Office of the Undersecretary of Defense, Research and Engineering (OUSD(R&E))
Basic Research Office (BRO)
23.B Small Business Technology Transfer (STTR)
Proposal Submission Instructions

INTRODUCTION

The Office of the Undersecretary of Defense, Research and Engineering (OUSD(R&E)) Basic Research Office (BRO) STTR Program aims to facilitate the transition of basic research to applied research by collaborations between academic researchers and small businesses, as well as stimulating technological innovation, strengthening the role of small business in meeting DoD research and development needs, fostering and encouraging participation by minority and disadvantaged persons in technological innovation, and increasing the commercial application of DoD-supported research or research and development (R&D) results. The BRO STTR program focuses on exploiting scientific discoveries from the DoD Basic Research Programs and providing a mechanism to further scientific development, maturation, and commercialization. **High-risk with potential for high-reward approaches are sought in addressing the scientific challenges described in the topics below**. These approaches should be stimulated by early research in academia supported by DoD basic research programs.

Proposers responding to a topic in this BAA must follow all general instructions provided in the Department of Defense (DoD) 23.B STTR Program BAA.

Proposers are encouraged to thoroughly review the DoD Program BAA and register for the DSIP Listserv to remain apprised of important programmatic and contractual changes.

- The DoD Program BAA is located at: https://www.defensesbirsttr.mil/SBIR-STTR/Opportunities/#announcements. Be sure to select the tab for the appropriate BAA cycle.
- Register for the DSIP Listserv at: https://www.dodsbirsttr.mil/submissions/login.

OSD BRO requirements in addition to or deviating from the DoD Program BAA are provided in the instructions below.

Specific questions pertaining to the administration of the OSD BRO STTR Program and these proposal preparation instructions should be directed to: Dr. Jennifer Becker, jennifer.j.becker.civ@army.mil

Phase I is to determine, to the extent possible, the scientific, technical, and commercial merit and feasibility of ideas submitted under the STTR Program. Proposals should concentrate on research or R&D that will significantly contribute to proving the scientific and technical feasibility and commercialization potential of the proposed effort, the successful completion of which is a prerequisite for further DoD support in Phase II. **Phase I proposals should clearly articulate the basic research advances that will be exploited. Phase I proposals should also include a tentative plan for Phase II. Evaluation of the Phase I proposal will include an assessment of not only the feasibility studies planned for Phase I, but the overall approach and product proposed at the end of Phase II.** The BRO anticipates funding up to two (2) STTR Phase I contracts to small businesses with their research institution partner for each topic. The BRO reserves the right to not fund a topic if the proposals received have insufficient merit.

The Phase I Base amount must not exceed $150,000 over a period of exactly 6 months and the Phase I Option amount must not exceed $100,000, with a period of performance of exactly 6 additional months.

PHASE I PROPOSAL GUIDELINES

The Defense SBIR/STTR Innovation Portal (DSIP) is the official portal for DoD SBIR/STTR proposal submission. Proposers are required to submit proposals via DSIP; proposals submitted by any other means will be disregarded. Detailed instructions regarding registration and proposal submission via DSIP are provided in the DoD STTR Program BAA.

Technical Volume (Volume 2)

The technical volume is not to exceed 15 pages and must follow the formatting requirements provided in the DoD STTR Program BAA. Technical volumes exceeding 15 pages will be deemed non-compliant and will not be evaluated**.**

Content of the Technical Volume

In addition to the Phase I proposal content specified in DoD STTR Program BAA, this program requires a narrative description on how early research in academic labs will be transitioned to the small business via this opportunity. In addition, the Phase I Technical Proposal must also include a preliminary Phase II Plan specifying the overall vision, approach, and potential product proposed at the end of Phase II. This must all be included within the 15 page limit for the technical volume.

Include, within the 15-page limit of Volume 2, an Option that furthers the effort in preparation for Phase II and will bridge the funding gap between the end of Phase I and the start of Phase II. Tasks for both the Phase I Base and the Phase I Option must be clearly identified. Option tasks should be those tasks that would enable rapid transition from the Phase I feasibility effort into the Phase II prototype effort.

