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3D Printing using Holography

Deepthi Sekhar[1], Supriya Dicholkar[2]
(Department of Electronics and Telecommunication Engineering, Atharva College of Engineering, India)[1,2]

Abstract: *3D printing is a field of interest for Industry and there are a number of research going on to incorporate and utilize advanced technologies aiming toovercome the and to overcome the shortcomingsexisting techniques.Recently holography technique was used to improve the 3D printing technique by printing the object as a whole instead of layer by layer deposition. Volumetric 3D printing is yet another application of holography which prints 3D objects instead of 3D images of objects(Holograms). In this new process flashes laser-generated, hologram-like images onto photosensitive resin, printing a 3D shape all at the same time rather than layer by layer. Holography is capable of recording and reconstructing 3D information, this shaping of the light field can enable direct 3D fabrication in photopolymer resins. Here we report the review and analysis of Volumetric 3D printing and various types of photosentive resins which can be used for the technique.*

Keyword: *Volumetric printing, Photopolymer, Holography, Spatial Light Modulator*

I. Introduction

The 3D printing technology is a boon to Industrial sector which enables to make materials/ single machine and it has much more complicated applications in science and technology. Researchers all over the world continue to explore the ways to improve the technology and the process of 3D printing, as well as vary the range of materials that can be used.To the former end, researchers at the Lawrence Livermore National laboratory have found an alternative tothe typical layer-based additive manufacturing process by using a combination of technologies—including lasersand hologram-like images—that significantly speeds the process from hours or days to mere minutes.3D volumetric printing would be more effective than the other light-based methods. Laser beams are used to transform a photosensitive monomer into a solid plastic. Volumetric 3D printing builds parts by overlapping three laser beams that define an object's geometry from three different directions. This creates a hologram-like 3D image suspended in the vat of resin.

Indeed, the approach allows for 3D-printed parts to be built significantly faster than other polymer-based methods and almost all of the commercial methods used today. Moreover, the costs of the method are low and it's flexible, fast, and geometrically versatile, opening up a significant new research direction for rapid 3D printing.Volumetric 3D printing also could allow for the fabrication of extra-soft materials such as hydrogels, which would otherwise be damaged or destroyed by fluid motion, researchers said. While the process is impressive and could be made even faster with a higher-power light source, it does have its limitations. There are restriction and compromises to be considered on part resolution and on the kind of geometrics of the model as too many lasers beams will not move through the space without changing. This means that extremely complex structures would require lots of intersecting laser beams and would limit the process. Researchers also aim to fine-tune the polymer chemistry and engineering of the process to ensure a high rate of success when printing because selection of appropriate photosensitive resin and the laser source is also important to obtain better output quality.

This paper comprises of review and analysis of 3D printing using conventional optical holography and various kinds of photosenstive material which can be utilized for the method.This is an analytical research paper in which the reader is introduced to the recent innovation in 3D printing technology in which Printing is done using light beams.

II. History of 3D Printing

3D printing is a nescenttechnology, which came into existence in 1984 at the hands of Chuck Hull who invented aprocess known as stereolithography, in which layers are added by curing photopolymers with UV lasers. 3D printing is a field of interest in fields like Industry, Biomedical, Robotics, Jewellery making etc.

There are a number of 3D printing techniques depending on the deposition process and materials used for printing. Some techniques melt and soften material to produce the layers, while others cure liquid materials using different complex and advanced technologies. Each method has its own advantages and drawbacks. Here are some common technologies:

- Stereo lithography – (SLA): position a perforated platform just below the surface of a vat of
- Stereo lithography – (SLA): Position a perforated platform just below the surface of a vat of liquid photo curable polymer. A UV (Ultra Violate) laser beam then traces the first slice of an object on the surface of this liquid, causing a very thin layer of photopolymer to harden. The perforated platform is then lowered to a certain extent and another slice is traced out and hardened by the laser. Another slice is then created, and then another, until a complete object has been printed and can be removed from the vat of photopolymer, drained of excess liquid, and cured.
- Fused deposition modelling (FDM): In this method, a hot thermoplastic is extruded from a Temperature-controlled print head to produce fairly robust objects to a high degree of accuracy.
- Selective laser sintering (SLS): This builds objects by using a laser to selectively use together successive layers of a cocktail of powdered wax, ceramic, metal, nylon or one of a range of other materials.
- Multi-jet modelling (MJM): This again builds up objects from successive layers of powder, with an inkjet-like print head used to spray on a binder solution that glues only the required granules together.

