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Proposal Number: 73616MSCF **Agreement Number: W911NF-18-1-0373**

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Report Date: 31-May-2019 Date Received: 28-Feb-2019
Final Report for Period Beginning 01-Sep-2018 and Ending 28-Feb-2019
Title: Meeting Support for the 2018 OSA Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator, 28-30 October, 2018
Begin Performance Period: 01-Sep-2018 **End Performance Period:** 28-Feb-2019
Report Term: 0-Other
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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: **STEM Participants:**

Major Goals: • Establish new directions for research with optically-active semiconductor defects that take advantage of the unique properties afforded by emerging materials.
• Bring together of a community of researchers with experience in opto-electronic, electrical, as well as opto-mechanically active materials to facilitate a survey of the field and recommendations for the most fruitful and relevant research directions that could lead to real-world applications.
• Develop new programs around niche or emerging areas within optics and photonics.
• Target topics and fields that do not have the critical mass needed to support an OSA topical meeting structure.
• Function to further the interest and support of promising topic areas, assessing the broader implications of the topic for future research and application.
• Explore possibilities for greater inclusion and propagation of the topic into peer-reviewed topical meeting and/or congresses or conferences.
• Encourage extensive formal and informal discussion and networking environment while establishing a sense of community among participants.
• Offer a valuable means of disseminating information and ideas in a way that cannot be achieved through the usual channels of communication – publications and presentations at large scientific meetings.

Accomplishments: The Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator was a three-day meeting to invigorate and explore opportunities and challenges for predicting, identifying, isolating, and utilizing promising new defect systems, particularly those in materials with unique optical, electrical, and mechanical properties. This small, invitation-only meeting gathered together experimental, computational, and theoretical scientists with experience in opto-electronic, electrical, as well as opto-mechanically active materials to discuss the future of quantum engineering with optically-active semiconductor defects. Through a combination of invited presentations and moderated group discussions, participants discussed recent progress in identifying and controlling new defect systems, addressed key challenges facing the field, and proposed solutions to overcome current limits and open new research areas. The hosts of this meeting were Audrius Alkauskas, Center for Physical Sciences and Technology, Lithuania; Lee Bassett, University of Pennsylvania, United States; and Kai-Mei Fu, University of Washington, United States.

The aim of this meeting was to kickstart discussions between experts in related but often non-intersecting communities that would advance materials, theory, and instrumentation to realize new quantum-coherent systems with unprecedented functionality. For example, the list of invited speakers included pioneers in the study of well-established defect-qubit systems like the diamond nitrogen-vacancy center, who could provide perspective on both the potential and challenges for using this system in applications ranging from secure quantum communication to nanoscale quantum sensing. At the same time, the program included experts in related areas of semiconductor defect science (e.g. for electronics, solid-state lighting, and laser physics), two-dimensional materials, and techniques for atomic-scale fabrication and characterization.

This meeting succeeded in creating an open environment where meaningful discussions took place concerning the prediction, creation, measurement, and use of systems designed around quantum defects. The results of those discussions are expected to lead to improved nanophotonic devices for quantum communication, quantum sensing, and better integration of those capabilities with nanoelectronic and nanophotonic device platforms. Those and other applications will impact the technical capabilities of the Army and other defense agencies for years to come and should lead to important enabling applications that will increase the economic competitiveness of the US.

Meeting Outcomes

The OSA Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator had a large impact in giving the participants both the understanding of differences between specific quantum defect systems (and therefore and understanding of what systems might be usable for specific applications) and where the research stands in predicting the behavior of different quantum defect materials. The standard system using nitrogen-vacancy centers in diamond was discussed, but also other important systems, such as defects in silicon carbide (SiC), zinc oxide (ZnO) and hexagonal boron nitride (h-BN). New two-dimensional material defects with heterostructures built from materials like Transition Metal Dichalcogenides (TMDs) were also discussed. The pros and cons of all of these systems were debated in detail, leading to a more complete understanding for all attendees of the current state-of-the-art. In addition, there was extended discussion about the current measurement techniques that are used to probe the host materials and defect species, including electron microscopy, a technique that can both image and create defects. There was fruitful discussion about using computational techniques to predict device parameters, including the relative merits of simpler phenomenological models, as well as how to determine the credibility of new computational techniques. Finally, there was an extended discussion about applications of quantum defect materials in such areas as quantum sensors, quantum communication, quantum memories, and quantum LEDs. There was detailed discussion (and debate) by the attendees about the best systems to use for various applications, especially since different applications placed different requirements on the host and defect properties.

It is expected that many new collaborations will come from the attendees of the meeting, especially from the younger researchers, who will be able to draw on the connections they made at the meeting with more senior researchers. The results of the meeting include a better understanding of the full scope of research in the area of defect engineering, including the theoretical modeling for specific host materials and defects, the measurement and testing of the resultant material systems, and the use of those systems for specific applications.

Significant Results

1. 40 individuals attended the meeting, including 82% from academia, 13% from government agencies and 5% corporations.
2. 30% of participants were international and 18% women attendees.
3. The Incubator featured 15 talks that presented a variety of topics over the course of two days.
4. The program included 6 moderated discussion periods where attendees explored opportunities and challenges for predicting, identifying, isolating, and utilizing promising new defect systems, particularly those in materials with unique optical, electrical, and mechanical properties.
5. The meeting included exposure to learning through invited talks, and also allowed smaller groups the intimate environment needed to nurture peer-to-peer relationships that help transfer knowledge and best practices.
6. The ARO grant funds were used to reduce the overall registration costs for all attendees by covering a portion of the general meeting costs.

Training Opportunities: Nothing to Report

Results Dissemination: The results of the Defect by Design Meeting have been disseminated to communities of interest through the following channels:
OSA website (https://www.osa.org/en-us/meetings/incubator_meetings/past_incubator_meetings/2018/osa_defects_by_design_incubator_quantum_nanophoto/)
OSA Blog (https://www.osa.org/en-us/the_optical_society_blog/2018/october/day_1_%E2%80%93_osa_incubator_defects_by_design_quantum_na/; https://www.osa.org/en-us/the_optical_society_blog/2018/october/day_2_defects_by_design_incubator/)

It is expected that the discussions and information exchanged during this meeting will directly lead to continuing high quality journal publications from all of the research groups that participated. During and right after the meeting a lively technical blog was posted online describing the highlights of the meeting (see above). In addition, an article is planned for publication in Optics and Photonics News, a technical magazine published by OSA.

