Current Research Topics for the DEVCOM ARL BAA For Foundational Research W911NF-23-S-0001

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The DEVCOM ARL Broad Agency Announcement for Foundational Research,
W911NF-23-S-0001,
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Link to all current ARL research topics

Available Army Research Office (ARO) Research Topics

The available Army Research Office (ARO) topics are listed in alphabetical order.

Army Research Office (ARO) Research Topic

Title: Computational Mathematics
Announcement ID: ARL-BAA-0034

TPOC: Radhakrishnan Balu, PhD - radhakrishnan.balu.civ@army.mil - (301) 394-4302
ARL Office: Army Research Office (ARO)
Discipline: Mathematics and Statistics;Physics
ARL Foundational Research Competencies: Mechanical Sciences;Network, Cyber, and Computational Sciences;Photonics, Electronics, and Quantum Sciences;Weapons Sciences
Army Modernization Priorities: Assured PNT;Network/C3I
Keywords: Mathematical modeling, Scientific computation, Fractional order methods, Mathematics of QIS, Atmospheric physics, Embedded simulation

Description:
The research strategy of this program is to focus on the following opportunities for crucial discoveries: innovative methodologies for solving currently intractable problems that take advantage of symmetry, conservation, and recurrence, that can adapt to both the evolving solution and to the evolving run-time resource allocation of modern computer architectures; novel algorithms that accommodate different mathematical models at different scales, interacting subsystems, and coupling between models and scales; methods that incorporate nonlocality through integral operators with advantageous representations. Research in this area will ultimately lead to the development of new mathematical principles that enable faster and higher fidelity computational methods, and new methods that will enable modeling of future problems.

Scientific computation is an essential component of scientific inquiry, complementing theory and experiment, and is also an essential element of engineering in both design and in failure autopsy. Simulations in support of inquiry, design, or autopsy often require expert knowledge in order to select methods that are compatible with the assumptions of the scenario at hand, require considerable skill to properly set up, require considerable time, memory, and storage on large scale parallel/distributed/heterogeneous systems to compute, and require considerable skill and effort to distill useful information from the massive data sets which result. Expert knowledge is also required to quantitatively estimate solution accuracy and to estimate the time and effort required to achieve a desired accuracy. Data has become ubiquitous and is potentially very valuable in increasing solution accuracy and/or decreasing the effort required to solve, but mathematically sound methods for incorporating data into accurate simulations are incomplete. Simulations are not always timely, with results often not being available until after they are needed, for example in calculating failure of New Orleans levees during Katrina and in revising those estimates based on real time surge data.

The emphasis in the Computational Mathematics program is on mathematical research directed towards developing capabilities in these and related areas. For problems that are not time-limited, research areas of interest include but are not limited to the following:

Advances in Numerical Analysis. Novel methodologies are sought for solving currently intractable problems. New ways of taking advantage of symmetry, conservation, and recurrence are of interest, as are new ways of creating sparsity and new computational structures which can adapt to both the evolving solution and to the evolving run-time resource allocation of modern computer architectures. Rigorous analysis is sought for each in order to enable error bounds, error distribution, and error control.

Mathematics for Quantum Information Systems (QIS). New mathematical constructs and understanding are sought in order to provide useful mathematical tools and language to others working to advance QIS. QIS goes far beyond quantum computing (QC), with focus also on quantum networking, quantum sensing, topological quantum computing, and topological phases of matter. Advances are sought in factors of von Neumann algebras, type II and type III, that are yet to be fully explored even after a century of studies from a QIS point of view. Topological quantum information processing going beyond anyons and in 3+1 spacetime dimensions are of interest. Exploration of noncommutative geometry from QIS point of view are important in pushing the field. Advances are sought in the language for quantum field theory as a basis for QIS and for the associated mathematical structures that are involved. New bases for QIS-based chemical and biological systems are just beginning; language and representations for these more-complex and messier-than-physics-based-systems are sought in order to enable new mathematical models. The QIS of metamaterials-based systems is very different from other systems, and new mathematics is sought that is capable of representing the unification of these disparate QIS themes.

