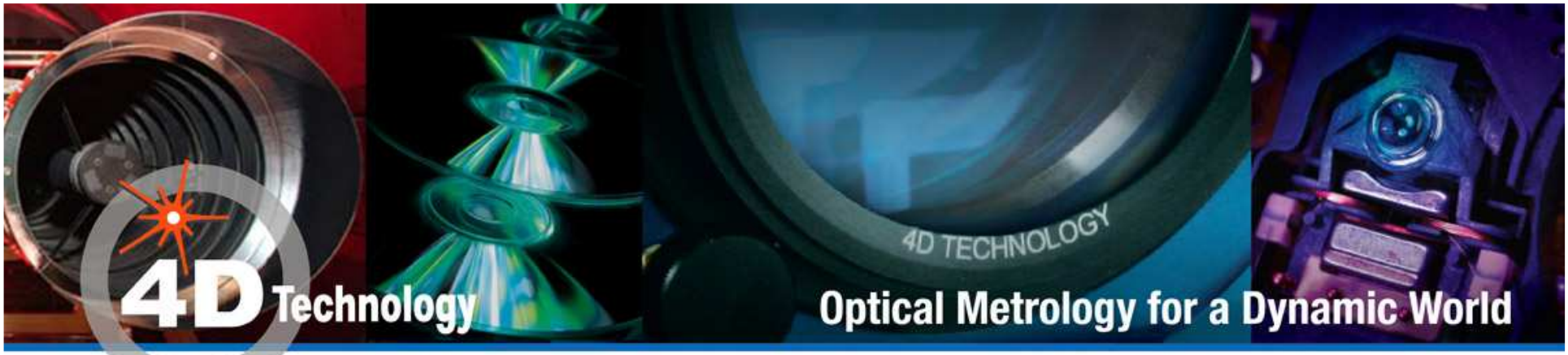


DUAL MODE INTERFEROMETER FOR MEASURING DYNAMIC DISPLACEMENT OF SPECULAR AND DIFFUSE COMPONENTS

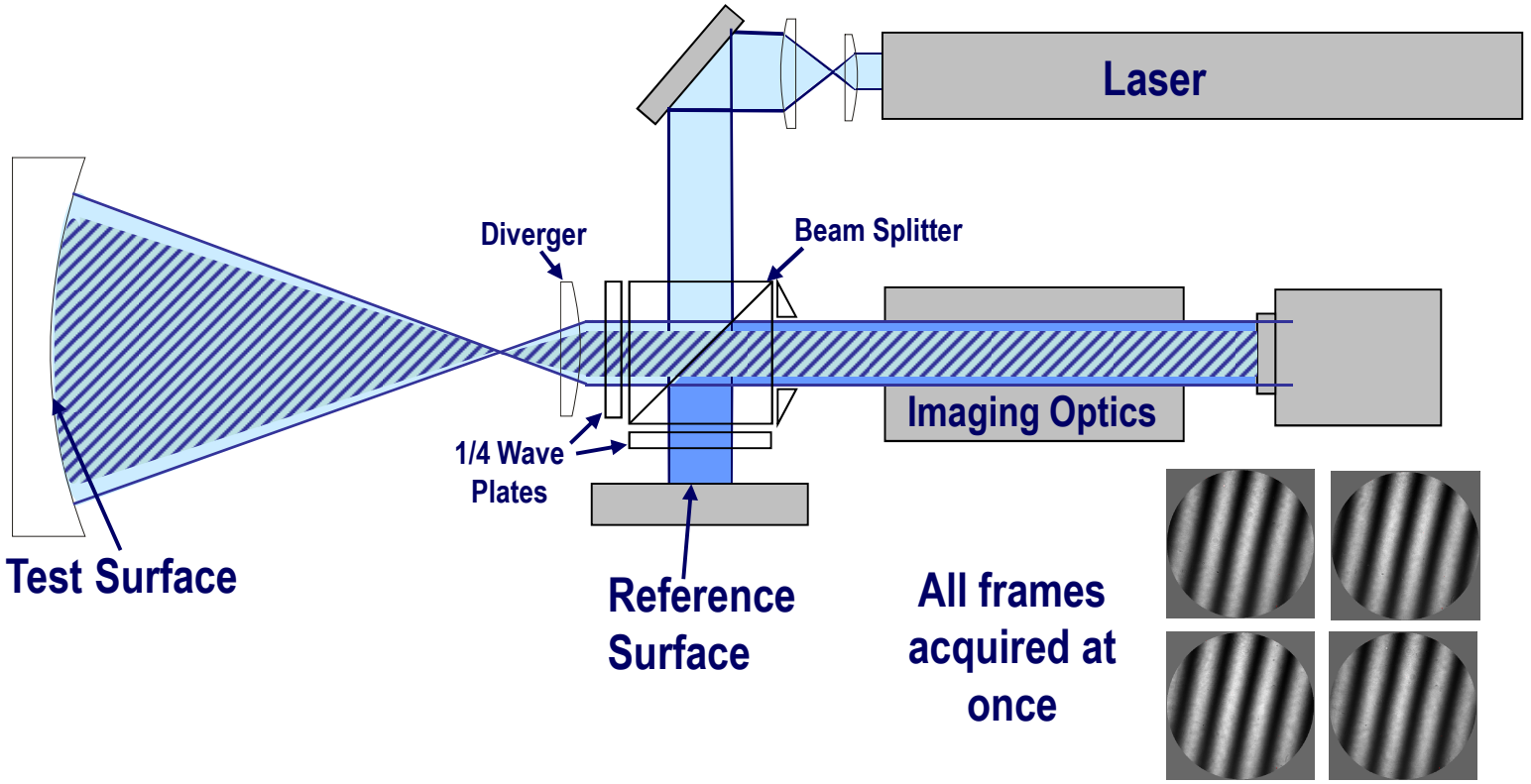
July 2009

Design Goals

Develop a compact single frame acquisition interferometer capable of operating as a traditional phase-shifting interferometer or an electronic speckle pattern interferometer with minimal required changes between configurations.

