2022 Laboratory University Collaboration Initiative (LUCI) Funding Opportunity Announcement

The Office Of The Under Secretary Of Defense For Research and Engineering (OUSD(R&E), Basic Research Office (BRO) is pleased to announce the 2022 Laboratory University Collaboration Initiative (LUCI) Competition is now open!

Submission of White Paper packages are due **Friday March 18th, at 11:59PM ET**.

Please view the current version of the FY22 LUCI Funding Opportunity Announcement here for additional information. Questions about white papers and eligibility can be submitted to the LUCI Administrators listed at the bottom of this page.

Topics of Interest:

The research topics of interest for the white-papers are described in broad terms in the Federal Opportunity Announcement (FOA) for the FY22 VBFF program, which can be found here. They include:

Area 1: Applied Mathematics and Computational Sciences
Area 2: Networks and Artificial Intelligence
Area 3: Cognitive Neuroscience
Area 4: Fundamentals of Bioengineering
Area 5: Quantum Information Science
Area 6: Electronics, Photonics Quantum Materials
Area 7: Engineered Materials and Structures
Area 8: Others Fields of Research

Please review the full announcement here to learn more about each topic area and also read the FY21 LUCI Awardee announcement below to learn more about projects that were selected during last competition. The FY22 LUCI webinar is expected to be held in early February 2022.

LUCI Administrators:

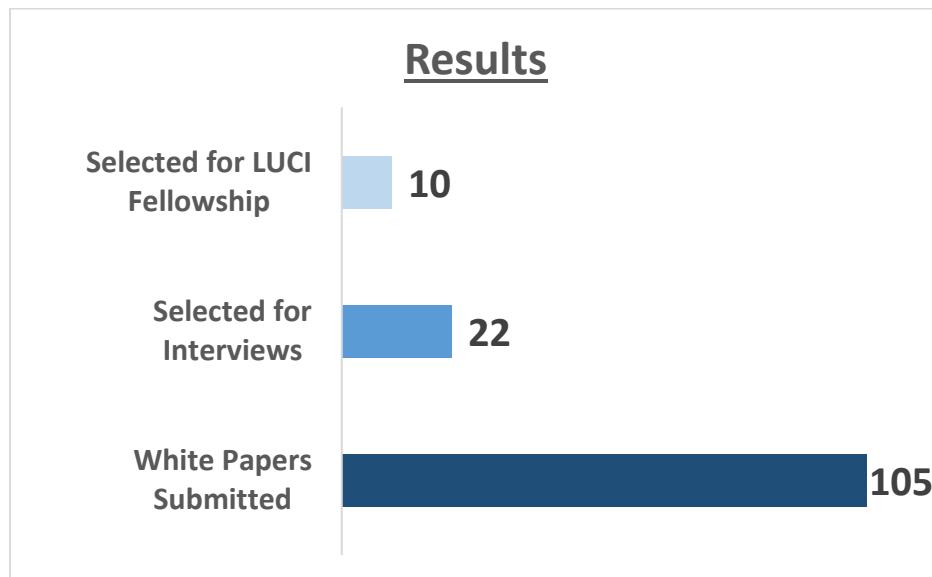Jean-Luc Cambier, Program Director

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2021 LUCI AWARDEE ANNOUCEMENTS

BACKGROUND: The Basic Research Office at OUSD (R&E) is pleased to announce the 2021 class of Laboratory-University Collaboration (LUCI) Fellows. LUCI fellows are highly accomplished 6.1 researchers in the DoD laboratories that wish to partner with top tier DoD-funded academic researchers.