Fractional Order Methods. As an alternative to high order methods and other less-local operators, fractional operators are another nonlocal operator that have proven to work well in modeling and have the advantage of not enforcing dubious assumptions of smoothness, especially at discontinuities and interfaces. However, the nonlocality of fractional operators also typically introduces a significant increase in computational load. Advances in novel efficient computational methods for these operators are of interest. Army systems often operate under rapidly-changing unpredictable and adverse conditions. It is desirable for models to be computationally simulated and fast enough to drive decision making, exercise control, and to help avoid disaster. Such simulations need to be created, run, and interpreted in better than real time. Research directed towards making this goal achievable is of interest, such as: Fast Methods for Atmospheric Physics. Modeling and prediction of local and mid-range atmospheric physics are a key part of the domain of operations. New exploratory efforts in fast algorithms for atmospheric physics have been identified as an area where new computational methods could make an important impact on problems of current and future Army interest. The emphasis of these efforts is on mathematical methods which have some promise of wider application rather than methods limited only to specific application areas.

Reduced Order Models. Full scale simulations are often not realizable in real time. In order to investigate the behavior of systems under a variety of possible scenarios, many runs are required. Reduced order models are one way to enable this. Possible methods to create these models include adaptive simplification methods based on singular value decompositions and reduced order numerics. To be useful, all such models should be equipped with reliable estimates of accuracy.

Problem Solving Environments. To enable rapid decision making that is driven by simulation, it is necessary to set up simulations very quickly and obtain results in an understandable format. Matlab is one current tool for such a problem solving environment. What are other approaches? Embedded Simulation. As algorithms become more efficient and computational devices shrink, it will become increasingly possible to use real-time simulation to drive control systems. New methods which address this goal are welcome, especially those which permit user- controlled and/or adaptively-controlled tradeoffs between speed and accuracy. Decision Making. One valid criticism of numerical simulation is that it takes so long to set up, run, and post-process the results that they cannot be used in a timely manner to guide decision making. Mathematical ideas that help address this problem are of interest.

Army Research Office (ARO) Research Topic

Title: Condensed Matter Physics
Announcement ID: ARL-BAA-0029

TPOC: Joe X. Qiu, PhD - joe.x.qiu.civ@army.mil - (919) 549-4297
ARL Office: Army Research Office (ARO)
Discipline: Materials Science;Physics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Photonics, Electronics, and Quantum Sciences;Sciences of Extreme Materials
Army Modernization Priorities: Assured PNT;Network/C3I
Keywords: Solid-state physics; Crystal lattices; Correlated oxides

Description:
This program strives to drive research that looks beyond the current understanding of natural and designed condensed matter, to lay a foundation for revolutionary electronic device concepts for future generations of warfighters.

Strong Correlations and Novel Quantum Phases of Matter. Understanding, predicting, and experimentally demonstrating novel phases of matter in strongly correlated solid state materials will lay a foundation for new technology paradigms for applications ranging from information processing to sensing to novel functional materials. Interest primarily involves strong correlations of electrons, but those of other particles or excitations are not excluded. This thrust is currently emphasizing endeavors to determine if material properties can be significantly altered by dressing bosonic states within materials with engineered fluctuations of the vacuum.

Topologically Non-Trivial Phases in Condensed Matter. Topologically non-trivial states of matter in solid state materials beyond the quantum Hall phases have shown a remarkable opportunity to advance our understanding of physics and provide a foundation for novel device concepts. This thrust emphasizes the interaction between magnetic order and topological states. A deeper understanding of these interactions is necessary to determine if meaningful device concepts can be built upon them. The thrust is also broadly interested in the discovery and engineering of new non-trivial phases, verification of non-trivial topologies and phase transitions between trivial and non-trivial topological states.

Unique Instrumentation Development. Advanced studies of SSP phenomena often require unique experimental techniques with tools that are not readily available. The construction and demonstration of new methods for probing and controlling unique quantum phenomena in solid state materials is of particular interest.

Army Research Office (ARO) Research Topic

Title: Materials Design
Announcement ID: ARL-BAA-0012

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ARL Office: Army Research Office (ARO)
Discipline: Chemistry;Materials Science;Physics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Photonics, Electronics, and Quantum Sciences;Sciences of Extreme Materials
Army Modernization Priorities: Soldier Lethality
Keywords: self-assembly, soft materials, colloids, functional materials, metamaterials,

Description:
The overarching goal of the Materials Design program is to establish new smart materials concepts by pursuing fundamental science that exploits multiple physical and chemical forces at play during directed self-assembly to create stimuli-responsive, multifunctional materials with designer geometries, hierarchical complexity, and the ability to dynamically switch among configurations, thereby enabling the future Warfighter to adapt to any environment or situation. Bottom-up materials science, functional materials, and soft materials are the unifying themes of the Materials Design program. The program supports experimental, theoretical, and computational advances to better design, create, understand, and manipulate novel functional materials from the bottom up. The foundations established here support the realization of 3D metamaterials, reconfigurable optics and electronics, bio-mimetic materials, and multi-functional materials that dynamically respond to their environment.