Cost Volume (Volume 3)

The Phase I Base amount must not exceed $150,000 and the Phase I Option amount must not exceed $100,000. Costs for the Base and Option must be separated and clearly identified on the Proposal Cover Sheet (Volume 1) and in Volume 3.

Company Commercialization Report (CCR) (Volume 4)

Completion of the CCR as Volume 4 of the proposal submission in DSIP is required. Please refer to the DoD STTR Program BAA for full details on this requirement. Information contained in the CCR will not be considered by OSD BRO during proposal evaluations.

Supporting Documents (Volume 5)

BRO will only accept Supporting Documents required by the DoD STTR Program BAA.

PHASE II PROPOSAL GUIDELINES

Phase II proposals may only be submitted by Phase I awardees. All Phase I awardees are eligible to submit a Phase II proposal. Please note that Phase II selections are based, in large part, on the success of the Phase I effort, so it is vital for small business concerns to discuss the Phase I project results with their BRO Technical Point of Contact (TPOC). The 30-day window to submit a Phase II proposal will commence at the end of the Phase I Base Period. The details on the due date, content, and submission requirements of the Phase II proposal will be provided to Phase I awardees by the BRO STTR PMO via subsequent notification. This will be the only opportunity to submit a Phase II proposal for the BRO topics. The BRO STTR Program *cannot* accept proposals outside the Phase II submission dates established. Proposals received by the DoD at any time other than the submission period will not be evaluated.

Phase II proposals are expected to be structured as follows: a 10-12 month base period not to exceed $850,000; a 10-12 month option period not to exceed $850,000. The entire Phase II effort should not exceed $1,700,000.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)

Technical and Business Assistance is not offered for the OSD BRO topics.

EVALUATION AND SELECTION

All proposals will be evaluated in accordance with the evaluation criteria listed in the DoD STTR Program BAA. The criteria will be in descending order of importance with technical merit, soundness, and innovation of the proposed approach being the most important, followed by qualifications of key personnel, and then followed by the commercialization potential. **Evaluation of the Phase I proposal will include an assessment of not only the feasibility studies planned for Phase I but the overall approach and product proposed at the end of Phase II.** Due to limited funding, the BRO reserves the right to limit awards under any topic. Awards will be made on the basis of technical evaluations using the criteria described in the DoD STTR Program BAA and availability of BRO STTR funds.

Only Government personnel will evaluate proposals with the exception of personnel from Strategic Analysis, Inc who will provide programmatic and administrative assistance for all topics.

Proposing firms will be notified of selection or non-selection status for a Phase I award within 90 days of the closing date of the BAA. Email notifications of selection or non-selection will be sent to the point-of-contact listed as the Corporate Official on the proposal Cover Sheet. Consequently, the e-mail address on the proposal Cover Sheet must be correct.

Requests for a debrief must be made within 30 calendar days of select/non-select notification as specified in the select/non-select notification. Please note debriefs are typically provided in writing via email to the Corporate Official identified in the firm proposal within 30 days of receipt of the request. Requests for oral debriefs may not be accommodated. If contact information for the Corporate Official has changed since proposal submission, a notice of the change on company letterhead signed by the Corporate Official must accompany the debrief request.

Refer to the DoD STTR Program BAA for procedures to protest the Announcement.
As further prescribed in FAR 33.106(b), FAR 52.233-3, Protests after Award should be submitted to: usarmy.rtp.aro.mail.sttr-pmo@mail.mil

AWARD AND CONTRACT INFORMATION

The Phase I Base amount must not exceed $150,000 over a period of exactly 6 months and the Phase I Option amount must not exceed $100,000, with a period of performance of exactly 6 additional months.

ADDITIONAL INFORMATION

Companies should plan carefully for research involving animal or human subjects, biological agents, etc. (Reference details provided in the DoD STTR Program BAA). The short duration of a Phase I effort may preclude plans including these elements unless coordinated before a contract is awarded.