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

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Participant: Michael Duncan
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
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Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Meeting Support for the 2018 Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator, 28-30 October 2018

CONFERENCE PROCEEDINGS

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Project Investigator:	Dr. Michael Duncan, mduncan@osa.org, 202-416-1902
Report Type:	Final

FOREWORD

The Optical Society received a grant in the amount of $20,000 from the U.S. Army Research Office (ARO) for the support of the 2018 Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator Meeting, which was held in Washington, DC, USA on 28-30 October 2018. This support is greatly appreciated.

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LIST OF APPENDIXES

Appendix A. Program Book

DISTRIBUTION STATEMENT

DISTRIBUTION A. Approved for public release: distribution unlimited.

ABSTRACT

The Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator was a three-day meeting held on 28-30 October, 2018 in Washington, DC. The meeting brought together experimental, computational, and theoretical scientists to discuss the future of quantum engineering with optically-active semiconductor defects. Through a combination of invited presentations and moderated group discussions, participants discussed recent progress in identifying and controlling new defect systems, addressed key challenges facing the field, and proposed solutions to overcome current limits and open new research areas.

The results of the meeting include a better understanding of the full scope of research in the area of defect engineering, including the theoretical modeling for specific host materials and defects, the measurement and testing of the resultant material systems, and the use of those systems for specific applications. This meeting succeeded in creating an open environment where meaningful discussions took place concerning the prediction, creation, measurement, and use of systems designed around quantum defects. The results of those discussions are expected to lead to improved nanophotonic devices for quantum communication, quantum sensing, and better integration of those capabilities with nanoelectronic and nanophotonic device platforms.

MAJOR GOALS

Incubator Program Goals

- Develop new programs around niche or emerging areas within optics and photonics.
- Target topics and fields that do not have the critical mass needed to support an OSA topical meeting structure.
- Function to further the interest and support of promising topic areas, assessing the broader implications of the topic for future research and application.
- Explore possibilities for greater inclusion and propagation of the topic into peer-reviewed topical meeting and/or congresses or conferences.
- Encourage extensive formal and informal discussion and networking environment while establishing a sense of community among participants.
- Offer a valuable means of disseminating information and ideas in a way that cannot be achieved through the usual channels of communication – publications and presentations at large scientific meetings.

Meeting Specific Goals

- Establish new directions for research with optically-active semiconductor defects that take advantage of the unique properties afforded by emerging materials.

- Bring together of a community of researchers with experience with experience in opto-electronic, electrical, as well as opto-mechanically active materials to facilitate a survey of the field and recommendations for the most fruitful and relevant research directions that could lead to real-world applications.

ACCOMPLISHMENTS

The Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator was a three-day meeting to invigorate and explore opportunities and challenges for predicting, identifying, isolating, and utilizing promising new defect systems, particularly those in materials with unique optical, electrical, and mechanical properties. This small, invitation-only meeting gathered together experimental, computational, and theoretical scientists with experience in opto-electronic, electrical, as well as opto-mechanically active materials to discuss the future of quantum engineering with optically-active semiconductor defects. Through a combination of invited presentations and moderated group discussions, participants discussed recent progress in identifying and controlling new defect systems, addressed key challenges facing the field, and proposed solutions to overcome current limits and open new research areas. The hosts of this meeting were Audrius Alkauskas, Center for Physical Sciences and Technology, Lithuania; Lee Bassett, University of Pennsylvania, United States; and Kai-Mei Fu, University of Washington, United States.

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The meeting discussed the following topics:

1. Why Defects?
   - What makes a “good” defect for quantum science & technology?
   - What existing application areas are best suited to quantum defects (and which are not)?
   - What new areas are ripe for exploration using quantum defects?

2. Defects in New Materials
    - How can we efficiently create & identify new defects?
    - How can we control defect creation and placement at the atomic scale?
    - What opportunities are provided by host materials “beyond group IV”?

3. Defects by Design
    - How can we predict defect properties to guide discovery?
    - What new theoretical tools are needed to give a holistic treatment and prevent “convergence to experiments”?
    - What is the importance and influence of the material host (e.g., dimensionality, composition, symmetry)? What are the most promising candidates?
    - How can we engineer desired defect properties (e.g., using nanophotonics, materials properties, device design, or active control schemes)?

Please see Appendix for a detailed schedule and list of presentations.

Meeting Outcomes

The OSA Defects by Design: Quantum Nanophotonics in Emerging Materials Incubator had a large impact in giving the participants both the understanding of differences between specific quantum defect systems (and therefore and understanding of what systems might be usable for specific applications) and where the research stands in predicting the behavior of different quantum defect materials. The standard system using nitrogen-vacancy centers in diamond was discussed, but also other important systems, such as defects in silicon carbide (SiC), zinc oxide (ZnO) and hexagonal boron nitride (h-BN). New two-dimensional material defects with heterostructures built from materials like Transition Metal Dichalcogenides (TMDs) were also discussed. The pros and cons of all of these systems were debated in detail, leading to a more complete understanding for all attendees of the current state-of-the-art. In addition, there was extended discussion about the current measurement techniques that are used to probe the host materials and defect species, including electron microscopy, a technique that can both image and create defects. There was fruitful discussion about using computational techniques to predict device parameters, including the relative merits of simpler phenomenological models, as well as how to determine the credibility of new computational techniques. Finally, there was an extended discussion about applications of quantum defect materials in such areas as quantum sensors, quantum communication, quantum memories, and quantum LEDs. There was detailed discussion (and debate) by the attendees about the best systems to use for various applications, especially since different applications placed different requirements on the host and defect properties.

