Transparent colored signage and display enabled by nanoimprinted multi-layer gratings

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With the popularity of transparent display, a promising approach of waveguide display [1] is developing rapidly, and has demonstrated various functionalities, such as augmented reality display [2] and glass-free 3D display [3]. The widely used gratings as optical elements can offer periodic refractive index modulations and provide momentum matching to split the incident light into multiple diffraction order beams. Because of this feature, gratings have been used extensively as the out-coupler of waveguide to extract light by diffraction, which interrupts the total internal reflection (TIR) of the propagating light. Here, we present a type of static transparent signage using flat glass and embedded multi-layer gratings, by which multiple patterns and colors with a wide field of view can be displayed.

The device is made on a piece of edge-polished glass, which can guide input light from the edges by TIR. Multi-layer gratings are used to extract light that propagates inside the glass in different directions. Grating of each layer is shaped into the specific pattern to be displayed. Each grating is designed to have a proper period and orientation in order to independently out-couple light incident from the corresponding edge. Three types of samples with a single-layer grating, two-layer gratings, and three-layer gratings on rectangular or hexagonal shaped glass are demonstrated. The embedded multi-layer gratings are made of titanium oxide (TiO_2) coated on imprinted and UV-cured polyurethane acrylate (PUA) resin. The multi-layer gratings are fabricated by repeating the nanoimprint three times using the corresponding grating molds, followed by electron beam evaporation of TiO_2 after each imprinting process. This type of transparent display offers the advantages of low cost, easy fabrication and wide field of view, and it is suitable for signage and decorative applications.

References:

[1] Eisen, L.; Meyklyar, M.; Golub, M.; Friesem, A. A.; Gurwich, I.; Weiss, V.; "Planar configuration for image projection," Appl. Opt. 2006 **45**, (17), 4005–4011

[2] Liu, Z.; Pang, Y.; Pan, C.; Huang, Z.; "Design of a uniform-illumination binocular waveguide display with diffraction gratings and freeform optics," Opt. Express 2017 **25**, (24) 30720-30731.

[3] Fattal, D.; Peng, Z.; Tran, T.; Vo, S.; Fiorentino, M.; Brug, J.; Beausoleil, R. G.; "A multi-directional backlight for a wide-angle, glasses-free three-dimensional display," Nature 2013 **495**, (7441), 348–351.

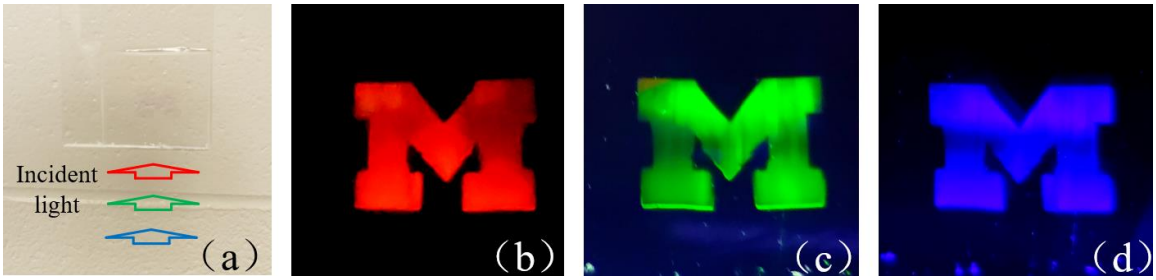

Figure 1. (a) Rectangular flat glass with a single-layer grating. (b)-(d) The monochrome pattern can have different colors by changing the wavelength of the input light.

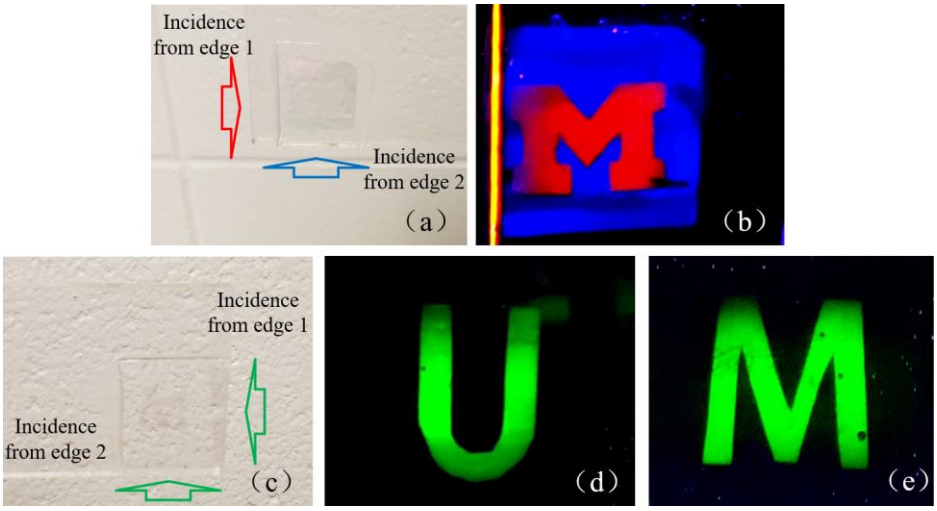

Figure 2. The first rectangular flat glass (a) has two-layer gratings with two complementary patterns. When blue light and red light are input from the two adjacent edges simultaneously, a two-color pattern (b) is lit up. The two-layer gratings on the second rectangular flat glass (c) have two separate letter patterns "U" (d) and "M" (e), which can be selectively displayed by switching light sources at different edges of the glass.

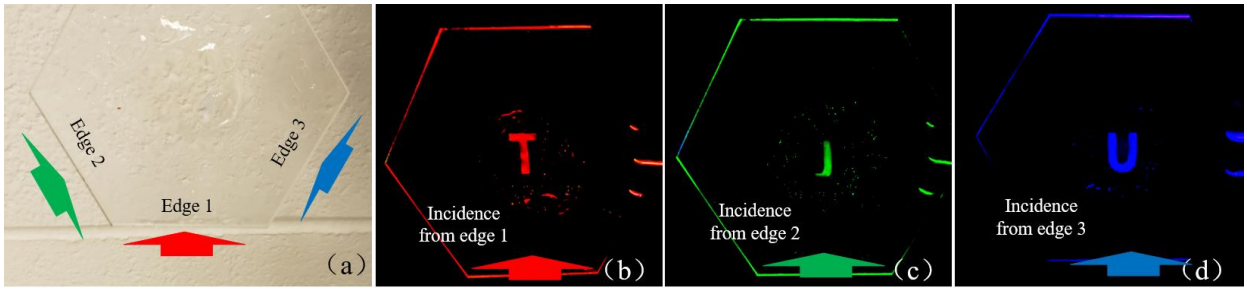

Figure 3. (a) Hexagonal flat glass with three-layer gratings. (b)-(d) Different letter patterns with different colors can be displayed when red, green, and blue light is input from the corresponding edges, respectively.