting ceramic electrolytes to enable both high-energy and high-power density lithium-air batteries.

PHASE I: Develop the materials and manufacturing processes to produce lithium-ion conducting ceramic electrolytes with room-temperature conductivity of 1 mS/cm or greater. The electrolyte must be capable of being spirally wound. Measure and report ionic conductivity and mechanical properties of the ceramic electrolyte and the electrochemical performance of a lithium-air cell employing these materials in a cylindrical format.

PHASE II: Incorporate the windable lithium-ion conducting ceramic electrolyte developed in Phase I into a lithium-air battery pack. Measure and report battery-relevant electrochemical characteristics of the lithium-air system. Assess the chemical and electrochemical stability of the battery as a function of temperature and discharge rate.

PHASE III: High-energy and -power density batteries will have a significant number of applications in military as well as commercial applications in which a compact, safe, and reliable portable power source is required.

REFERENCES:

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KEYWORDS: Lithium battery, lithium-air, lithium conductor, ceramic electrolyte

A09A-T012 TITLE: Synbiotics for Improved Warfighter Readiness and Performance

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: Diarrhea affects most military personnel deployed overseas, reducing troop readiness and personnel performance. During Operations Desert Shield and Desert Storm, 57% of troops were affected by one or more bouts of diarrhea. Twenty percent of those affected were unable to perform their tasks while afflicted. Pathogens that cause diarrhea may be antibiotic resistant. Using antibiotics also disturbs the gastrointestinal ecosystem, which often itself induces diarrhea. Consequently it would be useful to develop synbiotics – the synergistic combination of both pre- and probiotics to specifically prevent diarrhea in newly deployed warfighters.

DESCRIPTION: Probiotics are beneficial bacteria or yeast that eliminate pathogenic bacteria from the human body. Probiotics work by altering environmental conditions within the gastrointestinal system, by competing for nutrients and adhesion sites, by producing antimicrobial metabolites, by strengthening the non-immunological gut barrier, and by modulating both the immune and the non-immune defense mechanisms of the host. Active components of probiotics include surface proteins, nucleic acids, cell-wall fractions, short-chain and organic fatty acids, and antimicrobial enzymes. Various reports have demonstrated beneficial effects of probiotics on lactose tolerance, colon cancer, cholesterol, blood pressure, immune function, ulcers, irritable bowel syndrome, and colitis. Probiotics are widely consumed in foods such as yogurt and can be purchased over the counter in most health food stores.

Prebiotics, on the other hand, are functional food ingredients that improve host health by altering the bacterial composition in the large intestine. Syngergistic effects can be obtained by the complementary use of both prebiotics and probiotics. Research is needed to develop prebiotics and probiotics to specifically prevent diarrhea in deployed troops.

PHASE I: The investigators will identify appropriate species of bacteria and prebiotic compounds with high antagonistic and synergistic activity against diarrhea inducing organisms such as Salmonella and Shigella, and demonstrate the efficacy of their synbiotics. They will establish an animal model system and they will conduct initial safety and efficacy tests.

PHASE II: The investigators will demonstrate the safety and efficacy of their synbiotics in an appropriate animal system. They will develop and demonstrate that their synbiotics are shelf-stable under realistic military conditions. They will also demonstrate the safety and efficacy in humans, in conditions as close as feasible to those encountered by newly deployed troops in current operations. They will identify a partner with the resources, expertise, and interest in producing large amounts of safe, efficacious, and affordable synbiotics, or demonstrate in house capabilities. At the end of phase II all conditions should be in place for the immediate production of large amounts of synbiotics specifically tailored to prevent diarrhea in deployed troops.

Civilian Applicability: Pathogenic Escherichia coli alone causes 73,000 cases of diarrhea per year in this country. Diarrhea is particularly dangerous for children, the elderly, and the immunocompromised, and is the second largest cause of infant deaths. There is also a significant commercial market in pet and livestock food.

REFERENCES:

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KEYWORDS: probiotics, prebiotics, synbiotics, diarrhea

A09A-T013 TITLE: Iron Man: Novel Technologies for Autonomous Defense

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective of this STTR is to exploit human molecular biology to enable optimized human generated resistance to novel or unknown biological pathogens for which existing countermeasures are insufficient or do not exist.

DESCRIPTION: Eukaryotes and prokaryotes have waged war against each other over resources and survival for the last 1.5 billion years. Microorganisms have a profound advantage; being able to reproduce in twenty minutes instead of twenty years enables the prokaryote to be able to mutate and evolve to fit the environment in real time. While humans have become complacent with the discovery of antibiotics, the widespread evolution of antibiotic resistant bacteria and the discovery of horizontal gene transfer indicates that this too is just a temporary blip in the biological arms race. A new approach to controlling the effects of biological pathogens is long overdue.

One of the most scientifically promising approaches is to modulate the available levels of iron in human cells. A fierce competition exists between bacterial, fungal, and protozoan pathogens and their hosts for this element. However, when iron is limited, eukaryotic host cells can out-compete their prokaryotic denizens. Iron however is an essential nutrient, and inadequate iron levels in humans lead to a variety of significant health issues, including anemia and reduced cognitive function. Excessive iron levels also lead to an equally significant effects, such as increased cancer, heart disease, and reduced longevity.

The intent of this STTR research is to determine the optimum iron levels for force protection, and to develop methodology to quickly manipulate iron levels in vivo.

PHASE I: During Phase I the investigators will develop a solid and robust plan to determine the optimal human intracellular iron levels for optimal resistance to infectious pathogens.

PHASE II: During Phase II, the investigators will determine the optimal intracellular iron levels for warfighter protection against biological pathogens. They will also develop a simple, robust, highly accurate, and low cost method for quickly increasing and decreasing iron levels in humans in order to protect them against biological pathogens. They will determine the variability over time of iron levels within individual humans in order to determine optimum testing frequency. They will determine the efficacy of optimized iron levels by measuring the rate of spontaneous infections.

DUAL USE APPLICATIONS: The ability to protect against lethal or debilitating new and unknown biological pathogens is a critical area of biological defense that has hitherto been largely ignored. The ability to manipulate iron levels in vivo addresses this seminal weakness and would also have significant civilian applications. For example, if supplies of Cipro, or the anthrax or smallpox vaccine were inadequate or unavailable, iron manipulation could also be used to complement countermeasures to even well-known biological threats. Iron levels could also be optimized before sending soldiers into the field. Most importantly, however, this approach would be equally effective against novel natural pathogens such as SARs, as well as novel man-made pathogens including new or unknown biological warfare agents.

REFERENCES:
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KEYWORDS: pathogens, countermeasures, iron

A09A-T014 TITLE: Microbolometer focal plane array with reduced 1/f noise

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The goal of this research and development is to identify a material and fabrication process that reduces the 1/f noise below the current state-of-the-art.

DESCRIPTION: Current state-of-the-art uncooled infrared bolometers suffer from 1/f noise which leads to pixel-to-pixel non-uniformities in focal plane arrays (FPAs). An improvement in 1/f noise is paramount. A larger thermal coefficient of resistance (TCR) would also benefit the technology. Bolometer technology typically relies on VOx or amorphous silicon, but other materials have been considered. Oxides such as colossal magnetoresistive (CMR) manganites or others exhibiting metal-insulator transitions have shown some promise. Recent research indicates that these materials provide low noise and high TCR characteristics. While results are promising, noise characteristics depend on more than just the material. Device fabrication steps and bolometer design including detector area, bandwidth and integration time all play a role. This topic seeks a systematic study of bolometer FPAs utilizing novel oxides to determine if these materials indeed improve noise and TCR characteristics of focal plane arrays.

CMR manganites and/or other oxides exhibiting metal-insulator transition should be applied in a realistic bolometer focal plane array design and processing environment. Phase I is to consist of a modeling effort to compare the oxide-based bolometers with amorphous silicon and VOx based bolometers of equivalent device architecture. Phase II is to include the development of a proof of concept microbolometer FPA to demonstrate the validity of the modeling conducted in Phase I. Further efforts including refining of the model as well as design and prototyping of a promising device candidate are anticipated.

PHASE I: The offerer will provide a standardized design and fabrication process for oxide-based bolometer FPA. Using this design, the offerer will model, compare and report on the performance of oxide-based, VOx and amorphous Si FPAs with particular attention given to noise and TCR. The design must be compatible with current readout circuits.

PHASE II: The offerer will fabricate, test and evaluate the performance of a proof-of-concept oxide-based microbolometer FPA to demonstrate the validity of the model. Based on these results, the offerer will refine the model as necessary and used the model as a tool to design optimized oxide-based FPAs.

