White-light Optical Profilometry at Long Working Distances

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We devised a real-time, optical profilometry technique with rainbow-illuminated, volume-holographic imaging (RVHI), as shown in Figure 1. A white light source is first analyzed by a diffraction grating and the object is illuminated by the decomposed rainbow. After passing through a cylindrical lens, the rainbow is focused to the focal plane of a volume holographic lens [a volume holographic lens is a specifically designed volume hologram acting as a lens but with unique optical properties]. The diffraction grating, cylindrical lens, and the objective lens are chosen so that the rainbow projection on the focal plane satisfies the following coupled angular-wavelength shifting relation [1]:

$$\Delta \lambda \approx \frac{\Delta \theta}{\lambda}$$

Where $\lambda$ is the recording wavelength and $\Delta \theta$ is the desired angular shift to the optical axis of a color component in the rainbow, which has a wavelength shift $\Delta \lambda$. Therefore, all the in-focus points along the $x$ dimension are matched; in the $y$ dimension they are also Bragg matched because of degeneracy. Thus, the entire rainbow plane is Bragg matched, resulting in a broad field of view (FOV). When shifted out of focus, each point source in the rainbow becomes Bragg mismatched due to defocus, much as a narrow-band source at the same wavelength would [2]. With wide FOV, RVHI can map the height of a reflective object across the entire lateral frame at one shot, without additional scanning. For better accuracy, images of different depth layers can be captured and mapped to different sections of the camera plane by multiplexing holograms [3].

RVHI can be set up in an inclined scheme to further improve depth resolution for profilometry of step-wised objects at a long working distance [4]. The target object (micro-turbine, see Figure 2(a)) is placed 450mm away. Figure 2(b) and (c) show two raw images of a micro-turbine acquired by RVHI at the top surface and the substrate, respectively.

REFERENCES: