Request for Information (RFI)
DARPA-SN-20-43
Dots & Devices (D&D)

Responses Accepted: Until 4:00 PM (Eastern) on April 24, 2020
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Over the last decade, quantum dot materials have garnered interest because of their properties of tunable bandgap energies, quantum confinement, multi-exciton generation, and phonon quenching as well as the ability to be synthesized and assembled through solution processing techniques. These characteristics could potentially allow high performance and low-cost devices to be fabricated with variable and flexible form-factors. However, taking material advances demonstrated in laboratory studies and applying them to commercial devices is typically a difficult and time consuming effort. It is believed that improved models and design tools coupled with smart manufacturing and on-going developments in AI could provide a means to accelerate this process.

The Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office (DSO) is requesting information in multiple areas of research related to the accelerated development of quantum dot–based photon sensors for energies ranging from sub-eV to MeV. Applications of interest include infrared imaging, x-ray imaging, and high resolution gamma-ray spectroscopy. Specifically, this RFI seeks tools, approaches, and techniques that support the accelerated realization of quantum dot-based photon sensors and related devices for these applications. These may include:

1. multi-scale models that support predictive device performance;
2. advanced manufacturing techniques that facilitate the
    a. synthesis of quantum dots with desired properties at scale,
    b. manipulation and integration of quantum dots into layers and devices with desired performance,
    c. collection of quality in-situ, in-line, and test data[1]; and
3. workflows that incorporate aspects of artificial intelligence (AI) to enhance or move beyond the typical iterative design-make-test-analyze frameworks.

Quantum dot–based photon sensors of interest with desired performance characteristics are described below in three topic areas (TAs).

TA1 requests information on how the above tools, approaches and techniques could realize quantum dot-based gamma-ray detectors with high-purity germanium-like performance at room temperature operation with potentially non-planar form factors with the following desired characteristics:

- Energy resolution: < 1%
- Energy range: 30 keV to 3 MeV

[1] In-situ could be metrology within a process step, e.g. concentration or temperature; in-line could be metrology between processing steps, e.g. film thickness measurements or photoluminescence, and testing could be metrology including electrical tests of devices or test structures, e.g. IV curves or sheet resistances.

- Area: up to 10 cm x 10 cm, and potentially pixelated for imaging.
- Absorption equivalence: > 50% stopping power

TA2 requests information on how the above tools, approaches and techniques could realize quantum dot-based x-ray imagers with potentially non-planar form factors with the following desired characteristics:

- Energy resolution: < 1%
- Spatial resolution: < 150 µm
- Energy range: keV to 300 keV
- Area: exceeding 30 cm x 30 cm
- Absorption equivalence: > 50% stopping power

TA3 requests information on how the above tools, approaches and techniques could realize quantum dot-based high-performance mid-wave and long-wave infrared imagers with room temperature operation and the following desired characteristics:

- Detectivity (D*): > 1e11 Jones
- Spatial resolution: < 20 µm
- Area: 2048 x 2048 pixels

Related to the above tools, approaches and techniques, more accurate and computationally-efficient multi-scale quantum dot models could improve the design and integration of quantum dots and layers into device structures and facilitate optimization. Such models could include aspects of wave function engineering, quantum dot synthesis, assembly processes, and key interfaces while including means to quantify uncertainty. Multi-scale quantum dot models are envisioned to form an integral part of accelerated workflows in mapping a high-dimensional parameter space to desired dot, layer, and device properties. Multi-scale model inputs and outputs should be amenable to further AI optimization and be capable of making use of experimental data.

To enable the most effective devices for high resolution infrared through gamma ray sensing, new approaches will be needed in quantum dot synthesis and assembly. These could possibly include new techniques to deposit deep layers of precisely layered quantum dots, of potentially variable characteristics, that provide effective stopping power for photons while achieving reasonable large areas and maintaining excellent charge transport and collection properties.

