Project title: **Reconfigurable Optical Matter**

Project period: _x__ July 1, 2017 thru June 30, 2018 (1 fiscal year)

or

___ July 1, 2017 thru June 30, 2019 (2 fiscal years)

Resubmission: ___x__ No, this a new URA proposal

or

___ Yes, this is similar to a prior, unfunded ______ (URA, CTSI, PP, etc.) proposal.

Total funds being requested ($75,000 max): ___$70,000______

Pertinent contact information and academic appointment for all collaborators (the first-listed investigator will be primary contact and responsible for communication on behalf of all listed):

1 - Miguel Alonso, The Institute of Optics, Wilmot 212, miguel.alonso@rochester.edu, x5-7227
2 - Nick Vamivakas, The Institute of Optics, Wilmot Annex 101, nick.vamivakas@rochester.edu, x5-2089
Project title: **Reconfigurable Optical Matter**

**Brief Overview:** a non-technical summary of the proposed project (350 words max).

What is it you want to do? Why do you want to do it? How will you do it? What is the expected outcome?

**What we want to do & Why:** The optical control and levitation of dielectric particles with tightly focused laser beams has created a new regime in the coupling of light to mechanical resonators; so-called *Levitated Optomechanics*. PI Vamivakas is at the forefront of this effort (see ref. [1] below). In parallel, PI Alonso (see [2]) has pioneered approaches to generating unconventional light beams that have come to be known more broadly as *Structured Light*. The goal of the URA *Reconfigurable optical matter* is to make a bridge between these two distinct realms of optical physics – Levitated Optomechanics and Structured Light – to create a new frontier of optics and materials science that uses light as the glue to arrange collections of dielectric nano and/or micro-particles into molecules, crystals and non-crystalline arrangements.

**How we will do it:** To demonstrate the feasibility of our ideas we will implement a proof-of-principle experiment that relies on the theoretical framework discovered by PI Alonso and the experimental infrastructure in the lab of PI Vamivakas. The goal is to create a region of focused light that can support the reconfigurable optical binding of pairs of dielectric particles. By modulating the wavefront of the beam prior to focusing we will have a channel to modify particle binding in real time. Passive interferometric optical monitoring will reveal the nature and strength of the levitated particle binding.

**Expected outcome:** The scientific advances of the proposed URA will open a new frontier in optics by making a bridge between levitated optomechanics and structured light. The outcomes will not only be of interest to the previous communities, but will also create new opportunities for optics to inform materials science and condensed matter physics. We anticipate the products of this one-year program will be at least one journal publication and multiple conference talks. These preliminary results will serve to catalyze a National Science Foundation grant submission in the Fall of 2018. PI Vamivakas is also in preliminary discussions with the Condensed Matter program in the Basic Energy Science arm of the Department of Energy regarding this project.
**Project title:** Reconfigurable optical matter

**Budget:** a detailed description of how much you are requesting, the purposes for which you will use the funds, and justification for each.

Funds may be requested for graduate or undergraduate student stipends, for salary for assistants, for postdoctoral scholars, and/or technical staff. Summer salary support for faculty on 9 month appointments may be requested to the extent that it replaces salary that would be foregone (e.g., from summer teaching).

For each participating faculty member who has external grant support, please list, by grant, the title duration and amount of all active and pending awards, and provide a brief narrative summary (the grant summary may be sufficient).

**Budget justification:** Funds are requested to support two graduate students – one to work on theory and the other on experiment – as well as some funds to implement new beam preparation and measurement in the optical trapping apparatus.