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5. The meeting included exposure to learning through invited talks, and also allowed smaller groups the intimate environment needed to nurture peer-to-peer relationships that help transfer knowledge and best practices.
6. The ARO grant funds were used to reduce the overall registration costs for all attendees by covering a portion of the general meeting costs and for travel grants to key participants.

Invited Speakers and their Presentations

Overview & State of the Art, David Awschalom, University of Chicago, United States
Applications to Quantum Sensing, Fedor Jelezko, Ulm University, Germany
Applications to Quantum Communication, Dirk Englund, MIT, United States
History of Defect Discovery, Chris Van de Walle, UC Santa Barbara, United States
Efficient Defect Creation and Control, Jörg Wrachtrup, University of Stuttgart, Germany
Studying Single Defects in New Materials, Gregory Fuchs, Cornell University, United States
Imaging Defects with TEM, Eric Stach, University of Pennsylvania, United States
Imaging Defects with STM/AFM, Jay Gupta, Ohio State, United States
Device Fabrication at the Atomic Scale, Shashank Misra, Sandia National Laboratories, United States
Theoretical Tools for Predicting Defect Properties, Prineha Narang, Harvard University, United States
Capturing the Physics of Defect Qubits with First-Principles Theory, Ádám Gali, Hungarian Academy of Sciences, Hungary
Combining Experimental, Analytical, and Numerical Approaches, Rashid Zia, Brown University, United States
New Applications of Quantum Defects, Sophia Economou, Virginia Tech University, United States
Device Engineering with Rare Earth Dopants, Andrei Faraon, California Institute of Technology, United States
Defect Device Engineering with 2D Materials, Mete Atatüre, University of Cambridge, United States

DISSEMINATION

The results of the Defect by Design Meeting have been disseminated to communities of interest through the following channels:

- OSA website (https://www.osa.org/en-us/meetings/incubator_meetings/past_incubator_meetings/2018/osa_defects_by_design_incubator_quantum_nanophoto/)
- OSA Blog (https://www.osa.org/en-us/the_optical_society_blog/2018/october/day_1_%E2%80%93_osa_incubator_defects_by_design_quantum_na/; https://www.osa.org/en-us/the_optical_society_blog/2018/october/day_2_defects_by_design_incubator/)

It is expected that the discussions and information exchanged during this meeting will directly lead to continuing high quality journal publications from all of the research groups that participated. During and right after the meeting a lively technical blog was posted online describing the highlights of the meeting (see above). In addition, an article is planned for publication in Optics and Photonics News, a technical magazine published by OSA.

OSA INCUBATORS

Collaborate. Innovate. Discover.

Defects by Design: Quantum Nanophotonics in Emerging Materials

28-30 October 2018

OSA Headquarters, Washington D.C.

This program is supported in part by:

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OSA Incubator Defects by Design:
Quantum Nanophotonics in Emerging Materials

28-30 October 2018
Washington, DC USA

HOSTED BY:
Audrius Alkauskas, *Center for Physical Sciences and Technology, Lithuania*
Lee Bassett, *University of Pennsylvania, United States*
Kai-Mei Fu, *University of Washington, United States*

AGENDA

Sunday 28 October 2018

Afternoon Arrival/Hotel Check-in

18:00 Welcome Dinner
Leziz, 2016 P Street NW

Monday 29 October 2018

8:00 Breakfast
OSA Headquarters, 2010 Massachusetts Ave. NW

8:30 Welcome
Gregory Quarles, Chief Scientist, OSA, United States

8:45 Program Overview and Goals
Lee Bassett, University of Pennsylvania, United States

Session 1A: Why Defects?
Facilitator: Lee Bassett, University of Pennsylvania, United States

9:00 Overview & State of the Art
David Awschalom, University of Chicago, United States

9:30 Applications to Quantum Sensing
Fedor Jelezko, Ulm University, Germany

10:00 Coffee Break

10:30 Applications to Quantum Communication
Dirk Englund, MIT, United States

11:00 Discussion
What existing application areas are best suited to quantum defects (and which are not)?
What new areas are ripe for exploration?

12:00 Lunch, provided

Session 2A: Defect Discovery in New Materials
Facilitator: Kai-Mei Fu, University of Washington, United States

13:30 History of Defect Discovery
Chris Van de Walle, UC Santa Barbara, United States

13:50 Efficient Defect Creation and Control
Jörg Wrachtrup, University of Stuttgart, Germany

14:10: Studying Single Defects in New Materials
Gregory Fuchs, Cornell University, United States

14:30 Discussion
How can we efficiently create & identify new defects, particularly in emerging materials?
What opportunities are provided by materials beyond group IV?

15:20 Coffee Break

Session 2B: Defect Discovery in New Materials
Facilitator: Helena Knowles, University of Cambridge, United Kingdom

15:50 Imaging Defects with TEM
Eric Stach, University of Pennsylvania, United States

16:10 Imaging Defects with STM/AFM
Jay Gupta, Ohio State, United States

16:30 Device Fabrication at the Atomic Scale
Shashank Misra, Sandia National Laboratories, United States

Monday 29 October 2018

16:50 Discussion

How can we control defect creation, identification, and placement at the atomic scale?
How do we combine optical and structural imaging?

18:00 Dinner

La Tomate, 1701 Connecticut Ave, NW

Tuesday 30 October 2018

8:00 Breakfast

OSA Headquarters, 2010 Massachusetts Ave. NW

Session 3A: Defects by Design

Facilitator: Audrius Alkauskas, Center for Physical Sciences and Technology, Lithuania

8:30 Theoretical Tools for Predicting Defect Properties

Prineha Narang, Harvard University, United States

8:50 Capturing the Physics of Defect Qubits with First-Principles Theory

Ádám Gali, Hungarian Academy of Sciences, Hungary

9:10 Combining Experimental, Analytical, and Numerical Approaches

Rashid Zia, Brown University, United States

9:30 Discussion

How can we predict defect properties to guide discovery?
What new theoretical tools are needed to give a holistic treatment and prevent "convergence to experiments"?

