

Information for: Advertisers **Figure 1.** Scheme of a point-diffraction interferometer: optical interference occurs between the two wavefronts.

As with any interferometric technique, PDI interferograms must be interpreted to extract object wavefront information. The most accurate and effective way to measure both the magnitude and the sign of wavefront aberrations is to use phase-shifting (PS) interferometry. However, this advanced technique could not be used with the PDI because its common path design made it difficult to shift the phase of one beam relative to the other.

Different schemes were proposed to integrate PS into PDI configurations, <u>1-3</u> but the first to phase-shift the PDI was Kwon, who fabricated a pinhole in a sinusoidal transmission grating to produce phase-shifted interferograms. <u>4</u>Other designs used liquid crystals as a variable retarder. <u>5</u> One interesting PDI configuration based on liquid crystals was invented by Mercer and Creath under a NASA contract. Instead of a pinhole, they used a microsphere inside a liquid crystal layer to generate a spherical wavefront, while the aberrated wavefront was shifted electro-optically by the liquid crystal.<u>6-8</u>

We have designed a new PDI configuration based on a pinhole filter fabricated from a lithium niobate (LN) crystal,⁹ an optical material widely used in optics and optoelectronics. LN is transparent in a very wide spectral range (400–5500nm), hence its usefulness for numerous applications. Moreover, it also enables a very high frequency of phase-shift modulation.

A thin aluminum layer with a circular opening is fabricated on the surface of the crystal by conventional photolithography with subsequent aluminum deposition and liftoff (see Figure 2, inset). A uniform planar aluminum layer is deposited on the opposite face. The aluminum acts as electrode on both faces and as pinhole filter on the exit face of the crystal. The applied voltage causes a uniform phase shift over the aberrated wavefront while leaving unaffected the diffracted reference beam passing through the pinhole.

The optical configuration used for the experimental test is shown in Figure $\underline{2}$. A He-Ne laser beam at 632.8nm is expanded and then focused onto the PDI-LN. One lens of the optical setup is intentionally widely tilted to introduce severe off-axis aberrations in the tested wavefront.



Figure 2. Scheme of the optical setup of our interferometer. L_i : Lenses. PDI-LN: Point-diffraction interferometer. CCD: Camera. Insets: (a) Schematic drawing of the pinhole fabrication process; (b) optical microscope image of the resist dot and (c) of the subsequent aluminum opening structure obtained on the LN crystal surface.

During the application of the external voltage, the un-diffracted wavefront experiences a change of optical path length, due to the electro-optic effect. We apply a linear voltage ramp across the sample from -0.6 to 0.3 kV with continuous capture of the fringe pattern (10 frames per second) using a CCD. The images are digitized and stored in a PC. This allows us to select one or more sequences of phase-shifted images with unknown but constant PS step. The selected images are those acquired at specific voltage intensities differing by a constant voltage step. They can then be processed using the Carré algorithm¹⁰ to retrieve the aberrated wavefront.

Figure $\underline{3}$ shows the plot (in radians) of the retrieved phase of the aberrated wavefront, and the inset shows one of the four phase-shifted images of the fringe pattern.

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Figure 3. Phase map of the wavefront calculated with a Carré phase shift algorithm. Inset: One of the acquired fringe patterns.

In conclusion, we have described a new phase-shifting point-diffraction interferometer design based on a LN crystal pinhole. We have demonstrated the proof of principle of the device, testing it on a wavefront emerging from a tilted spherical lens. Our PDI design has several important advantages over other PDI configurations. The optical setup is very simple and highly stable to disturbing environmental noise, therefore eliminating requirements for quiet laboratory environments.

Pietro Ferraro, Simonetta Grilli

Istituto Nazionale di Ottica Applicata, CNR (INOA-CNR) Pozzuoli, Italy

Pietro Ferraro is a chief research scientist at INOA-CNR. He was previously a principal investigator at Alenia Aeronautics. He has published 90 papers in scientific journals, 150 papers at international conferences, and has been an invited speaker several times. He has also written three book chapters and has 10 patents. He was a guest editor for eight special issues in international journals and is a member of the editorial board of *Optics and Lasers in Engineering* (Elsevier).

Simonetta Grilli obtained her PhD at the Kungliga Tekniska högskolan (KTH) in Stockholm, and she is now a research scientist at CNR-INOA. Her current research activities include the noninvasive investigation of reversed domains and the fabrication of submicron structures. She has coauthored more than 20 papers in international journals and more than 40 conference papers.

Melania Paturzo

European Laboratory for Non-linear Spectroscopy (LENS), Università di Firenze Firenze, Italy

Melania Paturzo obtained a degree in physics with cum laude mention from the University of Naples. She subsequently began work at INOA-CNR. Her research interests are focused on optics. She is now a PhD student at the University of Florence. Her research activities involve the investigation of material properties by optical techniques. She has authored and coauthored 10 international publications.

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