The Science of Self-Assembly supports basic research into the multiple physical and chemical forces at play during directed, bottom-up 3-D assembly into super-structures incorporating multiple components. The goal is to design novel self-assembled materials that would be impossible to create using top-down techniques. Self-assembling materials systems of interest include: polymers; colloids; nanocrystals; liquid crystals; functional biomaterials; and/or hybrids of these materials. Emerging research foci include: non-equilibrium and dissipative self-assembly; 3-D photonic crystals and structural color; interactions between self-assembled materials and water; non-traditional assembly directing forces (e.g., turbulence); and in situ reinforcement learning or evolutionary algorithms to direct assembly towards desired targets.

Reconfigurable and Hierarchical Materials supports the design and synthesis of materials capable of reversible transformations, as well as hierarchically structured materials. The goal is to elucidate the design rules for creating novel functional materials with dynamic property contrast and/or emergent behavior, and develop new methods to “program” materials with the ability to respond in specific ways to external stimuli. Reconfigurable and hierarchical materials systems of interest include: bio-mimetic materials; liquid crystal elastomers; colloidal metamaterials; 3D/4D metamaterials; and active matter. Emerging research foci include: 3D/4D printing off functional materials with molecular-scale precision; materials that form reconfigurable networks;

Army Research Office (ARO) Research Topic

Title: Modern Optics
Announcement ID: ARL-BAA-0009

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ARL Office: Army Research Office (ARO)
Discipline: Physics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Network, Cyber, and Computational Sciences;Photonics, Electronics, and Quantum Sciences
Army Modernization Priorities:
Keywords:

Description:
The objective of this program is to promote a deeper understanding of the properties of light and the discovery of new optical effects that can improve Army capabilities. Most sensing and communications systems depend on light in some way. This program seeks transformational basic science discoveries in optical physics that are needed to enable dynamic control of light for remote sensing, information routing, and energy transmission. In order to accomplish this goal, the Modern Optics Program targets new or emerging phenomena related to quantum optics, light-matter interactions, structured light and ultra-short pulse lasers.

Quantum Photonics. This thrust seeks to push beyond the state of the art in photonics and integrated optical platforms, seeking novel functionality beyond classical limits on sensitivity, accuracy, and stability. Research efforts may include studies addressing complexity and loss in integrated optical systems, scalable realizations of multi-photon quantum states or quantum light sources, and novel laser platforms to probe or manipulate quantum information in physical qubits. Basic science understanding is needed to push integrated photonics into the quantum regime which will be essential for next generation quantum technology.

Meta-Optics. This thrust looks for novel functionality enabled by optical metamaterials. In this area, the conventional norms of classical optics will be broken. Examples include resolution beyond the diffraction limit, super-lensing, as well as subwavelength control of optical fields. Proposals related to non-Hermitian optics and the physics of exceptional points, where these concepts are utilized to fabricate photonic structures with novel properties and sensors with precision beyond the state of the art are sought. In general, any phenomena arising from optical metamaterials that would benefit the Soldier and improve Army capabilities will be considered.

Extreme Light. This thrust focuses on extreme light, meaning the examination of optical fields in extreme limits, such as shortest pulse and/or high intensity. General areas of study under this thrust include, THz formation, broadband localized radiation, coherent control of atomic and molecular energy states, plasma effects in materials, and relativistic plasma physics. Theoretical and experimental research efforts are needed to push beyond the state of the art in ultrafast science and to understand how extreme light interacts with matter.

Army Research Office (ARO) Research Topic

Title: Multi-Agent Network Control
Announcement ID: ARL-BAA-0031

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ARL Office: Army Research Office (ARO)
Discipline: Computer Science;Data Sciences and Informatics;Network Science
ARL Foundational Research Competencies: Military Information Sciences;Network, Cyber, and Computational Sciences;Weapons Sciences
Army Modernization Priorities: Long Range Precision Fires;Network/C3I;Next Generation Combat Vehicle
Keywords: Control, Reinforcement Learning, Quantum, Multi-Agent, Distributed, Data Driven, Networked Systems

Description:
The objective of the Multi-Agent Network Control program is to establish the physical, mathematical and information processing foundations for the control of complex dynamic networks with possibly multiple controllers that may operate using different information sets. The research program seeks the development of novel mathematical and computational methods for the modeling and control of the collective behavior of large-scale networked systems controlled by of heterogeneous agents which may or may not follow a common goal. Autonomy is central to program efforts to support anticipated dynamics of the future battle space. Requirements of such environments may include mobility, effective sensor coverage, efficient information flow, responsiveness to support the military goals of information superiority, dominant maneuver and precision engagement.

