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Hacking Blu-ray for High-Resolution 3D printing

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Abstract

A Blu-ray optical pick-up unit (BDOPU) is hacked and repurposed into core optics of a palm-size 3D printer for micro/nanoscale features printing. The BDOPU focuses 405 nm laser to a 319 nm spot (Gaussian waist diameter) that can polymerize a photopolymer on a substrate. A closed-loop three-axis nanopositioner actuates the substrate for three-dimensional printing. Multiple microscale line features are printed to evaluate the printing resolution. A preliminary experiment shows that the highest achievable horizontal printing resolution is 1.47 µm, which is smaller than that of conventional single-photon 3D printers.

1. Introduction

A Blu-ray optical pick-up unit (BDOPU) inside an optical drive is the core component for reading and writing optical storage media [1]. To read high-density data pits on a Blu-ray disc, the BDOPU equips an aspherical object lens that focuses 405 nm laser to a diffraction-limited spot. In the past decade, mass-produced Blu-ray OPUs unit price can go down to < 20 USD. Furthermore, the high-performance Blu-ray OPU can be hacked for applications in different fields.

The BDOPU provides a small single-photon laser spot that is ideal for stereolithography 3D printing [2]. In this study, we demonstrate a 3D printer that directly uses the BDOPU for polymerizing photopolymers without additional optics.

2. The BDOPU 3D printer

System Design

The BDOPU (Sanyo BD-415) equips 780/650/405 nm wavelength semiconductor laser diodes, collimator lens, objective lens and optical sensors in a compact form factor. Using the Blu-ray OPU directly for 3D printing can simplify the whole system optics design dramatically. Fig. 1(a) illustrates the 3D printer design. A BDOPU is placed above a closed-loop three-axis piezoelectric linear nanopositioner (SmarAct). Three precision screws are used for adjusting the distance and angle of the BDOPU between the printing substrate. The 405 nm laser emitted from the objective lens penetrates the cover glass and being focused on a silicon substrate fixed on a platform. The nanopositioner translates the platform with a range of x, y, z: 12, 21, 12 millimeters. The nanopositioner provides a closed-loop resolution of 1 nm that is beneficial for high-resolution 3D printing.

Both the OPU and the nanopositioner are controlled by a data acquisition card (National Instruments) through a LabView based control software. The BDOPU can emit a maximum laser power of 600 µW and the nanopositioner can achieve a maximum speed of 13,000 µm/s, which enables a potential of high-speed 3D printing.

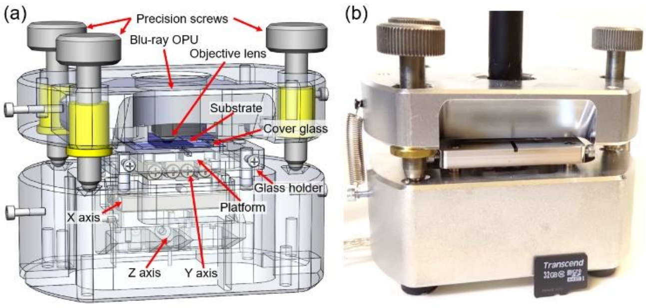

Fig. 1 The BDOPU 3D printing system. (a) a schematic diagram of the system. (b) a photo of the system.

Fig. 1(b) shows a photo of the BDOPU 3D printer. The housing is made of aluminum that can conduct the heat generated by the BDOPU and the nanopositioner efficiently. A micro SD card in front of the 3D printer is used for the size comparison. The compact size (length, width, height: 90, 55, 65 mm) 3D printer can reduce the thermal expansion and increase mechanical stability which are beneficial for high-resolution photopolymerization such as micro- and nanoscale features 3D printing.

