Towards A Transparent, Flexible, Scalable, and Disposable Image Sensor

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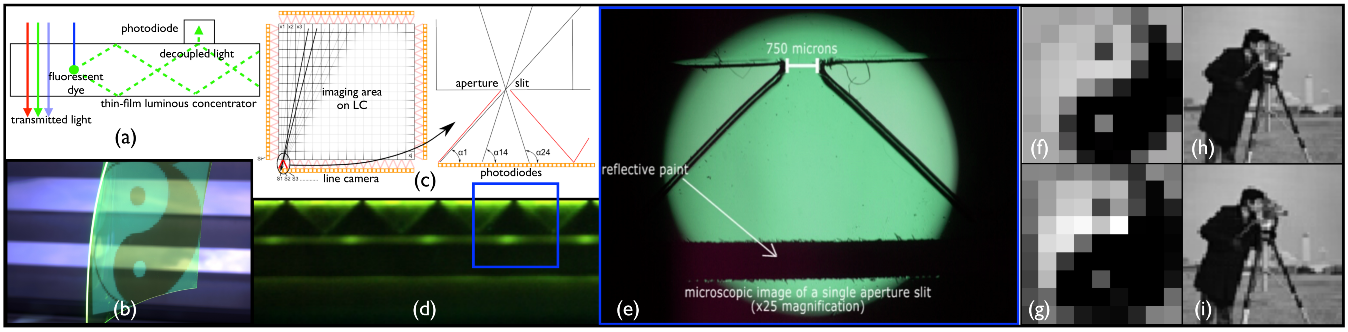

Figure 1: *Thin-film luminescent concentrator (LC) principle (a) and example (b). The film's edges are cut into triangular aperture slits (c,d,e) and photodiodes (four line cameras) are placed on the surfaces of these slits. This measures the light-transport of a two-dimensional light field within the LC film (c) that can be used to reconstruct the image focussed at the LC surface. Currently, only low resolution images have been reconstructed physically (e.g., ying-yang symbol, 9x9 pixels, f: ground truth, g: reconstruction), due to the limited sensitivity of the applied photodiodes. In simulations, higher resolutions have been possible (e.g., 64x64 pixels, h: ground truth, i: reconstruction).*

Abstract

Conventional optoelectronic techniques have forced image sensors to a planar shape. We present our first attempts towards a transparent, flexible, scalable, and disposable sensor that samples the light-transport of a two-dimensional light-field within a thin-film luminescent concentrator for reconstructing an image being focussed on the concentrator film.

CR Categories: I.4.1 [IMAGE PROCESSING AND COMPUTER VISION]: Digitization and Image Capture;

Keywords: light fields, light transport, image reconstruction, image sensor

1 Introduction

Thin-film luminescent concentrators (LC) are polymer foils comprising optically active molecules (doped with a fluorescent dye). They can be less than one millimeter thick, bendable and transparent. The foils are low cost (less than 10 EUR per square meter) and can be manufactured in almost arbitrary sizes. They are normally used for increasing the efficiency of solar cells with respect to supporting larger incident angles. Waveguides based on an LC forward the emitted light towards the edges of the LC by total internal reflection at an attenuation (transport loss) that is proportional to the travel distance. Photodiodes glued to the LC surface create an interface with higher optical density than air or the polymer of the LC. This causes light to be decoupled from the LC at the positions of the photodiodes.

2 Our Approach and Current Results

The correlation of the transport losses between discrete entrance points (i.e., pixels p) on the LC surface with many photodiodes (d) placed at the boundary of the LC surface can be represented with $s = Tp$, where T is the light-transport matrix that can be calibrated. In principle, an image focussed on the LC can be reconstructed with the inverse light transport ($p = T^{-1}s$), or with filtered backprojection. However, since each photodiode measures the integral of all pixel contributions, the light-transport matrix would be dense with a high condition number, and image reconstruction becomes very unstable (in particular in the presence of sensor noise). A tomographic reconstruction would be seriously undersampled.

For solving this problem, we cut the LC edges into triangular aperture slits and place the photodiodes appropriately on the surfaces of these slits. Reflective paint at the backside of the slits causes a higher decoupling efficiency.

With this, we are recording the transport of a two-dimensional light-field within the LC film using multiple 1D slit-cameras surrounding the imaging area. In this case, the light-transport matrix becomes sparse, its condition number is reduced, and more positional and directional samples are available for a tomographic reconstruction. Figure 1 illustrates this principle and our current results.

Multiple stacked LC layers with different wavelength responses can enable the reconstruction of color images. With multiple (sub-pixel-shifted) light-transport matrices, images can be reconstructed in a higher resolution.

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