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School of
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REFLECTIONS *by Partha Banerjee*

Welcome to 2019. REFLECTIONS was meant to project an optics connotation and summarize the happenings of the past year. Little did I know that this writing would involve a reflection of life and its value. On January 11, 2019, EOP lost its beloved Joe Haus. The suddenness of this very sad event makes one reflect on the meaning of life and its transitions, and appreciate life, and love and respect all. Joe was indeed a person everyone loved, and he loved them in return: his family, his students, colleagues and friends. His love stretched beyond UD to all parts of the country and around the world.

Joe would be proud of EOP's performance last year. He, Cong Deng and I went to teach at HUST over the summer and fall. Two students from HUST then joined us in the fall. EOP graduated 11 M.S. and 3 Ph.D.s. Four summer short courses were offered. LiDAR, co-taught by Paul McManamon and Ed Watson, was the most popular, with students coming in from around the country. Our faculty and students have co-authored 28 journal papers and several conference papers. Joe co-chaired his Nanophotonics conference in Wroclaw, Poland, in 2018.

The student chapter of the Optical Society, along with their counterparts at Purdue, co-hosted the OSA IONS conference, which was held in West Lafayette and Dayton. This was the only IONS conference in the U.S. last year. IONS was a major success, with invited talks from many eminent researchers, industry booths, and with talks and posters from the student participants. Congratulations to Josh Burrow, student chapter president, along with his team: John Hennen, Sarah Krug, Ankita Khanolkar, Zairui Li, Mallik Hossain, Yining Liu, and faculty adviser, Imad Agha, for making this happen.

Our faculty continues to excel in funded research. The National Science Foundation awarded Chenglong Zhao (PI) and Qiwen Zhan (Co-PI) over \$300K to study 3D additive manufacturing in the nanoscale. Joe, with Cong and Andrew Sarangan, received an STTR Phase II subcontract for \$350K for development of phase-change materials for optical limiting. Quantum Screening, a small company in Pasadena, California, began funding Joe and Cong to work on sensing of cancer biomolecules in saliva. The MURI program on atmospheric optics, headed by Mikhail Vorontsov at UD, received an extension for two more years with additional funding of \$500K. ONR gave a contract for \$200K to develop holographic techniques for monitoring 3D additive manufacturing. The Air Force Research Labs at Wright-Patterson Air Force Base continued to fund many of our graduate students through contracts with EOP.



JOSEPH WENDEL HAUS

1948–2019

Joe's career spanned over 35 years, nearly 20 were spent at UD. As an internationally recognized scholar and fellow EOP, Physics and ECE faculty member, Joe Haus impacted the field of electro-optics and photonics and the lives of students he mentored.

Joe passed away from an aggressive liver cancer just a few weeks after he celebrated his 70th birthday.

"The sudden passing of Joe Haus has shocked and saddened the entire School of Engineering family," said Eddy Rojas, dean of the School. "He will always be remembered as a kind, generous and sensitive individual who was devoted to his family, his life's work and his students."

"Dr. Haus was a great physicist with a humble heart," said Yiyi Guan, who received his doctorate under Dr. Haus in 2004. "As his student, I was inspired by his passions for science and innovation. His loving and caring for the students touched our hearts greatly and has changed the lives of many. The world lost a bright star, but Dr. Haus lives in our hearts forever."

Joe was born in Cleveland, Ohio, December 21, 1948. He received his B.S. and M.S. from John Carroll University in 1971 and 1972, respectively, and his Ph.D. from the Catholic University of America in 1975. His Ph.D. research was in the field of statistical mechanics. He then traveled to Germany and worked at the Nuclear Research Center in Jülich, and then as a research assistant at the University of Essen with Roy Glauber, who won the Nobel Prize in Physics in 2005. In Essen,

Joe made important contributions to superfluorescence, stimulated Raman scattering phenomena and published several papers on fundamental aspects of quantum noise.

After returning to the U.S., Joe began his studies of nonlinear optical and heterogeneous systems at the U.S. Army Missile Command (AMCOM) in Huntsville, Alabama, with Dr. Charles Bowden. He followed AMCOM with a move to New York as a faculty member in physics at Rensselaer Polytechnic Institute (RPI). At RPI, he developed an approach to calculating nonlinear optical properties in composite materials, worked with experimentalists to validate the theory and spent a year (1991-92) as the Hitachi Limited Quantum Materials Chair at the University of Tokyo Research Center for Advanced Science and Technology.

