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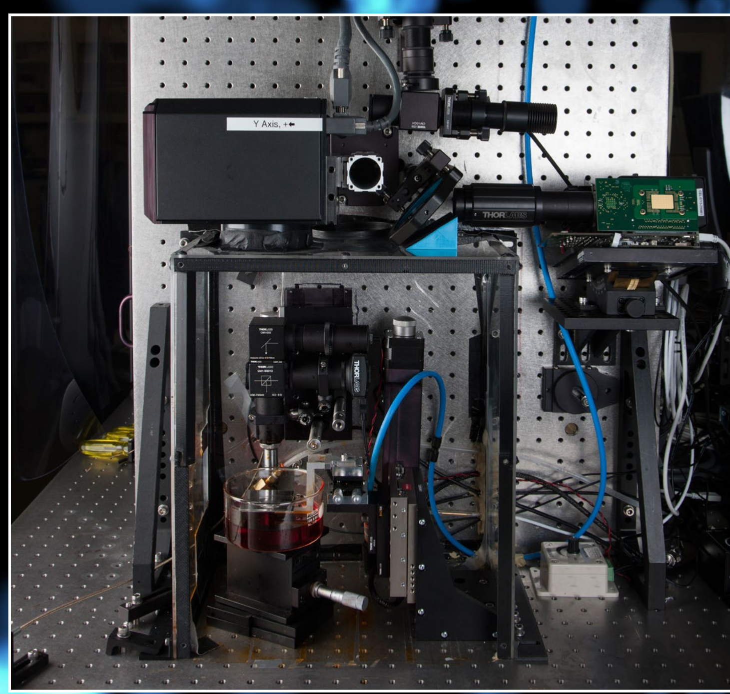
Large-Area Projection Micro-Stereolithography (LAPμSL)

Prepared for:

2015 R&D 100 Award Entry



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Large-Area Projection Micro-Stereolithography (LAPμSL)

VIDEO LINK: https://youtu.be/2gsFJs-tYbY

1. General Entry Information

A. Product brand name and name of submitting organization(s).

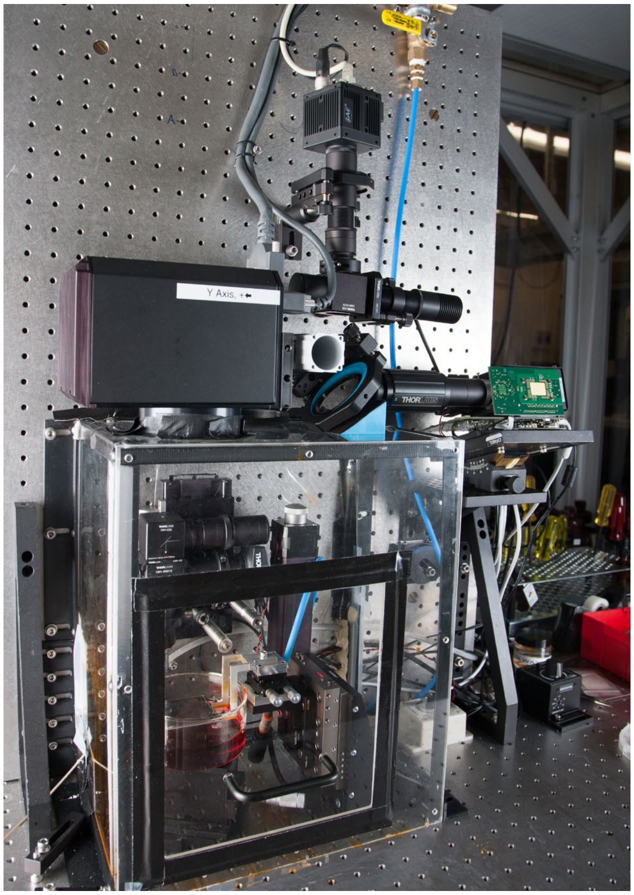
Large-Area Projection Micro-Stereolithography (LAPμSL)

Lawrence Livermore National Laboratory

B. Short description of the product (maximum 25 words).

The large-area projection micro-stereolithography (LAPμSL) system is a 3D-printing solution superior to all competing technologies in combining speed, large product size, and small feature size.

C. Product Photo(s).



D. Price in U.S. dollars.

The large-area projection micro-stereolithography (LAPμSL) system combines the advantages of laser-based stereolithography and digital light processing (DLP) stereolithography. This game-changing 3D printing solution can quickly and reliably print large products (hundreds of millimeters in size) with small, highly detailed features (tens of micrometers). No other technology available offers the same combination of large product size, small feature size, and speed (1,200 mm^3/hour with 50-μm features).

2. Product Description

A. What does the product or technology do? Describe the principal applications of this product.

LAPμSL is a stereolithography-based 3D-printing device that can fabricate products of substantial size yet containing highly detailed features, in contrast to other 3D printing techniques, which generally have to sacrifice overall product size to achieve small features. The LAPμSL system can produce large items (hundreds of millimeters in size) with small, highly detailed features (tens of micrometers) with a rapid speed of production (1,200 mm^3/hour with 50-μm features).