The LUCI program is very competitive. Below are the summary of the results:

Results

Category	Value
Selected for LUCI Fellowship	10
Selected for Interviews	22
White Papers Submitted	105

U.S. NAVAL RESEARCH LABORATORY	ARL	AFRL
3	5	2

Please find below the chart of 10 Fellows/co-Fellows that have been selected, and summaries of their projects:

PI	Project Title	Collaborator
Luke Johnson (NRL)	Statistical Formulation of Nonlinear Optics for Describing the Propagation of Partially Coherent, High Power Laser Beams	Thomas Antonsen (U. of MD)
Cyril Williams (ARL)	High Pressure Laser-Driven Shock Waves: Tabletop Generation and Characterization	Keith A Nelson (MIT)
Suya You (ARL)	Learning to Generate Synthetic Datasets for Machine Learning	Leonidas J. Guibas (Stanford)
Luke Baldwin and Christopher Crouse (AFRL)	Rethinking how we Synthesize Materials: Functionalization of Carbon Derived Nanomaterials using Continuous Flow Chemistry	Timothy Swager (MIT)
Patrick Taylor and Mahesh Neupane (ARL)	Distorted Bands in Topological Quantum Materials	Joseph Heremans (Ohio State University)
Dashiell Vitullo (ARL)	Highly Nonlinear Optical Cavities for Quantum Networks	Dirk Englund (MIT)
Sang-Yeon Cho and Weimin Zhou (ARL)	Low-dimensional Meta-Optics with Unusual Physical Properties for Novel Device Concepts	Andrea Alu (CUNY)
Jorge Benavides and Svetlana Harbaugh (AFRL)	Development of Semi-Specific Transcription Factor Arrays for Bio-signature Sensing	Andrew Ellington (UTA)
Stanislav Tsoi (NRL)	Revealing Electron Correlations in Moiré Superlattices by van der Waals Force Microscopy	Phillip Kim (Harvard U.)
Janice Boercker (NRL)	Coupling Infrared Excitons and Plasmons in Hybrid Nanostructures	Cherie Kagan and Christopher Murray (UPenn), Chad Mirkin (Northwestern)

Research Summaries

LUCI Fellow: Dr. Luke A. Johnson, US Navy Research Laboratory

University Collaborator: Prof. Thomas Antonsen (University of Maryland)

Title: *Statistical Formulation of Nonlinear Optics for Describing the Propagation of Partially Coherent, High-Power Laser Beams*

Project Description: The Department of Defense is currently exploring advanced concepts and applications for high-power lasers. For directed energy applications, they have potentially deep magazines, high precision, speed-of-light delivery, and the ability to cause scalable effects. But high-power laser beams intrinsically fluctuate shot-to-shot or develop fluctuations after transmission through media such as ocean surface waves or turbulent atmospheric layers. With the development of high-repetition rate, high-average power-pulsed lasers, it is critical to understand how initial field fluctuations evolve with the subsequent nonlinear propagation of the laser. This program will develop the statistical formulation of nonlinear optics by adapting analytic methods previously used for the study of two-dimensional, chaotic microwave cavities. By leveraging expertise developed by collaborator Prof. Thomas Antonsen (University of Maryland) in past MURIs, we plan on demonstrating the role that optical field fluctuations and correlations play in phenomena, such as, laser filamentation, modulation instabilities, and harmonic generation. This will enable enhanced control of high-power lasers in order to advance applications in directed energy, power beaming, and laser communications.

LUCI Fellow: Dr. Cyril Williams, US Army Research Laboratory
University Collaborator: Prof. Keith A Nelson (Massachusetts Institute of Technology)

Title: *High Pressure Laser-Driven Shock Waves: Tabletop Generation and Characterization*

A wide range of physical and chemical transformations are possible under shock loading at extreme pressures, but achieving shock pressures exceeding 100 GPa and reaching the TPa range has only been possible at large-scale facilities with limited access. The experimental throughput at such facilities are measured in units of few experiments per day. We propose to apply a laser-driven 2D shock focusing technique developed at the Institute for Soldier Nanotechnologies at MIT (ISN@MIT) to study samples fabricated from metallic alloys with ultra-fine and nanocrystalline grains developed at the US Army Research Laboratory (USARL). Measurements will be made on samples with dimensions of tens of microns under extreme shock pressures, with multiple measurements possible in a single hour. These studies will unveil the fundamental mechanisms that give rise to the enhanced mechanical properties and shock mitigation behavior of USARL advanced alloys. More broadly, the project will yield revolutionary advancement in the study of materials under extreme dynamic conditions at pressures approaching or reaching the TPa range to be accessed on an ordinary laser tabletop using commonly available commercial lasers.