In 1999, Joe joined the University of Dayton (UD) as director of the Electro-Optics (EO) graduate program and served until 2012. During his time as director, the Air Force Research Laboratory (AFRL) and the Ohio Third Frontier helped to fund multiple laboratories to conduct research in nanophotonics and laser radar. A \$6 million AFRL grant partially built and equipped the new Ladar and Optical Communication Institute (LOCI) and helped 30 students accomplish their graduate degrees. Joe, who was also the director of LOCI, raised additional funds, including \$1.5 million for the LOCI chair endowment (currently held by Mikhail Vorontsov) and \$1.5 million from an IDCAST grant.



(l-r): Joe Haus at EOP open house at KL; at lunch with Xuesong Gao and his parents at HUST; at a seminar by Dayan Ban from U. Waterloo.

JOSEPH WENDEL HAUS, 1948–2019 CONTINUED

Joe’s research in nonlinear properties of optical fibers began at UD. He examined the role of solitons in shaping the pulse in a cavity and found ways to engineer the laser cavity for greater stability. With associates from Mexico, including Baldemar Ibarra Escamilla from Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), he studied nonlinear polarization effects in optical fibers. He also studied photonic crystals and discovered a full band gap in a simple cubic symmetry photonic lattice that was not expected by the community. He combined his photonic crystals and nonlinear optics research and, in collaboration with Perry Yaney and Peter Powers, investigated second- and third-harmonic generation in nonlinear materials such as lithium niobate and in multi-layer photonic crystals.

While on sabbatical at AMCOM at the end of his directorship of EO, Joe worked with Dr. Michael Scalora’s group to develop a quantum tunneling theory for electrons in nanoscale metal systems. Back at UD, Joe collaborated with Karolyn Hansen from biology on the use of tapered optical fibers as efficient sensors for biomolecules. With EOP researcher Cong Deng, he worked on using these sensors in the detection of cancer cells in saliva. He worked actively with several members of EOP and Physics, including Paul McManamon, Ed Watson, Andrew Sarangan, Qiwen Zhan, Imad Agha, Andy Chong, Jay Mathews, and Chenglong Zhao and extensively published with them and their students.

During his illustrious career, Joe published two books:

Fundamentals and Applications of Nanophotonics and the 2nd edition of *Nonlinear Optics*, originally authored by Peter Powers. He has over 150 refereed journal publications and over 150 conference proceedings publications. He graduated over 10 Ph.D. and 20 M.S. students. He worked with several companies and with researchers at various universities, such as State University of New York at Buffalo (Paras Prasad) and Washington University in St. Louis (Parag Banerjee). He was the founding co-chair and organizer of the International Conference of Nanophotonics, associate editor of *Optics Express* for six years, associate editor of the *Journal of the European Optical Society*, and associate editor-in-chief of *Chinese Optics Letters*.

His recognitions include: Fellow of OSA, SPIE and APS; senior member of IEEE; honorary doctorate from INAOE; the Affiliate Societies Council of Dayton Award; and the UD Alumni Research Award.

Joe was an avid hiker, organizing EOP hikes every semester, rain, snow or shine, and has hiked Machu Picchu, Mt. Fuji, the Northeast 4000 footers, not to mention ADK 46, the highest peaks in the Adirondacks.

In Joe, one can find the qualities of a true mentor, scholar and scientist. He was the epitome of humbleness, simplicity and austerity. He is survived by his wife Jean, of 48 years, and children Alison, Michelle, Paul, Karin, Thomas and Monica.

RIP, Joe, we will keep the light on for you!



	EOP GRADUATES	
MAY 2018	AUGUST 2018	DECEMBER 2018
Edward Ruff, M.S.	Eric Turner, M.S.	Nouf Alanazi, M.S.
Gary Sevison, M.S.	Diane Beamer, Ph.D.	Kyle Epperson, M.S.
Xueyin Shi, M.S.		Samir Obyed, M.S.
Yimin Zang, M.S.		Carlos Sevilla, M.S.
Yiqing Zhou, M.S.		Behzad Bordbar, Ph.D.
James Zimnicki, M.S.		Pengfei Guo, Ph.D.
<i>Congratulations!</i>		

