Towards Expressive Optics: A Design System for Scene-Specific External Lens Filters

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Abstract

This study proposes an external lens filter system that enables users to design and realize optical effects based on their expressive intent. Through this system, users can freely configure both visual effects and geometric design elements, enabling them to fabricate custom lens filters tailored to their desired aesthetics. The filters are fabricated using a low-cost SLA 3D printer, and optical quality suitable for practical use is achieved through post-processing with spin coating. Furthermore, we demonstrate that the proposed method supports various visual expressions, including the control of optical effect regions through clear openings, the integration of multiple optical functions within a single filter, and the fabrication of fine typographic patterns whose visibility dynamically changes depending on the aperture setting.

CCS Concepts

• **Human-centered computing** → *Human computer interaction (HCI).*

Keywords

3D Print Optics, Digital Fabrication, Additive Manufacturing

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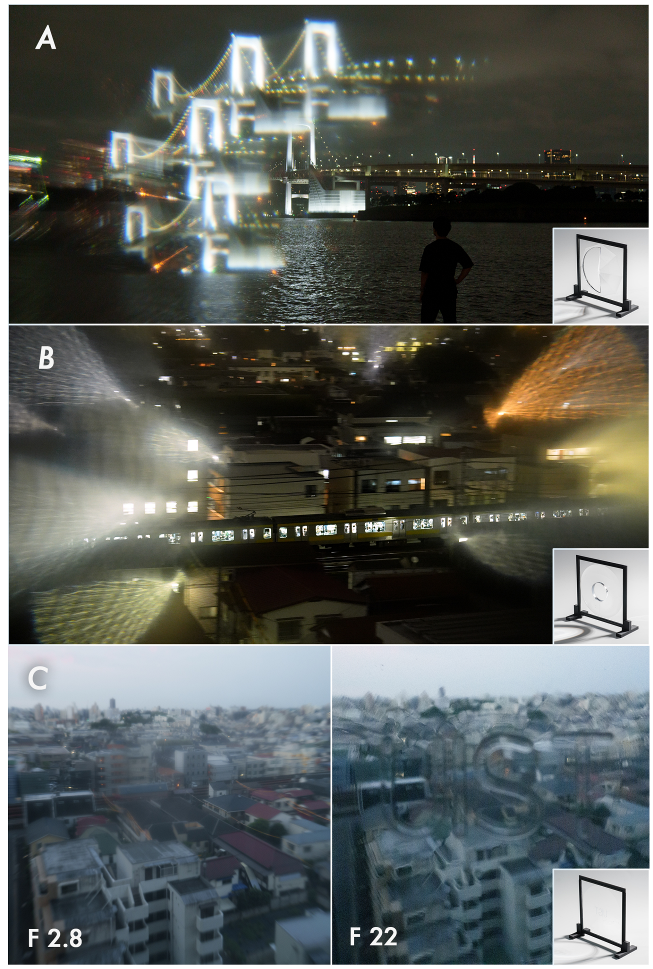

Figure 1: Effects of the fabricated lens filters. (A) Selective effects using a partial lens filter. (B) Complex light diffusion by combining multiple elements. (C) Variation in the typographic visibility depending on the aperture setting.

1 Introduction

In recent years, there has been growing interest in custom lenses for cinematic and visual production that enable physical, in-camera effects, thereby reducing reliance on post-production [3]. However, traditional lens fabrication requires high precision, making custom optics largely inaccessible to individuals and small-scale projects. Consequently, most creators rely on mass-produced components. Meanwhile, advances in 3D printing technology have enabled the application of additive manufacturing techniques to optical components production [7]. Specifically, the widespread availability of low-cost Stereolithography (SLA) 3D printers [6] has significantly facilitated the rapid and inexpensive fabrication of resin-based optics, including custom lenses [2, 4, 5] and Fresnel lenses [1]—quickly and inexpensively. However, this layer-by-layer process creates surface artifacts and geometric inaccuracies, leading to optical degradation such as scattering and refractive distortion. To address these issues, this study proposes a method for producing external lens filters using 3D printing, combined with post-processing

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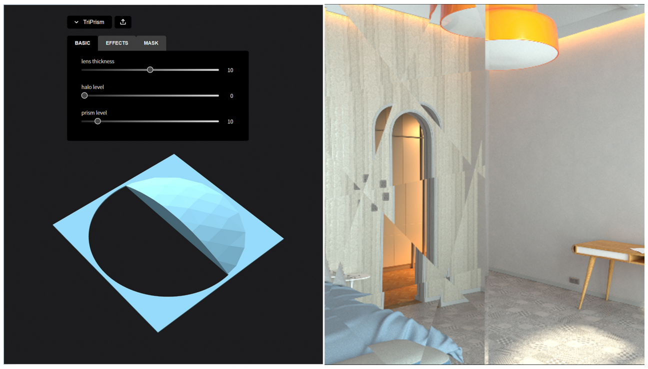

Figure 2: Design software supports lens filter creation. The left panel manages geometric design, while the right panel displays a preview of the resulting visual effects.

techniques such as spin coating to improve optical performance. Our system enables users to design custom optical effects and easily attach them to existing camera systems. Because these filters are externally mounted, the camera's original optical performance is preserved while allowing for creative augmentations. This approach also extends to devices with non-interchangeable lenses such as smartphones, thus expanding possible outcomes. Furthermore, our method enables the physical realization of cinematic effects during capture, such as selectively blurring regions outside the subject within the frame, or generating multiple images from specific objects or light sources. This physical optical processing at the time of shooting eliminates the need for software editing, which is particularly beneficial in video contexts where frame-by-frame manipulation incurs a high computational cost. In such cases, optical filtering is an efficient alternative.