Many applications would benefit from this capability to create complex shapes and small features, unlike other state-of-the-art 3D printers, which sacrifice overall part size in exchange for small feature size. Parts produced with LAPμSL can be used as master patterns for injection molding, thermoforming, blow molding, and various metal-casting processes. In post-processing, the LAPμSL's output can be coated with metal, ceramic, graphene, thin films, and many other materials. The original polymer can be removed via chemical means or heat, leaving structures that can be back-filled with various materials or left hollow for extremely light, complex, and large parts. LAPμSL can be used to quickly make these large parts with great complexity and detail. The increased speed and ability to manufacture parts with small features in a large-sized product distinguish LAPμSL from competing 3D printing techniques.

B. How does the product operate? Describe the materials, construction, or mechanism of action.

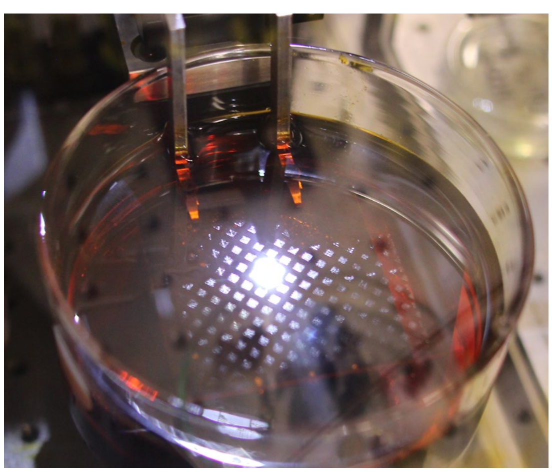
The LAPμSL is an image projection micro-stereolithography system that produces very small features over large areas rapidly, by using optical techniques to write images in parallel, as opposed to conventional techniques, which either require mechanical stage moves or the rastering of beams to expose pixels in series. LAPμSL combines the advantages of laser-based stereolithography (that is, large area and speed but poor resolution) and digital light processing (DLP) stereolithography (that is, fine details and speed but only over a small area), enabling the rapid printing of fine details over large areas.

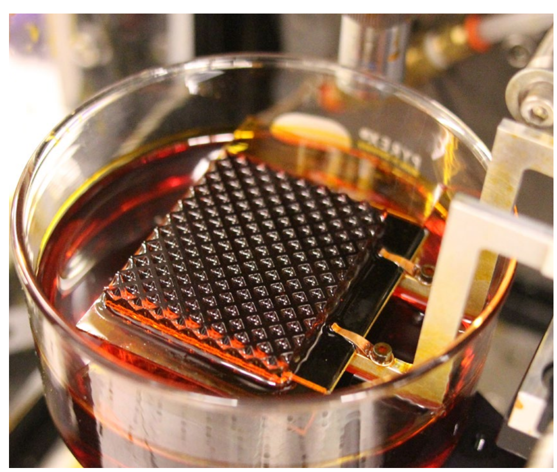
A structure being made in the resin reservoir of the LAPμSL. Structures either can be used straight out of the system or can be used as substrates for additional processing in which the structure is coated with metal, ceramic, or other material. The resin can be removed via chemical means or heat, leaving a structure made up of solid material or left hollow for extremely light, complex, and large parts.

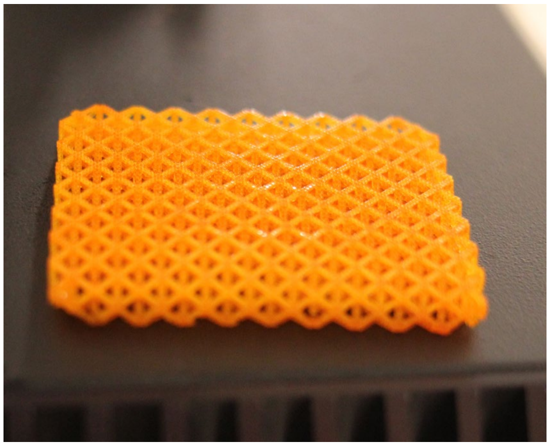
As with any DLP-based stereo lithography system, LAPμSL has at its heart a dynamically addressable spatial light modulator (SLM). We use a TI DLP5500 Digital Micromirror Device (DMD) encompassing on its surface several hundred thousand microscopic mirrors arranged in a rectangular array, corresponding to the pixels in the image to be displayed. Specifically, the Extended Graphics Array format DMD chip provides a 1,024 × 768 array of 10.8-μm-square pixels (corresponding to the 786,000 mirrors), all of which are brightly illuminated by an LED light source. Each mirror is commanded to be either on (reflecting the bright light onward) or off (directing the light out of the system to a heat sink). The image of this addressable DMD is ultimately projected onto the build plane. In this manner, complex masks can be dynamically written and used to print complex features.

Normal projection lithography projects the image of the DMD onto a single area. The size of this image therefore determines the size of the build area and the size of the smallest feature producible. Parts larger than this limited area require the build area to be physically moved

(left) A part being built up from resin and (right) coming out of the bath.