<table>
<thead>
<tr>
<th>Cost Estimate: UR-URA</th>
<th>Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget</td>
<td>12 months</td>
</tr>
<tr>
<td></td>
<td>07/01/17 - 6/30/18</td>
</tr>
<tr>
<td>B. Other Personnel</td>
<td></td>
</tr>
<tr>
<td>B.1 Graduate Student: 1 @ 100% FTE</td>
<td>30,000</td>
</tr>
<tr>
<td>Subtotal Salaries</td>
<td>30,000</td>
</tr>
<tr>
<td>B.2 Graduate Student: 2 @ 100% FTE</td>
<td>30,000</td>
</tr>
<tr>
<td>Subtotal Salaries</td>
<td>30,000</td>
</tr>
<tr>
<td>F. Other Direct Costs</td>
<td></td>
</tr>
<tr>
<td>1. Optics &amp; Optomechanics</td>
<td>10,000</td>
</tr>
<tr>
<td>Total Direct Costs</td>
<td>70,000</td>
</tr>
<tr>
<td><strong>Total Requested Amount</strong></td>
<td><strong>70,000</strong></td>
</tr>
</tbody>
</table>
Curricula Vitae: résumés (biosketches) for all applicants.

A. Nick Vamivakas
University of Rochester
The Institute of Optics
Rochester, NY 14627
Phone: (585) 275-2089
Email: nick.vamivakas@rochester.edu
FAX: N/A

A. Professional preparation:
Boston University, Boston, MA
BS Electrical Engineering 2001
Boston University, Boston, MA
MS Electrical Engineering 2003
Boston University, Boston, MA
PhD Electrical Engineering 2008
University of Cambridge, UK
PDRA Physics 2007-2011

B. Appointments:
2016-present Associate Professor, Institute of Optics, University of Rochester, Rochester NY
2011-2016 Assistant Professor, Institute of Optics, University of Rochester, Rochester NY
2009-2011 Lecturer, King’s College University of Cambridge, Cambridge, UK
2007-2011 Postdoctoral Fellow, Department of Physics, University of Cambridge, Cambridge, UK

C. Products
5 Products Most Closely Related


5 Other Significant Products


D. Synergistic Activities:

- **Selected Honors and Awards**: 2016 NSF CAREER Award, 2016 Hajim Outstanding Faculty Award. 2015 G. Graydon Curtis ’58 and Jane W. Curtis Award for Nontenured Faculty Teaching Excellence. 2013 recipient of the Quantum Electronics Young Scientist Prize. The International Union of Pure and Applied Physics awards the prize every two years. 2009 elected a Trappell Fellow at King’s College – one of the most prestigious Colleges within the University of Cambridge. 2007 awarded an Engineering and Physical Sciences Research Council (EPSRC) Early Researcher Award.

- **Broadening participation in science**: Track record of supervising and mentoring underrepresented individuals Science. Anna Kline (ugrad, 2014), Chitraleema Chakraborty (PhD), Laura Kinnitschke (PhD) and Tanya Malhotra (PhD).

- **Outreach to undergraduates and younger**: Director of Institute of Optics Photon Camp (2014 to present), Participated in 2012 USA Science & Engineering Festival

Miguel A. Alonso

University of Rochester
The Institute of Optics
Rochester, NY 14627

Phone: (585) 275-7227
Email: miguel.alonso@rochester.edu

A. Professional Preparation

<table>
<thead>
<tr>
<th>Institution</th>
<th>City, Country</th>
<th>Degree</th>
<th>Field</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Univ. Autónoma Metropolitana</td>
<td>Mexico City, Mexico</td>
<td>Eng. in Physics</td>
<td>Eng.</td>
<td>1990</td>
</tr>
<tr>
<td>University of Rochester</td>
<td>Rochester NY, USA</td>
<td>Optics</td>
<td>PhD</td>
<td>1996</td>
</tr>
<tr>
<td>Macquarie University</td>
<td>Sydney, Australia</td>
<td>Math. optics</td>
<td></td>
<td>1997-2000</td>
</tr>
</tbody>
</table>

B. Appointments

2016-present, Professor, The Institute of Optics, University of Rochester
2007-2016, Associate Professor, The Institute of Optics, University of Rochester
2003-2007, Assistant Professor, The Institute of Optics, University of Rochester
2000-2003, Researcher, CCF, Universidad Nacional Autónoma de México.