In this study, we develop a design and fabrication method for external lens filters using 3D printing to introduce "lens character"—aesthetic or expressive qualities—into photographic and cinematic imagery. Figure 2 shows the user interface of the proposed design software. This system allows users to freely design and implement custom optical effects aligned with their objectives, thereby enabling the cost-effective and flexible realization of scene-specific visual expressions.

2 SYSTEM

We developed the design software using Rhinoceros / Grasshopper, V-Ray, and JavaScript. It supports three fundamental lens filter geometries: Convex, Prism, and Polygon. Users can create detailed designs by adjusting values for each geometry. In the BASIC tab, users can set lens thickness, the central depression of the convex surface (Halo Level), and the sharpness of the prism elements. The EFFECTS tab provides density control for cross patterns and text or shape insertion, whereas the MASK tab allows users to select or deselect specific regions for the application of optical effects. By leveraging these functions to combine multiple effects and control their application area, the proposed system enables fine-grained adjustments of optical effects that were previously difficult to achieve. Furthermore, the design process uses V-Ray renders to display the optical effects. Once the design is complete, the lens is exported in a 3D-printable format. In this study, we assumed a full-frame mirrorless camera (ILCE-7M4, Sony) with a compatible standard zoom lens (SEL2470GM2, Sony) as the photographic apparatus. The filter was designed with a diameter of 86 mm to exceed the lens's native filter size. For ease of fabrication and handling, it was produced as a 100 mm square and attached to the camera.

Lens filters were fabricated from a highly transparent resin (New Clear Resin, SK Honpo) using an SLA 3D printer (Saturn 4 Ultra 16K, ELEGOO). For the fabrication process, a model was sliced using Chitubox at 0.02 mm layers with tuned parameters. After printing, the objects were washed with Isopropyl Alcohol (IPA) for 10 minutes. As a post-processing step, a UV-coating resin (UV-LED Coating Resin "Kirari", SK Honpo) was applied dropwise to cover the entire surface of one side and then spin-coated at 1720 rpm for approximately 30 seconds. Subsequently, the filters underwent a final cure for 3 minutes using a Form Cure to improve optical transparency and mechanical strength.

3 APPLICATIONS

This section introduces three applications that show the novel expressive capabilities enabled by the proposed system. Figure 1(A) shows a photograph captured using a lens filter incorporating a masked prism structure. In conventional photography, lens filters influence the entire image, often resulting in unintentionally excessive or cluttered expressions. By contrast, the proposed system allows users to define effect zones, enabling clear rendering of the human subject while selectively emphasizing only the light sources in the background. By mounting a lens filter with localized optical effects, users can introduce scene-specific visual expressions without compromising the performance of the existing optical system.

Figure 1(B) shows a photograph captured using a lens filter that combines multiple optical effects. We developed the lens filter by merging convex and cross forms around a central opening. In conventional lens filter systems, a single filter typically produces one type of optical effect. Therefore, achieving multiple effects often requires stacking several filters, which can introduce issues such as vignetting and optical aberrations due to increased thickness. The proposed system merges several optical elements into one filter, enabling the efficient achievement of the intended effects. In Figure 1(B), the central aperture retains native imaging quality intact. Simultaneously, in the peripheral area, the cross-filter structure emphasizes point light sources into a cross shape. Furthermore, the convex lens structure adds an impressive expression of spreading light rays, thereby realizing a composite visual effect.

Figure 1(C) shows a photograph captured using a filter featuring fine text structures formed on its surface. Conventional lens manufacturing, designed for mass production, limits detailed customization for individual expression. By contrast, the proposed system is based on 3D printing for small-batch production, enabling custom designs that are tailored to an individual's unique expressive needs. In this example, text with a thickness of 0.5 mm was integrated into the lens filter surface. This creates a unique visual effect where the text's visibility depends on the aperture: the text appears blurry when the aperture is wide open, but sharpens as it narrows.

In future work, we will enhance our high-precision surface polishing and coating techniques to suppress layer artifacts associated with 3D printing. We will also broaden strategies for wider aesthetics. The visual expressions created with this method are not only limited to large-scale camera equipment but are also fully applicable to small electronic devices such as smartphones and tablets. By further enhancing adaptability for these mobile devices, we aim to create an environment where a broader range of users can easily achieve visual effects tailored to their own expressive intentions.

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