Interferometer

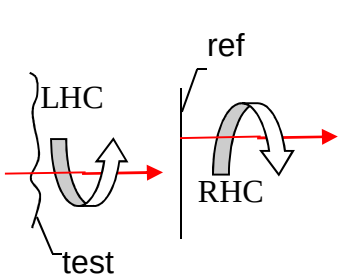
Dynamic Interferometry Advantages

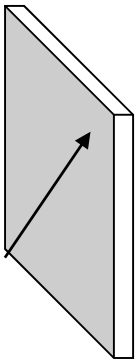


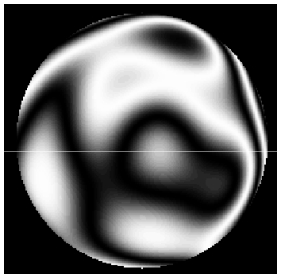
Dynamic Twyman-Green Interferometer

Dynamic Phase Shift Method

Use polarizer as phase shifter





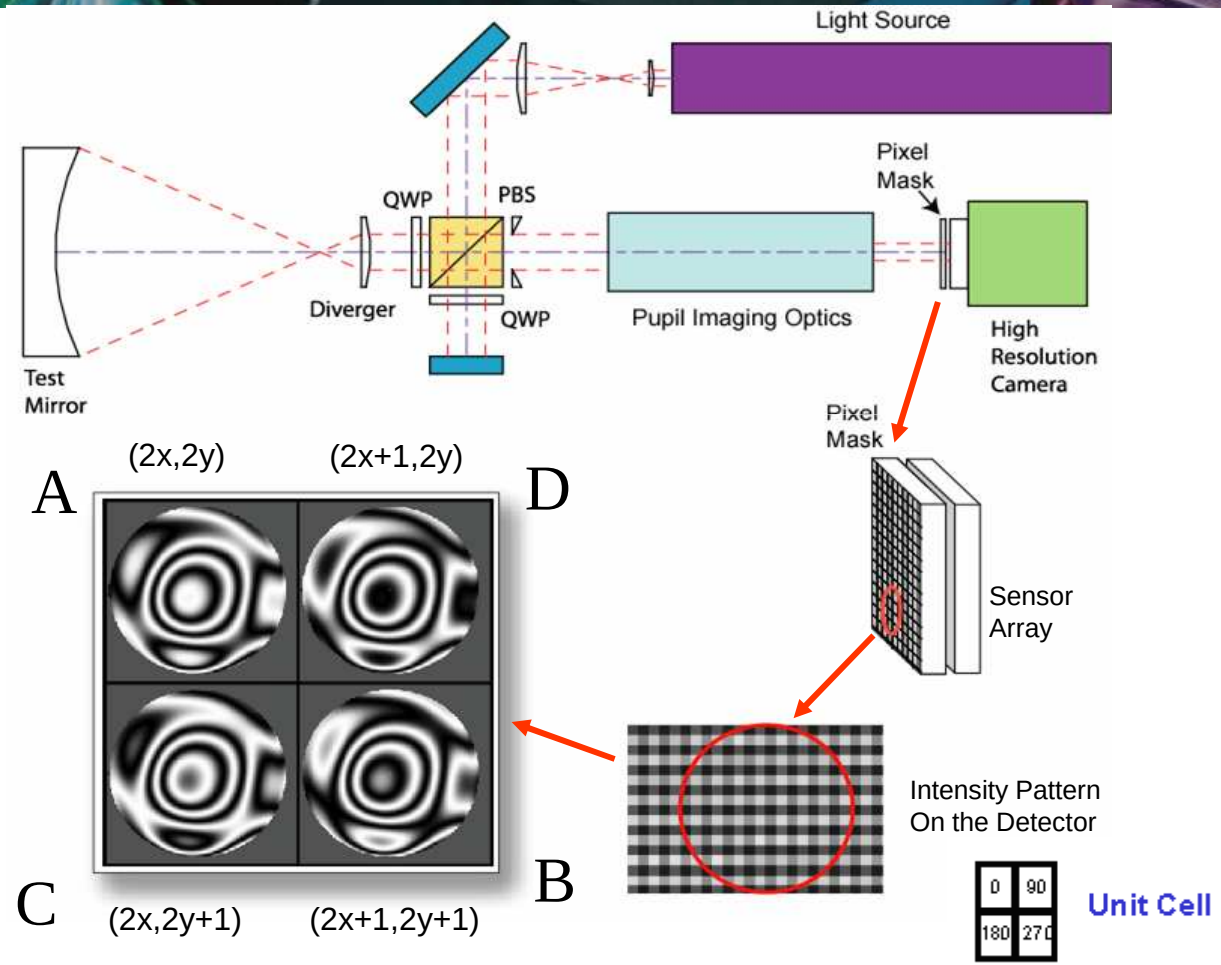


Circular polarized beams (θ) + linear polarizer (α) $\longrightarrow I = I_T(1+\gamma \mathrm{Cos}\,(\theta + 2\alpha))$