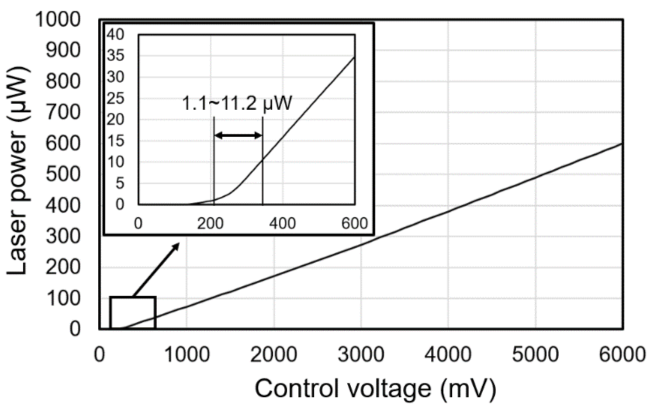

Fig. 2 The BDOPU laser power vs. control voltage. A zoom-in plot shows that the BDOPU 3D printing laser power is between 1.1 and 11.2 µW.

Printing Procedure

A commercially available UV-DLP 405nm photopolymer is used for the preliminary printing. Firstly, the OPU focuses the laser on the silicon substrate precisely through monitoring a focus error signal [3]. Then a drop of photopolymer is applied between the cover glass and the substrate and the BDOPU 3D printer starts 3D printing with a laser power between 1.1 and 11.2 µW (Fig. 2). The printed features are washed by Ethanol to dissolve photopolymer residue.

2. Preliminary 3D printing Results

Microscale Structures

A preliminary microscale printing result is shown in Figure 3. The laser power and the printing speed are 5.5µW and 2200 µm/s, respectively. The Fig. 2(a) shows the 3D printed structures before the washing process. After washing, the structures (size: 200, 180 and 160 µm) can be clearly seen.

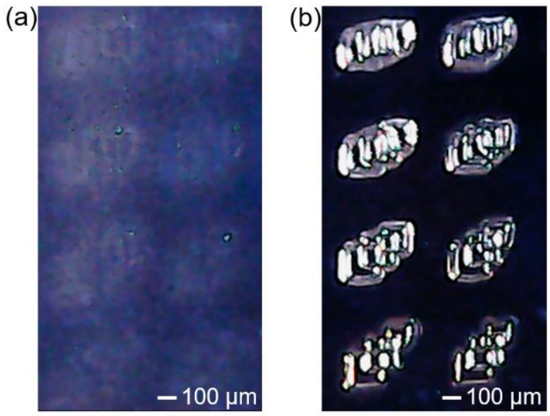

Fig. 3 3D printed microscale structures. (a) Before washing. (b) After washing.

Printing Resolution

Ladder shaped structures were printed to characterize the horizontal printing resolution of the printer. Fig. 4 shows a 1.47 µm width line feature printed with a laser power of 1.1 µW and a speed of 2,000 µm/s.

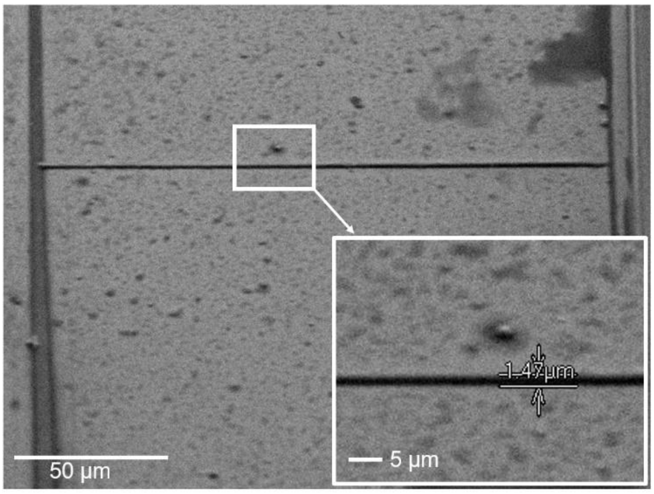

Fig. 4 SEM images of the ladder structure (200x1400 µm). A zoom-in image shows a line width of 1.47 µm.

3. Conclusions

Hardware hacking can repurpose a low-cost, high-performance and compact-size BDOPU into a high-resolution 3D printer. Furthermore, this 3D printer can successfully polymerize the photopolymer in microscale features with different laser power and speed settings. Thought the system is not yet optimized, the preliminary printing results show that the BDOPU 3D printer has a potential for nanoscale high-resolution 3D printing.

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