If the offeror proposes to employ a foreign national, refer to the DoD STTR Program BAA for definitions and reporting requirements. Please ensure no Privacy Act information is included in this submittal.

If a small business concern is selected for an STTR award, they must negotiate a written agreement between the small business and their selected research institution that allocates intellectual property rights and rights to carry out follow-on research, development, or commercialization (See Model Agreement for the Allocation of Rights).

END

OSD-BRO STTR 23.B Topic Index

O23B-001	Dispersion engineered electrically small antennas
O23B-002	Ultra-Compact Wideband Electro-Optic Modulator based on Ferroelectric Materials
O23B-003	Advanced Metrology of High Thermal Conductivity Materials and Interfaces

O23B-001 TITLE: Dispersion engineered electrically small antennas

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics

OBJECTIVE: Design, fabricate, and demonstrate electrically small antennas with enhanced bandwidth going beyond the fundamental bounds dictated by Chu’s limit. The proposed electrically small antennas should involve dispersion engineered matching loads using tailored dispersive materials or circuits that will allow tailoring the bandwidth independently from the stored energy in the system, resulting in electromagnetic radiation with higher data rates than conventional antennas. Dispersion engineering may be achieved through suitable electromagnetic design, metamaterial loading, and/or circuit loads implementing desirable frequency dispersion features. The final layout should include all relevant components to tune the antenna for operation beyond Chu’s limit.

DESCRIPTION: The need for broader bandwidth in electrically small antennas is one of the most challenging tasks in the general area of antenna design for energy and information transfer, and it is of particular relevance to DoD in the low-frequency regime. Significant advances have been recently made in the realization of electrically small antennas operating close to Chu’s lower bound on bandwidth, and theoretical proposals to overcome this bound have been put forward, with important opportunities for communication systems and energy harvesting. Chu’s lower bound on the quality factor of linear, passive, time-invariant, one-port dipole antennas characterized by a single resonance dictates the maximum achievable bandwidth for given volume and efficiency. Recently it has been recognized that simple matching networks with dispersive materials can overcome these constraints and operate beyond Chu’s lower bound. Dispersion engineering in the form of metamaterial loading, multiple coupled self-resonant modes and/or circuit loading relying on tailored loss and dispersion can be used to enhance the bandwidth of electrically small antennas beyond Chu’s lower bound, still retaining a passive approach. Antennas can be loaded with passive matching networks, which so far have been used to extend the bandwidth by coupling multiple resonances together in order to operate close to the Bode-Fano bound on matching bandwidth. This approach, however, comes with several drawbacks, including introduced signal distortion within the impedance bandwidth, large and dispersive group delay, and inefficiencies associated with a large stored energy.

The goal of this STTR is to demonstrate passive electrically small antennas targeting the HF or UHF band supporting data rates beyond state-of-the-art antennas that approachChu’s lower bound. The antennas should have a return loss of at least -6dB at the input port, with a radiation efficiency larger than 70%, an effective stored energy equal or lower than that based on operation with a single-resonant matching network, and a flat group delay across the enhanced bandwidth of operation. The demonstrated antenna should be low-profile, with or without a closely spaced ground plane.

PHASE I: In the Phase I effort, a complete design of a passive electrically small antenna operated beyond Chu’s lower bound shall be demonstrated. Proof-of-principle simulations based on accepted methods and computational techniques shall be provided. Comparison of performance metrics to include the bandwidth anticipated by the proposer, efficiency, group delay, and stored energy with conventional approaches to impedance matching of small antennas, should be carried out.

PHASE II: In the Phase II effort, the experimental procedures outlined and begun in Phase I shall be realized, and the fabrication and full characterization of the radiation properties of the devices shall be reported. The radiation pattern as a function of frequency across the bandwidth proposed in Phase I shall be verified, clearly demonstrating the behavior proposed in Phase I. Demonstration of broadband response well beyond Chu’s lower bound should be sought after. Comparison of performance metrics to include bandwidth, efficiency, group delay, and stored energy with conventional approaches to impedance matching of small antennas, should be carried out in the experiments, and a demonstration of higher data rates in a standard communication setup should be pursued.