Phase-shift depends on polarizer angle

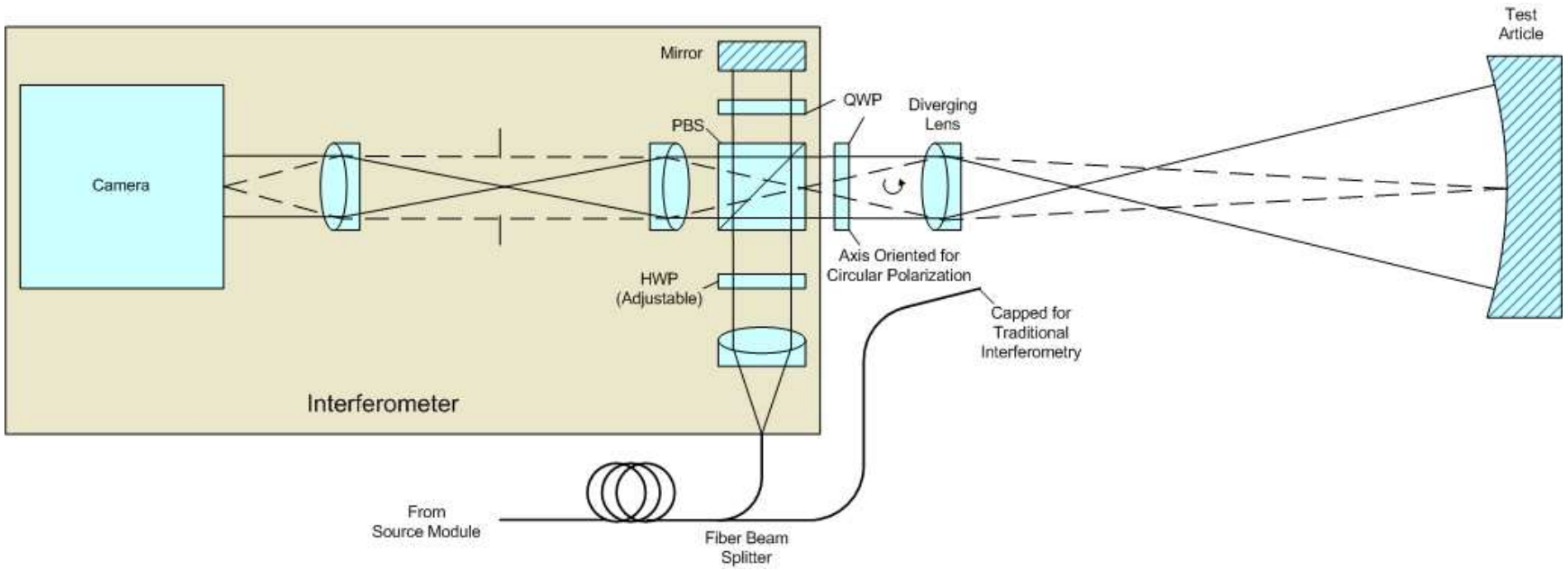
Kothiyal and Delsile, Appl. Opt. V24 n24 p4439 (1985)
Kemo, et. al, Appl Opt. V41 n 13 p2448 (2002)

Pixelated Phase Mask

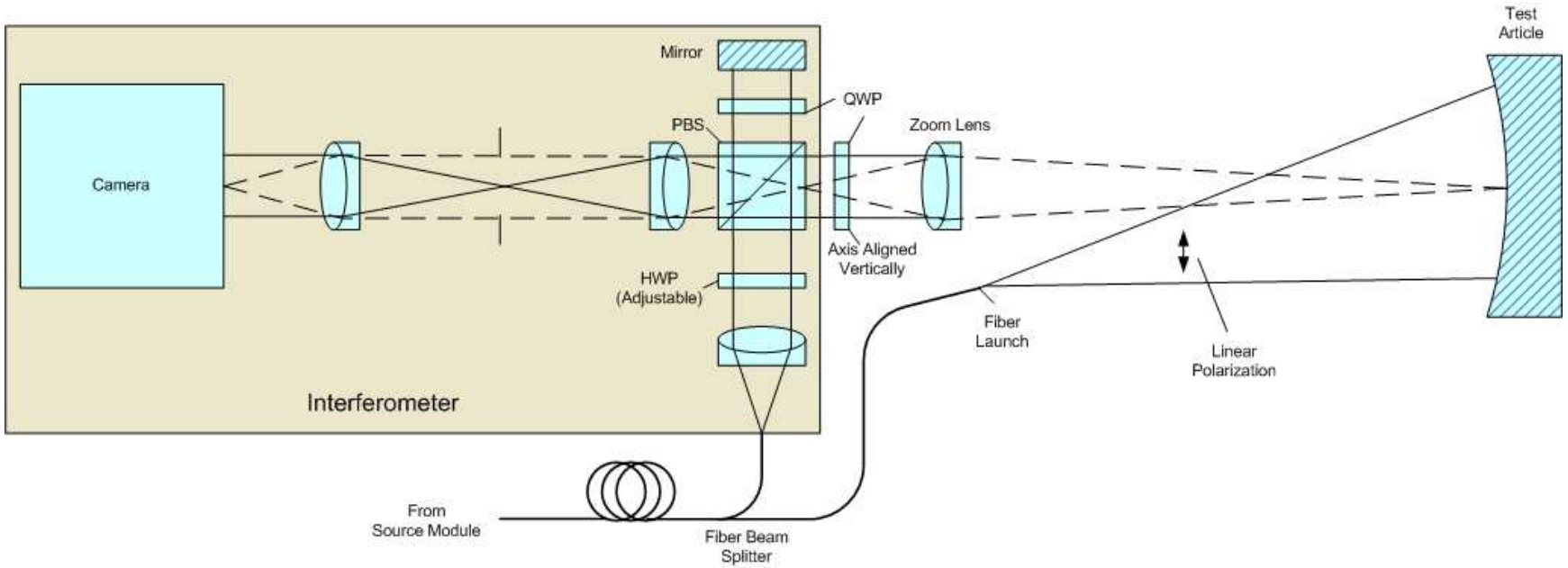


All frames acquired in one camera integration time!

