Microsystems Exploration Topic (μE)
DARPA-PA-21-05-01
Steerable Optical Aperture Receivers (SOAR)

I. Topic Description

The Defense Advanced Research Projects Agency (DARPA) is issuing a Microsystems Exploration topic (μE) inviting submissions of innovative basic or applied research concepts in the technical domain of miniature optical beam steering. This μE is issued under the Program Announcement for Microsystems Exploration, DARPA-PA-21-05. All proposals in response to the technical area(s) described herein will be submitted to DARPA-PA-21-05 and if selected, will result in an award of an Other Transaction (OT) for prototype project not to exceed $1,000,000.

A. Introduction

On both receive and transmit, optical beam steering is fundamental to the operation of broad classes of optical systems, such as those used for free-space optical communications (FSOC) and light detection and ranging (lidar). Today, optical beam steering is primarily accomplished by mechanical means, using a gimbal or motor to point the lenses of a telescope or other optical assembly. However, the size and weight of gimbal-based beam steering systems severely limits deployment on small and autonomous vehicles, whose proliferation for consumer and military applications increasingly calls for onboard FSOC and lidar capability.

Inspired by electronically steered phased arrays for high-performance radiofrequency systems, researchers in recent years have pursued a variety of gimbal-free optical beam steering methods that promise rapid, fine pointing control over wide-angle fields of view (FOV). Further, the rise of integrated photonics, in which microscopic devices on chips replicate the functions of discrete optics, offers dramatic size reduction and new, complex optical system architectures that are impractical at the macroscopic scale. This μE is intended to follow these trends by answering key outstanding questions on receiver performance, scalability, and integration.

B. Objective

Steerable Optical Aperture Receivers (SOAR) will identify promising new approaches to optical beam steering in miniature form factors, and experimentally demonstrate their operation in receive mode for small aperture sizes. The μE seeks to develop optical interfaces that can receive light from any direction without a priori knowledge of the incoming angle. The SOAR interface must actively steer the angle of acceptance in order to either (i) acquire and couple the input beam into a common output mode defined by the proposer, or (ii) detect the optical signal within the receiver interface. Proposers should assume that an input beam will impinge on the aperture from any angle within the FOV identified in Table 1.

DARPA expects that demonstrations will include a test setup that tunes the input angle as well as a control system that both sets the required steering configuration and reads out the input angle with precision equal to or better than the Table 1 angular resolution metric.

Phase 1 of SOAR will focus on receiver design and process development to determine whether the structure can be fabricated within the program. Phase 2 will proceed to receiver fabrication, with experimental metrics identified in Table 1. Phase 2 will also include a transceiver design study on

aperture scalability and system integration. The purpose of this continued analysis in Phase 2 is to determine the design and fabrication advances required to scale to operationally-relevant apertures, as well as the architecture or basic design of an optical transceiver system built around the receiver concept. The transceiver study goals noted in Table 1 represent the analysis design target, and study findings will assist in determining the feasibility of future program investments in miniature optical transceiver systems. While proposals to SOAR are accountable for meeting the experimental metrics defined in Table 1, proposals will also be evaluated upon compatibility with the transceiver study goals. Compatibility implies that:

a) The form factor of beam steering components can be miniaturized in volumes significantly smaller than 100 cc,
b) The physical mechanisms of the beam steering concept are consistent with scaling FOV and aperture area,
c) The physical mechanisms of the beam steering concept can be accomplished at high speed, with pointing time faster than 100 µs, and modest power consumption such that control of a large-area apertures can be accomplished with portable power supplies, and
d) The proposed choice of output mode will not dictate an impractical transceiver system architecture.