In summary, 3D printing is no more a fancy, it is spreading widely in a variety of applications, from simple domestic use to complicated industrial applications with decreasing cost and increasing efficiency. In future 3D printers will be the drive of a coming revolution that will change the whole face of industry.

III. 3D Printing using Holography

A generalized light-directed AM system comprises four key subsystems, which are (1) the light source and beam conditioning, (2) pattern formation, (3) pattern projection/delivery, and (4) the photopolymer resin. While the parameter space for a holographic lithography system is very broad [20, 21], two key considerations drive the overall technology choices and system architecture in this work. The first is that holographic shaping of the light field requires a source with a high degree of spatial and temporal coherence, for useful diffraction and interference. This system is therefore designed around a narrow spectral linewidth single-mode (TEM00) laser source. The second design consideration is that holographic beam shaping is most robust and straightforward with a phase-only spatial light modulator. With an appropriate phase pattern applied to this dynamic element the light field is Fourier-transformed by the projection optics to produce the desired intensity distribution at the build volume, photocuring the resin into the desired pattern.

In the current implementation, the 3D intensity pattern is produced by folding sub- regions of the projected light field using 45-degree mirrors placed in proximity to the final build volume. These sub-regions enter the build volume at right angles to one another, effectively forming intersecting beams, each of which carries an arbitrary image pattern. The intersection of these patterns results in a complex 3D pattern with controllable areas of high intensity, and with appropriately chosen exposure parameters the 3D structure is formed. This approach is one of several possible paths to obtaining complex 3D light patterns, and we address alternative configurations in the Discussion section. The overall optical layout is shown in Fig. 1, and key subsystems are described in greater detail below.

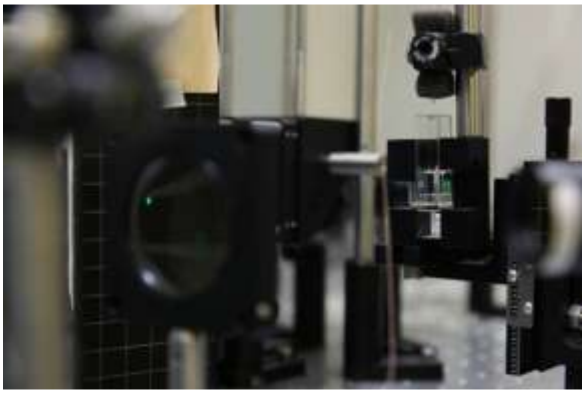

Figure 1: By using laser-generated, hologram-like 3D images flashed into photosensitive resin, researchers at Lawrence Livermore National Laboratory, along with academic collaborators, have discovered they can build complex 3D parts in a fraction of the time of traditional layer-by-layer printing. With this process, researchers have printed beams, planes, struts at arbitrary angles, lattices, and complex and uniquely curved objects in a matter of seconds. (Source: LLNL)

Laser Source and Beam Conditioning

The holographic principle allows the recording and reconstruction of 3D geometric information by capturing the amplitude and phase information contained within a light field. Holographic reconstruction requires the use of light waves capable of interference, which implies a single-frequency laser for temporal coherence. In addition, the light delivered to the SLM must ideally consist of flat phase-front plane waves, which implies spatial coherence. In this work, we use a Coherent Verdi V-6 532 nm DPSS laser, specified by the manufacturer to have a linewidth of < 5 MHz (<0.000005 nm, corresponding to a coherence length of >50 m). The output beam is slightly expanded and spatially filtered through a 25 µm pinhole, to improve the circularity and spatial coherence, then expanded again such that it reaches the SLM as a Gaussian beam with a 1/e2 diameter of approximately 20 mm. This is sized to approximately match the SLM diagonal, providing a balance in the trade-off between illumination uniformity, and efficient use of laser energy.

It is worth noting that the laser's minimal coherence length requirement is much shorter than that of the Verdi DPSS laser in our system: it must only exceed the path length differences between any light paths in the system that must interfere. In our configuration, this is only ~1 cm. However, additional coherence improves the contrast of reconstructed intensity fields at the build volume, thus benefitting lithographic fidelity; this remains to be rigorously characterized.

Build Volume and Photopolymer

Since we are interested in 3D structure formation within the bulk of a liquid photopolymer, rather than in layers at a surface, this requires a resin formulation that is minimally absorptive. The resin used here is poly(ethylene glycol) diacrylate (PEGDA, MW=250) with 0.04% (w/w) Irgacure 784, which is a titanocene free-radical photoinitiator with its absorbance spectrum extending to the 532 nm wavelength of the laser source. At the same time, the use of intersecting patterned beams requires optical access from at least three sides of the build volume. Therefore, to hold the resin volume of approx. 1 mL, we use a fluorometer cell (Starna Cells, 3-G-10) with 10×10×45 mm internal volume, and 1.25 mm thick polished glass sides and bottom. As with many resin-based systems, exposure doses vary depending on optical power density and geometry. With the 3-beam configuration, polymer parts were successfully produced using 12 s exposures at an estimated power of 30 mW/cm2 incident onto the cuvette from each side, corresponding to an estimated volumetric cure dose of ~45 mJ/mm3.

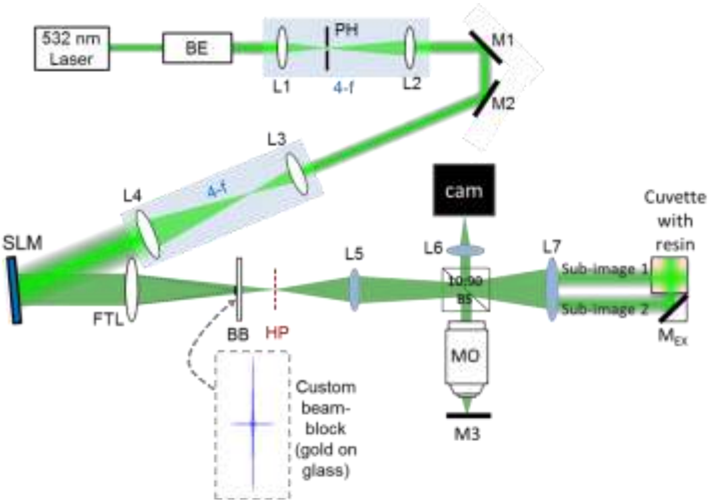

Figure 2: Optical configuration of the holographic 3D fabrication system.

IV. Conclusion

This work constitutes the first demonstration of direct fabrication of unsupported aperiodic 3D structures, using a "volume-at-once" unit operation for photopolymer curing, without requiring a layer-by-layer process. We anticipate that this paradigm in 3D fabrication will bring considerable advances in fabrication speed and geometric flexibility to the field of photopolymer-based AM. Additional geometric flexibility, as well as a larger overall build volume (or greater resolution in a small build volume), may be attained by using multiple SLMs illuminated by the same laser source, which project holographically interfering beams into the same resin volume.

Although the part quality achieved thus far is low, this is not an inherent limitation for this method. Additional speckle noise reduction by de-speckling techniques, in addition to optimization of curing parameters with adjustment of the intensity distribution in the three sub- images will enable high-quality part fabrication. To establish photopolymers for the production of class II or class III medical products by additive man- ufacturing it is essential to know which components of photopolymeric systems, consisting of monomers, pho- toinitiators and additives, are the determining factors on their biocompatible properties.

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