PURDUE, UD CO-HOST IONS MIDWEST USA



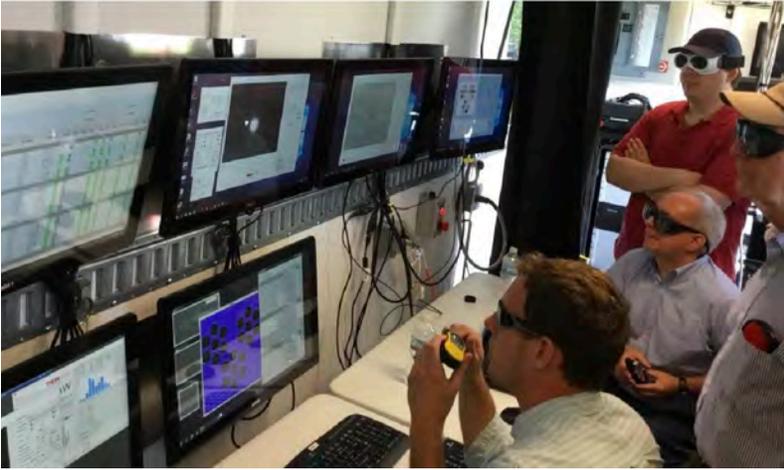
From August 2 to 6, 2018, University of Dayton and Purdue University Optical Society (OSA) student chapters hosted the 5-day IONS Midwest U.S. conference with 4 themes and 3 professional development workshops to bring to students one unified experience. IONS, the International OSA Network of Students, is a program that allows OSA student chapters to organize and manage regional meetings focused on technical and professional development content as well as networking with peers and luminaries. The first half of the conference was held at Purdue in West Lafayette, Indiana, the second half at the University of Dayton in Dayton, Ohio. The conference emphasized applied physics, optical engineering and applications in nonlinear optics, nanophotonics, quantum electronics, and laser technology. External sponsors included

Thorlabs, Leidos, Hammamatsu, Optonicus (now II-VI), ELI: Beamlines and Nikon. Plenary sessions included speakers, such as Nicholas Peters (Oak Ridge National Laboratory), Thomas Murphy (University of Maryland), Gaurav Bahl (University of Illinois – Urbana Champaign), Zubin Jacob (Purdue University), Chen-Lung Hung (Purdue University), Nathaniel Kinsley (Virginia Commonwealth University), Paul McMannon (Exciting Technologies), Augustine Urbas (AFRL), Rita Peterson (AFRL) and Ruyan Guo (University of Texas at San Antonio). The conference also featured professional development workshops including career/industry panels, entrepreneurial and scientific writing workshops. The panel discussions allowed students to ask questions about career choices, career preparation and transitioning between student and professional lifestyles. IONS Midwest U.S. held the first incorporation of a ComSciCon science communication workshop. ComSciCon is a series of workshops focused on the communication of complex and technical concepts organized by graduate students for graduate students. And, of course, there were students presenting their work. AT UD there were over 30 talks and 20 posters, with similar numbers at Purdue. Congratulations to Josh Burrow, John Hennen, Sarah Krug, Ankita Khanolkar, Zairui Li, Mallik Hossain, and Yining Liu from UD, and Deesha Shah, Keith McKinzie, Sam Peana, Sanjay Debnath, Soham Saha, Shaimaa Azzam, Oksana Makarova, Navin Lingaraju and Hsuan Hao Lu from Purdue whose tireless efforts made this event possible.



Worawee Saie, student of UD alum Prathan Buranasiri from King Mongkut University, Bangkok, Thailand (left), posing with (l to r): Yunyang Li, Hongwei Chen, Sichao Zhou, Hammid Al Ghezi, Ujitha Abeywickrema, and Pengfei Guo in front of the student poster at the SPIE Annual meeting in San Diego, CA, August 2018.

SMALL BUSINESS BECOMES BIG BUSINESS



A success story: In August 2018, Optonicus, LLC, a small business born and housed in EOP, was acquired by II-VI Optical Systems, Inc. to further develop and commercialize the Optonicus fiber array systems for DoD and industrial markets. The new company (II-VI-Optonicus) is committed to maintaining and further enhancing the established collaboration with UD EOP's Intelligent Optics Labs (IOL), retaining the Optonicus, LLC personnel at the leased office area, and continuing to make available lab space, lab equipment and infrastructure for joint use by the UD/IOL and II-VI-Optonicus teams.

II-VI, Inc. is a global leader in engineered materials, optoelectronic components and optical systems offering vertically integrated solutions for applications in materials processing, communications, military, life sciences, semiconductor equipment, automotive and consumer electronics. This merger provides unique opportunities for continuous advancement and growth of the Intelligent Optics technology pioneered by Optonicus for various applications and customer needs. In support of the mutual strategic vision that II-VI OS and Optonicus share, the combined team will enhance development, provide vertical integration, and bring

to the market, new products in the emerging areas of HEL directed energy (DE), advanced material processing and laser additive manufacturing (LAM), power beaming, laser communication, active imaging and remote sensing.