PHASE III DUAL USE APPLICATIONS: Focal plane arrays with reduced 1/f noise and increased TCR will be exceptionally valuable to first responders and for remote sensing applications such as meteorology and climatology.

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KEYWORDS: Bolometer, microbolometer, infrared detection, infrared imaging, infrared detector

A09A-T015 TITLE: Improved electrodes for low-loss radio frequency devices

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The goal of this research and development is to develop a metallization process that reduces loss in oxide-based ferroic radio frequency components.

DESCRIPTION: Oxide-based radio frequency (RF) components have many advantages over more traditional approaches as they are small, reliable and continuously tunable. However, there are disadvantages. The two most significant problems limiting the adoption of this advantageous technology are loss and temperature instabilities, especially at higher frequencies. To date, efforts toward solving these problems have focused almost entirely on optimizing the oxide material itself and much progress has been made. Little attention has been given to optimizing the electrode materials, the metal/oxide interface or the metallization process; all of which are inter-related. Given that the conductors provide the dominant loss mechanism, including insertion loss, for these devices, this is a critical design factor for high frequency components. The Conductor losses, namely the microwave surface resistance (Rs) and skin depth (ƒÔ) of the conductor are strongly influenced by both composition of the metal electrode, nature of the metal-active layer interface, and the processing science used to fabricate the electrodes (conductor and ground plane). In addition, it is important to recognize that the conductor loss contribution is also dependent on the geometry of the electrode layout.

This topic seeks a systematic study of electrode materials, the electrode/active layer interface, layout and fabrication process with a thorough characterization of the temperature and frequency dependence on RF device parameters with a special emphasis on loss. The development of low loss metallization demands immediate attention via process-property correlation systematic materials research. Thus in order to utilize low cost high performance perovskite oxide thin film as a non-linear dielectric at microwave frequencies the integration of theses tunable dielectrics with conductors that have low microwave surface resistance (Rs) and thin skin depth (ƒÔ) must be realized. The effort should focus on tunable RF devices functional within the X to Ka bands. By understanding how the electrodes specifically effect the device operation, one can design components and processes optimized for military and commercial application markets.

The offerer should develop an understanding of the trade-offs and parameter space between the electrode material, device operating environments (temperature and frequency) as well as consider compatibility with the process science protocols required to fabricate the perovskite oxide thin film on a bottom electrode (BE).

PHASE I: The offerer will (i) survey and report on the metallization of a notable candidate perovskite oxide thin film-based tunable RF device or suite of oxide-based devices operational within the X to Ka band frequency range and (ii) demonstrate the ability for an experimental systematic materials; i.e., interface and process science study plan focused on developing an integrated metallization-oxide based film heterostructure employing both top and bottom electrodes for tunable RF devices within this frequency range. The survey must fully characterized device(s) including the effects of (i) frequency across the tunable range and the (ii) temperature across the full military temperature range (-20 C to 125 C). Integration temperature minimization, cost, and ease of fabrication via industry standard metallization deposition technologies should also be considered. The report will develop a preliminary overview of the trade-offs and parameter space.

PHASE II: The offerer will theoretically and experimentally derive alternatives including electrode materials, asymmetric electrodes, and process. The effects due to intrinsic materials, structure and interface properties will be separated from extrinsic effects and related to device performance and dielectric response. The offerer will provide a complete report of the results including a materials development plan, electrode materials design and integration process; experimental demonstration focused on systematic materials study; i.e., interface and process science study focused on structure-process-property correlations of an integrated metallization-oxide based film heterostructure employing both top and bottom electrodes for tunable RF devices within this frequency range. The device design and integration process science will be optimized for microwave device architecture and operating environments

PHASE III DUAL USE APPLICATIONS: The results will serve as integral process(es) for tunable high-frequency components in numerous commercial applications including light-weight satellite communications, Local Multipoint Distribution Services (LMDS) systems, network analyzers and spectroscopic instrumentation.

KEYWORDS: Microwave, millimeter wave, X band, Ka band, filter, ferroics, ferroelectric, ferromagnetic

A09A-T016 TITLE: THz and Sub-THz MEMS-Fabricated Klystron Amplifier

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors, Electronics, Weapons

OBJECTIVE: To design, build, and demonstrate a new class of terahertz (THz) frequency vacuum electronics device useful for amplification and signal source generation at frequencies in the range 0.3-3.0 THz.

DESCRIPTION: Sources of THz and sub-THz radiation are useful for a variety of imaging and communications applications, including as illuminators for stand-off imagery of concealed weapons and explosives. Currently THz and sub-THz radiation are generated by a variety of techniques, ranging from free-electron lasers (FELs) equipped with electron 'wigglers' to optoelectrically-excited dipole antennae. Most robust (i.e., high output power) approaches to the generation of coherent continuous-wave THz radiation involve very large systems such as free-electron lasers (FELs) that are not portable or lightweight and that offer comparatively low power densities. Solid-state devices operating in this frequency range are limited by material properties in terms of power, efficiency, and robustness by material properties. MEMS-fabricated vacuum electronics devices offer the potential of portability, high power density, and low cost. However, MEMS vacuum electron device concepts demonstrated to date use traveling-wave-tube-type structures or other slow-wave structures and involve fabrication processes that are not highly-scalable, with electron gun and collector integration being particular challenges, making the end devices heavy and expensive. A particular challenge has been MEMS fabrication with sub-micron tolerances. Recently, precision MEMS fabrication technologies originally developed as part of an ARO and DARPA sponsored effort to manufacture micro-turbomachinery [5] and a UK effort to manufacture multi-layer copper interconnects [6] have yielded all of the new process steps required to enable fabrication of a THz-band MEMS klystron tube. In particular, these efforts have advanced two key fabrication technologies: (1) highly-uniform, precision-depth deep reactive ion etching (DRIE) of silicon; and (2) fusion-bonding of multiple etched wafers with sub-micron alignment tolerances. Both of these technologies have only matured to the level required for vacuum electronics within the past two years. By enabling the batch fabrication of a fully integrated gun, tube, and collector, these techniques hold the promise for device power densities in the 0.1-1 kW/cc range. Device efficiencies in the range of 1% to 10% and heat rejection rates in the range of 1-10 kW/cc make collector cooling a second key challenge. Advances in MEMS heat exchangers [7] address this challenge while remaining fully compatible with integration into a batch fabrication process. Finally, advances in pseudospark electron sources [8] promise further performance gains by eliminating the need for magnetic beam confinement. In order to obtain a high-gain batch-manufactured THz-band amplifier, this STTR will investigate the design of a new high-gain, narrow-bandwidth, THz amplifier; build and fully evaluate its performance; and quantify its improvement on threshold detection.

PHASE I: In Phase I, a complete design of a MEMS-fabricated klystron amplifier fabricated using DRIE etching and fusion bonding of Silicon will be conducted. The design of simple two-cavity devices arrayed on a 1 cm square die with the goal of producing a high-gain, narrow-bandwidth amplifier with an operating frequency of 200-400 GHz and a power density of 20 W/cm3 is desired. The direct leveraging of fabrication processes borrowed from the manufacture of MEMS turbomachinery is strongly encouraged. The electron gun, beam confinement system, and collector are required to be self aligning and integral to the device and should be compatible with cold cathodes and pseudospark electron sources. A mockup prototype of the resulting device design must be fabricated using the proposed fabrication process and the resulting geometry must be measured and characterized. The theoretical performance of an active prototype fabricated using the same process should be determined using MAGIC or a similar 3D particle-in-cell code.

PHASE II: A fully-functioning 350 GHz prototype klystron die-level array will be built and tested in a series of hot-test experiments designed to demonstrate the device's functionality and to evaluate its bandwidth and power conversion efficiency for comparison to prior simulations. The prototype device's performance will be fully evaluated, including possible substitution into a working military sensor. Actual delivered-system performance improvements will be the basis of final evaluation. All potential additional improvements will be documented, and the best will be included in a final prototype. The design should be amenable for redesign for operation at 650 GHz as well a range of other frequencies for inclusion into a battery of devices operating at different frequencies with little or no modification to the fabrication process. A clear pathway for the incorporation of a depressed collector, a pseudospark electron source, and other efficiency-improving features should be included.

PHASE III: This work will produce an integrated wafer-level array of devices capable of operating as transmit/receive components for communications or as an illumination source for imaging and detection applications. This new technology will have commercialization opportunities for such military relevant applications as standoff imaging of concealed threats (weapons and explosives); ultra-wideband short-range communications; short-range and point monitoring of chemical, biological and explosive agents. This same technology would find dual-use, private-sector applications such as advanced laboratory components for scientific characterization studies; materials/process monitoring in commercial manufacturing; and ultra-fast data processing.