C. Products

5 products most closely related


5 other significant products


D. Synergistic Activities

- **Editorial duties:** Associate Editor (2001-2007) and Deputy Editor (2007-2014) for *Optics Express*. Associate Editor (2014-) for *Optica*. Member of *Optics Express*’ 20th Anniversary Committee (2017). Chairman of *Spotlight on Optics* (2009-2016).

- **Evaluation duties:** Former member of the OSA’s Adolph Lomb Medal Committee, and the external evaluation committees for the Università Roma Tre’s Physics Department (Rome, Italy). Current member of the OSA’s Joseph W. Goodman Book Writing Award Committee, and of the external evaluation/advisory committees of the Centro de Investigación Científica y de Estudios Superiores de Ensenada CICESE (Ensenada, Mexico), the Centro de Investigaciones en Optica CIO (Mexico), and the Rochester Institute of Technology’s School of Physics and Astronomy (Rochester, US).

- **International educational activities, particularly to students from economically developing countries:** Instructor of the *Preparatory School in Optics* at the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy (yearly from 2006 to 2017), the *International Workshop on Optics and Photonics* at Cadi Ayyad University in Marrakech, Morocco (2010), the *School on Modern Optics* in Puebla, (2013), the *Adolph Lohmann LAOP Workshop on Physical Optics* in Cancun, (2014), the *Joseph H. Eberly LAOP Workshop on Classical and Quantum Correlations* in Guadalajara, Mexico (2017). OSA and SPIE Traveling Lecturer in Mexico City (2015), Bogotá, Besançon, and Guadalajara (2016).

- **Outreach:** Co-organizer and instructor of monthly outreach activities to groups of minority high-school students (2005-2008), and instructor in many other outreach activities (2005-present), including those organized by Society of Hispanic Professional Engineers (of which I am the UR faculty advisor), BOCES, Rochester City School District, and the University of Rochester.