By teaming with different parts of the II-VI family of companies, Optonicus will have an opportunity to bring our adaptive fiber array technology to emerging markets of advanced laser material processing and LAM. We believe that the next generation of metallic laser material processing and 3-D printing systems will utilize adaptive fiber array laser sources that can provide capabilities for on demand alteration of material properties.

Since 2010, Optonicus, LLC, founded by Mikhail Vorontsov, has provided help in maintenance of the UD/IOL facilities and equipment (repair/replacement). Optonicus has also provided funds to enhance UD/IOL capabilities via modification of infrastructure and access to unique equipment developed and/or purchased by the company.

Optonicus and UD teams have jointly participated in several high-profile experimental campaigns including long-range (149 km) atmospheric propagation and imaging experiments between Hawaii and Maui Islands (2009, 2010), DARPA Sea Hawk coherent beam combining field experiments (2016-2018), and joint Optonicus, UD and University of Notre Dame experiments on laser link between two flying aircraft (2018-2019). Planned for 2019 and 2020 are laser power beaming field experiments in Hawaii, and White Sands, New Mexico.

Optonicus provides continuous support of EOP via: (a) offering jobs for UD graduates; offering summer internships for UD undergrad and grad students; (c) support of faculty members on a consultant basis; (d) helping students with their research projects; (e) providing free access to the Optonicus developed software product (WONAT) for use during course work; (f) support maintenance, and software upgrades of the UD/IOL high performance computer purchased through the IOL DURIP funds.