LUCI Fellow: Dr. Suya You, US Army Research Laboratory
University Collaborator: Prof. Leonidas J. Guibas (Stanford University)

Title: *Learning to Generate Synthetic Datasets for Machine Learning*

Synthetic data with ground-truth labels is becoming a vital component in machine learning (ML) pipelines for the purposes of training, benchmarking, and diagnosing cutting-edge ML algorithms, due to the lack of sufficient annotated real-world data, especially in military mission-related contexts. Traditional way of using modeling tools or simulators to manually creating synthetic data is a tedious and non-scalable task. Recent advances in deep generative modeling have led to tremendous breakthroughs in synthetic image generation, but they lack controllability of the output and offer no guarantees that the generated images are fully consistent with real-world object structures and semantics. As a result, an important performance issue arises when deploying the synthetic models, due to the domain gap existing between synthetic and real-world domains. This gap must be adequately reconciled; otherwise, intolerable erroneous inferences are entailed, preventing AI agents from successful operations in the real-world environments. Synthetic data generation has been a major bottleneck in most current machine learning pipelines, which needs to be immediately addressed to facilitate DoD research and development in autonomy, artificial intelligence and machine learning. This LUCI research, in collaboration with Professor Leonidas Guibas at Stanford, aims to systematically study innovative theory and practical solutions, consisting of a synergistic suite of novel approaches for generating high-quality synthetic data with realistic structure, geometry, and appearance, together with full semantic annotations, in ways that are controllable, efficient, and automated. The core of the research consists of two novel technical pillars named "Learning-for-Synthesis" and "Synthesis-for-Learning" that, for the first time, enable ML synthetic training data to be produced respecting the functional and physical properties of real 3D scenes.

LUCI Fellow: Dr. Luke Baldwin, US Air Force Research Laboratory
Co-PI: Christopher Crouse, US Air Force Research Laboratory
University Collaborator: Prof. Timothy Swager (Massachusetts Institute Technology)

Title: *Rethinking how we Synthesize Materials: Functionalization of Carbon Derived Nanomaterials using Continuous Flow Chemistry*

The capacity to engineer materials for defense applications is built on our ability to employ synthetic methods to create novel materials and compounds, including the modification of nanomaterials. Carbon derived nanomaterials, such as carbon nanotubes and graphene, are an attractive class of materials with unique physical, mechanical and electronic properties. As a result of their relatively low reactivity however, their chemical modification, or functionalization, typically requires high temperatures, long reaction times, and a large excess of reagent. To address these limitations, our proposal aims to explore continuous flow chemistry as an emergent method to functionalize carbon nanomaterials. Flow chemistry, where chemical reactions are performed in millimeter diameter tubing, offers efficient mixing & heat transfer, high pressure, scalability, automation, and the ability to generate reactive species in a controlled manner. The objective of this LUCI is to explore innovative covalent and non-covalent functionalization methods, performed in a flow reactor, to modify carbon derived nanomaterials and control their properties. Furthermore, this proposal will investigate the application of machine-learning techniques to map the chemical reaction space and optimize synthetic methods for nanomaterial functionalization in flow. This collaborative effort between Dr. Baldwin, Dr. Crouse and Professor Timothy Swager at Massachusetts Institute of Technology is expected to provide innovative approaches to chemically modify nanomaterials and provide a new pathway towards the discovery of novel materials for sensors, optoelectronics and composites.

LUCI Fellow: Dr. Patrick Taylor, US Army Research Laboratory
CoPI: Mahesh Neupane, US Army Research Laboratory
University Collaborator: Prof. Joseph Heremans (Ohio State University)