10:20 Coffee Break

Session 3B: Defects by Design

Facilitator: Christoph Becher, Saarland University, Germany

10:40 New Applications of Quantum Defects

Sophia Economou, Virginia Tech University, United States

11:00 Device Engineering with Rare Earth Dopants

Andrei Faraon, California Institute of Technology, United States

11:20 Defect Device Engineering with 2D Materials

Mete Atatüre, University of Cambridge, United States

11:40	Discussion *How can we engineer desired defect properties, e.g., using nanophotonics, materials properties, device design, or active control schemes?*
12:30	Lunch, provided
13:30	**Wrap-up Discussion** *Identification of key opportunities and objectives.*
14:00	Adjourn

OSA Incubator Defects by Design: Quantum Nanophotonics in Emerging Materials

KEY QUESTIONS

The goal of the Incubator is to highlight new directions for research with optically-active semiconductor defects that take advantage of the unique properties afforded by emerging materials. Building on recent success in harnessing select defects like the diamond nitrogen-vacancy center for diverse applications in quantum information processing, quantum optics, nanophotonics, magnetometry, and biosensing, an opportunity exists to identify systems in new materials that are optimized to improve the performance of applications like these, or that can enable entirely new avenues of research. Recent discoveries of quantum emitters in low-dimensional semiconductors, for example, promise exciting new opportunities. Given the vast number of potential materials and defect systems, however, it remains a major challenge to theoretically predict and experimentally identify promising candidates in a systematic way.

Specifically, we aim to address the following key questions and themes:

- **Why Defects?**
  - What makes a "good" defect for quantum science & technology?
  - What application areas are best suited to quantum defects (and which are not)?
  - What new areas are ripe for exploration using quantum defects?

- **Defects in New Materials**
  - How can we efficiently create & identify new defects?
  - How can we control defect creation and placement at the atomic scale?
  - What opportunities are provided by host materials "beyond group IV"?

- **Defects by Design**
  - How can we predict defect properties to guide discovery?
  - What new theoretical tools are needed to give a holistic treatment and prevent "convergence to experiments"?
  - What is the importance and influence of the material host (e.g., dimensionality, composition, symmetry)? What are the most promising candidates?
  - How can we engineer desired defect properties (e.g., using nanophotonics, materials properties, device design, or active control schemes)?

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OSA Incubator Defects by Design: Quantum Nanophotonics in Emerging Materials

PARTICIPANT BIOGRAPHIES

Victor Acosta

Victor Acosta (CV, Google Scholar) is an Assistant Professor of Physics at the University of New Mexico (UNM) and is affiliated with UNM's Center for High Technology Materials. Victor did his PhD research in AMO physics in Dmitry Budker's group at UC Berkeley, graduating in 2011. From 2011-2013, Victor was a postdoc in Charles Santori and Ray Beausoleil's group at HP Labs, working in quantum nanophotonics. From 2013-2015, Victor was a research scientist at Google [x] Life Sciences (now Verily), where he worked on nanoparticle-based molecular imaging. At UNM, Victor's current research interests include quantum sensing and imaging with diamond NV centers and nonlinear optics and bioimaging with other solid-state defects.

Audrius Alkauskas

Audrius Alkauskas finished obtained PhD from the University of Basel, Switzerland, and worked as a post-doctoral research at EPFL (Switzerland) and University of California Santa Barbara. Since 2014 he is a Principal Researcher and group leader at the Center for Physical Sciences and Technology (FTMC) in Vilnius, Lithuania, and professor at the Physics Department of Kaunas University of Technology (KTU) in Kaunas, Lithuania. The research interests of his group consist of first-principles theory of radiative and nonradiative processes in semiconductors, and defects for quantum information processing.

Mete Atatüre

Mete Atatüre is a Professor of Physics at the University of Cambridge and the principal investigator of the Quantum Optical Materials and Systems Group (QOMS) located at the Cavendish Laboratory. QOMS is an experimental research group with a broad research portfolio on quantum science and applications using solid-state light-matter interfaces. In particular, both defect- and confinement-based quantum emitters in atomically thin layered materials and diamond are part of the material platforms studied actively for direct applications in quantum communications and networks. Mete Atatüre received his Bachelor of Science degree in 1996 from Bilkent University Physics Department in Turkey. He joined the Quantum Imaging Laboratory at Boston University for his PhD studies on multi-parameter photonic quantum entanglement. From 2002 to 2007, he worked as a Postdoctoral Fellow in the Quantum Photonics Group at ETH Zurich focusing on optical control of spins in semiconductor quantum dots. He joined the Physics faculty of the University of Cambridge in 2007 and established QOMS. He is a Fellow of the Institute of Physics and the Turkish Science Academy.

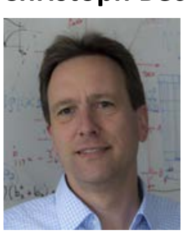
David Awschalom

David Awschalom is the Liew Family Professor and Deputy Director of the Institute for Molecular Engineering at the University of Chicago, and a Senior Scientist at Argonne National Laboratory. Before arriving in Chicago, he was the Director of the California NanoSystems Institute and Professor of Physics, Electrical and Computer Engineering at the University of California – Santa Barbara. He works in the emerging fields of spintronics and quantum information engineering, where his students develop new methods to explore and control the quantum states of individual electrons, nuclei, and photons in the solid state. His group explores optical and magnetic interactions in semiconductor quantum structures, spin dynamics and coherence in condensed matter systems, and implementations of quantum information processing in semiconductors and nanostructures. They create a variety of femtosecond-resolved spatiotemporal spectroscopies and micromagnetic sensing techniques aimed at exploring charge and spin motion in the quantum domain, as well as materials synthesis methods to fabricate single crystal systems with embedded quantum states. His research includes implementations of spin-based quantum information processing with potential applications in computing, imaging, and encryption. Professor Awschalom received the American Physical Society Oliver E. Buckley Prize and Julius Edgar Lilienfeld Prize, the European Physical Society Europhysics Prize, the Materials Research Society David Turnbull Award and Outstanding Investigator Prize, the AAAS Newcomb Cleveland Prize, the International Magnetism Prize and the Néel Medal from the International Union of Pure and Applied Physics, and an IBM Outstanding Innovation Award. He is a member of the American Academy of Arts & Sciences, the National Academy of Sciences, the National Academy of Engineering, and the European Academy of Sciences.