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KEYWORDS: Terahertz, High Gain, Narrow Bandwidth, Vacuum Electronics, Klystron, Communications, Phased Array

A09A-T017 TITLE: Retrodirective Noise Correlating Radar with Real-Time Imaging of Sniper Bullets and Terrain

TECHNOLOGY AREAS: Sensors, Weapons

OBJECTIVE: Leverage recent breakthroughs in retrodirective noise-correlating (RNC) radar to develop and demonstrate a new technological capability for imaging sniper bullet trajectories along with the local terrain environment. The envisioned RNC radar system should be capable of detecting the high-velocity threat projectiles and registering their trajectories to a background mapping of the local terrain in real-time to provide visual display tools to warfighters.

DESCRIPTION: Radar-based tracking and imaging tools for the real-time detection and geo-locating of high-velocity, short-range threats such as rocket-propelled grenades and large-caliber bullets represents a unique and extremely important new technology for Force Protection and Homeland Security. Because the response time for these types of threat scenarios must be tens of milliseconds or less, it is a requirement that the envisioned radar system possesses extremely short detection and acquisition times, and should thus be “auto-cued”. Retrodirective noise-correlating (RNC) radar is a new breakthrough modality that combines three elegant RF techniques: (1) retrodirective array antenna architecture in the transmitter and receiver [1]; (2) noise transmission and noise-correlative signal processing [2]; and (3) high-gain, band-limited feedback between each receive antenna element and its conjugate transmit element. Here, the technique is to initially illuminate the target by a broad radiation pattern which is refined (i.e., focused onto the target) by the resulting strong cross-correlation in the reflected noise power between adjacent elements in the receiver which is enhanced by signal processing techniques such that “auto-cuing” and target detection is achieved in just a few radiative round-trips through free space. A U.S. Army SBIR program has recently built upon initial theoretical assessments of this noise cross-correlation and rapid target acquisition technique [4], and the experimentally demonstrated potential of a simple set of two-element transmit and receive arrays [4] to successfully demonstrate a fully functioning Ku-Band RNC with the ability to provide tracking information (i.e., in the form of raw data) rapidly enough to allow for real-time responses on the battlefield. More specifically, documented field testing demonstrated this new RNC system capable of tracking typical incoming bullet fire (e.g., 50 cal and 0.233 cal) rapidly enough (30 ms) for locating snipers during the time-of-flight of the bullet, and therefore, it also has the potential to counter a single-shot assault (i.e., due to the inherent technological potential it has for achieving sub-time-of-flight tracking response). This new RNC radar breakthrough strongly motivates the rapid pursuit of a combined tracking and imaging system that would provide the warfighter an unprecedented capability for dynamically displaying sniper assaults on the battlefield. Here, the new radar technology would be integrated with advanced data processing and battlefield visualization algorithms emerging from DoD research programs (e.g., [5]) to provide real-time imaging of the projectile assaults overlaid onto the surrounding 3-D terrain and environment. Once established, this automatic ballistics search-track-imaging system would provide to individual soldiers a unique capability for rapidly determining the location of threats that would reduce injuries and casualties. Here, a system design is envisioned with a vehicle mounted radar and data processing base unit that would be wireless interfaced to man-carrier miniature imaging displays.

PHASE I: Identify and assess available camera technology useful for generating dynamic panoramic views of the battlefield and surrounding environment and determine requirements for daytime and nighttime operation. Investigate and assess available software algorithms and techniques required for real-time processing of both the RNC radar tracking data; performing the back-track calculations for the sniper bullets; and overlaying the data for terrain and surrounding environment. The Phase I effort should also produce overall design specifications for required hardware interfaces between the RNC radar; data processing/simulation unit; and the imaging display.

PHASE II: Develop and demonstrate the hardware components and software algorithms required for demonstrated the envisioned automatic ballistics search-track-imaging system. Here, all functional aspects of the deployable system should demonstrated for real-time detection and display of sniper-scenario bullet trajectories superimposed upon a realistic terrain and environment of the type encountered in typical battlefield and/or urban situations. Note while this does not require a completely integrated and battle-ready packaged system, the combined technology should demonstrate: adequate collection of both RNC tracking data and terrain/environment data; processing and superimposing of bullet trajectories and terrain/environment data; and wireless interface to functional imaging display.

PHASE III DUAL USE COMMERCIALIZATION: The radar technology developed under this topic has important relevance to reducing threats from incoming projectiles (e.g., bullets) and offers critically important advantages in military applications where speed and resolution are needed for protecting the warfighter. Therefore, the primary commercialization opportunity is for active sensor systems which have important relevance to both the military and private sector to reduce the threat of adversaries and terrorist groups. However, this technology will have dual use applications in private sector areas where rapid-radar acquisition is needed such as in tracking aircraft and vehicles, severe weather monitoring, diagnostics for rapidly moving components, etc.

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KEYWORDS: Retrodirective Noise Correlating Radar, bullet detection and tracking, terrain and environment visualization

A09A-T018 TITLE: Engineered Catalysts, Catalysts Supports, and Designs for Logistics Fuel Reforming

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Design and build a logistics fuel reforming reactor based on novel catalysts or reactor design that enhance catalysts durability and reduce cost.

DESCRIPTION: The use of heavy hydrocarbon middle distillate fuels (e.g. kerosene based fuels, JP-8, diesel fuel) as a feed stock poses a number of challenges. Primary among these challenges is the selection of appropriate catalysts and operating conditions to maximize the production of hydrogen while avoiding carbon formation and sulfur poisoning. Key to the introduction of fuel cells for mobile applications will be a greater understanding of the performance of reforming catalysts and how these catalysts perform with various organic compounds present in the fuel.

The fuel processing subsystem is projected to represent 35-40% of the total cost of a mobile power system [1-2]. A major contributor to the cost of reforming logistics fuels is the use of noble metal catalysts (Pt, Rh, Ru). Noble metal catalysts are used because of their high activity, sulfur tolerance and good stability at high operating temperatures. Recent research into alternative materials [3-8] and designs [9-10] indicate that performance and durability improvements, and cost reduction can be achieve through the use of lower cost catalyst materials and supports, and/or designs that significantly improve heat and mass transfer resulting in improved reactor performance and minimizing the amount of catalysts used.

PHASE I: Conduct research, development and experimentation to validate that selected catalyst(s) and/or design(s) can reform logistics fuels (JP-8 and diesel fuel) and result in good performance, durability and reduced cost.

PHASE II: Demonstrate long-term stability and carbon formation avoidance in the presence of organic sulfur compounds and polycyclic aromatic hydrocarbons. Impact of organic sulfur compounds found in logistics fuels on catalysts performance and life should also be investigated. Phase 2 will result in laboratory breadboard catalyst reactor(s) for Government validation and verification of performance.

PHASE III DUAL USE APPLICATIONS: Mature the catalyst(s)/reactor design for integration with an appropriate fuel cell power source. Demonstrate physical integration and thermal integration of the reactor and fuel cell through laboratory demonstrator design, fabrication and test. Fuel cell power sources operating on middle distillate fuels have could be employed in many military and commercial applications, such as, auxiliary power units on long-haul trucks used for engine idle reduction or as power sources onboard ships in the marine industry.

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KEYWORDS: catalyst, fuel reforming, fuel cell, power source

A09A-T019 TITLE: Improved Sensing Using Simultaneous Orthogonal Spectroscopic Detection

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical, Sensors

OBJECTIVE: To develop and field a noncontacting, chemical identification system with greater probability of detection, reduced probability of false detection and increased sensitivity utilizing the combined spectral information from both Raman and fluorescence spectroscopies. The intent is to increase the information collected by fusing the structural information encoded in the Raman spectrum and the molecules electronic state gleaned from the native fluorescence. Currently systems exist and are fielded that use either Raman or fluorescence spectroscopy. In some cases the Raman spectra show significant interference from fluorescence, because their signatures overlap. By collecting the fluorescence and Raman signals orthogonally, we intend to show that the complementary information in each spectrum can increase the probability of detection (PD) and reduce the probability of false alarm (PFa).