PhaseCam 6000 Traditional Layout



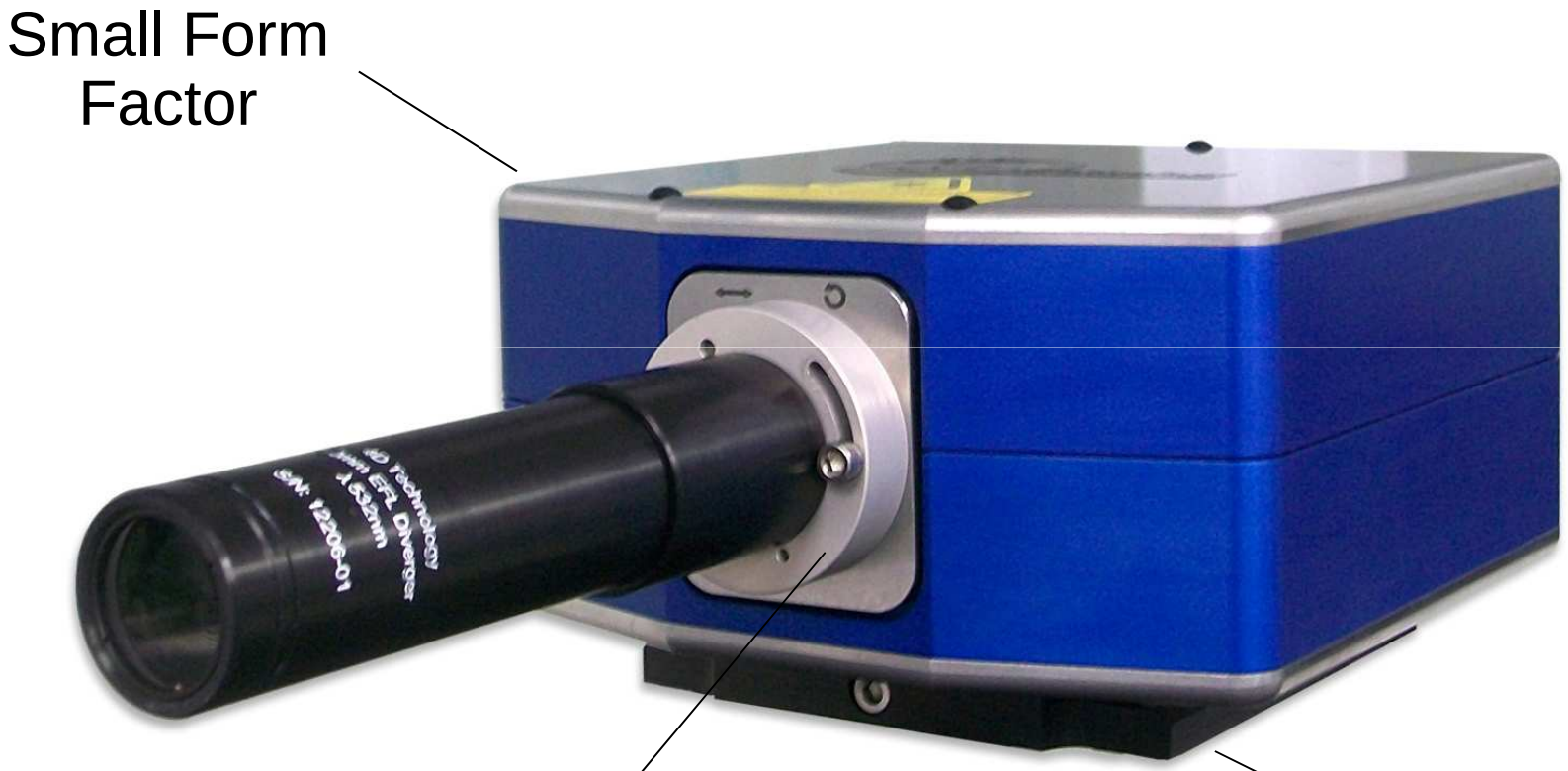
PhaseCam 6000 ESPI Layout



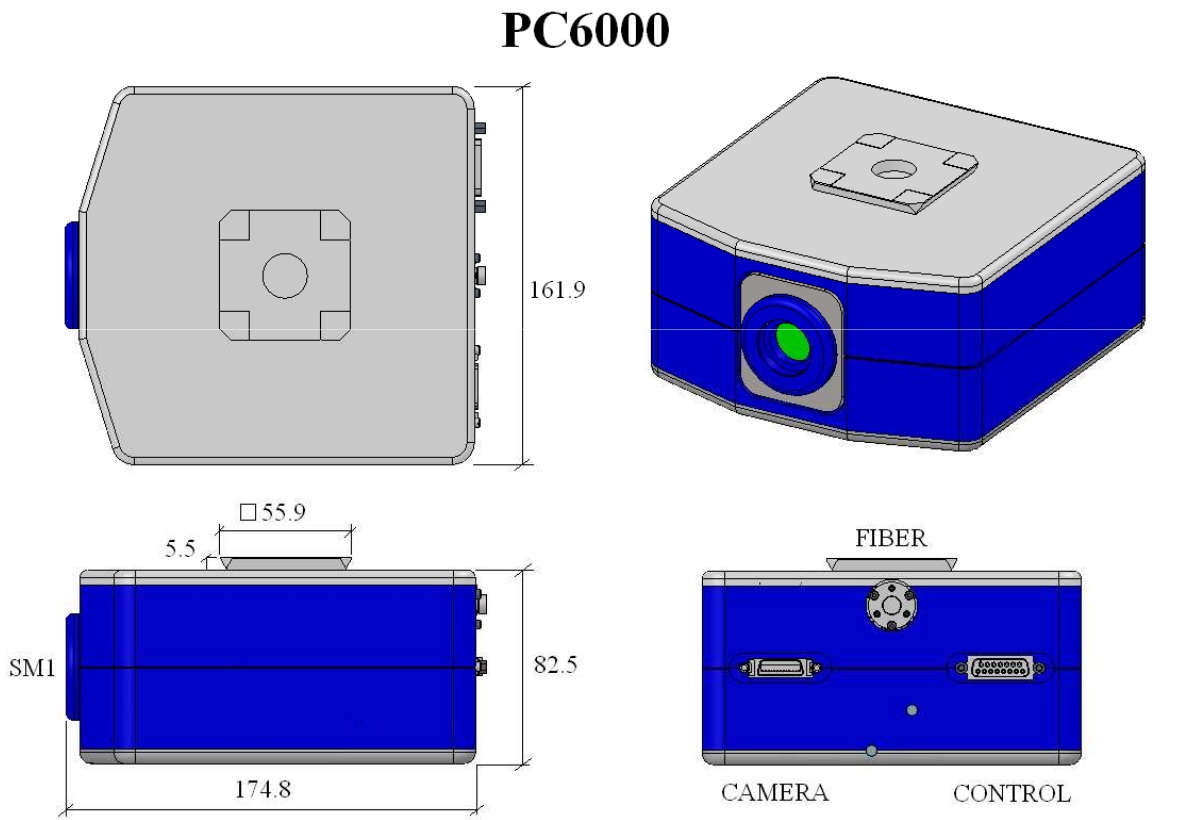
To Switch Modes:

- Set Output Polarization to Linear State
- Replace Diverging Lens with Zoom Lens
- Illuminate Test Article with Fiber

PhaseCam 6000 Image

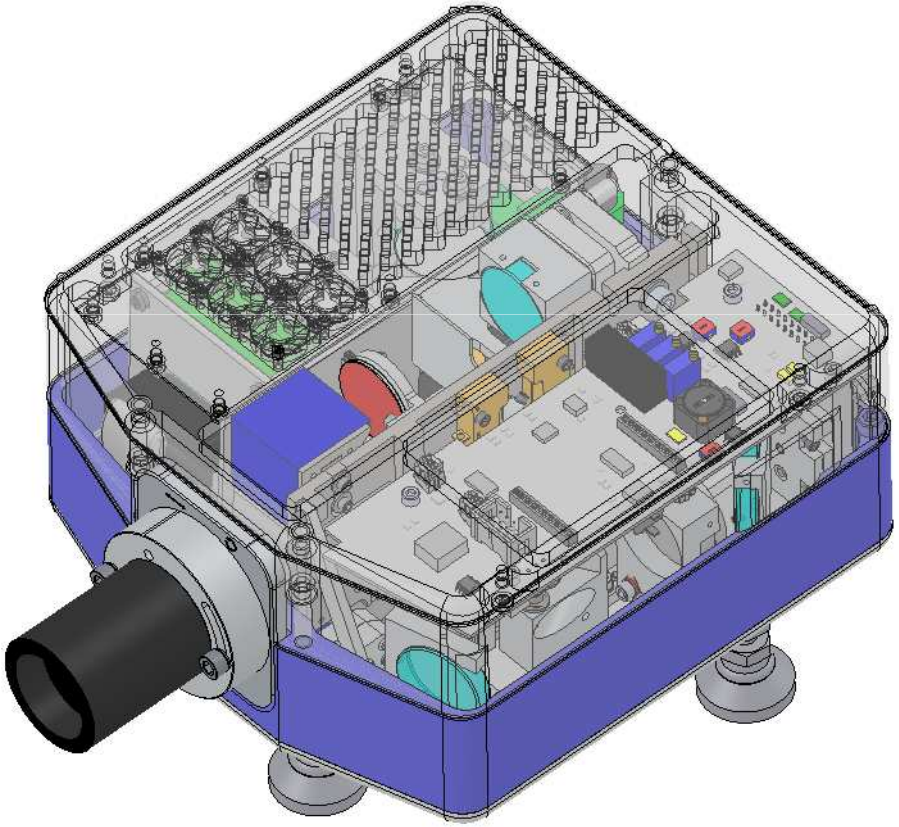


PhaseCam 6000 Dimensions



Motorized Controls

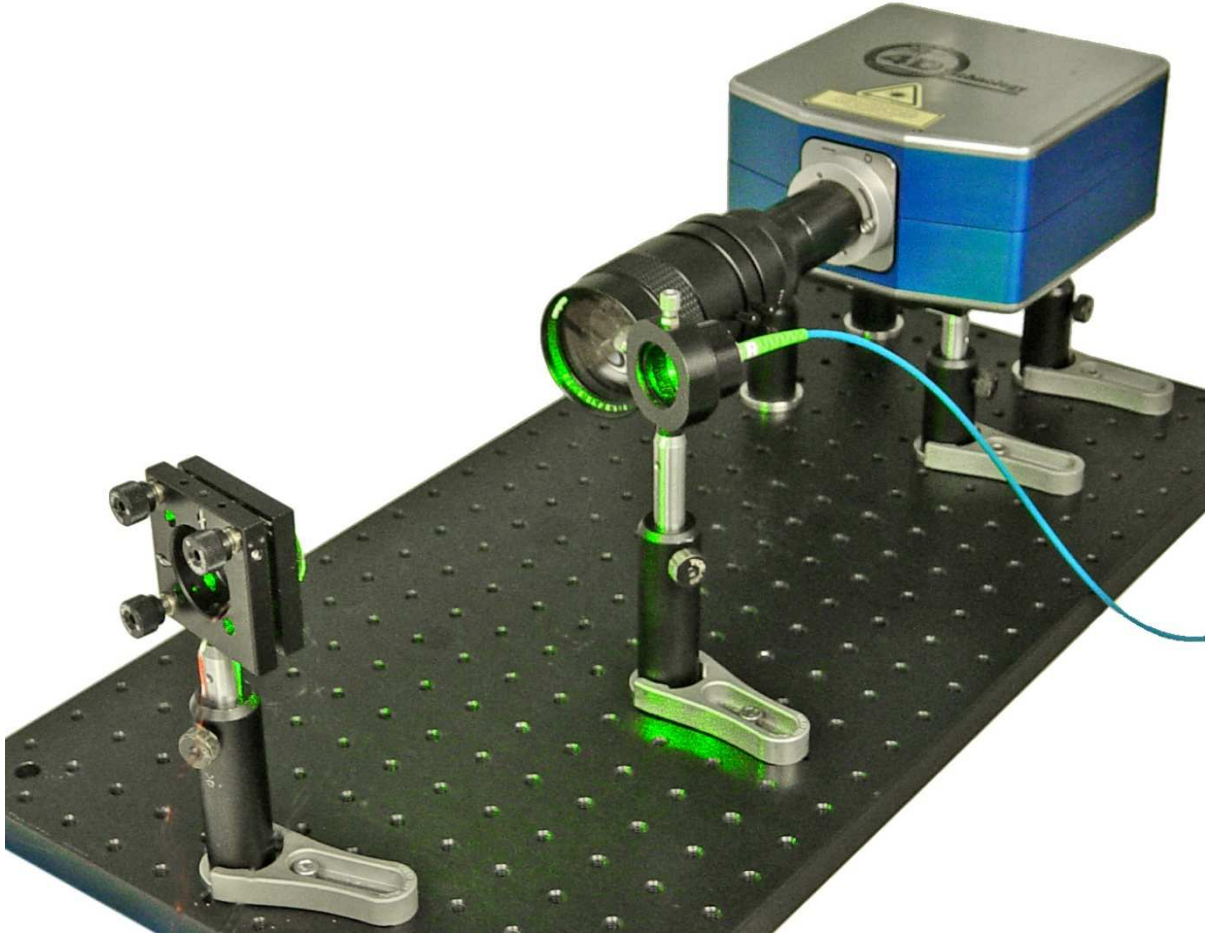
- Three Motorized Operator Controls
  - Focus
  - Beam Balance
  - Reference Beam Block
- Managed by Internal Control Board
- Operated From Hand Controller