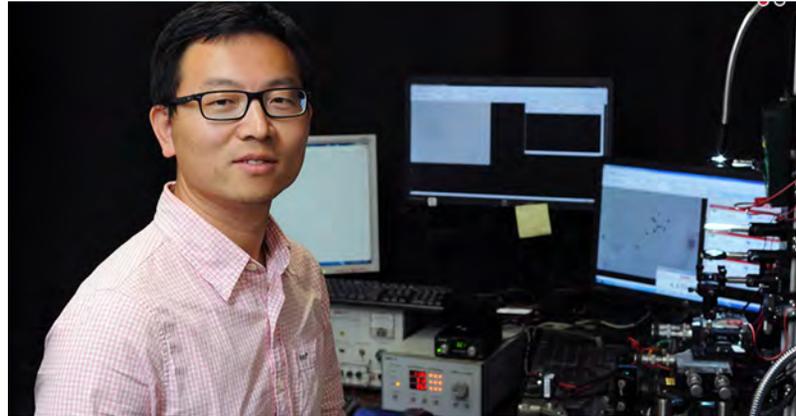
SELECTED JOURNAL PUBLICATIONS

- R. Gnawali, **P. P. Banerjee**, **J. W. Haus**, V. Reshetnyak, and D. R. Evans, "Optical propagation through anisotropic metamaterials: Application to metallo-dielectric stacks," *Opt. Comm.* **425**, 71-79 (2018).
- U. Abeywickrema, **C. Zhao**, and **P. P. Banerjee**, "Estimation of thermocapillary force during laser trapping of confined microbubbles in a liquid," *Opt. Engr.* **57**, 064106 (2018).
- D. Beamer, U. Abeywickrema, and **P. P. Banerjee**, "Statistical analysis of polarization vectors for target identification," *Opt. Engr.* **57**, 054110 (2018).
- Y. A. Garbovskiy, D. R. Evans, **P. P. Banerjee**, and A. V. Glushchenko, "Static and dynamic electro-optical properties of liquid crystals mediated by ferroelectric polymer films," *RSC Adv.* **8**, 1889-1898 (2018).
- I. V. A. K. Reddy, A. Baev, E. P. Furlani, P. Prasad, and **J. W. Haus**, "Interaction of structured light with a chiral plasmonic metasurface: Giant enhancement of chiro-optic response," *ACS Photonics* **5**, 734-740 (2018).
- M. Scalora, M. A. Vincenti, D. de Ceglia, N. Akozbek, M. J. Bloemer, C. De Angelis, **J. W. Haus**, R. Vilaseca, J. Trull, and C. Cojocar, "Harmonic generation from metal-oxide and metal-metal boundaries," *Phys. Rev. A* **98**, 023837 (2018).
- L. A. Herrera-Piad, **J. W. Haus**, D. Jauregui-Vazquez, Y. Lopez-Dieguez, J. M. Estudillo-Ayala, J. M. Sierra-Hernandez, J. C. Hernandez-Garcia, and R. Rojas-Laguna, "A dual modality optical fiber sensor," *J. Modern Opt.* **65**, 342-347 (2018).
- P. Guo, J. A. Burrow, G. A. Sevison, A. Sood, M. Asheghi, J. R. Hendrickson, K. E. Goodson, **I. Agha**, and **A. Sarangan**, "Improving the performance of Ge₂Sb₂Te₅ materials via nickel doping: Towards RF-compatible phase-change devices," *Appl. Phys. Lett.* **113**, 171903 (2018).
- **A. Sarangan**, J. Duran, V. Vasilyev, N. Limberopoulos, I. Vitebskiy, and I. Anisimov, "Broadband reflective optical limiter using GST phase change material," *IEEE Photonics J.* **10**, 1-9 (2018).
- C. Ni, J. Jia, M. Howard, K. Hirakawa, and **A. Sarangan**, "Single-shot multispectral imager using spatially multiplexed fourier spectral filters," *J. Opt. Soc. Amer. B*, **35**, 1072-1079 (2018).
- R. Yahiaoui, J. A. Burrow, S. M. Mekonen, **A. Sarangan**, **J. Mathews**, **I. Agha**, and T. A. Searles, "Electromagnetically induced transparency control in terahertz metasurfaces based on bright- bright mode coupling," *Phys. Rev. B* **97**, 155403 (2018).
- **A. Sarangan**, "Design of metal-dielectric resonant-cavity thin-film structures using the effective reflectance index method," *J. Opt. Soc. Amer. B*, **35**, 2294-2301 (2018).
- H. Chen, S. Zhou, G. Rui, and **Q. Zhan**, "Magnified photonic spin-Hall effect with curved hyperbolic metamaterials," *J. Appl. Phys.* **124**, 233104 (2018).
- H. Li, K. Yan, Y. Zhang, C. Gu, P. Yao, L. Xu, R. Zhang, J. Su, W. Chen, Y. Zhu, and **Q. Zhan**, "Low-threshold high-efficiency all-fiber laser generating cylindrical vector beams operated in LP₁₁ mode throughout the entire cavity," *Appl. Phys. Exp.* **11**, 122502 (2018).
- R. Chen, F. Sun, J. Yao, J. Wang, H. Ming, A. Wang, and **Q. Zhan**, "Mode-locked all-fiber laser generating optical vortex pulses with tunable repetition rate," *Appl. Phys. Lett.* **112**, 261103 (2018).
- R. Chen, X. Zhang, J. Wang, Q. Zhao, A. Wang, and **Q. Zhan**, "Scalable detection of photonic topological charge using radial phase grating," *Appl. Phys. Lett.* **112**, 122602 (2018).
- Y. Zhang, H. Li, C. Dai, L. Xu, C. Gu, W. Chen, Y. Zhu, P. Yao, and **Q. Zhan**, "All-fiber high-order mode laser using a metal-clad transverse mode filter," *Opt. Exp.* **26**, 29679-29686 (2018).