Table 1. SOAR Performance Goals

Metric	Units	Phase 1^	Phase 2	
		Receiver Design Study	Receiver Experimental Metrics	Transceiver Design Study
Key Deliverables	-	Design Data	Test Data	Simulation Data, Basic Design Data
Operation Mode	-	Rx only	Rx only	Tx and Rx
Field of View	degree	30° × 30°	30° × 30°	120° × 120°
Aperture Area	mm × mm	0.03 × 0.03	0.03 × 0.03	10 × 10
Coupling Loss	dB	10*	10*	3**
Angular Resolution†	diffraction limit	2x	2x	2x
Operating Wavelength‡	µm	1.5 or Proposer Defined	1.5 or Proposer Defined	1.5 or Proposer Defined
Power Consumption Density§	µW/µm^2	10	10	0.2
Beam Pointing Time	µs	-	-	100
Side Mode Suppression	dB	-	-	20
System Volume	cc	-	-	100

^ Receiver design study to be completed by month 6 detailed in an end of phase report with simulations justifying performance and fabrication methodology towards achieving the experimental metrics in Phase 2
* Including only the summed series insertion losses of components in beam path
** Ratio of output mode power to input mode power
† Angular resolution must be demonstrated by reading out the angle of incidence from the controller of the optical receiver for multiple input beams
‡ Operation in the optical C band is assumed, but proposers may define a different wavelength by providing a justification based on a compelling use case of the technology
§ Areal power density required to steer the aperture, approximately equal to power per element for proposals pursuing an optical phased array (OPA) approach

Proposals should identify the relevant device-level parameters required to accomplish concepts. For example, an optical phased array (OPA) approach operating at 1.5 µm would entail at least 100 elements with 3 µm pitch to meet Table 1 experimental goals, and scalability to greater than

10^8 elements with half-wavelength pitch to support transceiver design study goals. Considering that a nominal OPA architecture includes a phase shifter and free-space coupler in each element, such requirements demand novel component development beyond the capabilities of planar integrated photonics, wherein modulators commonly employ millimeters of propagation to accumulate significant phase shifts. In addition to footprint challenges, the power consumption required to tune each phase shifter could potentially sum to Watts of power to steer a large-scale aperture.

Note that OPA parameters are only provided in the above paragraph as an example, as SOAR is technology-agnostic and open to any concept that meets the Table 1 experimental metrics and are compatible with transceiver design study goals. Proposals utilizing innovative methods including, but not restricted to, two-dimensional OPAs, non-planar integrated photonics, optical metasurfaces, directional optical scattering techniques, and discrete micro-optics are of interest. Concepts that leverage motorized steering of discrete optics are unlikely to enable either high-speed steering or miniature optical transceivers, and are therefore not of interest. While SOAR does not require the ability to generate multiple simultaneous beams, this capability is of interest to DARPA and should be noted in proposals for concepts that enable such a goal.

C. Structure

Proposals submitted to DARPA-PA-21-05 in response to the technical area of this μE topic must be UNCLASSIFIED and must address two independent and sequential project phases: a Phase 1 Feasibility Study (base) and a Phase 2 Proof of Concept (option). The period of performance for these phases are 8 months for the Phase 1 base effort and 10 months for the Phase 2 (option) effort. Combined Phase 1 base and Phase 2 option efforts proposed to this μE topic should not exceed 18 months. The Phase 1 (base) award value should not exceed $400,000. The Phase 2 (option) award value should not exceed $600,000. Both Phase 1 and Phase 2 value limits include any performer cost share. The total award value for the combined Phase 1 and Phase 2 is limited to $1,000,000. This total value includes both Government award funding and any performer cost share, if required or proposed. Please review DARPA-PA-21-05 for requirements regarding cost share. The anticipated program funding will be 6.2. Therefore, research conducted by universities (prime or subcontractor) would be considered fundamental research and research conducted by all other organizations (prime or subcontractor) would be restricted (non-fundamental) research.

Proposals should clearly detail:

- The proposed receive optical interface concept and method of beam steering
- The components and fabrication processes required to accomplish the concept
- Experimental, simulation, and/or analytical evidence to support meeting Phase 2 experimental metrics
- Compatibility factors supporting transceiver design study goals
- A constructive technical development plan and schedule
- Risks and risk mitigation strategies

The Government reserves the right to select for negotiation all, some, one, or none of the proposals received in response to this topic announcement. Additionally, the Government reserves the right to award all, some, one, or none of the options on the agreements(s) of the Phase 1 performers based on available funding, Phase 1 technical performance, and an assessment of the feasibility of the approach.