Dovetail Mounting

Mount Directly to Dovetail or Via Mounting Adapter

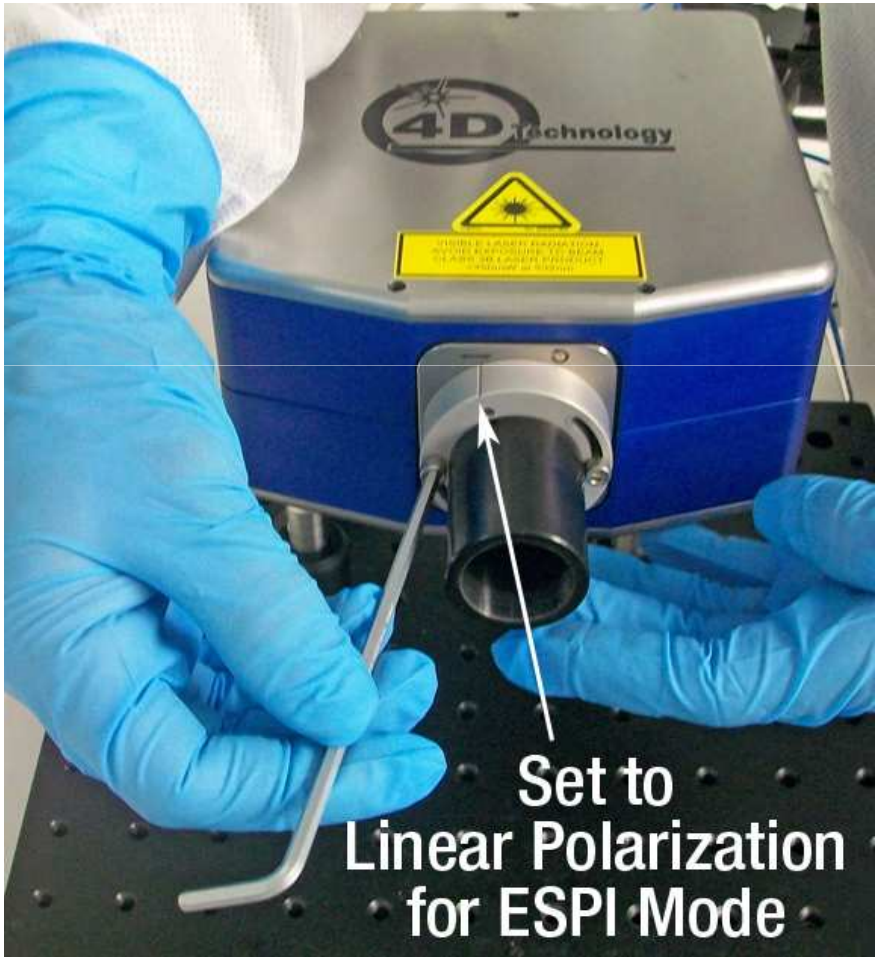
PhaseCam 6000 ESPI Measurement Image



Polarization Control

Set to Circular Polarization for Traditional Operation

Set to Linear Polarization for ESPI Operation or to Mitigate Strays from Diverging Optics



PhaseCam 6000 ESPI™ Benefits

- Dual Operation
- Vibration Insensitivity
  - Four phase-shifted frames acquired simultaneously
  - Integration time = As low as 30us
- Small Form Factor
  - Dimensions (5.37” x 6.88” x 3.25”)
- Polarization Control
  - Accommodates dual mode operation
  - Facilitates low return diverging optics
- Motorized Controls
- Easy to Use
  - ESPI subtraction algorithms are built into measurement control software, 4Sight.

> 3 orders of magnitude faster than conventional temporal phase-shifting interferometers!