Title: *Distorted Bands in Topological Quantum Materials*

The emergence of topological insulator (TI) phenomena has changed the trajectory of condensed matter physics, and presages revolutionary solid-state devices for electro-optical sensing and low-power electronics for the warfighter. The feature of TI materials that would enable such new device technologies is the presence of spin-momentum-locked Dirac-like surface states that are both immune to backscattering and acutely sensitive to circularly polarized light. A key challenge to transitioning these game-changing TI technologies to the warfighter is enabling the dominance of Dirac-like transport at 300 K. To do so requires reducing unwanted scattering between the Dirac-like states and parasitic bulk states. Dr. Taylor and Prof. Jos. Heremans at The Ohio State University will explore the basic science of novel band-structure distortions such as incorporating both resonant and magnetic dopants in TI that work to prevent dissipative scattering between the Dirac surface states and bulk states. If successful, new pathways to position the Fermi level within the bulk bandgap of TIs will be obtained and these desirable TI device capabilities can be transitioned to US DoD systems.

LUCI Fellow: Dr. Dashiell Vitullo, US Army Research Laboratory
University Collaborator: Prof. Dirk Englund (Massachusetts Institute Technology)

Title: *Highly Nonlinear Optical Cavities for Quantum Networks*

Nonlinear optical interactions enable one light field to control another with a nearly instantaneous response time, and they have tremendous potential for enabling fast optical information processing. These interactions can take place when different light fields are combined in a suitable ("nonlinear") material. The interactions are fundamentally weak (low success probability), but the interaction strength can be greatly enhanced in a low-loss optical cavity that confines light into nanoscale volumes. Dr. Vitullo (ARL) and Professor Dirk Englund (MIT) will collaboratively develop optical cavities that maximize nonlinear interaction strength while simultaneously minimizing the amount of light lost, to produce cavities that are suitable for distributing and controlling quantum light. This enables creation of quantum networks, which are platforms that support applications in secure communication and remote sensing. This fundamental research paves the way towards disruptive speed improvements for classical information processing using optical neural networks, and game-changing SWaP-c improvement for quantum networks through enabling optical quantum information processing at room temperature.

LUCI Fellow: Dr. Sang-Yeon Cho, US Army Research Laboratory
Co-PI: Dr. Weimin Zhou, US Army Research Laboratory
University Collaborator: Prof. Andrea Alù, The City University of New York

Title: *Low-dimensional Meta-Optics with Unusual Physical Properties for Novel Device Concepts*

 Current photonic systems include the traditional bulky 3D free-space optics, fiber-optic-based devices/systems, and integrated semiconductor-waveguide-based photonic circuits, comprising of a group of discrete components. Those devices are separately designed and independently optimized to control the properties, such as amplitude, phase, and polarization of optical beams. Recently, 2D metamaterial-based devices, namely metasurfaces, have emerged as a new class of optical devices that are based on extraordinary optical phenomena and have great potential for replacing most of the existing optical devices. There are many applications that require both free-space optical transmission/reception and optical signal processing, such as 5G optical Wi-Fi, laser communications, and free-space optical time transfer for positioning, navigation and timing. In this LUCI project, the ARL researchers and Prof. Andrea Alù's group at CUNY will jointly develop a radically different integrated photonic platform using low-dimensional meta-optic components for handling both free-space and in-plane optical signal processing in a single chip-scale photonic system. The researchers at ARL will explore new meta-optic-based devices and systems for the Army's critical applications, such as Positioning Navigation and Timing and free-space optical communications. This LUCI program will allow us to build a strong collaboration and partnership with the university researchers so that new academic scientific discoveries can be transitioned to ARL's R& D activities directly addressing DoD's technology needs.

LUCI Fellow: Dr. Jorge Benavides, US Air Force Research Laboratory
Co-PI: Dr. Svetlana Harbaugh, US Air Force Research Laboratory
University Collaborator: Prof. Andrew Ellington, University for Texas Austin

Title: *Development of Semi-Specific Transcription Factor Arrays for Bio-signature Sensing*

The goal of this project is to develop a pipeline to engineer the affinity of transcription factors (TFs) to become semi-specific for chemically-related molecules associated with Warfighter's health and performance. A novel and rapid approach to TFs engineering will be applied to naturally occurring specialist (bind their targets with high selectivity) and semi-specific (respond to multiple targets) TFs in whole cells and their associated cell-free transcription systems to create recognition elements that bind classes of biomarkers related to conditions like stress and fatigue, such as catecholamines or indolamines. We will explore the use of a large array of these semi-specific TFs to classify biosignatures, which we defined as a set of biomarkers associated with a specific condition, mimicking the function of the senses of smell and taste. TFs activation will result in the synthesis of specific transcripts to be captured in an electrode array for high density interrogation of biomarker responses to different stressors and, potentially, identification of novel biosignatures.