D. Schedule/Milestones

Proposers must address the following Research Project Objectives, metrics, and deliverables, along with fixed payable milestones in their proposals. The task structure must be consistent across the proposed schedule, Task Description Document (TDD), and the Vol. 2 - Price Volume. If selected for award negotiation, the fixed payable milestones will be directly incorporated into Attachment 3 of the OT agreement ("Schedule of Milestones and Payments") with milestone amounts calculated based on the proposed accumulation of monthly amounts up to each milestone date. Please see the sample OT for Prototype provided as an attachment to DARPA-PA-21-05.

Phase 1 Tasks:

- Receiver design and simulation
- Fabrication process development
- Aperture component fabrication and characterization

Phase 1 efforts should result in a finalized receiver design and an established process capable of fabricating the structure. Performers will be advanced to Phase 2 based on simulation results consistent with achieving Table 1 experimental metrics, and evidence that the structure can be fabricated and tested by the end of the Phase 2 period of performance. While the Phase 1 period of performance will be 8 months to complete tasking, a phase transition briefing is required by month 6 to ensure adequate time to execute Phase 2 options.

Phase 2 Tasks:

- Fabrication of aperture
- Construction of multi-angle input beam test setup
- Test of receiver
- Scalability and integration design study

The outcome of the Phase 2 should consist of an experimental demonstration of the prototype receiver and a paper study on scalability and integrability. Together, these data will be used to determine the feasibility of future DARPA investments that incorporate gimbal-free optical beam steering into operationally-relevant aperture sizes and compact optical transceiver systems.

Fixed milestones for the program must include:

Milestone #	Milestone	Exit Criteria /Deliverable	Due Date
Phase 1			
1	Initial optical design including simulation data; Begin fabrication process development	Milestone Report	Month 1
2	Complete optical design including simulation data; Fabrication process development results; Begin aperture component fabrication	Milestone Report	Month 3
3	Phase transition briefing	Milestone Report	Month 6
4	Complete fabrication process development and demonstration of each process step; Characterize aperture components	Milestone Report	Month 8
Phase 2			
5	Begin aperture fabrication; Begin construction of test setup; Begin scalability and integration design analysis	Milestone Report	Month 9
6	Interim report on fabrication progress and results; Initial test data; Interim analysis results	Milestone Report	Month 12
7	Complete fabrication; Begin characterization of final aperture devices	Milestone Report	Month 15
8	Complete testing; Deliver report on experimental data; Deliver design study report on scalability and integration analyses	Milestone Report, Experiment Report, Analysis Report	Month 18

For planning and budgetary purposes, proposers should assume a program start date of December 12, 2022. Schedules will be synchronized across performers, as required, and monitored/revised as necessary throughout the program.

All proposals must include the following meetings and travel in the proposed schedule and costs:

- To foster collaboration between teams and disseminate program developments, a two-day Principal Investigator (PI) meeting will be held approximately every six months. For budgeting purposes, plan for three two-day meetings over the course of 18 months: two meetings in the Washington, D.C. area and one meeting in the San Francisco, CA area.
- Regular teleconference meetings will be scheduled with the Government team for progress reporting as well as problem identification and mitigation. Proposers should also anticipate at least two site visits by the DARPA Program Manager during which they will have the opportunity to demonstrate progress towards agreed-upon milestones.

E. Deliverables

Phase 1 and 2 deliverables will be reports detailing the results of the Phase 1 and 2 milestones as

indicated in Section D. This includes the submission of narrative reports and supporting PowerPoint presentations via teleconference or in person for each milestone.

II. Award Information

Selected proposals that are successfully negotiated will result in the award of an OT for prototype project. See Section 3 of DARPA-PA-21-05 for information on awards that may result from proposals submitted in response to this notice.

Proposers must review the model OT for Prototype Agreement provided as an attachment to DARPA-PA-21-05 prior to submitting a proposal. DARPA has provided the model OT in order to expedite the negotiation and award process and ensure DARPA achieves the goal of Microsystems Exploration, which is to enable DARPA to initiate a new investment in less than 90 days from each μE topic announcement. The model OT is representative of the terms and conditions that DARPA intends to award for all Microsystems Exploration Awards. The task description document, schedule of milestones and payments, and data rights assertions requested under Volumes 1, 2, and 3 will be included as attachments to the OT agreement upon negotiation and award.

