Mobile Microscopy, Sensing and Diagnostics through Computational Photonics

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My research focuses on the use of computation/algorithms to create new optical microscopy, sensing, and diagnostic techniques, significantly improving existing tools for probing micro- and nano-objects while also simplifying the designs of these analysis tools. In this presentation, I will introduce a new set of computational microscopes which use lens-free on-chip imaging to replace traditional lenses with holographic reconstruction algorithms. Basically, 3D images of specimens are reconstructed from their "shadows" providing considerably improved field-of-view (FOV) and depth-of-field, thus enabling large sample volumes to be rapidly imaged, even at nanoscale. These new computational microscopes routinely generate >1–2 billion pixels (giga-pixels), where even single viruses can be detected with a FOV that is >100 fold wider than other techniques. At the heart of this leapfrog performance lie self-assembled liquid nano-lenses that are computationally imaged on a chip. These self-assembled nano-lenses are stable for >1 hour at room temperature, and are composed of a biocompatible buffer that prevents nano-particle aggregation while also acting as a spatial "phase mask." The field-of-view of these computational microscopes is equal to the active-area of the sensor-array, easily reaching, for example, >20 mm^2 or >10 cm^2 by employing state-of-the-art CMOS or CCD imaging chips, respectively.

In addition to this remarkable increase in throughput, another major benefit of this technology is that it lends itself to field-portable and cost-effective designs which easily integrate with smartphones to conduct giga-pixel tele-pathology and microscopy even in resource-poor and remote settings where traditional techniques are difficult to implement and sustain, thus opening the door to various telemedicine applications in global health. Some other examples of these smartphone-based biomedical tools that I will describe include imaging flow cytometers, immunochromatographic diagnostic test readers, bacteria/pathogen sensors, blood analyzers for complete blood count, and allergen detectors. Through the development of similar computational imagers, I will also report the discovery of new 3D swimming patterns observed in human and animal sperm. One of this newly discovered and extremely rare motion is in the form of "chiral ribbons" where the planar swings of the sperm head occur on an osculating plane creating in some cases a helical ribbon and in some others a twisted ribbon. Shedding light onto the statistics and biophysics of various micro-swimmers' 3D motion, these results provide an important example of how biomedical imaging significantly benefits from emerging computational algorithms/theories, revolutionizing existing tools for observing various micro- and nano-scale phenomena in innovative, high-throughput, and yet cost-effective ways.

Biography: Dr. Aydogan Ozcan received his Ph.D. degree at Stanford University Electrical Engineering Department. After a short post-doctoral fellowship at Stanford University, he was appointed as a research faculty at Harvard Medical School, Wellman Center for Photomedicine in 2006. Dr. Ozcan joined UCLA in 2007 and he is currently the Chancellor's Professor at UCLA and an HHMI Professor with the Howard Hughes Medical Institute, leading the Bio- and Nano-Photonics Laboratory at UCLA Electrical Engineering and Bioengineering Departments, and is also the Associate Director of the California NanoSystems Institute at UCLA.

Dr. Ozcan holds 33 issued patents and 20+ pending patent applications for his inventions in telemedicine, mobile health, nanoscopy, wide-field imaging, lensless imaging, nonlinear optics, fiber optics, and optical coherence tomography. Dr. Ozcan gave more than 35 plenary/keynote talks and 300+ invited talks and is also the author of one book, the co-author of more than 450 peer reviewed publications in major scientific journals and conferences. In addition, Dr. Ozcan is the founder and a member of the Board of Directors of Holomic/Cellmic LLC, which was named a Technology Pioneer by The World Economic Forum in 2015.

Prof. Ozcan received several major awards including the 2011 Presidential Early Career Award for Scientists and Engineers (PECASE), which is the highest honor bestowed by the United States government on science and engineering professionals in the early stages of their independent research careers. Dr. Ozcan received this prestigious award for developing innovative optical technologies and signal processing approaches that have the potential to make a significant impact in biological science and medicine; addressing public health needs in less developed countries; and service to the optical science community including mentoring and support for underserved minority undergraduate and graduate students. Dr. Ozcan also received the 2015 UCLA Postdoctoral Scholars Mentoring Award for his commitment to training and mentoring of postdoctoral researchers. In addition, Dr. Ozcan received the inaugural Rahmi M. Koc Science Medal, the International Commission for Optics (ICO) Prize, the inaugural SPIE BioPhotonics Technology Innovator Award, the Army Research Office (ARO) Young Investigator Award, SPIE Early Career Achievement Award, NSF CAREER Award, NIH Director's New Innovator Award, the Office of Naval Research (ONR) Young Investigator Award, the IEEE Photonics Society Young Investigator Award and the MIT's Technology Review TR35 Award for his seminal contributions to near-field and on-chip imaging, and telemedicine based diagnostics.

Prof. Ozcan is also the recipient of the 2016 IEEE Photonics Society Distinguished Lecturer Award, 2013 and 2015 Microscopy Today Innovation Awards, 2012 Popular Science Brilliant 10 Award, 2012 National Academy of Engineering (NAE) The Grainger Foundation Frontiers of Engineering Award, 2011 Innovators Challenge Award presented by the Rockefeller Foundation and mHealth Alliance, the 2010 National Geographic Emerging Explorer Award, the 2010 Bill & Melinda Gates Foundation Grand Challenges Award, the 2010 Popular Mechanics Breakthrough Award, the 2010 Netexplorateur Award given by the Netexplorateur Observatory & Forum in France, the 2009 and 2016 Wireless Innovation Award organized by the Vodafone Americas Foundation as well as the 2008 Okawa Foundation Award, given by the Okawa Foundation in Japan.

Prof. Ozcan was selected as one of the top 10 innovators by the U.S. Department of State, USAID, NASA, and NIKE as part of the LAUNCH: Health Forum organized in 2010. He also received the 2012 World Technology Award on Health and Medicine, which is presented by the World Technology Network in association with TIME, CNN and AAAS. Dr. Ozcan is a Fellow of SPIE, OSA, IEEE and AIMBE, and is a Lifetime Member of AAAS, SPIE and OSA.