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Broadly defined, optical interferometry refers to constructive and destructive intensity modulation when light waves are superimposed onto a detector. It is a remarkable phenomenon, simultaneously revealing the wave nature of light and enabling sensitive measurements of distances. As optical engineers, we are most often interested in harnessing interferometry for precise metrology of wavefronts, distances, displacements, or surface form or texture. By extension, we also quantify temperature, strain, or even gravity waves using length transducers that are sensitive to these effects.

As is the case with many technology areas, there have been significant advances in precision, speed, and physical modeling of optical interferometers. In addition to these improvements, one of the most notable advancements for this centuries-old technique is the dramatic increase in the range of applications for interferometry. In this special section, we have collected 13 exemplary papers to illustrate not only technology advances, but also the increased breadth of practical application for what was not so long ago a specialized physics experiment.

Many of the new applications for interferometry have been enabled by steady improvements in instrument design and data analysis. Shiguang Wang describes how best to design laser Fizeau interferometers for the high lateral resolution requirements of modern optics fabrication using analytical and numerical modeling of the coherent phase transfer function. Yassine Tounsi et al. propose phase derivative estimation in orthogonal directions based on Riesz transform from a single speckle correlation fringe, while Orlando Medina et al. consider improvements to phase unwrapping—a basic problem in interferometric wavefront analysis, particularly in the presence of noise. On a more fundamental level, James Smith et al. describe the use of quantum mechanically entangled photons for measurement processes for super-sensitivity and super-resolution. His development of closed-form expressions for the optimal detection operators leads to optimal resolution for maximum visibility and minimum phase error.

The paper by Anthony Yee and Duncan Moore provides an example of solid instrument design for optical elements created by new optics manufacturing techniques. The system developed by Yee and Moore leverages the sensitivity of interferometry for profiling the index of refraction of gradient index optics while overcoming the challenges of operating in the infrared (3.39 μm). The rapid development of fabrication techniques for aspheric optics has presented its own challenges, as described by Christof Pruss et al., in their paper on the titled wave interferometer (TWI). The TWI is an extraordinary instrument with dynamic measurement capability well beyond the traditional limits of interferometric optical testing, using a technique pioneered at the Institute for Technical Optics and now integrated into a commercial system.

In many cases, interferometric metrology has paralleled manufacturing innovations that have stressed established measurement methods. Igarashi Akiori et al. examine the use of phase-shifting digital holographic microscopy for quantifying the refractive index distribution in glasses welded by ultrashort laser pulses. Carlos Gomez et al. contribute best-practice guidance to areal surface metrology of additive manufacturing parts—an application that relies heavily on the most recent advances in coherence scanning techniques in interference microscopy. Martin Fay and Thomas Dresel demonstrate the full 3-D imaging of thin transparent surface films, using physical modeling of the interference effect at high magnifications in white light.

A persistent challenge relates to noise or environmental conditions. This is the case for the work described by Ziliang Lyu et al., who employ wavelength-scanning interferometry for resolving depth. Their work focuses on overcoming large impulse noise—sometimes referred to as salt noise—resulting from sharp and sudden disturbances in the image signal. Their approach is to use the phase frequency in Fourier space to recover the phase maps. Wang Sheng et al. consider two-dimensional (2-D) velocity measurement of a flow field in the extreme conditions typical of combustion studies, relying on Rayleigh scattering with a Fabry—Perot interferometer.

One of the more unexpected application areas for interferometry is in the life sciences and biological imaging. Curtis Larimer et al. employ an ingenious microfluidic imaging cell to assess bacterial growth and biofilm development. The dynamic metrology of biofilms has applications ranging from dental plaque to water filters, and interference microscopy offers unique capabilities for biofilm imaging thanks to its high axial resolution and large depth of field. Quantitative phase imaging of biological cells is another exemplary life science application, for which Jianglei Di et al. propose a dual-wavelength holographic instrument based on lateral shearing. The simple common-path design proposed by this group improves the temporal stability and reduces speckle noise.

We hope that this special section provides readers with an overview of the advances and expanding applications of interferometry, as well as a perspective on current research directions. We would also like to take this opportunity to thank the contributing authors and the staff of *Optical Engineering* in helping to compile this special section on interferometry.

Peter de Groot is a physics PhD specializing in applied optics, with an emphasis on dimensional metrology. His research has led to 135 U.S. patents and over 150 technical papers, tutorials, and book chapters. He is a Fellow of the SPIE, a Fellow of the Optical Society of America, an honorary professor at the University of Nottingham, a returned Peace Corps volunteer, a recipient of the SPIE Rudolf Kingslake Medal in Optical Engineering, and an active member of the applied optics community.

Erik Novak received his PhD in optical sciences from the University of Arizona in 1998 under Dr. James Wyant and has been director of business development at 4D Technology since 2013. He has been developing instrumentation for precision metrology for more than 25 years for numerous industrial applications. He has received five R&D 100 awards, holds over a dozen patents, and has more than sixty publications and book chapters related to surface measurement and industrial process control.