LUCI Fellow: Dr. Stanislav Tsoi, US Navy Research Laboratory
University Collaborator: Prof. Phillip Kim (Harvard University)

Title: *Revealing Electron Correlations in Moiré Superlattices by van der Waals Force Microscopy*

Electron systems exhibit a wide range of physical behavior. The simplest and best understood system is non-interacting electrons, exemplified by the technologically important class of semiconductors. In contrast, strongly correlated electron systems are governed by interactions between electrons, which often leads to unusual behavior, e.g. superconductivity. Understanding strongly correlated systems requires detailed measurement of physical quantities containing the correlation information, e.g. the dielectric function. This program will attempt to access the elusive wavevector-dependence of the dielectric function by probing van der Waals interactions of a correlated electron system realized in moiré superlattices with a nanoscale tip of the atomic force microscope. A potential payoff includes identification of the specific electron interactions responsible for correlations and clarification of the mechanisms of high-temperature superconductivity.
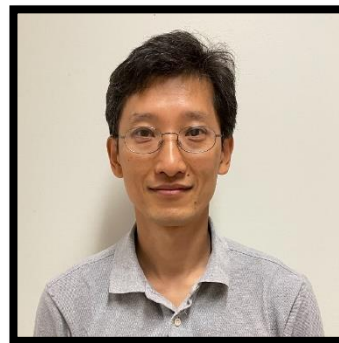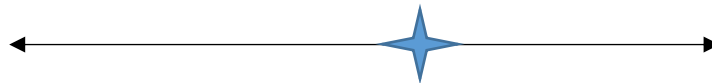
LUCI Fellow: Dr. Janice Boercker, US Navy Research Laboratory
University Collaborator: Profs. Cherie Kagan and Christopher Murray (University of Pennsylvania), Chad Mirkin (Northwestern University)

Title: *Coupling Infrared Excitons and Plasmons in Hybrid Nanostructures*

As a result of their size dependent optical properties, high quantum yields, and low manufacturing costs, colloidal inorganic nanocrystals are attractive for novel infrared (~ 1 µm to ~5 µm) technologies; however, they suffer from the absorption-extraction compromise and detrimental effects from non-radiative recombination. Our solution to these two limitations is to create hybrid nanostructures that combine an excitonic material with a plasmonic material. In collaboration with Prof. Chad Mirkin (Northwestern), Prof. Cherie Kagan (UPenn), and Prof. Christopher Murray (UPenn), we propose to controllably couple excitons to plasmons in hybrid nanostructures using three parallel strategies, 1) connecting an excitonic and plasmonic material in uniform core/shell nanocrystal structures 2) assembling both excitonic nanocrystals and plasmonic nanocrystals in ordered binary superlattices 3) using template-confined DNA-mediated assembly to combine one excitonic and one or two plasmonic nanocrystals into a vertical architecture. We will be using doped plasmonic nanocrystals for the plasmonic component as the more commonly used metallic nanocrystals have resonances limited to the visible spectra range. In all three proposed hybrid nanostructure architectures, the plasmonic and excitonic materials are intimately connected, which allows the exciton to couple with the plasmon thereby resulting in increased absorption and faster radiative recombination rates. The magnitude of these enhanced properties will be directly related to the strength of the exciton-plasmon coupling. Thus, the main scientific goal of this project is to develop the basic chemistry knowledge required to realize these novel hybrid nanostructures, and then to investigate the basic physics of how the design of these structures affects the coupling strength and overall enhancement of emission and absorption, with an eye towards maximizing this coupling. Success of this program will provide the DoD with critical new technologies such as room temperature, low SWaP-c (size, weight, power, and cost), highly efficient, infrared photodetectors and skillfully tailored light sources such as single-photon emitters.