Distributed and Time-Varying Control of Networked Systems
Distributed control techniques play a major role in the analysis and synthesis of networked systems. They have been successfully used in robotics for replicating self-organized behaviors found in nature (e.g., bird flocking, fish schooling, and synchronization) and in developing applications such as formation control, rendezvous, robot coordination, and distributed estimation. Many dynamic systems are, or can be made time-varying, and they may be subject to possibly abrupt transitions of the states, and hard to predict disturbances and external effects. Innovative methods that incorporate, and even exploit time varying nature of distributed systems for establishing their stability, robustness and optimality is of interest. Analysis and control of networked non-linear systems where standard linearization methods are not satisfactorily applicable is also sought. Potential use of techniques such as geometry, graph theory, topological analysis and other innovative methods are encouraged.

Data Driven Control and Learning
Control of systems with unknown dynamics and methods to reduce their uncertainties has been part of mainstream control systems research, examples of which include Reinforcement Learning (RL), Adaptive Control, and in general data driven control. Reinforcement Learning is shown to be closely related to Stochastic Dynamic Programming, which enabled successful leveraging of

significant body of research of the latter. However, data driven controls such as RL face significant challenges, including computational complexity, very long convergence times, and lack of sufficiently rich training data. Hybrid approaches that properly incorporate prior or learned models of the systems to be controlled into the problem formulation are emerging and their furthering is encouraged in this program. Broadly, research to address fundamental issues in data driven control is sought. Those include, but not limited to, efficient computation methods that allow real-time operations without sacrificing precision, scalability, optimization algorithms that address the occurrence of multiple local minima encountered in learning and developing systematic methods for reliable transfer of learning from other experiments. Use and advancing of control theoretical tools such as stability analysis, non-convex optimization, and other innovative approaches to address these open problems is encouraged. New insights to RL algorithms which may extend, modify, or replace standard Markovian formulations are desired. Extensions of RL techniques to networked systems featuring multiple controllers with applications to autonomy and coordination among interacting agents are sought. Innovative research focused on adaptive control, and system identification techniques to reduce uncertainties and facilitate optimal or near-optimal control is also in scope.

Control of Quantum Systems and novel applications of control theory

Innovative tools and methodology from control theory could provide new insights and approaches to pave the path for solving some of the outstanding problems in quantum, such as maintaining coherence and stability of Quantum Qubits and their entangled states. Capabilities enabled by quantum computers are expected to surpass their classical counterparts in the future. However, maintaining the desired state of qubits remains a fundamental problem encountered in the realization of quantum computers and quantum networks. Adaptation of control theoretical tools and approaches in enhancing the stability of coherence of qubits and reducing the impact of noise in quantum gates and their operations could provide new research opportunities in the control of networked quantum systems.

Researching and devising other applications of control theory in areas that are relevant to the Army and that could advance the state of control theory itself is of interest. Among novel applications of potential interest is the study of control functions acting on neural circuits that are distributed in the brain. These interactions include synchronization, but their fundamental principles and underlying mechanisms are not well understood. Modeling and analysis of these phenomena could provide novel research opportunities in the control of networked systems. Similarly, study of biological systems has unveiled control architectures that are not encountered in industrial control systems. Understanding the principles, analyzing the effectiveness of such naturally occurring control systems and their potential adaptation to the control of man-made applications could be an area of fertile research.

Army Research Office (ARO) Research Topic

Title: Optoelectronics
Announcement ID: ARL-BAA-0019

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ARL Office: Army Research Office (ARO)
Discipline: Electronics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Energy Sciences;Military Information Sciences;Network, Cyber, and Computational Sciences;Photonics, Electronics, and Quantum Sciences;Sciences of Extreme Materials
Army Modernization Priorities: Air and Missile Defense;Network/C3I;Next Generation Combat Vehicle
Keywords: optoelectronics, photonics, semiconductor

Description:
Research in this subarea includes novel semiconductor structures, processing techniques, and integrated optical components. The generation, guidance and control of UV through infrared signals in semiconductor, dielectric, and metallic materials are of interest. The Army has semiconductor laser research opportunities based on low dimensional semiconductor structures (quantum dots, wells, wires, etc.) operating in the eye-safer (>1.4), 3-5, and 8-12 microns regions for various applications, such as LIDAR, infrared countermeasures, and free space/integrated data links. Components and sources in the UV/visible spectral ranges (particularly < 300 nm) may be of interest as well. Research is necessary in semiconductor materials growth and device processing to improve the efficiency and reliability of the output of devices at these wavelengths. However, near infrared or wavelength agnostic device advances can be explored for potential impact on various material systems and wavelengths of interest.

Research that leads to an increase in the data rate of optoelectronic structures is sought. Interfacing of optoelectronic devices with electronic processors will be investigated for full utilization of available bandwidth. Electro-optic components will be studied for use in guided wave data links for interconnections and optoelectronic integration, all requirements for high-speed full situational awareness. Optical interconnect components are needed in guided-wave data links for computer interconnection and in free-space links for optical switching and processing. For high-speed optical signal processing as well as potential for power scaling, research on individual and 1 or 2-D arrays of surface or edge-emitting lasers is necessary. Spectral and coherent beam combining approaches for integrated photonics need more exploration. Research addressing efficient, novel optical components for high-speed switching based on electro-optic materials, nanostructures, metamaterials or other regimes may be of interest. Emitters and architectures for novel display and processing of battlefield imagery are important.

Research on components and sub-elements of photonic circuits used in neuromorphic photonic information processing and computation are of interest. Photonic processing within a photonic integrated circuit (PIC) requires smaller and more energy efficient modulator devices on the order of 5 microns and 1 femtojoule/bit. Modulation bandwidth of 10 Gb/s or more, and insertion loss of 0.1 dB or less are needed to cascade modulators with less than 1 dB/cm total loss. Modulation and bit resolutions of 12 bits or more and floating-point calculations will be required for PIC processor implementations. Other advances leading to enhanced analog computing performance regimes including energy efficient and high-speed photodetectors and light sources (most likely coherent) are sought. Exploration of ideas leading to enhanced use of photonic interactions in both 2D and 3D architectures that take advantage of photonic degrees of freedom (wavelength, polarization, spatial modes, etc.) will be considered. While quantum communications and quantum integrated photonics are not focused upon per se, low bit energy signals (photon count < 500) may be considered. Such research could impact single photon, quantum optics regimes due to similar signal to noise considerations.

Army Research Office (ARO) Research Topic

Title: Quantum Information Science
Announcement ID: ARL-BAA-0023

TPOC: Sara Gamble, PhD - sara.j.gamble.civ@army.mil - (919) 549-4241
ARL Office: Army Research Office (ARO)
Discipline: Computer Science;Materials Science;Physics
ARL Foundational Research Competencies: Military Information Sciences;Network, Cyber, and Computational Sciences;Photonics, Electronics, and Quantum Sciences
Army Modernization Priorities: Assured PNT;Network/C3I;Next Generation Combat Vehicle
Keywords: quantum information science, quantum sensing, quantum computing, quantum entanglement, quantum networking

Description:
Quantum mechanics provides the opportunity to perform highly non-classical operations that have the potential to result in beyond-classical capabilities in sensing, precision measurement, computation, and networking. The quantum information science program seeks to understand, control, and exploit such non-classical phenomena for revolutionary advances beyond those possible with classical systems. An overarching interest is the exploration of small systems involving small numbers of entangled particles. There are three primary areas of interest within the program.

Foundational Quantum Physics
Experimental investigations of a fundamental nature of quantum phenomena that are potentially useful for quantum information science are of interest. Examples include coherence properties, decoherence mechanisms, decoherence mitigation, entanglement creation and measurement, nondestructive measurement, complex quantum state manipulation, and quantum feedback. An important objective is to ascertain the limits of our ability to create, control, and utilize quantum information in multiple quantum entities in the presence of noise. Systematic materials science based and/or focused research which identifies and/or mitigates decoherence mechanisms is also of interest. Models of machine learning that are based on the foundations of quantum physics are of interest. Theoretical analyses of non-classical phenomena may also be of interest if the work is strongly coupled to a specific experimental investigation, such as proof-of-concept demonstrations in atomic, molecular, and optical (AMO) or other systems.