SELECTED JOURNAL PUBLICATIONS CONTINUED

- C. Wan, Y. Yu, and **Q. Zhan**, “Diffraction-limited near-spherical focal spot with controllable arbitrary polarization using single objective lens,” *Opt. Exp.* **26**, 27109-27117 (2018).
- Y. Xue, Y. Wang, S. Zhou, H. Chen, G. Rui, B. Gu, and **Q. Zhan**, “Focus shaping and optical manipulation using highly focused second-order full Poincaré beam,” *J. Opt. Soc. Am. A* **35**, 953-958 (2018).
- **Q. Zhan** and Q. Gan, “Editorial for special issue on advances in metasurfaces,” *Chin. Opt. Lett.* **16**, 050001-050004 (2018).
- P. Qiu, D. Zhang, M. Jing, T. Lu, B. Yu, **Q. Zhan**, and S. Zhuang, “Dynamic tailoring of surface plasmon polaritons through incident angle modulation,” *Opt. Exp.* **26**, 9772-9783 (2018).
- C. Xu, K. Yan, C. Gu, P. Yao, L. Xu, and **Q. Zhan**, “All-fiber laser with flat-top beam output using a few-mode fiber Bragg grating,” *Opt. Lett.* **43**, 1247-1250 (2018).
- R. Chen, J. Wang, X. Zhang, A. Wang, H. Ming, F. Li, D. Chung, and **Q. Zhan**, “High efficiency all-fiber cylindrical vector beam laser using a long-period fiber grating,” *Opt. Lett.* **43**, 755-758 (2018).
- L. Gong, B. Gu, G. Rui, Y. Cui, Z. Zhu, and **Q. Zhan**, “Optical forces of focused femtosecond laser pulses on nonlinear optical Rayleigh particles,” *Photonics Res.* **6**, 138-143 (2018).
- D. Zhang, L. Zhu, J. Chen, R. Wang, P. Wang, H. Ming, R. Badugu, M. Rosenfeld, **Q. Zhan**, C. Kuang, X. Liu, and J. R. Lakowicz, “Conversion of isotropic fluorescence into a long-range non-diverging beam,” *Methods and Applications in Fluorescence* **6**, 024003 (2018).
- J. Chen, C. Wan, and **Q. Zhan**, “Vectorial optical fields: recent advances and future prospects,” *Science Bulletin* **63**, 54-74 (2018).
- M. S. Alam and **C. Zhao**, “Nondestructive approach for additive nanomanufacturing of metallic nanostructures in the air,” *ACS Omega* **3**, 1213-1219 (2018).
- F. Karim, E. S. Vasquez, and **C. Zhao**, “Fabricated nanogap-rich plasmonic nanostructures through an optothermal surface bubble in a droplet,” *Opt. Lett.* **43**, 334-336 (2018).

CHENGLONG ZHAO AND QIWEN ZHAN DO 3D ADDITIVE MANUFACTURING IN THE NANOSCALE



What Mikhail Vorontsov and his team, including II-VI-OPTONICUS, is doing in the macroscale, EOP faculty Chenglong Zhao and Qiwen Zhan are trying to emulate in the nanoscale. The National Science Foundation has awarded Chenglong (PI) and Qiwen (Co-PI) \$317,158 to study a new manufacturing process for building three-dimensional structures that are 1,000 times smaller than the diameter of a human hair.

The process is similar to 3D printing and uses a laser to assemble 100-nanometer-sized particles on a flexible substrate through precise electrical manipulation. Unlike current nanoscale fabrication techniques, it can be done under ambient conditions without expensive equipment and doesn't alter or damage the materials.

The three-year grant supports the fundamental study of this new manufacturing process. The award also supports the work of a doctoral student in Chenglong's Nanophotonics & Nano-manufacturing (NPNM) Laboratory.

In May, Chenglong also received a UD STEM catalyst grant with assistant professor of biology, Yvonne Sun, and assistant professor of chemical and materials engineering, Erick Vasquez, to detect and identify foodborne bacteria. More details can be found at

<https://www.udayton.edu/blogs/artssciences/2018-stories/19-10-08-nano-manufacturing.php> and

at the Youtube link:

https://www.youtube.com/watch?v=-_xY6OFZx1Y&utm_source=cerkl&utm_medium=email&utm_campaign=newsletter-12122018&cerkl_id=3823364&cerkl_ue=7iCZVbYQq7pLQNuPknyUts2Vf5i%2BsLKE4Ax6tuL9j1E%3D

2018 DEAN'S FELLOW: REMONA HEENKENDA



When Dean Rojas announced a new fellowship program in the School of Engineering, EOP was most excited, since it is a graduate program where most of its students are funded. As applications kept coming, EOP faculty looked out for a bright scholar, domestic or international, who would be befitting this fellowship. They did not have to look far – Remona Heenkenda was graduating with her M.S. from Wright State University (WSU) and had great credentials. She was our unanimous choice, just like UD was her's.

Remona was born and raised in Sri Lanka, a tiny island known as the pearl of the Indian Ocean. Being the youngest in the family, she was always inspired to follow her dreams, which lead her in a direction towards learning science. She obtained a bachelor's degree in physics with a first-class distinction from the University of Sri Jayewardenepura, Sri Lanka, and came to the United States to pursue her graduate studies in physics at WSU.

“UD offers one of the finest electro-optics programs in the nation. The program is well designed to train students both in the theoretical and practical aspects, leading them in a successful career path,” says Remona. “As students, we get the opportunity to expand our research experience with highly knowledgeable and experienced faculty members, who are also great mentors. I recently joined Dr. Andrew Sarangan's research group and hope to make a significant contribution to their research work.” EOP is happy Remona was its first recipient of this fellowship.

The Dean's fellowship will grow to support a total of three EOP students through their graduate studies in the long term.



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