As discussed in DARPA-PA-21-05, Section 5, "Application and Submission Information," proposers may suggest edits to the model OT for consideration by DARPA and provide a copy of the model OT with track changes as part of their proposal package. It is strongly encouraged that proposers include comments providing rationale for any suggested edits of a non-administrative nature. Suggested edits may be rejected at DARPA's discretion. In order to ensure that DARPA achieves the Microsystem Exploration goal of award within 90 days from the posting date of the μE topic announcement, DARPA reserves the right to cease negotiations if the parties fail to reach an agreement on OT award terms and conditions within this time period. If edits to the model OT are not provided as part of the proposal package, DARPA assumes that the proposer has reviewed and accepted the award terms and conditions to which they may have to adhere and the sample OT agreement provided as an attachment, indicating agreement with the listed terms and conditions applicable to the specific award instrument.

III. Eligibility

See Section 4 of DARPA-PA-21-05 for information on who may be eligible to respond to this notice.

IV. μE Topic Responses

Responses to this μE topic must be submitted as full proposals to DARPA-PA-21-05 as described therein. All proposals must be unclassified.

A. Proposal Content and Format

All proposals submitted in response to this notice must comply with the content and format instructions in Section 5 of DARPA-PA-21-05. All proposals must use the templates provided as Attachments to the PA and follow the instructions therein.

Information not explicitly requested in DARPA-PA-21-05, its Attachments, or this notice may not be evaluated.

B. Proposal Submission Instructions

See Section 5 of DARPA-PA-21-05 for proposal submission instructions.

C. Proposal Due Date and Time

Proposals in response to this notice are due no later than 4:00 p.m. Eastern on October 13, 2022. Full proposal packages as described in Section 5 of DARPA-PA-21-05 must be submitted per the instructions outlined therein *and received by DARPA* no later than the above time and date. Proposals received after this time and date may not be reviewed.

Proposers are warned that the proposal deadline outlined herein is in Eastern Time and will be strictly enforced. When planning a response to this notice, proposers should take into account that some parts of the submission process may take from one business day to one month to complete (e.g., registering for Unique Entity ID or TIN, renewing entity registration in SAM.gov).

V. Proposal Evaluation and Selection

Proposals will be evaluated and selected in accordance with Section 6 of DARPA-PA-21-05. Proposers will be notified of the results of this process as described in Section 7.1 of DARPA-PA-21-05.

VI. Administrative and National Policy Requirements

Section 7.2 of DARPA-PA-21-05 provides information on Administrative and National Policy Requirements that may be applicable for proposal submission as well as performance under an award.

VII. Point of Contact Information

Dr. Jonathan Hoffman, Program Manager, DARPA/MTO, SOAR@darpa.mil

VIII. Frequently Asked Questions (FAQs)

All technical, contractual, and administrative questions regarding this notice must be emailed to SOAR@darpa.mil. Emails sent directly to the Program Manager or any other address may result in delayed or no response.

All questions must be in English and must include name, email address, and the telephone number of a point of contact. DARPA will attempt to answer questions publically in a timely manner; however, questions submitted within 7 days of the proposal due date listed herein may not be answered.

DARPA will post an FAQ list under the μE topic on the DARPA/MTO Opportunities page at

(http://www.darpa.mil/work-with-us/opportunities) The list will be updated on an ongoing basis until one week prior to the proposal due date. In addition to the FAQ specific to this notice, proposers should also review the Program Announcement for Microsystems Exploration General FAQ list on the DARPA/MTO Opportunities page under the Program Announcement (DARPA-PA-21-05).

To aid in the proposal preparation process, a Proposal Preparation Checklist and Tips document has been provided with the μE topic announcement on sam.gov. This document can also be found along with the FAQ posted on the DARPA/MTO Opportunities page at (http://www.darpa.mil/work-with-us/opportunities).