Quantum Sensing and Metrology
This research area seeks to explore, develop, and demonstrate multi-particle coherent systems to enable beyond classical capabilities in sensing and metrology. Central to this research area is the exploration of small systems involving a few entangled particles. Topics of interest include the discovery and exploration of (a) multi-particle quantum states advantageous for sensing and metrology, (b) quantum circuits that operate on multi-particle quantum states to enable beyond-classical capabilities, and (c) methods for the readout of quantum states. Other research topics of interest include theory to explore multi-particle quantum states useful for beyond classical capabilities, quantitative assessment of capabilities and comparison to classical systems, efficient

state preparation, quantum circuits for processing these states as quantum bits, readout techniques, decoherence mitigation and error-correction for improved performance, supporting algorithms as a basis for processing circuits, connections between the solution of hard computational problems and overcoming classical limitations in sensing and metrology, entanglement as a resource, and suitable physical systems and key demonstration experiments.

Quantum Computation and Quantum Networking

Quantum computing and networking will entail the control and manipulation of quantum bits with high fidelity. The objective is the experimental demonstration of quantum logic performed on several quantum bits operating simultaneously, which would represent a significant advance toward that ultimate goal of beyond classical capabilities in information processing. Demonstrations of quantum feedback and error correction for multiple quantum bit systems are also of interest. There is particular interest in developing quantum computation algorithms that efficiently solve classically hard problems, and are useful for applications involving resource optimization, imaging, and the simulation of complex physical systems. Examples include machine learning, parameter estimation, constrained optimization, and quantum chemistry, among others. The ability to transmit information through quantum entanglement distributed between spatially-separated quantum entities has opened the possibility for new approaches to information processing. Exploration of quantum networking of information and distributed quantum information processing based on entanglement is of interest. These include the exploration of long-range quantum entanglement, entanglement transfer among different quantum systems, and long-term quantum memory.

Army Research Office (ARO) Research Topic

Title: Solid State Electronics and Electromagnetics
Announcement ID: ARL-BAA-0028

TPOC: Joe X. Qiu, PhD - joe.x.qiu.civ@army.mil - (919) 549-4297
ARL Office: Army Research Office (ARO)
Discipline: Electronics;Materials Science;Physics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Network, Cyber, and Computational Sciences;Photonics, Electronics, and Quantum Sciences
Army Modernization Priorities: Network/C3I
Keywords: Electronics; Heterostructures; Devices

Description:
This research area emphasizes efforts to discover and create unique electromagnetic phenomena in solid-state materials and structures. Innovative research is sought in areas involving quantum phenomena, internally and externally induced stimulus, and novel transport and electromagnetic interaction effects in solid-state electronic structures. This basic research will address issues related to design, modeling, fabrication, testing and characterization to include the ability to individually address, control, and modify structures, materials and devices, and the assembly of such structures with atomic-scale control into systems. It will seek to realize advanced device concepts with revolutionary capabilities.

This program will explore the latest developments in semiconductor materials and device physics, such as negative capacitance transistors, tunneling field effect transistors and ultra-wide bandgap materials. More importantly, it will emphasize scientific discoveries in the frontier of nanoelectronic materials and structures. Scientific opportunities in this research include, but are not limited to, quantum-confined structures (nano-tubes/-wires/-dots) and large- scale precise alignment and integration of these structures to create collective behaviors; 2D atomic crystals and their heterostructures; complex heterostructures of 2D crystals, topological insulators, Dirac and Wely semimetals and other dissimilar nanoelectronic materials potentially leading to unique interfacial phenomena; spintronic, valleytronic, and mixed domain (charge/spin/quantum degrees of freedom) device concepts. Of interest are quantum transport phenomena such as ballistic transport and hydrodynamic flow, dissipationless transport in topologically protected edge states, and pseudo-relativistic transport of massless Dirac fermions. Exotic electromagnetic phenomena which require theoretical formulations beyond the well-established Maxwell’s equations, such as axion electrodynamics, chiral anomaly and spontaneous symmetry breaking, are also relevant. Interfacial proximity effects in these heterostructures that lead to unique electromagnetic properties will also be considered.

This document updated as of 9/28/2023

Army Research Directorate (ARD) Research Topic

Title: High Voltage/High Frequency Power Switching Devices
Announcement ID: ARL-BAA-0060

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ARL Office: Army Research Directorate (ARD)
Discipline: Electronics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Energy Sciences
Army Modernization Priorities: Air and Missile Defense;Future Vertical Lift;Next Generation Combat Vehicle
Keywords: HV semiconductors, power switches

Description:
Research into semiconductor power devices in the following three thrust areas:

1. Device design and fabrication of monolithic and hybrid voltage-controlled SiC or GaN high-temperature high-field power devices.
2. High-temperature high-field insulator materials for use as gate dielectric and field passivation layers for application to SiC and/or GaN power devices.
3. Advanced Technology Computer-Aided Design (TCAD) modeling methods, techniques and/or material models that advance computational efficiency or accuracy.