Electronic Speckle Pattern Interferometry Basics

ESPI Measurement

- Speckle noise prevents the direct measurement of surface shape when measuring a diffuse surface
- Subtracting two measurements results in correlation fringes
- Measurements are made at different points in time and the change in the surface is measured

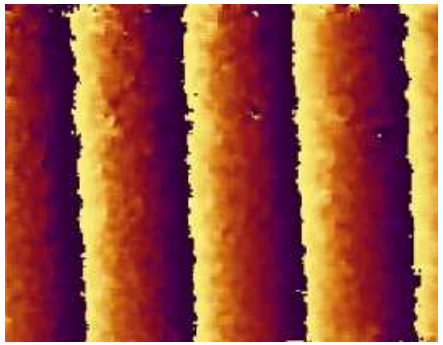
$$\Delta opd = 2\Delta z = \frac{\Delta\phi_s}{2\pi}\lambda_s \qquad \Delta\phi_s = \Delta\phi_1 - \Delta\phi_2$$

Interferogram Subtraction

B) Interferogram domain (diffuse and specular surfaces)

Stetson - 8 frame phase-difference

$$\Delta Z = \frac{\lambda}{2}\operatorname{atan}\left(\frac{[D_0 - B_0][A(t) - C(t)] - [A_0 - C_0][D(t) - B(t)]}{[A(t) - C(t)][A_0 - C_0] + [D_0 - B_0][D(t) - B(t)]}\right)$$



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Unwrapping

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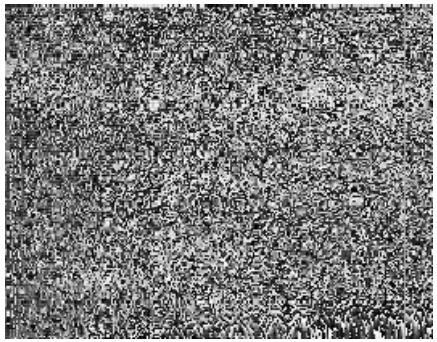

A,B,C,D(t)

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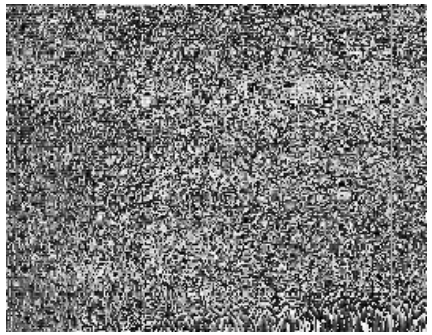
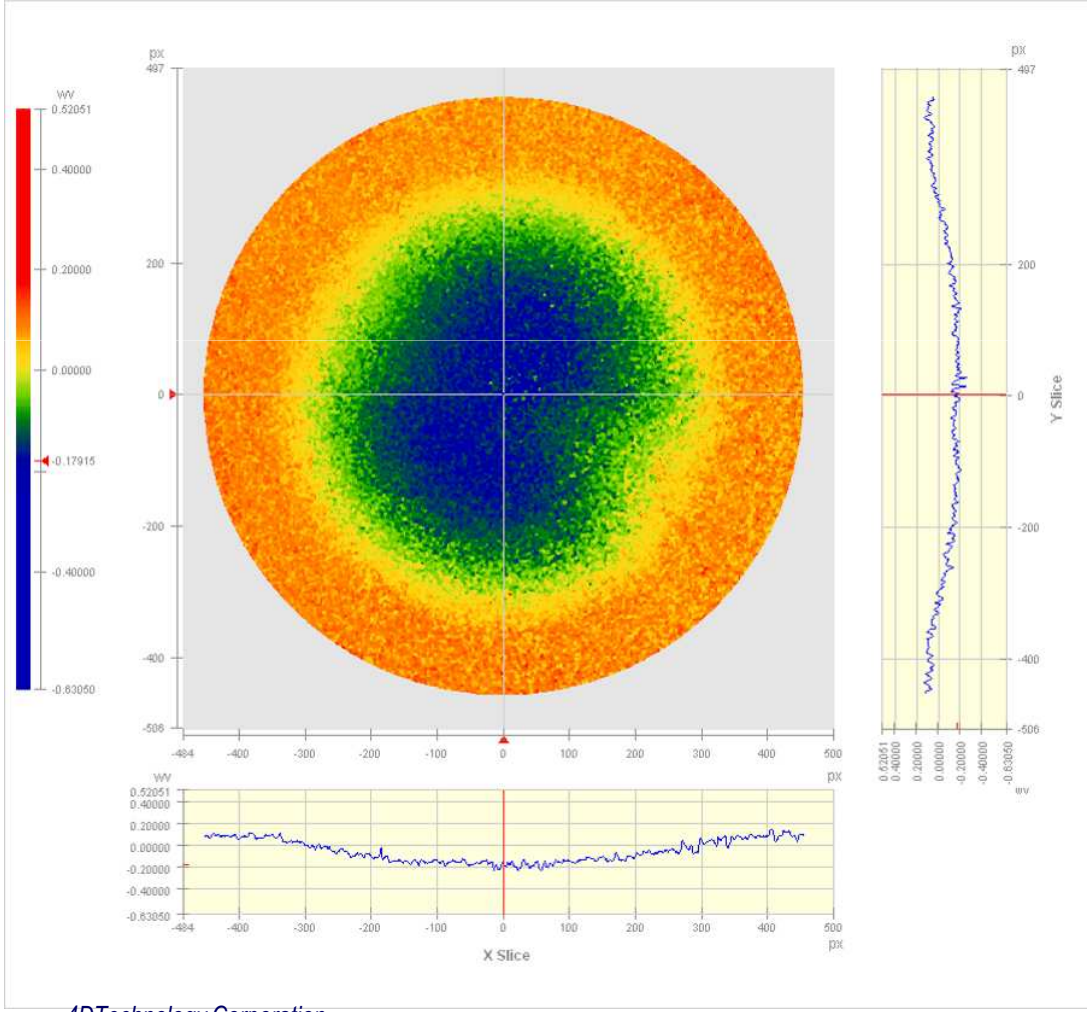