Lee Bassett

Lee Bassett is an Assistant Professor of Electrical & Systems Engineering and responsible for the Quantum Engineering Lab (http://nanoquant.seas.upenn.edu/) at the University of Pennsylvania. Following undergraduate studies at the Pennsylvania State University (BS Physics, 2004), Lee traveled to the United Kingdom as a Marshall Scholar and NSF Graduate Research Fellow to complete the MASt (Part III) in Mathematics (2005) and PhD in physics (2009) at the University of Cambridge, the latter for his work on low temperature quantum electronics in III/V semiconductor devices. From 2009-2013 he was a Hewlett Packard Postdoctoral Fellow at the University of California, Santa Barbara. He received the NSF CAREER award in 2016 and the Ford Motor Company Award for Faculty Advising in 2018.

Christoph Becher



Christoph Becher received his PhD in physics from the University of Kaiserslautern, Germany, in 1998 working on the generation of non-classical light from semiconductor lasers. He extended the scope of his scientific work during two post-doc positions: at University of California, Santa Barbara (1999-2000) he worked with Atac Imamoglu on the first demonstration of single photon emission from self-assembled semiconductor quantum dots and cavity-QED experiments; at University of Innsbruck, Austria (2001-2005), he joined Rainer Blatt’s group and was part of the team demonstrating the first quantum gate with trapped ions, generation of multi-ion entangled states, implementation of simple quantum algorithms and cavity QED with trapped ions. Since 2005 he holds the position of full professor of physics at Saarland University, Saarbruecken, Germany. His research interests are in the field of quantum technologies for quantum communication & networks and quantum optics, in particular quantum information and magnetometry with color centers in diamond, cavity quantum electrodynamics with color centers in diamond, microresonators (fiber-based cavities, photonic crystal cavities), single photon nonlinear optics, quantum frequency conversion and single photon sources for metrology and quantum communication. In the context of “quantum defects” Christoph Becher has – together with others – pioneered work on silicon-vacancy color centers in diamond, establishing them as interesting candidate for quantum bits. His current interests in this field extend to the general class of “group IV – vacancy” defects in diamond.

Edward Bielejec

Edward Bielejec received a PhD in Physics from the University of Rochester in 2002. He has been with Sandia National Laboratories for more than 15 years. He has worked in the Ion Beam Laboratory for the last 12 years concentrating on the areas of radiation effects in semiconductor devices and materials as well as using ion beams to modify and fabrication advanced device structures. This includes producing single atom devices into a variety of substrates using focused ion beam implantation.

Stanley Breitweiser

Alex received his B.S. in Mathematics from the University of Chicago and his M.S. in Physics from New York University. He is currently at the University of Pennsylvania where his research broadly focuses on mesoscopic quantum systems and their potential applications to emerging technologies, ranging from nano-scale devices to general purpose information processing.

Guido Burkard

Guido Burkard’s research is focused on the theory of solid-state quantum information processing, with emphasis on spin qubits in semiconductor quantum dots and defects. Other active research topics include the study of 2D materials, hybrid quantum systems, and time-domain quantum optics. After obtaining his physics degree at ETH Zurich (Switzerland) and Ph.D. (2001) from the University of Basel (Switzerland), Guido Burkard was a postdoctoral researcher with the IBM T. J. Watson Research Center at Yorktown Heights, New York. After faculty appointments in Basel and Aachen, he became a full professor at the University of Konstanz in 2008.

Sam Carter

Dr. Samuel G. Carter is an experimentalist in the area of condensed matter physics with interests in optically active quantum dots, defect spins in solids, ultrafast optical control, and quantum information science. He received his Ph.D. in Physics in 2004 at the University of California, Santa Barbara, working with Professor Mark Sherwin on terahertz-driven quantum wells. After postdoctoral studies at NIST and the University of Colorado, Boulder with Professor Steve Cundiff on ultrafast optical spectroscopy of semiconductors, he joined the Naval Research Laboratory in Washington, DC in 2007. There he works in the Electronics Science and Technology Division on developing solid state implementations for quantum information science and technology.

Dominique Dagenais

Dominique M. Dagenais is Program Director in the Electronics, Photonics and Magnetic Devices. Her interest is in Optoelectronics. After receiving her Diplôme d'Ingénieur from the Ecole Supérieure d'Optique in Orsay, France, she spent a year at the Institute of Optics, University of Rochester where she defended a thesis on uniform pellet illumination for Laser fusion. She then joined the French Atomic Energy Commission, working on high power Nd:YAG laser propagation, before coming to the Boston area, where she developed beam shaping optics for CO_2 lasers at the AVCO Everett laboratories. In 1987 she joined the Naval Research Laboratory Optical Sciences division where she helped design and deploy the first three-axis fiber magnetic sensor, and demonstrated record sensitivity. In 1999 she joined Alcatel and supported the development of novel optoelectronic active and passive devices for WDM fiber telecommunication.

Cyrus Dreyer

Cyrus Dreyer did his Ph.D. in Materials at UCSB advised by Chris G. Van de Walle, and a postdoc at Rutgers University with David Vanderbilt. He is now an assistant professor in the Department of Physics and Astronomy at Stony Brook University and an affiliated associate research scientist at the Center for Computational Quantum Physics at the Flatiron Institute. His research involves developing and implementing first-principles techniques based on density functional theory to determine the properties of electronic materials. He is interested in point defects in semiconductors both from a device efficiency, and a quantum application perspective. Previously, he did work exploring nonradiative processes at defects and how they affect the efficiency of electronic devices.