Army Research Directorate (ARD) Research Topic

Title: Novel Solid State Lasers and Laser Materials
Announcement ID: ARL-BAA-0053

TPOC: Mark Dubinskiy, PhD - mark.dubinskiy.civ@army.mil - (301) 394-1821
ARL Office: Army Research Directorate (ARD)
Discipline: Materials Science;Physics
ARL Foundational Research Competencies: Energy Sciences
Army Modernization Priorities: Air and Missile Defense;Future Vertical Lift
Keywords: laser, Raman, solid-state, fiber, bulk, crystalline

Description:
The Army is interested in research on innovative gain media, for example laser-quality ceramics with emphasis on engineerable doping and index profile (e.g., gradient doping, sharp-step waveguiding structures, planar and circular, with sub-10-micrometer diffusion zone); solid-state materials for high-gain stimulated Brillouin scattering (SBS); specialty fibers and fiber lasers suitable for high average powers and power scaling (e.g., fibers with glass compositions having an ultra-low SBS gain and/or ultra-high Raman gain; low-loss fully crystalline double-clad, i.e., crystalline core/crystalline cladding, fibers; glass fiber designs with developed mode selection mechanisms or self-mode selection; fiber designs with specialty wavelength-selective properties, e.g., for Raman suppression); advanced laser materials for diode-pumped eyesafe lasers (e.g., based on high and ultra-high thermal conductivity hosts, environmentally stable ultra-low-phonon hosts, or gain materials with exceptionally high emission/absorption cross-sections).

Army Research Directorate (ARD) Research Topic

Title: Quantum Entanglement Science and Efficient Light-Matter Interaction
Announcement ID: ARL-BAA-0052

TPOC: Brenda L VanMil – Brenda.l.vanmil.civ@army.mil - (301) 394-0979
ARL Office: Army Research Directorate (ARD)
Discipline: Materials Science;Physics
ARL Foundational Research Competencies: Photonics, Electronics, and Quantum Sciences
Army Modernization Priorities: Assured PNT;Network/C3I
Keywords: quantum; positioning, navigation, timing (PNT); quantum information science; atomic clocks; entanglement; quantum sensing;

Description:
Over the past century, the quantum principles of superposition, electronic structure, and uncertainty relations gave us tremendous advances in a number of applications relevant to the military, including atomic clocks, magnetometry, positioning/navigation/timing (PNT), and gravimetry. While these areas can still be improved through technological advances, next-generation gains in sensing and in secure communications will occur through the concept of quantum identicality and quantum entanglement.

Our efforts conduct cross-cutting foundational research to exploit quantum effects for (1) novel sensors and capabilities, (2) beyond-classical sensor performance limits using entanglement, and (3) entanglement-enhanced information processing, decision-making, and security. Research emphasizes strong light-matter interfaces, including cavity quantum electrodynamics (QED) and nanophotonic integration. Examples of relevant research include electromagnetic field sensing using Rydberg atoms, solid-state "atomic" clocks, solid-state defects for sensing and quantum information, nanophotonics, and building blocks of entanglement distribution (quantum memories, repeaters, hybrid interfaces, etc).

Army Research Directorate (ARD) Research Topic

Title: Quantum Information Science and Positioning, Navigation, and Timing (QIS-PNT)
Announcement ID: ARL-BAA-0051

TPOC: Adam Schofield, PhD - adam.r.schofield2.civ@army.mil - (443) 395-0621
ARL Office: Army Research Directorate (ARD)
Discipline: Materials Science;Mechanics;Physics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences;Photonics, Electronics, and Quantum Sciences
Army Modernization Priorities: Assured PNT
Keywords: positioning, navigation, and timing (PNT); quantum information science; quantum sensing

Description:
The Quantum Information Science and Positioning, Navigation, and Timing (QIS-PNT) Essential Research Program (ERP) is the Army's leader in continuously transforming quantum information science and PNT to outpace our adversaries through discovery and innovation of novel sensing capabilities and quantum approaches to ensure seamless navigation and communication across all combat environments.

Mission
provide the expertise and component technologies to foster transformational improvements to the accuracy and resiliency of Army PNT and quantum sensing capabilities that improve the maneuver, FIRES, and communication capabilities of the future force.