- **Selected Honors and Awards:** Edward Peck Curtis Award for Excellence in Undergraduate Teaching, University of Rochester (2013); Fellow, Optical Society of America (2009-); CAREER Award, National Science Foundation (2005).
<table>
<thead>
<tr>
<th>Award Status</th>
<th>Title</th>
<th>Source</th>
<th>Location</th>
<th>Total Amount</th>
<th>Start</th>
<th>End</th>
<th>Person month calend</th>
<th>Person month acad</th>
<th>Person month summ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>Exploiting multidimensional classical optical entanglement for enhanced spatial scene recognition</td>
<td>Office of Naval Research PI</td>
<td>University of Rochester</td>
<td>$750,000</td>
<td>06/01/2015</td>
<td>05/31/2017</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Current</td>
<td>Ultrasensitive force metrology with an optically levitated nanocrystal</td>
<td>Office of Naval Research PI</td>
<td>University of Rochester</td>
<td>$576,265</td>
<td>06/01/2014</td>
<td>05/31/2017</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Current</td>
<td>INSPIRE: Classical entanglement in optical science and engineering</td>
<td>National Science Foundation co-PI</td>
<td>University of Rochester</td>
<td>$750,000</td>
<td>06/01/2015</td>
<td>05/31/2019</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Current</td>
<td>EFRI 2-DARE: Two-dimensional nanopores with electro-optical control for next generation biotechnological applications</td>
<td>National Science Foundation co-PI</td>
<td>UPenn</td>
<td>$2,000,000 (UR gets ~100K/year)</td>
<td>08/01/2015</td>
<td>07/31/2019</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Current</td>
<td>Microcavity polaritonics based on van der Waals heterostructures</td>
<td>Air Force Office of Scientific Research PI</td>
<td>University of Rochester</td>
<td>$598,278</td>
<td>9/1/2015</td>
<td>8/31/2018</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Current</td>
<td>CAREER: Quantum photonics with quantum dots in van der Waals heterostructures</td>
<td>National Science Foundation PI</td>
<td>University of Rochester</td>
<td>$411,856</td>
<td>01/01/2016</td>
<td>12/31/2021</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Current</td>
<td>Quantum vacuum modes as a probe</td>
<td>Army Research Office PI</td>
<td>University of Rochester</td>
<td>$510,000</td>
<td>01/01/2016</td>
<td>12/31/2019</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Current</td>
<td>Augmented Reality Display Exploiting NanoStructured and Freeform Surfaces</td>
<td>Oculus coPI</td>
<td>University of Rochester</td>
<td>$925,340</td>
<td>01/01/2016</td>
<td>12/31/2019</td>
<td>0</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Current</td>
<td><strong>Current Ultrafast time-space imaging via induced coherence</strong></td>
<td>University of Rochester</td>
<td>University of Rochester</td>
<td>$70,500</td>
<td>07/01/2016</td>
<td>06/31/2017</td>
<td>0</td>
<td>0</td>
<td>0/0</td>
</tr>
<tr>
<td>Pending</td>
<td><strong>Ultrafast dynamics of cavity polariton condensates based on van der Waals heterostructure excitons</strong></td>
<td>Air Force Office of Scientific Research PI</td>
<td>University of Rochester</td>
<td>$510,000</td>
<td>07/15/2017</td>
<td>07/14/2018</td>
<td>0</td>
<td>0</td>
<td>0/0</td>
</tr>
<tr>
<td>Pending</td>
<td><strong>Preparing the quantum ground state of levitated mechanical oscillators</strong></td>
<td>Office of Naval Research &amp; Army Research Office PI</td>
<td>University of Rochester</td>
<td>$510,000</td>
<td>07/15/2017</td>
<td>07/14/2018</td>
<td>0</td>
<td>0</td>
<td>0/0</td>
</tr>
<tr>
<td>Pending</td>
<td><strong>Levitated optomechanics: From fundamental physics to novel sensing and quantum science</strong></td>
<td>Office of Naval Research PI</td>
<td>University of Rochester</td>
<td>$607,367</td>
<td>06/01/2017</td>
<td>05/31/2020</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pending</td>
<td><strong>Nanoscale Quantum Imaging</strong></td>
<td>Keck PI</td>
<td>University of Rochester</td>
<td>$1,600,000</td>
<td>07/01/2017</td>
<td>06/31/2020</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pending</td>
<td><strong>EXTREME: Multifunctional optical combiner based on hybrid nanostructured and freeform surfaces</strong></td>
<td>DARPA PI</td>
<td>University of Rochester</td>
<td>$2,912,273</td>
<td>07/01/2017</td>
<td>06/31/2020</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pending</td>
<td><strong>Leveraging quantum concepts in classical optics for advanced scene characterization</strong></td>
<td>ONR PI</td>
<td>University of Rochester</td>
<td>$2,912,273</td>
<td>07/01/2017</td>
<td>06/31/2020</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Award Status</td>
<td>Title</td>
<td>Source</td>
<td>Location</td>
<td>Total Amount</td>
<td>Start</td>
<td>End</td>
<td>Person month calend</td>
<td>Person month acad</td>
<td>Person month summ</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------</td>
<td>--------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Current</td>
<td>New Paradigms in Light-Based Measurements Using Unconventional Polarization States</td>
<td>National Science Foundation co-PI</td>
<td>University of Rochester</td>
<td>$535,977</td>
<td>07/01/2015</td>
<td>06/30/2018</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Current</td>
<td>GAANN Program – Fellowships in Optical Sciences and Engineering</td>
<td>Department of Education PI</td>
<td>University of Rochester</td>
<td>$885,834</td>
<td>09/01/15</td>
<td>08/31/18</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Current</td>
<td>CEFO-4 Understanding the Effects of MSF errors</td>
<td>National Science Foundation and industrial partners associated with Center for Freeform Optics PI</td>
<td>University of Rochester</td>
<td>$150,985</td>
<td>01/01/16</td>
<td>12/31/18</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Project title: Reconfigurable optical matter

Project Narrative (not more than 3 pages that address the following):

In language intelligible to the non-specialist, describe what you intend to do, and explain why it would be important to scholars and/or society generally. Explain what you expect to be the outcome of the work, and its scholarly or other impact. Explain how the different disciplinary talents brought to the project by the participating faculty add special value.