DESCRIPTION: The specific objectives of the program can be enumerated as follows:
1. Modify and/or adapt a commercial spectrometer(s) for collection of both Raman and fluorescence signals simultaneously.
2. Specific modeling goals include:
    a. Comparison of the Raman and fluorescence signals of specific target analytes acquired at various excitation signals.
    b. Prediction of optimal experimental conditions and instrumental parameters to collect Raman and fluorescence spectra orthogonally.
    c. Estimation of the effect of spectral resolution and spectral bandwidth of both the fluorescence and Raman signals on the PD and PFa in spectral matching algorithms.

3. Demonstration of non-contact biological and chemical identification using fused Raman and fluorescence spectroscopy.
4. Development of statistical classification algorithms to identify and determine the relative concentration of a threat analyte based on its Raman and fluorescence spectra.

PHASE I: (Feasibility Study) Phase I research will be restricted to showing improved probability of detection, improved analyte specificity, and reduced probability of false detection using the fused Raman and fluorescence spectra. The effort should include sufficient modeling and experimental data to demonstrate the trade offs in excitation wavelengths of both the fluorescence and Raman signals, spectral windows utilized, and the advantage gained in fusing the two types of spectroscopy.

PHASE II: (Prototype Delivery) Phase II research will result in the delivery of a beta system or at a minimum a brass-board prototype capable of identifying biological organisms, chemical warfare agents, toxic industrial chemicals, and explosive mixtures on surfaces. The system should have sufficient algorithm development to complete the data acquisition, preprocessing of the data, statistical analysis of collected spectra and classification analysis in real time and on board the instrument.

PHASE III DUAL USE APPLICATIONS: (Both Commercial and DoD Applications)
Commercial applications of this technology include non-intrusive interrogation of sealed transparent containers for quality assurance, law enforcement and international treaty verification. Law enforcement uses could include crime scene investigation; illicit drug identification; inspect food containers and hazardous waste containers.

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KEYWORDS: Raman spectroscopy, Fluorescence, Sensor Fusion

A09A-T020 TITLE: Broadband agile wavelength laser for chemical aerosol detection

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: We are seeking an advanced compact transmitter emitting at least 100 mJ/pulse with significantly improved inter-band coverage from 9-12 ƒÝm for standoff detection of battlefield chemical aerosol agents at ranges of 3-5 km.

DESCRIPTION: Prior work with the FAL (Frequency Agile Laser) sensor shows that it is very capable in detection of biological aerosols by DISC (Differential Scattering) and chemical vapors by DIAL (Differential Absorption Lidar) in the LWIR (Long Wave Infrared). It is required to extend this target interrogation capability to the important cases of chemical aerosols, chemical aerosols mixed with vapor, and both target types mixed with interferents. The FAL CO2 laser presently operates in the 9.3-10.7 ƒÝm wavelength range on the four normal bands which is sufficient to probe features of biological aerosol and battlefield chemical vapor agents. However, there are clefts between the four normal CO2 laser bands where some important chemical aerosols such as GA and VX cannot be probed. In addition, there are chemical aerosol and vapor agent features in the 11-11.5 ƒÝm region that would improve detection. By extending band coverage of the normal CO2 laser the masking effects of battlefield interferents would be reduced and the robustness of detection algorithms would be improved by use of a wider data base.

PHASE I: Perform analysis and feasibility study. Develop conceptual designs for the laser critical components and the demonstrator laser, including a means to achieve rapid wideband wavelength tunability. Provide a detailed development plan for design, fabrication, and testing of the wavelength agile, broadband, compact transmitter to be carried out in the Phase II program.

PHASE II: Use the results of Phase I to develop any critical laser components required for the demonstrator laser. Fabricate, demonstrate, and deliver the new broadband transmitter, including all components required to achieve full functionality. Provide a roadmap for development of the transmitter into a fieldable brassboard device for integration with the FAL sensor.

PHASE III DUAL USE APPLICATIONS: The result of Phase II will be demonstration of a transmitter for a single sensor that can detect a large array of both chemical and biological battlefield agents in their various forms as well as a number of toxic agents found in the civilian chemical industry. In addition to a number of different military deployments, the new transmitter will support diverse applications in civilian WMD (Weapons of Mass Destruction) defense, pollution monitoring, and mapping of clouds from chemical process and transport accidents.

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KEYWORDS: Laser standoff detection, chemical and biological defense, long wave infrared laser transmitter

A09A-T021 TITLE: Optimized Drying of Nano sized anisotropic particles in suspensions to improved aerosol dispersions.

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop a cost effective and scalable method for drying nano sized anisotropic particles suspended in solutions without damaging the original material. Particles of interest include high aspect ratio metal flakes with major dimensions between 5 to 10ums and minor dimensions 50 to 100nm. Other areas of interest are conductive Nano sized fibers with major dimensions from 2 to 10um and minor dimensions of 20 to 50 nm.

DESCRIPTION: Infrared and millimeter wave obscurant materials are currently produced with wet attritor milling or colloid chemistry techniques. The resulting suspended particles are well dispersed in solvents or other carrier liquids. Traditional drying techniques using air and spray drying have a propensity to agglomerate these nano size (in one dimension) particles. Capillary forces during the drying process tend to pull together individual particles, degrading their optical and electrical properties. Attractive Van der Waals forces also play a major role in particle agglomeration. Freeze drying techniques have been used in the past, but it is uncertain how much damage is caused to these thin materials when exposed to temperature extremes. New and novel techniques that employ gentler processing techniques are needed. Novel processes utilizing ultrasonic or electrostatic concepts in combination with other techniques could be explored to dry nano sized, anisotropic materials. These materials will be in direct support of the Joint Program Manager (JPM) Reconnaissance and Platform Integration Bi-spectral Obscurant program to start in fiscal year 2009.

PHASE I: (Feasibility Study)
Develop a laboratory scale drying process that can remove anisotropic particles in suspensions with minimum or no agglomeration of particles. The use of coatings to keep particles separated may be employed for aids in dispersion of the material in a dry form. Produce 500 to 1000 gram quantities of the dried materials that Army will provide in suspensions. Agglomeration must not exceed 10% of sample to facilitate aerosolization of these particles. Demonstrate improvements over traditional drying techniques by measuring the extinction coefficients and yields of mass airborne concentrations utilizing the Southwest Research Institute (SRI) aerosol nozzle. Government facilities at ECBC will be used to measure the performance.

PHASE II: Scale-up the improved drying process for capability to produce 10-kilogram runs and perform product quality tests. Aerosol chamber tests will be conducted to measure the visible, IR and microwave attenuation performance and to characterize the particles. In Phase II, a design of a manufacturing process to commercialize the production of low-cost drying techniques should be developed. A total of 50 kilograms of material will be produced and delivered to the government.

PHASE III DUAL USE APPLICATIONS: This product is a material that can be integrated into current military applications that can benefit from uniform distribution of particles that are fee of agglomerates. Composite materials produced with non-agglomerated particles will have better stability and performance characteristics using less raw materials. Examples include UV resistance materials, Improved Electromagnetic Interference (EMI) shielding, vehicle parts and combat uniforms. Bi Spectral (visible and IR) obscurants would be a new military application along with improve IR obscurant materials. Industrial applications include electronics, fuel cells/ batteries, furnaces and others.

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KEYWORDS: Material Drying, Agglomeration, obscurant, aerosol,

A09A-T022 TITLE: Standoff Laser-Induced Thermal Emission (LITE) of CB Materials

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: Determine the feasibility of laser induced thermal (infrared, IR) emission (LITE) from the thermally desorbed, fragmented, and excited biochemicals from bacteria and protein biological material, chemical agent simulants, and explosives. Devise and apply detection algorithms to classify the biological challenge and identify chemical species. Extend the investigations to a short range (about 50 meters) standoff capability with appropriate emission collection optics.

DESCRIPTION: The Joint Services have a need for an active standoff system that detects and classifies contaminated surface areas with chemical, biological, and explosive (CBE) substances. Military spectroscopy systems exist that have been applied to the interrogation of CB aerosols and chemical vapor. These systems include passive Fourier Transform IR, passive frequency agile lidar (FAL), and active differential absorption lidar (DIAL) in the Joint Services Lightweight Standoff Chemical Agent Detector (JSLSCAD) for the detection of chemical vapor and bioaerosol clouds, where lidar stands for light detection and ranging. Recently, hyperspectral imaging systems have shown great promise for a real time and temporal display of chemical clouds.