Sophia Economou

Sophia Economou is a theoretical physicist working at the interface of quantum information science, condensed matter physics and quantum optics. She is an associate professor in the Department of Physics at Virginia Tech since 2015. Prior to that she was a staff Research Physicist at the Naval Research Lab (2009-2015). She earned her bachelor's degree in Physics from the University of Crete, Greece in 2000 and her PhD from the University of California, San Diego in 2006. Her research focuses on understanding and designing 'quantum hardware' for future quantum technologies. Her interests include quantum computing and communication, spin qubits, nanophotonics, superconducting qubits, quantum control and decoherence.

Dirk Englund

Dirk Englund received his BS in Physics from Caltech in 2002. Following a Fulbright year at TU Eindhoven, he earned an MS in electrical engineering and a PhD in Applied Physics in 2008, both from Stanford University. He was a postdoctoral fellow at Harvard University until 2010, when he started his group as Assistant Professor of Electrical Engineering and of Applied Physics at Columbia University.

In 2013, he joined the faculty of MIT's Department of Electrical Engineering and Computer Science. Dirk's research focuses on quantum technologies based on semiconductor and optical systems. Recent recognitions include the 2011 Presidential Early Career Award for Scientists and Engineers, the 2011 Sloan Research Fellowship in Physics, the 2012 DARPA Young Faculty Award, the 2012 IBM Faculty Award, an 2016 R&D100 Award, the OSA's 2017 Adolph Lomb Medal, and the 2017 ACS Photonics Young Investigator Award.

Annemarie Exarhos

Annemarie Exarhos received her B.A. in Physics from Lawrence University in 2007 and both her master's (2010) and Ph.D. (2015) in Physics from the University of Pennsylvania where her thesis focused on spectroscopic studies of the optical, magnetic, and electronic anisotropies of graphene oxide. Her postdoctoral research at the University of Pennsylvania (2015-2017) involved the creation and optical characterization of quantum emitters in wide-bandgap semiconductors, particularly in low dimensional systems such as hexagonal boron nitride. She served as a Visiting Assistant Professor of Physics at Lawrence University during the 2017-2018 academic year. This fall, she began a position as an Assistant Professor of Physics at Lafayette College where her research is centered around applying novel spectroscopic techniques to identify and characterize quantum emitters in new and novel anisotropic systems.

Andrei Faraon

Andrei Faraon is a Professor of Applied Physics at California Institute of Technology. He works in the fields of nano-scale quantum photonics and optical meta-materials. Currently he is interested in quantum photonic systems based on rare-earth doped materials and defects in silicon carbide.

Michael Flatté

Michael E. Flatté received the A.B. degree in physics from Harvard University in 1988 and the Ph.D. degree in physics from the University of California, Santa Barbara in 1992. After postdoctoral work at the Institute for Theoretical Physics at the University of California, Santa Barbara and in the Division of Applied Sciences at Harvard University, Michael Flatté joined the faculty at The University of Iowa where he was Director of the Optical Science and Technology Center from 2010-2017. His current research interests include spin dynamics in semiconductors, ferrites, and metals, optomagnonics, carrier dynamics in narrow-gap semiconductor superlattices, single-dopant properties in semiconductors, novel spintronic devices and solid state realizations of quantum computation. He has over 200 publications and an H-index (web of science) of 40. He is a fellow of the American Association for the Advancement of Science and of the American Physical Society, and was Chair of the Division of Materials Physics of the APS from 2016-2017.

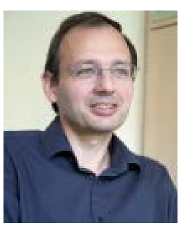
Kai-Mei Fu

Kai-Mei Fu received her A.B. in Physics from Princeton University in 2000 and her Ph.D. in Applied Physics from Stanford University in 2007 where she worked with Yoshihisa Yamamoto on GaAs donors as qubit candidates. She worked on the nitrogen-vacancy center in diamond as a research associate at HP Labs, Palo Alto before joining the faculty at the University of Washington. Her research group focuses on (1) understanding and engineering the quantum properties of point defects in crystals and (2) defect device integration for quantum information and sensing applications.

Gregory Fuchs

After teaching high school physics and chemistry for five years, Fuchs enrolled at Cornell University in 2001, earning his Ph.D. in Applied Physics in 2007. Afterward, he moved to the University of California, Santa Barbara as a postdoctoral associate. In 2011, he joined the Cornell faculty of Applied and Engineering Physics. In 2012 he received a Young Investigator Award from the Air Force Office of Scientific Research, in 2013 he received both an Early Faculty Career Award from the National Science Foundation and the Presidential Early Career Award for Scientists and Engineers sponsored by the Department of Defense. In 2014 he received the Early Career Award from the Department of Energy. Fuchs' research group focuses on two main areas: (i) developing new materials and methods for spintronics, for which they recently invented a spatiotemporal magnetic microscope that uses heat instead of light to probe spin dynamics at the nanoscale and (ii), understanding and controlling semiconductor defect-based qubits and quantum emitters using photons and phonons.

Adam Gali



Adam Gali is a chief scientific advisor in Wigner Research Centre, the leader of "Lendület" Semiconductor Research Group, founder of Wigner Advanced Materials Integrated Laboratory (ADMIL) and Optically Detected Magnetic Resonance Laboratory for Quantum Technology, an associate professor at Budapest University of Technology and Economics, Doctor of Science of the Hungarian Academy of Sciences. He studies the magneto-optical properties of point defects in semiconductors and semiconductor nanostructures by means of ab initio methods and experimental techniques, to develop efficient biomarkers, solar cells and solid state defect quantum bits. He recently has developed and implemented ab initio methods to fully characterize the most prominent solid state quantum bit, nitrogen-vacancy center in diamond. He suggested divacancy in silicon carbide as an alternative to nitrogen-vacancy center that was later proven in experiments. The implemented ab initio methods can be applied to other solid state defect quantum bits in three- and two-dimensional materials.

Sara Gamble

Sara currently manages a quantum information science research program for the U.S. Army Research Laboratory's Army Research Office (ARO). The program seeks to understand, control, and exploit quantum phenomena to enable beyond classical capabilities. Specific research interests include foundational quantum physics; quantum sensing, imaging, and metrology; and quantum computation and quantum networking. Prior to her time at ARO, Sara worked for semiconductor equipment manufacturer KLA-Tencor in a dark-field microscopy group. She obtained a PhD in Applied Physics from Stanford University in 2010 and a BS in Physics from the University of Florida in 2003.