PHASE III DUAL USE APPLICATIONS: The Phase III work will demonstrate the reliability and scalability of the proposed antennas, their compact form factor including the matching network and feed, and their integrability in standard communication systems, including applying relevant modulation strategies for signal communications. A partnership with industry to commercialize the technology will be created, aiming for both DoD as well as scientific and civilian applications.

REFERENCES:

1. L. J. Chu, “Physical limitations of omni-directional antennas”, J. Appl. Phys. 19, pp. 1163-1175, 1948;
2. Yaghjian, Arthur D. "Overcoming the Chu lower bound on antenna Q with highly dispersive lossy material." IET Microwaves, Antennas & Propagation 12.4 (2018): 459-466;
3. Yaghjian, Arthur D., and Steven R. Best. "Impedance, bandwidth, and Q of antennas." IEEE Transactions on Antennas and Propagation 53.4 (2005): 1298-1324;
4. A. Mekawy, H. Li, Y. Ra’di, and A. Alù, "Parametric Enhancement of Radiation from Electrically Small Antennas," Physical Review Applied, vol. 15, no. 5, p. 054063, 05/27/ 2021

KEYWORDS: electrically small antennas; Chu’s limit; dispersion engineered

O23B-002 TITLE: Ultra-Compact Wideband Electro-Optic Modulator based on Ferroelectric Materials

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics; Quantum Science; Space Technology; Advanced Materials

OBJECTIVE: Develop a new ultra-compact, wideband, electro-optic modulator by exploiting ferroelectric materials for the purpose of radio frequency (RF) photonic link applications in DoD platforms.

DESCRIPTION: The replacement of the coaxial cable used in various onboard RF/analog applications with RF/analog fiber optic links requires ruggedized, high dynamic range and wideband electro-optic modulators. Current military communications and electronic warfare systems require ever increasing bandwidths while simultaneously requiring reductions in size, weight and power (SWaP). Replacement of the coaxial cabling would provide increased immunity to electromagnetic interference, reduction in size and weight, and an increase in bandwidth and power, however it requires an innovative modulator to complete the system. The ability to harness and control the electro-optic effect in a sub-micron-thick film of a ferroelectric could revolutionize optical switches used in Si photonics. To fully realize the tremendous potential of this novel concept, ferroelectric materials on silicon, which have the largest electro-optic coefficients known for a low loss material, show promise. Recent advances in film growth methods that allow for fabrication of ferroelectric transition metal oxides directly on Si created ground-breaking opportunities in silicon photonics, a hybrid technology combining semiconductor logic with optical information technologies.

The desired electro-optic modulators used in RF/analog fiber optic links must be compatible with distributed feedback (DFB) lasers with greater than 100 mWatts of single-mode fiber coupled optical power. These modulators in the future might have dual outputs for use with balanced photo detector receivers which would enable a higher link gain, a lower noise figure and a higher spur free dynamic range, as required in DoD systems. A minimum 3 dB optical bandwidth of up to 40 GHz is required, with V-pi less than 5V at 40GHz and below, and it must be compatible with emerging systems out to 100 GHz. A twofold reduction in SWaP requirements as compared to current electro-optic modulators must be achieved without any degradation in device performance. A future major challenge that must be analyzed is to develop a new compact modulator packaging approach that can achieve operation over a minimum temperature range of -40 to +120 degrees Celsius to avoid material specific phase transition, this will likely require active temperature controls to operate. This key criterion must be met without sacrificing modulator bandwidth and drive voltage efficiency, while demonstrating low optical insertion loss at fiber-coupled DFB laser powers up to 200 mWatts, and possibly higher in the future.

PHASE I: Develop a ferroelectric on silicon modulator fabrication process, demonstrate feasibility of the modulator with a supporting proof of principle bench top experiment, and analyze electro-optic modulator performance to meet the target metrics identified above.