Except for flame spectrophotometry and inductively coupled plasma-mass spectrometry, there is no evidence of LITE investigations in the 2-12 micron IR region in the literature for CBE materials. Classical laser induced emission is effected by laser induced breakdown spectroscopy (LIBS) technology. Essentially, LIBS spectral signatures arise only from metal ions, C, H, O, N, and for a few small molecules such as CN, C2, and PO in the ultra-violet and visible (UV-VIS) regions. A plasma or bright spark is produced which fragments samples to the atomic and diatomic states. However, LITE energies delivered to the surface are below the onset of air breakdown or plasma creation. LITE energies can provide for a more stable and reproducible set of thermal fragmentation conditions on a sample as compared to LIBS. Relatively large detection and identification bearing thermal fragment species from the original CBE sample can be produced and their emission detected in the IR region than that of generic atomic species. These partial breakdown products and hot molecular species may be a source of much more detailed information for substances in the vicinity of the laser heating region than a distribution of elements. A favorable situation exists with high contrast LITE IR signatures from ambient air and surface background.

Current military capabilities for active and passive sensing spectroscopy systems are remote or standoff in nature and have very limited spectral ranges for collecting radiation signatures. The present topic expands the spectral region in a typical experimental interrogation, compared to that of standoff systems as listed above, with which to address military significant substances.

The LITE concept can afford a means for detection and potential identification of CBE materials on surfaces such as concrete, plastic, steel, trucks, buildings, and high value vehicles.

PHASE I: (Feasibility Study)
1) Design a series of systematic laser experiments to establish the basis for a demonstration of the LITE phenomenology in the fingerprint 6-16 micron (1600-600 cm-1) region.
2) Optimal sets of laser parameters shall be investigated to convert CBE particles on surfaces into meaningful products/fragments in the vapor state. Collect IR emission spectra of CBE species at different laser parameters and temporal conditions.

3) Construction of a LITE CBE signature library consisting of the thermal emission signatures of the LITE event to afford functional group and whole molecule analyses.
4) Produce different distributions of sample thermal fragment products and IR emission spectra at different sets of laser parameters and iterate them to fit thermodynamic and kinetic modeling and prediction equations.

PHASE II: (Prototype Delivery)
1) Perform an engineering performance study for the breadboard design of a LITE platform to include the laser source with variable power output, focusing optics, sample translation stage at various distances from the laser source, collection optics that are tailored for receiving distances up to 50 meters, and detection spectrometer(s) to capture the 2-12 micron emission from the laser induced thermal products.
2) Develop a system model of the LITE hardware concept and present a baseline performance analysis of the system.
3) Perform limit of detection studies for select CBE materials to demonstrate the feasibility of acquiring useful signatures. Investigate temporal emission characteristics in the 1-300 microsecond emission decay timeframe.
4) Develop a set of preliminary Receiver Operational Characteristic (ROC) curves for the LITE concept platform for CBE sample detection.

PHASE II DUAL USE APPLICATIONS:
There are many environmental and military mission applications for a standoff sensor for surface CBE contamination. A rugged, sensitive, and flexible CBE detector/identifier will benefit the environmental monitoring community by providing standoff capabilities for remote CBE surface contamination. In addition, first responders such as civilian support teams, fire departments, and military post-blast reconnaissance teams have a critical need for a rugged and versatile sensor that can be transported to the field to test for possible CBE contamination on many types of surfaces.

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KEYWORDS: Chemical detection, chemical identification, biological detection, biological classification, infrared emission spectrum, laser induced thermal emission, bacteria, chemical agent, explosives.

A09A-T023 TITLE: Develop Degradation Resistant Multifunctional Composite Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop advanced polymer matrix composite materials for novel layered structural protective systems for protection of physical assets and protection of personnel that have multifunctional capabilities such as remote sensing of on-set of degradation conditions and electromagnetic shielding to defeat emerging adaptive threats.

DESCRIPTION: Currently used materials for military construction lack the multifunctional capabilities to self diagnose, while providing for layered protective systems that incorporate multiple defeat mechanisms for the mitigation of blast, ballistic, and debris and to protect selected/designated civilian personnel from the effects of weapons including the kinetic, nonkinetic, chemical, biological, nuclear, explosives, projectiles, and provide for electromagnetic (EM) shielding.

Advanced fiber reinforced polymer (FRP) composite materials have been increasingly used in many applications relevant to the Army's transformation. This is because FRP composites possess properties that give them several advantages over traditional materials. In general, FRP composites offer high stiffness and strength to weight ratios and are durable in harsh environments. Hardened facility construction and protective structures enhance the sustainability of the Army by reducing the Class IV logistics requirements. Additionally, they aid survivability when used as protective armor or as barriers against blast. The Army has used FRP composites for applications ranging from the seismic rehabilitation of structures, high-performance tank armor, composite skins in planes and helicopters, blast protection fabric systems, rotorcraft blades, to ballistic protective inserts (BPI) in personnel armor. Currently used materials for military construction lack the capability to self diagnose defects. There is a need for a new generation of multifunctional materials that have these enhanced capabilities built into the materials.

Recent laboratory investigations indicate that carbon nanotubes (CNTs) additives can improve mechanical properties and provide enhanced thermal and electrical conductivity [1]. Multifunctional materials additive can be used to develop degradation-resistant materials, resistant to UV degradation and atmospheric corrosion. For example, microcapsules and other additives, contained within the matrix, can also provide strain evaluation capability with embedded electrically or optically active smart materials[3]. Furthermore, they could also have EMI shielding properties to prevent electromagnetic interference of sensitive electronic circuits housed within.

Past approaches have entailed adding particles with unique properties, such as magnetostrictive materials, to provide for distributed sensing/remote sensing of stress or strain state [3]. So far, none of these technologies has made it from the laboratory to large scale composites. The goal of this SSTR would be to develop promising technologies into full scale components.

PHASE I: Investigate the feasibility of innovative multifunctional materials that have high strength and stiffness with the capability of sensing and reporting when degradation conditions are present or have occurred, which may take the form of corrosion or ultraviolet degradation that would degrade strength and stiffness. For example, electrical or optical properties of the composite material may be interrogated remotely for stress condition. Also, investigate the feasibility of adding electromagnetic shielding capability to mitigate EM Threats. Demonstrate the capabilities at the laboratory scale, and down-select the most promising technologies for further development. Predict the strength and stiffness of composite materials that contain carbon nanotubes, and microcapsules.

PHASE II: Design and test high strength high stiffness multifunctional EM shielding materials for construction of C4ISR equipment and facilities that increase service life by at least 30%. Develop methods and materials that can add multifunctionality to FRP composite materials. Develop self-healing composites with microcapsules containing chemicals to interact with the resin chemistry and increase degradation resistance, and report when degradation conditions are present or have occurred, with the approach of scaling up to full sized composite components.

PHASE III (DUAL USE): Commercialize multifunctional composite materials for use as components in non-military buildings and structures in industrial and extreme (such as highly corrosive) environments. The resulting components would have high stiffness, higher strength and increased service for increased service life. These lightweight long-lasting components would also find applications in the ground transportation industry, and particularly in the aerospace industry. Furthermore, EM shielding materials may be used as housing to protect delicate electronic materials from electromagnetic interference, which would otherwise limit the useful life of electronic components.

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KEYWORDS: multifunctional materials, composites, electromagnetic shielding, self-healing, self-sensing

A09A-T024 TITLE: Impact of Climate Change on Military Compounds in the Environment

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes, Biomedical

OBJECTIVE: Develop analytical tools to assess potential effects of global climate change on fate and transport of military compounds in the environment and associated human health and environmental risks.

DESCRIPTION: Military-related activities produce many different chemicals, a portion of which potentially could contaminate soil. DOD has been using multimedia models and structure-activity analyses to predict fate and transport, environmental partitioning, persistence, and spatial extent of contamination associated with military compounds. Possible outcomes of climate change such as increased flooding or local temperature changes could alter fate and transport properties of military-related compounds as well as impair ecosystem health in many contaminated and disturbed sites. Recent studies (Valle et al., 2007, Bloomfield et al., 2006) have started exploring the influence of climate change on contaminant fate and transport in the environment. An analytical tool, allowing decision makers to model the variables in complex environmental systems, would aid in specific understanding of cause-and-effect relationships in present and future climate change scenarios. The tool must be adaptable to diverse microclimates, geomorphologies, contaminant properties and sources, and local anthropogenic impacts, and a range of plausible future circumstances resulting from global climate change must be accessible. Feedbacks between exogenous stressors (due to climate, human activity, etc.) and fate and transport mechanisms (leaching, volatilization, biotic and abiotic degradation, ecological uptake) must be accounted for and the tool should facilitate identification of causal patterns and interventions to support achieving desired endpoints. Since detailed modeling of climatic change impact is impossible due to inherent uncertainty, methods of multi-criteria decision analysis, Bayesian methods and fuzzy logic (Linkov et al., 2006, Sullivan et al., 2007) may be utilized to fuse heterogeneous information related to this topic and to support remedial and abatement policy related to military compounds in the environment.