Explain how (and, if relevant, where) you and your collaborators will undertake the work, and how you expect it to develop/unfold over the period of the award. Where special skills or techniques are required at any point, make clear who will supply them. If the proposed work has multiple stages, explain the sequencing of stage; if any stage depends on the successful completion of earlier ones, explain how you will adapt to failure to complete the earlier stage.

Provide references (sparingly) where these provide important theoretical of methodological background.

What we want to do and why it is important: We want to demonstrate the formation of an optical molecule by using a focused laser to bind two dielectric nanoparticles into a single unit. The binding will be tailored in-situ by modifying the light that is used to bind the particles. These proof-of-principle studies will provide the foundation for a bigger research effort into complex reconfigurable optical matter. The controlled assemblage of matter on micron length scales that can be easily reconfigured will provide new insights into materials science and condensed matter physics as well as new opportunities for electro-optical technologies.

Why this team: PI Alonso is an expert in theoretical optics and structured light [2,3]. He has discovered analytical approaches to understand the complex distribution of electromagnetic energy in the focal region of a lens. This is critical to design and engineer optical environments that can promote the formation of optical matter – the stable trapping and levitation of multiple nano- and microparticles. One of the major research efforts in the lab of PI Vamivakas is levitated optomechanics [1,4]. His laboratory has most of the requisite infrastructure in place to make the first experimental demonstrations of optical matter formation in vacuum environments. Working closely with PI Alonso an experiment will be constructed to make these first of their kind measurements.

Brief Technical Overview: The proposed program will draw on the theoretical advances of PI Alonso and the state-of-the-art laboratory infrastructure of PI Vamivakas to synthesize ideas from structured light and levitated optomechanics. Figure 1(a) presents an image of a single optically levitated nanoparticle that is trapped by an “elementary” beam. An elementary beam creates the trapping landscape illustrated in Fig. 1(b). The particle experiences an optical force that results in its seeking out the location in space with the highest energy density (red region in Fig. 1(b); the center of the plot). In all levitated optomechanics experiments to date, both in the Vamivakas lab as well as in other labs, the beam used to levitate the particle has been an elementary beam and only single particle experiments have been demonstrated. The vision of the proposed program is to focus “complex” beams, so-called structured light, to create exotic and controllable trapping landscapes that can support the controlled interaction of multiple nano- and/or microparticles.

Figure 1. a) Image of an optically levitated nanoparticle (from PI Vamivakas). We will extend these experiments to involve multiple particles. b) Optical force field generated by focusing an elementary beam. The particle is pulled to the center, red region, in the plot.
What is structured light? Structured light refers to optical beams that have non-uniform amplitude, phase and polarization structure across a plane that is orthogonal to the beam’s propagation direction. When such beams are focused, the structure in the beam can conspire to create a highly irregular (but controllable) distribution of electromagnetic energy and polarization in the lens focal region. Polarizable dielectric particles seek out regions that exhibit local maxima in the focused field’s energy density and the local polarization can induce both torsion and rotation. Remarkably, all these properties can be engineered by designing the structured light beam to be focused. Our laboratory implementation for structured light generation will involve both static transparent and semi-transparent masks as well as spatial light modulators for dynamic structured light generation. The later hardware is already available in the lab of PI Vamivakas.

From the theoretical point of view, our goal is to develop an efficient and intuitive method for designing optical force fields for one or several particles whose size is small (Rayleigh regime) or even comparable (Mie regime) to the light’s wavelength. These force fields will be created by using focused laser beams coming from one lens, or from two lenses at either side of the particles. The theory will be based on methods that are currently developed in the Alonso group for expressing a focused field in terms of analytic expressions that are exact solutions to the Maxwell equations; for example [3]. These solutions constitute what is known as a complete basis, meaning that they can be combined to express any arbitrary focused field. Further, they contain several free parameters that control degrees of freedom of the field that will play an essential role in this project. Having analytic mathematical expressions for the fields not only will allow fast computations but will also provide important insight into the design of force and torque fields with controllable degrees of freedom, related to the focused light’s spatial distributions of intensity, phase, and polarization. These three attributes of the field correspond to different mechanisms of interaction between light and small particles.