PHASE II: Optimize the growth and processing techniques required for the modulator fabrication. Initially the modulators will likely be stand-alone devices but by the end of phase II a roadmap must be developed for transition to heterogeneous fabrication of integrated systems. At the end of phase II demonstration of greater than 2 square centimeters of high-quality single domain ferroelectric material must be attained, along with a demonstration of reliable fabrication processes for either fiber coupled or integrated modulators exceeding 3dB optical bandwidth at frequency 40GHz or higher and identification most pertinent direction and use of optical coefficients, i.e., r_{33} or r_{42}.

PHASE III DUAL USE APPLICATIONS: Perform extensive modulator reliability and durability testing. Develop packaging for both stand alone and integrated systems. Transition the demonstrated technology to Air platforms and interested commercial applications. The technology would find application in commercial systems such as fiber optic networks and telecommunications.

REFERENCES:

1. A. Rahim, A. Hermans, B. Wohlfeil, D. Petousi, B. Kuyken, D. Van Thourhout and R. Baetsa, “Taking silicon photonics modulators to a higher performance level: state-of-the-art and a review of new technologies,” Adv. Photonics 3, 024003 (2021);
2. S. Abel, F. Eltes, J. E. Ortmann, A. Messner, P. Castera, T. Wagner, D. Urbonas, A. Rosa, A. M. Gutierrez, D. Tulli, P. Ma, B. Baeuerle, A. Josten, W. Heni, D. Caimi, A. A. Demkov, J. Leuthold, P. Sanchis and J. Fompeyrine, “Large Pockels effect in micro- and nano-structured barium titanate integrated on silicon,” Nature Materials 18, 42 (2019);
3. C. Xiong, W. H. P. Pernice, J. H. Ngai, J. W. Reiner, D. Kumah, F. J. Walker, C. H. Ahn, and H. X. Tang, "Active Silicon Integrated Nanophotonics: Ferroelectric BaTiO3 Devices," Nano Letters 14, 1419 (2014).

KEYWORDS: Ultra-Wideband; Electro-Optic Modulator; Dual-Output; Extended Temperature Range; Analog Fiber Optic Links

O23B-003 TITLE: Advanced Metrology of High Thermal Conductivity Materials and Interfaces

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics

OBJECTIVE: Develop a turnkey system to measure the thermal conductivity and thermal boundary resistance of wide bandgap semiconductor films, interfaces, and substrates.

DESCRIPTION: Future military platforms will require high-power converters for propulsion, sensors, and directed energy systems. The power densities for these converters necessitate high-voltage, high-efficiency power switches based on the application of wide bandgap (WBG) and ultra-wide bandgap (UWBG) semiconductor thin films, because of their wide bandgaps and high breakdown fields. An added benefit of these materials is their intrinsically large thermal conductivities, which can help to mitigate extreme temperature rises during power cycling and high-power operation. For example, isotopically pure diamond can have thermal conductivities of 3000 $W \cdot m^{-1} \cdot K^{-1}$, low defect AlN films were recently shown to have thermal conductivities over 300 $W \cdot m^{-1} \cdot K^{-1}$, and homoepitaxially grown GaN films can have thermal conductivities near 200 $W \cdot m^{-1} \cdot K^{-1}$. However, these large thermal conductivities are often not observed when WBG materials are integrated into power devices. It is well known that defects arising from material growth, interfaces from heterogeneous integration, and dopant species used to tune electrical properties all scatter phonons leading to reductions in thermal conductivity. The resultant reduced thermal conductivity, itself a temperature-dependent quantity, in integrated materials compromise high power devices and can lead to device failure and/or dictate lower max power thresholds. Given the large thermal resistances that occur at heterogeneous interfaces, especially at interfaces of WBG and UWBG materials, measurements of thermal boundary resistances in the 1-100 $m^2 \cdot K/GW$ range are similarly crucial to and predictive of reliable device operation.