PHASE I: (Feasibility Study) Develop methodology and prototypical software. The principal model used in the initial phase of the study should dynamically predict environmental partitioning, persistence, and spatial extent in multiple media for a single site and small set of compounds. The major parameters of the model should include chemical and medium properties and meteorological inputs, available under different assumed regimes of climate change. The model output should take the form of a structured qualitative or quantitative description of the system dynamics, with key driving variables and feedbacks clearly identified. Phase I should result in prototypical software, which would be refined and extended in Phase II.

PHASE II: (Prototype Delivery) Phase II should result in a working software platform with flexible application to a range of geographical region types (such as temperate continental interiors and tropical coasts) and military-related contaminants. Software design should be automated to allow implementation using globally available terrain, geology, vegetation/land cover, and meteorology datasets. Prototypical tools for using the model output for prioritization and decision support should be developed.

PHASE III DUAL USE APPLICATIONS: Assessment of the modeling results for various sites. Use guidelines must be developed and tools for prioritization and decision support should be finalized. The evaluation of the commercial product would be performed in this phase.

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KEYWORDS: Military Compounds, Climate Change, Decision Support Systems, Modeling, Risk Analysis

A09A-T025 TITLE: Non-invasive assay to discriminate between mild-Traumatic Brain Injury (TBI) and Post traumatic Stress Disorder (PTSD)

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective of this research topic is to solicit the development of a reliable, non-invasive set of tests that measure changes in motor and/or sensory cranial nerve function to improve the discrimination between mild-Traumatic Brain Injury (mTBI) and Post Traumatic Stress Disorder (PTSD) diagnosis. The assessment items and instructions should be contained in a container approximately the size of a laptop computer case and the tests should be able to be administered outside of the physician's office or clinic. The occurrence of mTBI is under-diagnosed, both by the warfighters and by Army corpsmen. If these injuries could be detected objectively, quickly, and non-invasively medical personnel would be able to begin early interventions.

DESCRIPTION: Since 2001, more than 1.5 million troops have deployed in OEF/OIF. Improved protective equipment (body armor and vehicle armor) has resulted in significantly more soldiers surviving serious injuries than in past conflicts (Okie, 2005). Treatment records from Walter Reed Army Medical Center indicate that, between 2003 and 2005, 59% of OIF/OEF returnees that had been near an explosion suffered a TBI (Gondusky and Reiter, 2005). Overall the percentage of soldiers sustaining mild or concussive TBI is estimated at 18% (Hoge, et al. 2008). Soldiers suffering mTBI may have no external injuries and appear normal.

In addition, a large number of soldiers returning from Afghanistan and Iraq suffer from symptoms of PTSD. Nearly 19,000 OIF/OEF veterans were seen for PTSD at VA medical centers from fiscal years 2002-2005 (Cross, Dept. of VA, 2006.) A recent report commissioned by the Department of Veteran's Affairs to assess the current body of knowledge for PTSD determined that significant gaps exist in both diagnosis and treatment of this disorder. As is the case in many mTBI patients, individuals with PTSD may also appear normal with no external injuries.

Distinguishing between mTBI and PTSD is complicated due to partial overlap in symptoms, including irritability, sleep problems, fatigue, and memory/concentration difficulties. Key to this topic development is that the axonal injury that characterizes TBI is not part of the clinical picture of PTSD. Accurate, early diagnosis of each condition is critical to prevent the development of chronic disease and subsequent impairment. The development of rapid, non-invasive, reliable testing is needed to discriminate between the subtle cognitive deficits of mTBI and PTSD.

Unlike PTSD, TBI has a unique physical origin that is distinguishable from mental illness or psychological disturbance and can be differentiated by sensitivity to motor and/or sensory changes in cranial nerve function. mTBI can result from both Diffuse Axonal Injury, due to twisting or rotational injury to the brain, or from a Contra Coup injury, in which a specific area of brain injury located directly opposite to the site of impact to the head that results from linear violent collisions of the brain with the skull. Both injuries produce cranial nerve damage identified by well-described dysfunctions. These dysfunctions can be utilized as indicators that the patient has suffered a TBI. This topic solicits proposals that would seek to develop devices for testing the function/dysfunction of cranial nerves, including but not limited to: cranial nerve I, the olfactory nerve; cranial nerve VI, the abducens nerve; and cranial nerve XII, the hypoglossal nerve. This testing battery should be able to performed in virtually any setting and shall not require trained neurological screening skills. It is important to note that while a positive screen will not diagnose mTBI, it will indicate a high level of suspicion for mTBI and help to prevent misdiagnosis, resulting in appropriate mTBI management and reduced symptom related morbidity.

PHASE I: The contractor will identify which cranial nerves will be targeted and will design and develop a set of tests that will effectively discriminate relatively subtle changes in the function of those nerves. The methodology utilized to identify the targets, rationale and feasibility should be clearly elaborated upon as well as a description of how a diagnosis of mTBI is currently determined without the proposed innovation. The approach will be supported by documentation of proof of concept and data regarding the scientific validity of the proposed innovation.

We envision a battery of simple tests of cranial nerve dysfunction that can be easily administered by medics in the field and by physician’s assistants and nurses in the medical center/VA system. Ideally the testing materials will be consolidated into a portable kit, will contain no perishable items, and include a manual describing the use of the materials and guidelines for interpretation of the results. An example of how one might detect damage to the olfactory nerve would be to administer a smell identification test, such as the standardized, forced-choice University of Pennsylvania Smell Identification Test. These tests do not require specialist neurological training to conduct and the outcomes are clearly “yes” or “no”.

The contractor will develop the work plan for testing in human volunteers. Human testing will require approval by the Human Research Protections Office at the US Army Medical Research and Materiel Command. Phase I should include submission of appropriate regulatory documents necessary to execute Phase II using human subjects.

PHASE II: This Phase will validate the potential of proposed tests to quantitatively assess/determine the range of baseline values that do not indicate mTBI in control subjects and in subjects with documented mTBI to appropriately evaluate differences in cranial nerve function. Statistical analysis of the results will indicate how many positive answers are suggestive that a mild traumatic brain injury has occurred.

PHASE III Dual Use Applications: This detection system will allow the unit medic to assess, with a high level of accuracy, whether a warfighter has sustained a mTBI. Further, the development of mTBI screening tool that can be an easily administered by first responders outside of the clinical setting will have far-reaching implications and applications for use in both military and civilian populations. If successful, this mTBI detection assay has the potential to greatly reduce the numbers of patients whose brain and/or psychological injuries go undetected or misdiagnosed thereby leading to chronic cognitive/psychological decline. It is anticipated that the development of this detection methodology for mTBI will have commercial potential in many settings.

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KEYWORDS: post traumatic stress disorder, PTSD, traumatic brain injury, TBI, cranial nerve dysfunction

A09A-T026 TITLE: <u>Development of Bacteriophage Therapy for Treatment of A. baumannii Infected Wounds</u>

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop an antibiotic solution or substance consisting of least three different lytic bacteriophages that kill Acinetobacter baumannii for eventual use in human wound infections.

DESCRIPTION: Wound infections resulting from combat injuries are traditionally treated with surgical debridement, irrigation and systemic and/or local antibiotics. The antibiotics available are rapidly becoming less effective due to the increasing prevalence of multi-drug resistant bacteria. (1-3) This has accelerated the need for safe and effective antimicrobial treatment options. Bacteriophage (or phage) therapy has been proposed as an alternative or adjunct to chemical antibiotics. Bacteriophage therapy is currently used to prevent and treat bacterial infections in some former Eastern block countries such as the Republic of Georgia and Ukraine. Anecdotal studies have indicated that they are safe and effective in many types of wounds. (3) Well designed preclinical and clinical trials for wound treatment using bacteriophages are scarce. Therefore, the major research effort will be focused on the discovery, testing and development of a bacteriophage mixture to treat wound infections in humans. The resulting product must (a) contain at least three phylogenetically different types of lytic bacteriophage to A. baumannii, (b) be completely non-toxic when used topically, including exposed bone, intramuscularly and intravenously in humans, (c) be stable at the temperature and pressure extremes encountered in transportation to and storage in austere locations worldwide, (d) not promote the development of antibiotic resistance or increased pathogenicity of A. baumannii.

PHASE I: Isolate at least three different lytic bacteriophage types against a variety of A. baumanni strains. Completely characterize the phage types to include burst size, virulence, host specificity and phylogenetic difference. Develop a matrix in which to store the bacteriophage product that will maintain stability in extreme environments. Develop a method for testing safety and efficacy of the bacteriophage mixture in two animal wound models.

PHASE II: Test stability of the phage mixture under the extreme environmental conditions indicated above. Fully research the bactericidal activity, toxicity and pharmacokinetics of the phage mixture in in vitro and animal models in accordance with FDA guidance. Complete the prototype compound for use in preclinical and human clinical trials. Complete a synopsis of a proposed phase I clinical trial. Schedule the initial pre-Investigational New Drug (IND) meeting with the United States Food and Drug Administration.

Phase III: Commercialize the product to a pharmaceutical company for GMP production, filing an IND with the FDA, and clinical testing in humans.

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KEYWORDS: Bacteriophage Therapy, A. baumannii, Infected Wounds, antibiotic solution

A09A-T027 TITLE: <u>A Real-Time, Non-Invasive Monitoring System of Combat Casualties for Early Detection of Hemorrhagic Shock During Transport and Higher Echelon Medical Care</u>

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop an advanced decision-support medical monitor driven by algorithms that provide real-time processing of physiologic signals for the purpose of tracking early physiological compensations due to hemorrhaging in humans. The algorithm will run in real time on a resource constrained portable device. The final device should provide a wireless connection between the patient and monitor and the monitor should be capable of monitoring multiple patients simultaneously.

DESCRIPTION: Emergency medical treatment is imperative when time and distance limit quick casualty evacuation. The “golden hour,” the first 60 minutes following a traumatic injury, has long been recognized by medical personnel as vital to saving lives. Since hemorrhagic shock remains a leading cause of death on the battlefield (1), it is critical to provide medics with real time monitoring of soldiers with traumatic injuries. The determination of the severity of a soldier’s hemorrhage is required in order to establish triage categories, evacuation priority, and required interventions. In trauma patients, standard vital signs such as arterial pressure, heart rate, arterial oxygen saturation and mentation are monitored periodically during transport, when abnormal, they clearly are related to mortality and prompt rapid evacuation and immediate interventions. However, these changes are relatively late secondary markers (decompensated physiologic responses) rather than primary manifestations of hemorrhagic shock, and as such may not provide the first responder with adequate information regarding triage categories, evacuation priority and required interventions (2,3,4). Of primary importance is the ability to estimate reductions of central blood volume easily and non-invasively from currently measured and/or novel measured physiological signals. While novel measurements that reflect physiological compensation (e.g., heart rate variability [HRV]) are being extensively studied to diagnose a wide variety of conditions (2,5), there is growing research to indicate that no single measure alone is sufficient to accurately assess the severity of hemorrhage in trauma patients. The ability to accurately and reliably determine the severity of blood loss and to predict when a hemorrhaging patient needs more advanced interventions or more aggressive treatment could significantly reduce the mortality rate of combat casualties. This capability would provide the first responder with an earlier indicator of hemorrhage severity than current measures, and therefore may assist the first responder with triage decisions. Additionally this capability would provide higher level providers with a non-invasive means of monitoring central volume and the hemorrhaging patient's response to resuscitation when operating in austere environments.

PHASE I: Demonstration of proof-of-concept algorithm to analyze standard vital signs or other novel physiologic signals for tracking physiological compensations due to hemorrhaging in humans and to determine the hemorrhage severity of the patient. Contractors should explore novel approaches for the analysis of physiological signals which can lead to the development an effective plan for real-time implementation. In Phase I, the algorithm will process, in near real time, continuous physiological signals related to blood loss. The contractor is encouraged to explore novel physical signals, however current non-invasive physiologic signals such as the electrocardiogram (ECG), photoplethysmogram (PPG) aka Portapres®, oxygen saturation (SpO2), respiratory measures, and blood pressure (BP) may provide a good starting point to derive the necessary physiologic information. The algorithm will process each of the individual physiological signals and extract the necessary parameters to robustly determine the hemorrhage severity of an individual patient. In order to accomplish this objective, the use of machine learning techniques to implement the algorithm is encouraged. The successful algorithm will be required to process noisy physiological signals while still maintaining robust performance in tracking the physiological compensations due to hemorrhaging. The contractor will be given access to a progressive hypovolemia data set produced at the US Army Institute for Surgical Research. Contractors are also encouraged to use other hypovolemia or hemorrhagic shock data sets for the development of their algorithm.

PHASE II: The contractor will further develop and optimize the hemorrhage severity detection algorithm across various data sets. Optimization of the algorithms will utilize both simulated and actual trauma patient data. In addition, the contractor will implement the hemorrhage severity detection algorithm in a real-time portable device. The device will also provide the capability to archive the data along with the results. The device will be tested with both actual and simulated data sets. Evaluations of the system will encompass: data quality, real-time operation, performance measures (e.g. probability of detection and false alarm rate), robustness, and consistency.

PHASE III: The contractor will provide a device capable of providing near real-time estimates of hemorrhage severity that would assist combat and civilian medics in triage prioritization and intervention decision early in the progression of hemorrhage. The device should provide a wireless connection between the patient and monitor and also be capable of monitoring multiple patients simultaneously. The final device must provide IEEE compliant wireless and a physical connector to allow connection to individual computers and computer networks. Such a device could save lives by providing critical information on hemorrhage severity, and should be of great commercial interest for all branches of the U.S. armed services as well as pre-hospital and trauma centers around the world.

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KEYWORDS: medical monitors; clinical decision-support; trauma; hemorrhagic shock; machine learning algorithms; vital signs

A09A-T028 TITLE: Multisensory/Multimodal Interfaces for Robotic Surgery

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective of this topic is to develop a multisensory and multimodal interface for robotic surgery (M/MIR). Robotic surgery could be significantly improved through the use of multisensory interfaces (visual, auditory and tactile sensory displays) and novel human centered command and control input devices. By returning to the surgeon a kinesthetic and somatosensory environment familiar to open procedures and exploiting the inherent multisensory data fusion capabilities of the human brain to reduce surgeon workload and errors, M/MIR systems should augment surgeon performance and patient care.

DESCRIPTION: Telesurgery has the potential to reduce the time between battlefield injury and definitive treatment for a warfighter by providing a method for a surgeon geographically removed from the injured servicemember to rapidly intervene, without having to wait for tactical casualty evacuation to a definitive treatment center. While telerobotic systems are being developed to provide this capability more effectively in the field [1,2], teleoperated surgical (telesurgical) systems typically utilize visual presentation as the dominant method of conveying information to the surgeon. This visual overload can make simple maneuvers difficult, time consuming, fatiguing and stressful [3,4,5] and lead to increased surgical errors, longer intra-operative sessions and a dramatic fall in productivity. This limits the potential effectiveness of telesurgery in the field, across long distances, and even when in close proximity to the patient. Multisensory/multimodal interfaces have been shown to improve interactions with robotic systems [6]; this topic seeks to develop specific telesurgical multisensory/multimodal interfaces to restore some level of perception similar to direct surgeon interaction with tissues. The interface also would facilitate surgical performance through adaptive automation of surgical end effectors and tasks. Potentially, a telesurgeon using a modular M/MIR system should be able to interface with different manufacturers' end effector robots to perform procedures on patients located in multiple locations, provided that the sensory and control interfaces were able to provide sufficient workload reduction and enhancement of situation awareness. This would enable a breakthrough for definitive surgical care for wounded servicemembers in the modern battlespace.

PHASE I: Conduct a detailed design and feasibility study to define a prototype sensory and control interface for the M/MIR system as described above. Studies should evaluate augmented visual, auditory and tactile sensory displays and ergonomic control input devices that allow a surgeon to operate more effectively than with current console based telesurgical systems.

This study should include (1) the types of sources and the sensory information to be displayed, (2) the types of multisensory displays, (3) integration of supervisory-controlled automation (4) control input system design, and (5) expected performance of the system.

PHASE II: Based on the detailed design of phase I, a prototype M/MIR system should be fabricated and demonstrated during Phase II. The performance of the prototype should be quantitatively tested and characterized. The evaluation data will be used to refine the initial prototype, improve its performance and validate improvement of surgeon performance of military relevant procedures. FDA will be approached to determine requirements for clearance should system prove efficacious.