Importantly, this RFI is soliciting responses on potential processes and approaches that enable complete device fabrication and that can be efficiently matured and implemented at scale and at low cost in commercial manufacturing. These potential processes should take advantage of current state of the art manufacturing processes currently used for photon, x-ray and gamma-ray detection, but could be informed by non-traditional techniques being applied to other application spaces. For example, advances in smart manufacturing technology could provide connected tooling that can generate and efficiently make available detailed metrology at the process step, layer, and device levels. Further, connected tooling could offer opportunities for real-time feedback control, optimization, and the coordination of high throughput screening (HTS) and experiments.

Finally, RFI responses on workflows that incorporate aspects of AI to enhance or move beyond typical iterative design-make-test-analyze frameworks are requested to potentially accelerate the development of high performance quantum dot based photon sensors. Such workflows are envisioned to make use of the multi-scale models and the advanced manufacturing techniques discussed above to optimize per cycle learning and device performance. For example, reinforcement learning could be applied to optimize HTS or recommend parameters for more computationally intensive device simulations in characterizing the design space. Similarly, multi-objective optimization techniques could be used to develop a device architecture that maximizes the information gained per sensed photon. Also of interest are variational methods which could provide a more natural representation for the underlying data, the quantification of uncertainty, and effective self-regularization.

Responses are desired for accelerating development from quantum dot design through complete device fabrication at Technology Readiness Level 5 and Manufacturing Readiness Level 5.

Any information that provides proof of feasibility, such as existing modeling, simulation, or empirical data, should be included. Please provide any documentation that outlines risks in the proposed approach and predicted costs to achieve a proof of concept demonstration as well as timeframes and proposed methods for judging progress and success of the approach.

Respondents may address multiple topic areas; however, a separate submission is required for each TA.

SUBMISSION FORMAT

Respondents to this RFI are encouraged to be as succinct as possible, while also providing actionable insight. Page limits for each section are indicated below. Format specifications for responses include 12-point font, single-spaced, single-sided, 8.5 by 11-inch paper, with 1-inch margins in MS Word or Adobe PDF format (and, as applicable, PowerPoint).

Respondents are responsible for clearly identifying proprietary information. Responses containing proprietary information must clearly mark each page containing such information with a label such as "Proprietary" or "Company Proprietary." DO NOT INCLUDE ANY CLASSIFIED INFORMATION IN THE RFI RESPONSE.

A. Cover Sheet (1 page): Provide the following information.
    1. Response Title
    2. Technical point of contact name, organization, telephone number, and email address
    3. Indicate the Topic Area(s) addressed by the response

B. Technical Description (7 pages)

C. Bibliography/References (2 pages)

D. Graphic Overview Slide (Optional): If desired, include a single PowerPoint slide that graphically depicts the main ideas of the response.

SUBMISSION INSTRUCTIONS AND CONTACT INFORMATION

All responses to this RFI must be emailed to DARPA-SN-20-43@darpa.mil. Responses will be accepted any time from the publication of this RFI until 4:00 PM (Eastern) on April 24, 2020. Early responses are encouraged.

All technical and administrative correspondence and questions regarding this RFI should also be sent to the same email address. Emails sent directly to the Program Manager may result in delayed/no response.

ELIGIBILITY

DARPA invites participation from all those engaged in related research activities and appreciates responses from all capable and qualified sources including, but not limited to, universities, university-affiliated research centers (UARCs), Federally-Funded Research and Development Centers (FFRDCs), private or public companies, and Government research laboratories.

DISCLAIMERS AND IMPORTANT NOTES

- This is an RFI issued solely for information and new program planning purposes; it does not constitute a formal solicitation for proposals. In accordance with FAR 15.201(e), responses to this RFI are not offers and cannot be accepted by the Government as such.
- Responses do not bind DARPA to any further actions related to this topic, including requesting follow-on proposals from respondents to this RFI.
- Submission is voluntary and is not required to propose to a subsequent Broad Agency Announcement (BAA) (if any) or other research solicitation (if any) on this topic.
- DARPA will not provide reimbursement for costs incurred in responding to this RFI.
- Respondents are advised that DARPA is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI.
- DARPA will disclose submission contents only for the purpose of review. Submissions may be reviewed by the Government (DARPA and partners); Federally Funded Research and Development Centers (FFRDCs); and Scientific, Engineering and Technical Assistance (SETA) support contractors.