Fairy Lights in Femtoseconds: Aerial and Volumetric Graphics Rendered by Focused Femtosecond Laser Combined with Computational Holographic Fields

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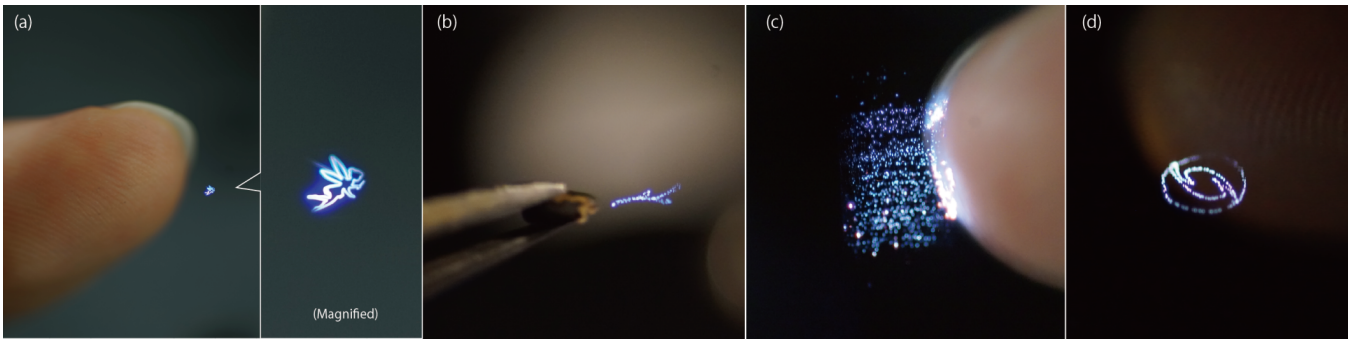

Figure 1: *Application images of Fairy Lights, aerial and volumetric graphics in air rendered by femtosecond lasers. (a) A "fairy" flying in front of a finger. (b) A "sprout" coming out from a seed. (c) Interference between a point cloud and a finger. (d) The SIGGRAPH logo.*

We envision a laser-induced plasma technology in general applications for public use. If laser-induced plasma aerial images were made available, many useful applications such as spatial aerial AR, aerial user interfaces, volumetric images could be produced. This technology could be used not only for aerial images, but also volumetric displays in certain media, e.g., in a water-filled pool. This would be a highly effective display for the expression of three-dimensional information. Volumetric expression has considerable merit because the content scale corresponds to the human body; therefore, this technology could be usefully applied to wearable materials or spatial user interactions. Further, laser focusing technology can add an additional dimension to conventional projection technology, which is designed for surface mapping, while laser focusing technology is capable of volumetric mapping. This technology can be effectively used in real-world-oriented user interfaces.

High-power lasers are used to generate voxels in the air. The basic concept was discussed and the working principle was demonstrated using a nanosecond laser in [Kimura et al. 2006] and a rendering speed of 100 dot/sec was achieved. Later, adoption of a femtosecond (100 fs) laser and 500 dot/sec was achieved. The color of light dots in these systems was nearly white. An in-water type of laser-based volumetric display was developed [Kimura et al. 2011] and 50,000 dot/sec was achieved. While no detailed principle was discussed, we infer that this in-water type is not based on laser plasma but laser-induced cavitation. The green light dots generated by a green laser can be explained as diffusion of the incident laser by microbubbles.

In this study, we use femtosecond lasers with pulse durations of 30 fs, 100 fs, and 269 fs. This leads to calmer and safer plasma generation that can be incorporated into our daily lives. The design space and possible scenarios of the plasma-based 3D display are discussed. In addition, we use an optical device, called the spatial light modulator (SLM), to modify the phases of light rays and produce various spatial distributions of light based on interference.

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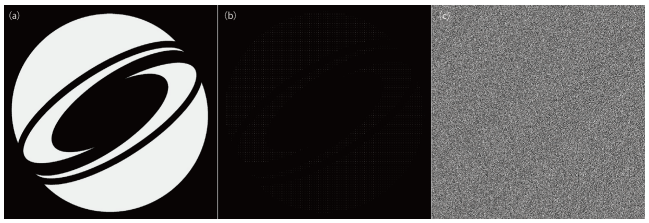

Figure 2: *Example of a computer-generated hologram (CGH). (a) An original image, (b) a converted spot-array image, and (c) a CGH to be displayed on the SLM.*

A liquid crystal SLM (LCSLM) is used in this study, which contains a nematic liquid crystal layer. The molecule directions within this layer are controlled by electrodes, i.e., pixels, and the phases of light rays reflected by this layer are spatially modulated according to the directions of the liquid crystal molecules. In other words, this device acts as an optical phased array. An example of a computer-generated hologam (CGH) is shown in Figure 2.

Figure 1 shows example images renderd in air by a femtosecond laser. While the instantaneous energy is sufficiently high to induce a plasma in air, the time-avarage energy of a femto-second laser is so weak that one can touch the plasma images with a finger.

References

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