A multi-order octet truss built with the LAPμSL. The overall size is 40 mm × 50 mm × 5.5 mm, and the small struts are 110 μm in diameter. This demonstrates the ability of LAPμSL to create macroscale products with microscale features—and at high production speed.

via mechanical means and are limited by the allowable cost that the user is willing to pay for small mechanical stages and fixturing. LAPμSL has no need for mechanical stage movement as the image is optically scanned over a large build area. The image is very small, allowing for tiny features, with no overall size penalty stemming from this small image of the DMD as the image is moved to cover a large area. In this way, the highly detailed features contained in one DMD image are coordinated with many others and are quickly scanned and projected to their respective location in the LAPμSL build plane. Thus, large parts with small features are built, with a ratio of overall product size to smallest feature of greater than 1,000:1.

The LAPμSL directs the image about the build area by a moving galvanometer mirror pair. The mirrors point to the correct location and briefly stop, and the image is projected to cure the monomer at that location with the correct pattern. The exact location where the image is focused is precisely coordinated with the image produced by the DMD. The image is sharply focused over a large area by using a flat-field scan lens, which produces a flat image plane over a large area. (Conventional optics have an image plane that corresponds to a fixed radius from the optic, resulting in a curved plane of best focus, whereas a flat-field lens has a flat image plane). The size of the build plane is limited by the size over which the flat-field lens can produce an acceptable image, which can be very large—hundreds to thousands of square millimeters. Furthermore, the user is not limited to producing a single large part: As many parts as can fit on the build plane can be produced at once, making LAPμSL ideal for high-volume commercial production.

A closeup of the features of the product shown in the previous figure. The small struts are 100 μm in diameter. This demonstrates the amazingly fine features that LAPμSL can achieve in a macroscale product.

3. Product Comparison

A. Supply a matrix or table showing how the key features of your product compare to existing products or technologies. Use numerical figures to represent performance metrics. For price, and capital and operating costs, use actual dollar amounts or a relative scale ($$, $$$) to show a comparison.

Printer	Build area (mm)	Smallest feature size on XY axis (μm)	Smallest height on Z axis (μm)	Fastest speed (mm3/min)	Type of production*
LLNL LAPμSL	60 × 60 × 50	30	10	51	Top-down scanning DLP
LLNL LAPμSL II	160 (diameter) × 50	10	10	705	Top-down scanning DLP
LLNL PμSL	2.52 × 1.41	5	10	0.174	Top-down DLP
Kudo3D Titan 1	190 × 110 × 254	100	35	240	Bottom up-DLP
Envision Perfactory Micro	160 × 100 × 228	50	25	113	Bottom-up DLP
DB9 Creator	102 × 78 × 206	70	100	391	Bottom-up DLP
3D Systems Project 1200	43 × 27 × 150	56	30	270	Bottom-up Laser SLA
Asiga Freeform Pico 2		39	50	163	Bottom-up DLP

* DLP = digital light processing; SLA = stereolithography

B. Describe how your product improves upon competitive products or technologies. Describe limitations of your product.

Unique in the marketplace, LAPμSL is the only optically scanned DLP system. This gives it an advantage in applications that need tiny features over a large area. A laser-scanned system can cover a large area, but each feature has to be drawn individually, the result being that small features or complex details considerably slow down the build speed. The advantage of LAPμSL is the small image of the DMD, essentially projecting 750,000 details at once over a small area. A standard DLP system projects an image to one location, which can contain a lot of detail, but to make a part larger than a single image the build area or the optical system itself must be physically moved, which involves extra staging, time, and cost—typically necessitating a tradeoff between product size and feature size. The LAPμSL scans the image only and therefore can cover a very large area quickly and still maintain both resolution and speed.

The system currently is limited by the resin used and by the power of the light source used. However, simple improvements in power delivered will increase the build speed linearly, and the state of resin development is progressing very quickly. The system's fundamental technique can take advantage of improvements in these two basic parameters. Furthermore, the technique supports bottom-up printing.

In addition, the system offers an excellent solution to the challenge of rapidly manufacturing complex parts of significant size. For such applications, no other system available can deliver on all these parameters as well as the LAPμSL can.

4. SUMMARY (MAXIMUM 200 WORDS)

The LAPμSL is the only 3D printer capable of simultaneously delivering high build speed, large product size, and small features. Other DLP printers can achieve good results by trading off speed for product size, or build area for small feature size, or small features for speed. However, LAPμSL is a game-changing solution for applications requiring excellence in all three parameters. This is made possible with the innovative combination of detailed DLP imaging and image scanning to cover a large area. This hybrid approach is unique in the industry and could be scaled up to even larger build volumes, for practical industrial production. Funding for this technology was provided by the Defense Advanced Research Projects Agency and by Lawrence Livermore National Laboratory's Laboratory Directed Research and Development Program.

5. CONTACT INFORMATION

Please provide names and contact information (title, organization, phone number, email) for each of the following individual associated with the entry submission:

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6. AFFIRMATION

By submitting this entry to R&D Magazine you affirm that all information submitted as a part of, or supplemental to, this entry is a fair and accurate representation of this product. You affirm that you have read the instructions and entry notes and agree to the rules specified in those sections.

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