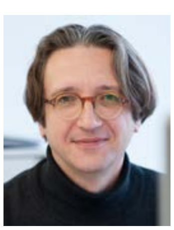
Jay Gupta

Education 2002 PhD, Physics UCSB 1996 B.S. Physics, Univ. Illinois Urbana-Champaign 1996 B.S. Chemistry, Univ. Illinois Urbana-Champaign Awards 2017 Ohio State Faculty Diversity Enhancement Award 2007 Beckman foundation young investigator award 2007 NSF CAREER award 2007 ACIPA Outstanding young physicist award 2005 IBM Research Division award: spin-flip spectroscopy 2002 IBM Research Division award: molecule cascades My research program is focused on exploring the evolution of electronic, magnetic and optical properties in nanometer-scale structures. My interest in this general theme has developed over the years, starting from quantum mechanics courses I took as an undergraduate at UIUC and continuing to my PhD thesis at UCSB, which was focused on ultrafast optical studies in semiconductor quantum dots. I then took a postdoctoral position at IBM-Almaden to learn the technique of scanning tunneling microscopy and apply it to nanostructures on the atomic scale. Since starting at Ohio State in 2004, I have set up a lab which is integrating STM and optical techniques to enable new capabilities for studying the properties of nanostructures as their size is varied from one to thousands of atoms. Our goal is to study fundamental problems that can help lead to next-generation energy conversion and computing technologies. On a personal note, I am an avid bicyclist, reader and whistler.

Anthony Hoffman

Anthony Hoffman is an Associate Professor in the Department of Electrical Engineering at the University of Notre Dame. His research interests include optical materials and devices for the mid- and far-infrared, light-matter interactions in semiconductors, intersubband physics, and optical metamaterials. He serves as an Associate Editor of Optics Express.

Fedor Jelezko



Fedor Jelezko is a director of the Institute of Quantum Optics and fellow of the Center for Integrated Quantum Science and Technology (IQST) at Ulm University. For his scientific achievements in the field of solid state quantum physics, he has received several honors, in particular, membership of Heidelberg Academy of Sciences, the Walter Schottky Prize of the German Physical Society, Zeiss

Research Award and State research Award of Baden-Württemberg. His research interests are at the intersection of fundamental quantum physics and application of quantum technologies for information processing, communication, sensing, and imaging.

Roland Kawakami
Roland Kawamaki is a professor in the Physics Department of the Ohio State University. He has been working on spintronics and optoelectronics in two dimensional materials, with recent interest in single photon emission.His technical expertise includes molecular beam epitaxy, optical spectroscopy, electron transport, and scanning tunneling microscopy.

Helena Knowles

Dr. Knowles is a Postdoctoral Fellow working at Harvard on controlling single-atom thin materials using defects in diamond. She holds a PhD from the University of Cambridge, and an MSc from ETH Zurich. From 2014 to 2018 she was a Research Fellow at St John's College, University of Cambridge. Her work focuses on using quantum optics tools and defects in diamond to perform nanoscale quantum imaging in biological and solid-state systems.

Neil Manson

Neil Manson I'm the one on the right. The keen student supervised the early crystal growth. At Australian National University since 1973 and involved in low temperature spectroscopy of rare earth ions, transition metal ions, color centers and diamond. Particular emphasis on studies of the nitrogen-vacancy center in diamond. First paper in 1987 and 40 before 'single center era' Most paper recent on arXiv18078889.

Matthew Markham

Dr. Matthew Markham received his MPhys and PhD degrees in Physics from the University of Southampton, UK. Since starting at Element Six in 2007 he has focused on diamond synthesis for applications in quantum technologies. Matthew is now a Principal Research Scientist managing a range of diamond quantum technologies projects looking at application in magnetic sensing and quantum information processing.

Christian Pederson

Christian is a second year graduate student at the University of Washington in Kai-Mei Fu's lab. He completed his undergraduate degree at Carnegie Mellon University. He is currently researching charge state conversion of the Silicon-vacancy center in diamond.

Lukas Razinkovas
Lukas Razinkovas is a PhD student from Lithuania, Vilnius. His supervisor is Dr. Audrius Alkauskas and his main research interests are deep point defects in solids. At the moment Lukas is working on electron-phonon interactions and dynamic Jahn-Teller effect.

Shashank Misra
Shashank Misra earned his Ph. D. in Physics from the University of Illinois at Urbana-Champaign in 2005, and has been, since 2013, a research staffer at Sandia National Laboratories. His research interests have revolved around developing instruments, techniques, and devices that provide new access to exotic phases in quantum materials, quantum phase transitions, and quantum effects in semiconductors. More recently, his interests have turned to using chemical vapor deposition and STM-based lithography to fabricate atomically-precise dopant devices in semiconductors. These include making physics-enabled transistors for everything from cryogenic analog (metal-insulator transition-based) to room-temperature digital (band-to-band tunneling) applications, and engineering donor arrays to serve as analog quantum simulations of interesting many-body systems. Finally, he also uses coherent manipulation to explore basic interactions in the silicon MOS quantum dot- phosphorus donor qubit system.

Prineha Narang

Prineha Narang is an Assistant Professor at the John A. Paulson School of Engineering and Applied Sciences at Harvard University. Prineha's research interests lie in exploring and expanding the understanding of excited state and non-equilibrium phenomena to develop novel quantum engineered materials and devices with applications in sensing and photodetection, quantum information processing, as well as energy conversion.

