Brightness and Color Enhancement on a Reflective Display Using a Holographic Directional Diffuser

Jian Ma, Kirby Li, Mark Phung, Chung-Po Huang, Tallis Chang, and John Hong
Qualcomm MEMS Technologies, Inc., San Jose, CA 95134, USA
Tel.:408-546-3029, E-mail: *jianma@qmt.qualcomm.com*

The principle of Brightness and Color Enhancement Hologram (BCEH) for a reflective display is based on a usage model that has an indoor light source illuminating the display at an angle (e.g., about 45º), and the viewing angle is near normal to the display surface. For a reflective display with a specular reflection surface, such as a MEMS display (e.g., a Qualcomm® Mirasol™ display) or reflective liquid crystal display, a diffuser is required to achieve a comfortable viewing. However, the reflection intensity of such displays drops very quickly when the viewing angle deviates from the specular direction of the illumination source. To view the display with a sufficient brightness, the viewing angle shall be near the specular angle of the illumination (e.g., -45º), which is not the natural viewing angle. Additionally, the image quality (e.g., contrast and color saturation) is affected at specular direction due to specular reflection from cover glass and other layers. The function of BCEH is to bend (diffract) certain amount of light rays (e.g., about 50%), to near normal to the display surface. The light rays diffracted by the BCEH is subsequently reflected from the display and are normal to the display allowing an enhanced near normal viewing. Additionally, the color blue shift associated with interferometric based displays is automatically corrected at the normal viewing. This is illustrated in Fig. 1. The BCEH master film is recorded with two collimated "white" laser beams in ~45º angle as depicted in Fig. 2. The "white" laser is a mixture of three laser beams of red, green and blue wavelengths with proper intensity ratios according to the wavelength sensitivity of the hologram film. Two diffusers of proper haze are inserted in the beam paths for introducing both beam bending and diffusion in a single BCEH film. The holographic medium used in the experiment is Bayer Bayfol® HX photopolymer of 20um thickness. The master BCEH hologram is used to replicate copies through a single beam replication process (Fig. 3) via recording the BCEH replications through the interference between 0th order and 1st order beams. Figs. 4 to 6 show the result and comparison between BECH and a regular diffuser applied to Qualcomm® Mirasol™ displays. A 10X brightness improvement was demonstrated using a BCEH.

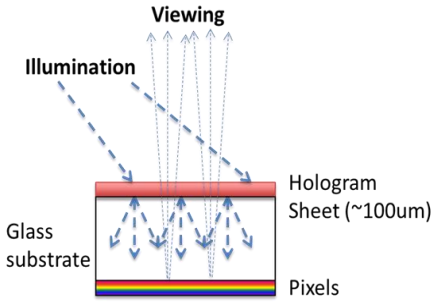

Fig.1 Principal of BCEH

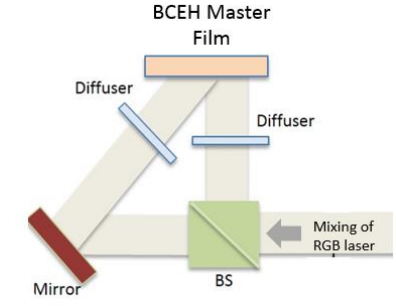

Fig.2 Master BCEH recording

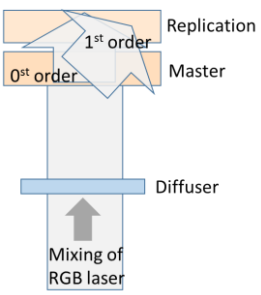

Fig.3 BCEH replication

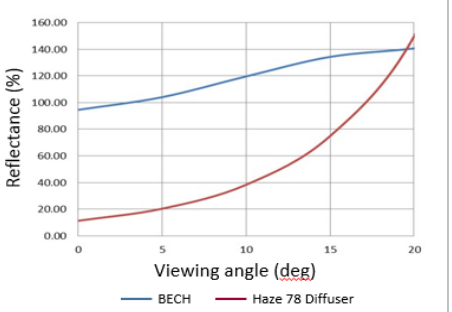

Fig.4 Comparison of reflectance between BCEH and a regular diffuser attached on a Qualcomm® Mirasol™. and with a near collimated illumination at ~45º.

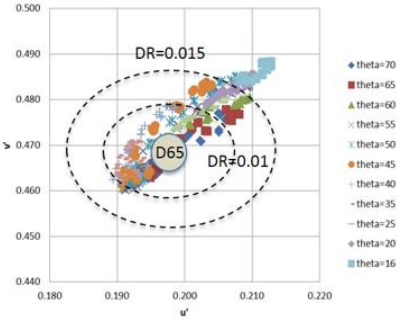

Fig.5 The measured color deviations from D65 with BCEH are mostly ≤0.01 with near collimated D65 illuminations at different azimuthal and elevation angles.

Fig.6 Visual comparison of BCEH and regular diffuser assembled in Qualcomm® Toq™ smartwatches with an indoor ceiling lights illuminating at ~ 45º.