PHASE III: Telesurgical technology can be used in various military and civilian applications where an surgical specialist is not available locally, must remain out of harm's way, or where the patient can not be transported. In this phase, additional testing to meet FDA requirements will be completed and FDA clearances obtained. Commercialization of the resulting application will occur. The successful system will be presented to the appropriate Army and DoD acquisition authorities for consideration of initiation of technology insertion into the Military Healthcare System. Additional funding may be provided by DoD sources but the awardee must also look towards civilian funding sources to continue the process of translation and commercialization. The M/MIR system resulting from the technology developed under this Small Business Innovative Research would ensure that surgical expertise could be distributed, automated and delivered in an effective manner to warfighters serving their country across the world. This technology could save the lives and limbs of our injured warfighters.

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KEYWORDS: Man machine interface, Surgical Robotics, Multisensory, Telesurgery, Automation, Console

A09A-T029 TITLE: Robotic System for Natural Orifice Transluminal Endoscopic Surgery

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To develop a new robotic system that enables Natural Orifice Transluminal Endoscopic Surgery (NOTES) and improves surgical care of warfighters and their families.

DESCRIPTION: Natural Orifice Transluminal Endoscopic Surgery (NOTES) has the potential to favorably disrupt surgery in a manner similar to the laparoscopic revolution of the early 1990's (e.g. Kalloo et al, 2004; Grady, 2007; The Oregon Clinic, 2007). NOTES could dramatically change surgery as it eliminates skin incisions by gaining access to structures of interest through natural orifices. Theoretically, NOTES could improve diagnosis and therapy across surgical specialties while limiting postoperative pain, recovery, and wound infections.

Current NOTES systems are rudimentary and based upon flexible endoscopic systems commonly used to evaluate organs such as the stomach and colon. NOTES based upon current endoscopic platforms is challenging secondary to the limited by the size of natural orifices, difficulty passing multiple instruments simultaneously through these orifices, and limited force that can be generated perpendicular to the axis of long, flexible instruments. To achieve widespread application of NOTES that will improve the cost, quality and access of surgical care, an enabling robotic platform is required.

Surgical robotics is now recognized as a major driving force advancing minimally invasive surgery. The first robots for abdominal surgery appeared in the mid 1990's. These surgical robots are controlled by a surgeon at a console and serve in a master-slave relationship with the surgeon controlling the robotic instruments. Based upon technology originally developed by the Defense Advanced Research Projects Agency, the da Vinci system (Intuitive Surgical, Inc) is the only general surgery system commercially available. Advantages of the daVinci include articulated movement of instruments within the patient, tremor reduction, and motion scaling. While the daVinci is routinely used to remove the prostate gland and uterus, it cannot be directly applied to NOTES because it is too large and cannot navigate the complex curved geometry imposed by natural orifice access.

A novel, modular surgical robotic system could facilitate NOTES. The robotic system components should be introduced through a natural orifice or pre-existing traumatic wounds and leverage complementary technologies such as advanced materials, fabrication, computing, telecommunication, power, imaging, directed energy, and automation. Examples of possible robotic solutions that could overcome the challenges posed by complex curved geometries include modular components that assemble within the patient as well as serpentine robots with surgical end effectors.

The proposed NOTES robotic system should allow an average surgeon to perform routine surgical procedures in an outpatient setting and thereby improve the quality and cost-effectiveness of surgical care. While the system should be flexible and scalable enough for use across surgical specialties, it initially should target a specific unmet military need in a single surgical specialty. An example of a military relevant procedure is natural orifice diagnosis and treatment of acute appendicitis at a role 2 facility with return of the warfighter to active duty within 6 hours of surgery.

PHASE I: Phase I proposals must demonstrate: (1) an eclectic expertise across relevant disciplines such as surgery, engineering, and medical device design, (2) a specific unmet military surgical need, and (3) a robotic system that facilitates performance of key tasks necessary to address the unmet need via clinically relevant natural orifice surgery. During Phase I, the proposed robotic system will be iteratively and rigorously designed. The design should incorporate: relevant standards that facilitate use and interoperability; inexpensive commercial-off-the-shelf components that minimize cost; and modularity that maximizes flexibility, scalability and use across multiple surgical specialties. At the completion of Phase I, the investigators will provide a detailed design of the robotic NOTES system. Phase I deliverables also include a detailed proposal for fabrication and validation of the prototype system within Phase II.

PHASE II: The prototype designed in Phase I will be fabricated. The prototype will be evaluated and refined as necessary via inanimate experiments that simulate key aspects of the specified surgery. The prototype system will be validated via rigorous experiments in which the specified surgery is performed in a relevant animal model.

PHASE III: In this phase additional testing to meet FDA requirements will be completed and FDA clearances obtained. Commercialization of the resulting application will occur. The successful system will be presented to the appropriate Army and DoD acquisition authorities for consideration of initiation of technology insertion into the Military Healthcare System. Additional funding may be provided by DoD sources but the awardee must also look towards civilian funding sources to continue the process of translation and commercialization. The system will facilitate military and civilian wide application of NOTES.

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KEYWORDS: Minimally Invasive Surgery, Robotic Surgery, Natural Orifice Transluminal Endoscopic Surgery (NOTES)

A09A-T030 TITLE: Incremental Learning for Robot Sensing and Control

TECHNOLOGY AREAS: Ground/Sea Vehicles, Biomedical, Human Systems

OBJECTIVE: Develop a robotic control system that incrementally learns driving commands based on current sensor inputs and past experience.

DESCRIPTION: The real world is too complex, ill conditioned, and variable to directly program an autonomous robot's control system. Autonomous robots therefore need to learn how to adaptively respond to sensor input. Due to the vast amounts of information that can be involved, the learning system needs to be trained incrementally, discarding prior data. The system needs to be capable of generating and updating its internal models in real-time. There should be little difference between the learning algorithms used in training and those used in execution.

There has been much work in learning with a variety of algorithms. One of the larger recent defense programs in learning and robotics was DARPA's Learning Applied to Ground Robotics (LAGR). While great progress was made under this effort, the issue of learning in robotics remains unsolved. The algorithms continue to be relatively brittle and do not really adapt to new environments, but still require a significant amount of hand tuning. The LAGR program was perhaps too ambitious, trying to achieve full autonomous driving in unstructured outdoor environments with one or two cameras. For this STTR effort, more flexible learning is expected, but on a more limited problem set. Offerors should explain why the proposed learning algorithm would perform better than current state of the art.

One method for training has the robot driving around by itself discovering associations between sensor inputs and control decisions. However, there are catastrophic situations, such as driving off a cliff or over a person, which one wants the system to learn, but not experience. An alternative methodology is to learn from example by having a user teleoperate the vehicle, with the system learning the association between sensor inputs and driving commands. In this case, research would also involve determining the most effective teleoperation strategy in order to generate a reliable autonomous driving system. A combination of these two approaches may provide a better overall solution.

Sensors of interest include look-ahead sensors, such as cameras, lasers, sonars and radars, as well as proprioceptive sensors, such as accelerometers, gyroscopes, odometers, and motor current and voltage sensors. Of interest are difficult perception tasks, such as determining which obstacles a vehicle can drive over or through, estimating how fast a vehicle can drive and turn on the terrain ahead, and reliably detecting people of various sizes and configurations. It is acceptable to have different models for different environments and to have the system determine which is the appropriate model for the current environment. Seeding the system with an initial batch learning process is also acceptable.

The topic is seeking a flexible learning system for an unmanned ground vehicle, which can truly learn when encountering data that it has not seen before. The system needs to be able handle large amounts of data, such as from video or a laser scanner, and therefore must be incremental in nature. A learning system such as this is required for successful implementation of autonomous vehicles in real world scenarios.

PHASE I: The first phase consists of algorithm formulation, perception task selection, and training methodology definition. The feasibility of achieving real-time operation and a comparison against other algorithms shall be required in the final report.

PHASE II: The second phase consists of a full implementation of the system, including sensors. At the end of the contract, the incremental learning capabilities of the prototype system shall be demonstrated in a suitable outdoor environment. Deliverables shall include the prototype system and a final report, which shall contain documentation of all activities in this project and a user's guide and technical specifications for the prototype system.

PHASE III DUAL USE APPLICATIONS: Commercial applications include many UGV applications, such as security and inspection, hazardous waste monitoring, and planetary exploration. Military applications include robotic mule, scout vehicles, security and inspection.

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4. http://www.cse.fau.edu/~zhong/papers/oskm_ijcnn05.pdf (Efficient Online Spherical K-means Clustering)

5. http:// www.cs.toronto.edu/~dross/ivt/RossLimLinYang_ijcv.pdf (Incremental Learning for Robust Visual Tracking)

6. http://www.darpa.mil/IPTO/programs/lagr/lagr.asp (Learning Applied to Ground Robotics)

KEYWORDS: learning, robotics, perception