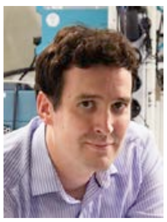
Jason Smith

Jason is Professor of Photonic Materials and Devices in the Department of Materials at the University of Oxford. He is an Associate Director of the UK Hub in Networked Quantum Information Technologies (NQIT) in which he leads the effort on diamond quantum technologies, and is a Tutorial Fellow in Materials at Mansfield College. He is founder and Director of spin-out company Oxford HighQ Ltd. Jason obtained his DPhil in condensed matter physics from the Clarendon Laboratory, Oxford in 1996 and his research has since focused on solid state optoelectronics and quantum technologies. During his research career he has worked on semiconductor quantum dots (epitaxial and colloidal), single photon detectors, photovoltaics and 2D materials. His current core interests are the engineering of diamond colour centres and optical microcavities. When Jason is not at work he enjoys running, preferably in the hills (of which there are very few around Oxford).

Eric Stach
Eric Stach is a Professor in the Department of Materials Science and Engineering at the University of Pennsylvania. He received his B.S.E from Duke University, M.S.M.S.E. from the University of Washington, his Ph.D. in Materials Science and Engineering from the University of

Virginia. He has held positions as Staff Scientist and Principal Investigator at the National Center for Electron Microscopy at the Lawrence Berkeley National Laboratory, as Associate, then Full Professor at Purdue University, and as Group Leader at the Center for Functional Nanomaterials at the Brookhaven National Laboratory. He is a Co-founder and Chief Technology Officer of Hummingbird Scientific. He is also Secretary of the Board of Directors for the Materials Research Society. His research focuses on the development and application of advanced methods for in-situ and operand characterization of materials using transmission electron microscopy methods.

Tim Taminiau



Tim Taminiau is a PI at QuTech at the Delft University of Technology, where he studies quantum physics and information based on solid-state defect spins. He graduated from the University of Twente in 2005 and obtained a Pd.D. at the Institut de Ciències Fotòniques (ICFO) in Barcelona. Before returning to the Netherlands as a Marie Curie fellow in 2011, Tim investigated optically active defects and dopants at the California Institute of Technology and Brown University. Tim's has been rewarded the European Fresnel prize for his fundamental contributions to quantum optics. Key personal grants include a European Marie Skłodowska-Curie Fellowship and the Veni and Vidi career grants of the NWO (The Netherlands Organisation for Scientific Research).

Chris Van de Walle

Chris Van de Walle is a Distinguished Professor of Materials and the inaugural recipient of the Herbert Kroemer Endowed Chair in Materials Science at the University of California, Santa Barbara. Prior to joining UCSB in 2004, he was a Principal Scientist at the Xerox Palo Alto Research Center (PARC). He received his Ph.D. in Electrical Engineering from Stanford University in 1986, and was a postdoc at IBM Yorktown Heights (1986-1988) and a Senior Member of Research Staff at Philips Laboratories in Briarcliff Manor (1988-1991). He has published over 400 research papers, holds 24 patents and has given over 190 invited and plenary talks at international conferences. Van de Walle is a Member of the National Academy of Engineering, a Fellow of the APS, AVS, AAAS, MRS, and IEEE, as well as the recipient of a Humboldt Award for Senior US Scientist, the David Adler Award from the APS, the Medard W. Welch Award from the AVS, and the TMS John Bardeen Award.

Ronald Walsworth

Ron Walsworth is on the Physics faculty at Harvard University and is also a Senior Physicist at the Smithsonian Institution. He leads an interdisciplinary research group that develops precision measurement tools and applies them to problems in both the physical and life sciences. Current areas of research include: new approaches to the search for dark matter; astronomical detection of Earth-like planets around other stars; and the development of quantum sensors and novel NMR tools, with applications ranging from condensed matter physics to neuroscience to Earth & planetary science.

Joerg Wrachtrup

Joerg Wrachtrup is a Professor and Director of the 3rd Institute of Physics, University of Stuttgart (2000, continuing) as well as a Max Planck fellow at the MPI for Solid State Research Stuttgart. He has pioneered the field of single spin physics by initially doing the very first single electron and subsequently the first single nuclear spins experiments. By combining optics and spin resonance he discovered defects in insulators, most notably defects in diamond, as a valuable system for quantum information processing in novel type of detectors for electric and magnetic fields. He and his group pioneered biophysical application of these novel sensor techniques. His current research interest is geared towards application of quantum enhanced sensing in bio and medical sciences. Professor Wrachtrup has published over 250 papers in refereed journals with 15 Nature and Science papers, plus reviews in both over the past 5 years. In 2011 and 2017, he was awarded an Advanced Research Grant of the European Research Council, the Leibniz Price of the German Science Foundation in 2012, the Bruker Prize in 2013 and the 2014 Max Planck Research Award.

Tian Zhong

Dr. Tian Zhong received his B.Eng. degree from Nanyang Technological University Singapore and completed his S. M and Ph.D. degrees in Electrical Engineering from MIT. From 2014-2017, He did his postdoc at California Institute of Technology, as an Institute of Quantum Information and Matter postdoc fellow. In early 2018, he joined the Institute for Molecular Engineering at the University of Chicago as an assistant professor. His research focuses on developing enabling nanophotonic and molecular technologies for building efficient, global-scale Quantum Internet. In the past decade, Dr. Zhong's work has contributed to the progress in nanoscale quantum light-matter interfaces as fundamental building blocks of a quantum network node, as well as high-throughput quantum communication links interconnecting distant nodes. He has pioneered rare-earth quantum nanophotonics as attractive technology with exceptional coherence properties. By leveraging the modern photonic technologies, he has developed a versatile rare-earth nanophotonic platform that could enable scalable quantum optical networks.

Rashid Zia

Rashid Zia is the Dean of the College and Associate Professor of Engineering & Physics at Brown University. His research group works at the interface of electrical engineering, materials science, optical physics, and physical chemistry to study how light interacts with solid-state quantum emitters, including atoms, defect centers, ions, molecules, and quantum dots. For this work, he has received a National Science Foundation CAREER Award and a Department of Defense nominated Presidential Early Career Award for Scientists and Engineers (PECASE). Rashid is a Fellow of the Optical Society, and has served as a Fellow of the National Forum on the Future of Liberal Education. He was also the lead PI for the Air Force sponsored Quantum Metaphotonics & Metamaterials MURI program.