**Step 1; Structured Light Optical Levitation:** As a first step, we will consider force fields that can trap a single particle. We will consider, for example, a strongly focused version of what we have called a “full Poincaré beam”, which is a beam that has a different polarization at each point [2]. We expect that the properties of the force and torque distributions for this case will depend strongly on the size of the particle, to the point that small particles would spin in one direction while larger ones would spin in the opposite direction. By using the analytic solutions mentioned earlier together with variational methods, we plan to design other fields that maximize the dependence of force or torque on specific physical properties of the particles, such as size or refractive index. The laboratory infrastructure in the lab of PI Vamivakas can be easily modified to incorporate structured light for optical levitation experiments. The hardware also exists to measure particle trajectories, torque and rotation.

**Figure 2.** Preliminary calculations in 2D. (a) Force field created by a focused field with three intensity maxima for a particle of a given size and refractive index. (b) Trajectory followed by a particle being trapped in one of the maxima. The particle is shown in two colors to be able to see the rotation due to torque. The initial position for the particle’s center is indicated by a cross. (c) Effect of a particle (with larger refractive index) on the same field.

**Step 2, Optical Molecules:** We will also use these tools to design fields with more than one trap for the particles. Figure 2(a) presents some preliminary calculations on possible landscapes that can trap multiple particles. The polarization at the different trap positions is a degree of freedom that will be
explored as a mechanism for controlling this binding. As illustrated in Fig. 2(b), particles will experience torque in the vicinity of the top energy density maximum. Again, we expect that the proposed theoretical formalism will facilitate the description of this coupling mechanism and allow comparisons with experiments. The case of multiple traps will be particularly interesting, since it will be used to explore optical binding between particles trapped at different locations caused by scattering of light from one to the other(s). For example, as illustrated in Fig. 2(c), particles within the focal region modify the trapping landscape and will influence the equilibrium coordination of multiple particles. The experimental hardware in the lab will need to be slightly modified to observe the optical binding, but can be easily implemented. We will rely on an interferometric measurement technique that is sensitive to particle separation. Ultimately fringe spaces on our detector will reveal particle separations.

References:
Appendix:

Attach documentation supporting the research project: support letter(s), references, bibliography, footnote(s), etc. Support letters from department chairs are welcome. [Matching funds, from school dean(s) or (research) dean designate of all faculty named on this application, will be requested during the review process by the senior vice president for research.]
Dear University Research Award Evaluation Committee:

March 17, 2017

It is with great pleasure that I provide this support letter for the University Research Award proposal submitted by Professor Miguel Alonso and Professor Nick Vamivakas from The Institute of Optics. Their joint proposal “Reconfigurable optical matter” is extremely innovative and will revolutionize how we understand matter formation and stability. I would expect the results of this University Research Award to impact materials science, information processing, optical sensing, and imaging technologies.

The general research theme of Miguel and Nick’s proposal is an innovative connection between Miguel’s expertise in Structured Light and Nick’s expertise in Levitated Optomechanics. When successful this will position our Institute to be international leaders in a potentially new research area they have named Reconfigurable Optical Matter. I anticipate these results would be well received by funding agencies such as the NSF and DOE and may even have relevance for AIM photonics testing.

As the Director of The Institute, I will provide Miguel and Nick with the support they need to achieve success in their project. I am confident that support for this program will ensure that the University and The Institute continue to be viewed as pioneering in its research efforts and will certainly enable Miguel and Nick to establish preliminary research results in this area that will lead to external funding.

Best regards,

Xi-Cheng Zhang
M. Parker Givens Professor and Director