Principle of the *TruImagE* Digital Holographic Microscopy System

The *TruImagE* Digital Holographic Microscopy system is a useful tool for the real-time imaging, measurement, and analysis of three-dimensional wavefront distributions. The true object profile can be obtained from the quantitative phase map and known refractive index.

1. Digital Holography

The Digital Holography technique includes two steps: the recording of interference of light and reconstruction by diffraction of light. The first step is the recording of interference of light (Fig. 1).

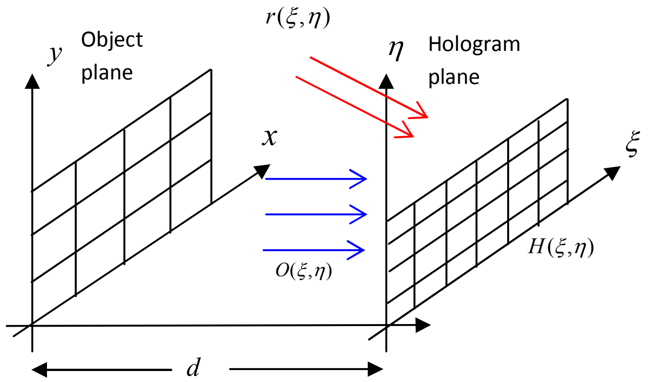

Fig.1. Recording of a digital hologram

The reference wave $r(\xi,\eta)$ and the object wave $O(\xi,\eta)$ interfere with each other at the hologram plane where a CCD is placed to record the hologram $H(\xi,\eta)$.

$$
\begin{aligned}
H(\xi,\eta) &= [O(\xi,\eta)+r(\xi,\eta)]\cdot[O(\xi,\eta)+r(\xi,\eta)]^* \\
&= |O(\xi,\eta)|^2 + |r(\xi,\eta)|^2 + O(\xi,\eta)\cdot r^*(\xi,\eta) + O^*(\xi,\eta)\cdot r(\xi,\eta) \\
&= |A_o(\xi,\eta)|^2 + |A_r(\xi,\eta)|^2 \\
&\quad + A_o A_r \exp\{i[\varphi(\xi,\eta)-\varphi_r(\xi,\eta)]\} \\
&\quad + A_o A_r \exp\{-i[\varphi(\xi,\eta)-\varphi_r(\xi,\eta)]\}
\end{aligned}
$$

The second step is the reconstruction by diffraction of light (Fig. 2)

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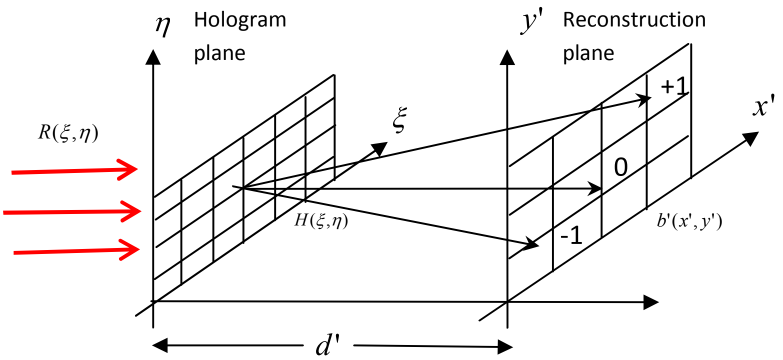

Fig.2. Reconstruction of a digital hologram

A reference light $r(\xi,\eta)$ illuminates the hologram plane and the reconstructed information is obtained at the reconstruction plane. In digital holography, the reconstruction process is realised through algorithms based on the Rayleigh-Sommerfeld diffraction equation

$$b'(x',y') = \frac{1}{i\lambda}\iint H(\xi,\eta)r(\xi,\eta)\frac{\exp\{ik\rho\}}{\rho}\cos\Theta d\xi d\eta$$

where $\rho = \sqrt{d'^2 + (\xi - x')^2 + (\eta - y')^2}$, $H(\xi,\eta)$ is the hologram, and $b'(x',y')$ is the reconstructed object at the image plane.

We can then obtain the intensity $I(x',y')$ and phase $\varphi(x',y')$ distributions

$$I(x',y') = |b'(x',y')|^2$$

$$\varphi(x',y') = \arctan\frac{\mathrm{Im}[b'(x',y')]}{\mathrm{Re}[b'(x',y')]}$$

2. *TruImagE* Digital Holography Microscopy System

The *TruImagE* Digital Holographic Microscopy system uses a single cube beamsplitter (SCBS) in a patent-pending configuration so as to both split and combine a diverging spherical wavefront emerging from the microscope objective (MO) and obtain a high-resolution image (Fig. 3). The light wave transmits from the test sample plate and is incident on the SCBS with its central semi-reflecting layer placed at a small angle away from the light propagation direction. The test sample is located in the left half of the beam path which is reflected by the central semi-reflection layer of the SCBS and acts as the object arm of the interferometer (indicated by the rays in red). Light in the right half transmits through the central semi-reflecting layer and acts as the reference arm (indicated by the rays in blue). An off-axis digital hologram is obtained and recorded by the CCD camera. The digital hologram is numerically reconstructed in real-time using the TruImagE software.

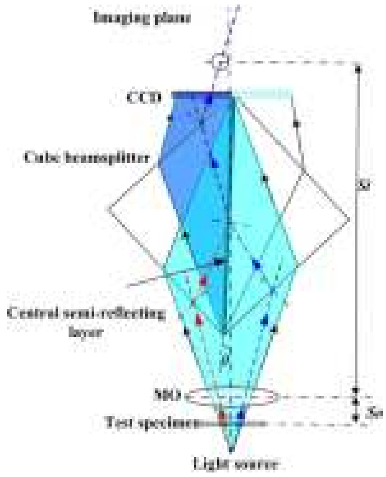

Fig.3 Schematic of the *TruImagE* Digital Holographic Microscopy System

Since the system is a common-path interferometer, the reference arm travels the same distance as the object arm. The spherical phase curvature is physically compensated by each other during interference. The constant phase that remains is independent of time, rendering the setup insensitive to external vibrations.

The *TruImagE* system can provide 3D measurement with nanometric axial resolution in real-time for light-transmitting microscopic samples in material and life sciences. It is ideal for characterising a single microlens as well as inspecting the uniformity of the microlenses across a whole array by comparing neighbouring microlenses.