A_0,B_0,C_0,D_0

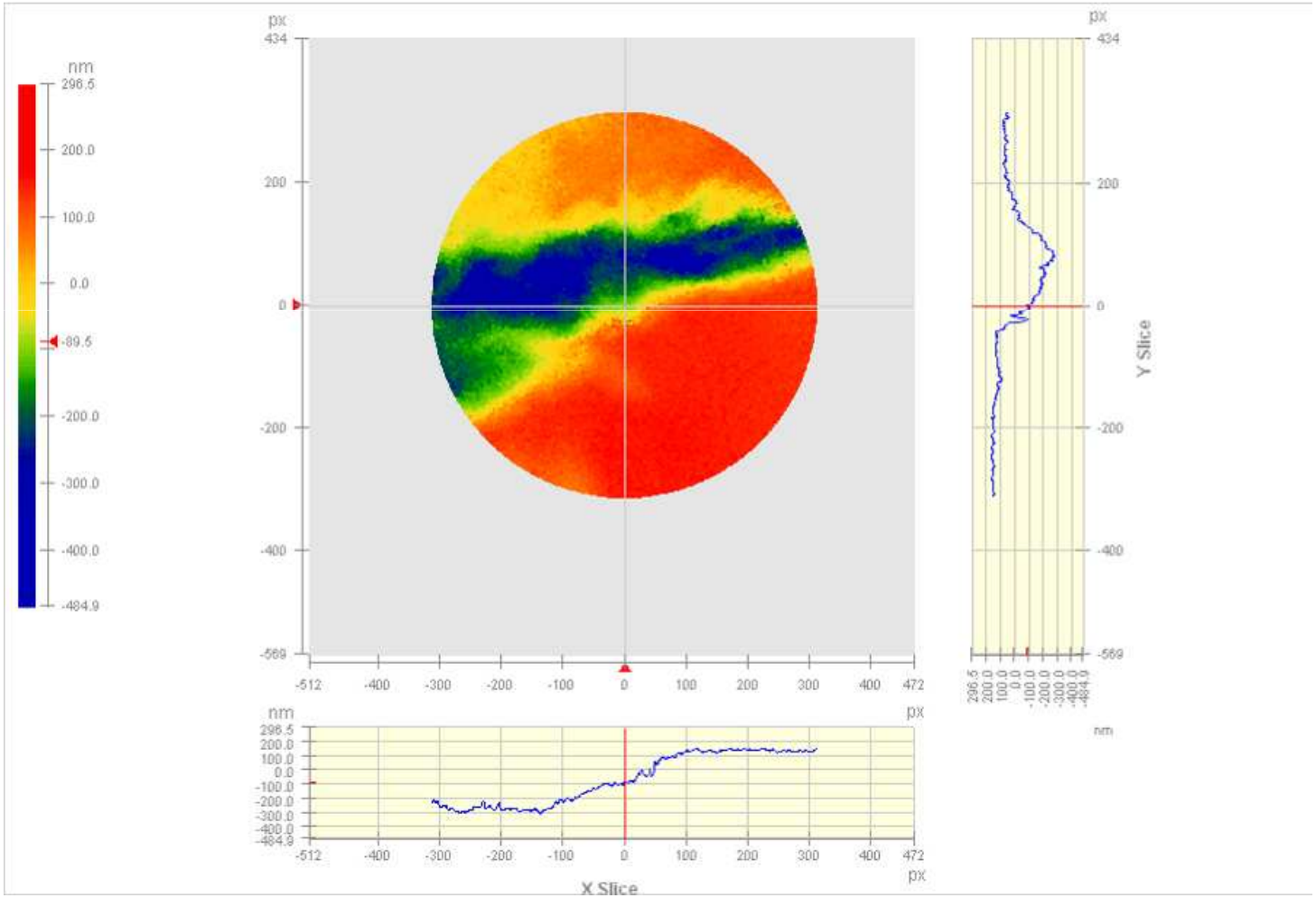
Dynamic Measurements

Asynchronous Measurement of Buzzer in ESPI Mode

- Natural Frequency = 4.1KHz
- Integration Time = 30us



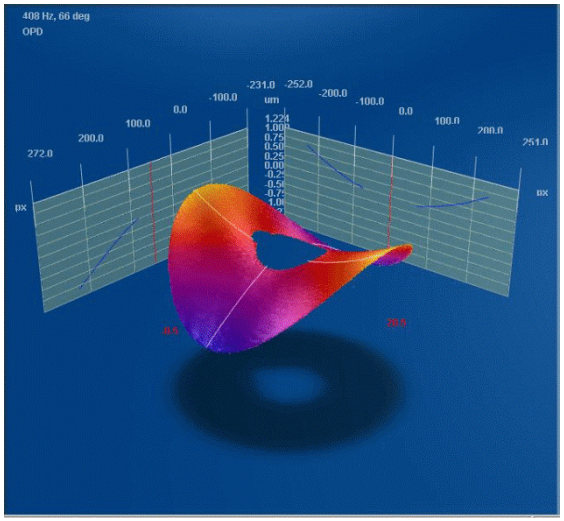
Dynamic Air Flow Measurement in ESPI Mode



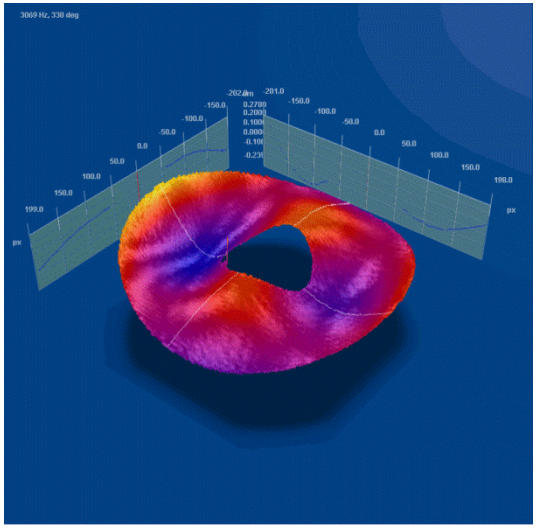
Modal Analysis Option in Traditional Mode

Modal Analysis quantifies deformation through actuation cycle, detects resonance modes

- Acquire 3D info without contacting the sample
- Includes cables, D/A converters and synchronization software



408 Hz Resonance



3069 Hz Resonance

Modal Analysis phase movies