The current state-of-the-art for laboratory measurements are thermoreflectance-based techniques that can measure the thermal conductivity of thin films with accuracy significantly higher than that available in commercial systems. Further, control of laser spot sizes these techniques allows for micron-scale spatial resolution of thermal conductivity on sample surfaces, which can reveal spatial inhomogeneities due to dislocations, defects, grain boundaries, and other growth-related phenomena. A major limiting factor in the use of these thermoreflectance techniques for wide scale materials characterization is their complicated, free space design on open optical tables that is not conducive to turnkey operation, even with a highly-skilled technician operating and aligning these systems full time. An additional limitation is the need for user-friendly and versatile instrument control software and analysis codes that can be widely used to acquire and analyze measurement data. The development of a reliable, repeatable, and fully automated tool that harnesses the sensitivities and resolution of free-space thermoreflectance systems is thus a key to establishing consistent and common measurements of materials for DoD applications. This necessitates a system design that does not require optical maintenance or alignment of laser paths to ensure day-to-day repeatability and accuracy when operated by different users. Such a tool would be of significant use for testing a wide array of materials for both military and civilian applications, including hybrid electric vehicles. Recent advances in fiber-optic-based thermoreflectance systems show promise to meet these requirements; however, any approach that has potential to achieve the desired measurement capabilities will be considered.

PHASE I: Establish design of a temperature-dependent (25-225 °C) thermal conductivity measurement system that can produce highly accurate (± 5%) and reproducible (± 1%) measurements of the thermal conductivity in both thin films and bulk substrates of wide bandgap semiconductors, as well as thermal boundary resistance in the 1-100 $m^2 \cdot K/GW$ range across semiconductor interfaces at the wafer scale. The system should have micrometer area resolution and depth resolution capable of measuring atomically thin interfaces/contacts to thin films and buried substrates with device relevant length scales. The system should be designed for ease and repeatability of measurements among multiple users. Demonstrate the capability of measuring the thermal conductivity of materials ranging from 0.1 $W \cdot m^{-1} \cdot K^{-1}$ to 2000 $W \cdot m^{-1} \cdot K^{-1}$ through experimentation or detailed modeling. Perform an initial estimate of size, weight, and cost of production unit, as well as technical risks to be addressed during potential Phase II.

PHASE II: Refine Phase I design and fabricate a fully-functional prototype system having automated data collection and analysis capabilities. The system should be able to measure thermal conductivity of materials as high as 3000 $W \cdot m^{-1} \cdot K^{-1}$, measure thermal boundary resistance independently from thermal conductivity of materials, and resolve these properties and thermal resistances of thin film stacks with dimensions and temperatures appropriate for power electronic devices, as well as perform these measurements on an electronic device or test structure under nominal voltage and current operating conditions. Data reduction should be available in analysis codes with GUIs that can rapidly analyze large data sets. Deliver a fully operational prototype of the measurement system, including appropriate control and analysis software, to the Navy for evaluation.

PHASE III DUAL USE APPLICATIONS: Develop final design and manufacturing plans using the knowledge gained during Phases I and II in order to support transition of the technology for Navy use and adoption in the WBG/UWBG device community. A thermal conductivity measurement tool of this design will enable cost- and time-effective material evaluation of high-power devices.

REFERENCES:

1. D. G. Cahill, "Analysis of heat flow in layered structures for time-domain thermoreflectance," Review of Scientific Instruments 75, 5119-5122 (2004);
2. A. J.. Schmidt, R. Cheaito and M. Chiesa, "A frequency-domain thermoreflectance method for the characterization of thermal properties," Review of Scientific Instruments 80, 094901 (2009);
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4. Naval Power and Energy System Technology Development Roadmap. https://www.navsea.navy.mil/Resources/NPES-Tech-Development-Roadmap/;
5. U. S. Drive Electrical and Electronics Technical Team Roadmap. https://www.energy.gov/eere/vehicles/downloads/us-drive-electrical-and-electronics-technical-team-roadmap

KEYWORDS: Thermal Conductivity; Thermal Boundary Resistance; Thermoreflectance; Wide Bandgap Semiconductors