Goals and Objectives
1. Provide a suite of PNT technologies that can be tailored and fused to improve the Army's ability to meet diverse platform/system/mission requirements
2. Improve availability and precision synchronization of time beyond current GPS time transfer capabilities
3. Provide improved resilience of position information at GPS-level accuracy and precision greater than GPS
4. Improve access to and integrity of navigation and communications information
5. Identify, develop, and evaluate quantum mechanical principles and quantum phenomena to support revolutionary advances in sensing capabilities, including clocks, sensing, and communications

Army Research Directorate (ARD) Research Topic

Title: Quantum networking for communications, distributed entanglement and information processing
Announcement ID: ARL-BAA-0082

TPOC: Quantum Networking Team - devcom-arl-quantum-networking@army.mil
ARL Office: Army Research Directorate (ARD)
Discipline: Computer Science;Network Science
ARL Foundational Research Competencies: Network, Cyber, and Computational Sciences
Army Modernization Priorities: Network/C3I
Keywords: Quantum optics, quantum information distribution, trapped ion quantum information, quantum entanglement distribution, quantum networking experiment/theory

Description:
The Army seeks proposals in the development of quantum networks to advance performance metrics across a range of applications, including information distribution/security/processing, logistics, conventional networking and computing.

Technical areas of interest include experimental and theoretical work in the following topics:

- Quantum network connectivity, including methods for preservation and characterization of quantum signals, including polarization preservation, frequency-control and timing distribution for network control.
- Development of quantum-based networking models involving quantum information distribution, processing, error-correction and protocols for state characterization and tomography.
- Strong light-matter interfaces including nanophotonic light manipulation and quantum frequency conversion.
- Trapped ion quantum networking, including photon-mediated entanglement-based networking.
- Quantum networking technologies for quantum nodes, quantum information generation, routing, detection, measurement and control.
- Entanglement-enhanced information processing, decision-making, and data security.

Army Research Directorate (ARD) Research Topic

Title: RF-to-THz Devices and Integrated Circuit Technology
Announcement ID: ARL-BAA-0063

TPOC: Dmitry A. Ruzmetov, PhD - dmitry.a.ruzmetov.civ@army.mil - (301) 394-0423
ARL Office: Army Research Directorate (ARD)
Discipline: Electronics;Materials Science;Physics
ARL Foundational Research Competencies: Electromagnetic Spectrum Sciences
Army Modernization Priorities: Air and Missile Defense;Long Range Precision Fires
Keywords: RF, UWB, diamond

Description:
ARL is interested in research on innovative electronic substrates, epitaxial materials, devices, monolithic circuits, and integration techniques for digital, mixed-signal, RF, millimeter-wave to Terahertz (THz) applications, including radar, communications, electronic warfare, and sensor systems. Research should involve materials, devices, integrated circuits, and subsystems built upon advanced Si-based, III–V, III-nitride, and II-VI materials, ultra-wide bandgap semiconductors (i.e. diamond), novel device structures, nano-technology innovative circuit topology, and multi-level, and/or heterogeneous integration technology. The research may also include related device, circuit, subsystem, and system level CAD modeling and analysis to achieve optimal performance.

Army Research Directorate (ARD) Research Topic

Title: Techniques and Sources Enabling Major Power Scaling of Diode-Pumped Solid-State Lasers (fiber and bulk)
Announcement ID: ARL-BAA-0054

TPOC: Mark Dubinskiy, PhD - mark.dubinskiy.civ@army.mil - (301) 394-1821
ARL Office: Army Research Directorate (ARD)
Discipline: Materials Science;Physics
ARL Foundational Research Competencies: Energy Sciences
Army Modernization Priorities: Air and Missile Defense;Future Vertical Lift
Keywords: Pump couplers, splicing dislike materials, fiber-coupled diode modules

Description:
The Army is interested in innovative highly efficient pump-coupling techniques; innovative pump diode and active medium cooling techniques (e.g., cooling via optically transparent highly thermoconductive materials); passive and active laser beam/aperture combining methods; advanced fiber splicing techniques, as it pertains to splicing silica glass to dislike materials, e.g., alternative glasses, as well as YAG, Sapphire, silicon nitride materials; laser wavelength shifting techniques and materials for achieving high average powers with emphasis on eye-safety and emission in best atmospheric propagation bands; development of surface patterning techniques with anti-reflection and high reflection properties. Of special interest is research and development enabling fiber-coupled laser diode sources with output brightness exceeding current state-of-the-art by a factor of 10 or more.