FP NanoPrinter™

Unique multi-material 3D nanofabrication platform

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TECHNOLOGY

Recognized by the Science Magazine in 2019 & 2022

Femtosecond Projection (FP) NanoPrinter enables ultrafast 3D nanofabrication by combining a regenerative femtosecond laser amplifier with a digital micromirror device (DMD), where the DMD simultaneously functions as a blazed grating and a programmable binary mask to generate a depth-resolved programmable light sheet via spatial and temporal focusing. Synchronization between the femtosecond light sheet and a precision positioner enables the creation of arbitrarily complex 3D micro- and nano-structures with a lateral and axial resolution of 140 nm and 175 nm, respectively, and a fabrication rate of approximately 100 mm^3/hr [1]. Comparing with conventional two-photon lithography (TPL) systems that perform microfabrication via a serial point-by-point scanning process, the FP NanoPrinter defines an entire plane that contains hundreds of thousands of voxels in a single exposure (i.e., 1 - 10 milliseconds), thereby improving the fabrication rate by three orders of magnitude than state-of-the-art commercial solutions (Note that commercial systems typically print at a rate of 0.1 mm^3/hr at this resolution.) This allows the FP NanoPrinter to effortlessly fabricate large-scale 3D structures with overhanging parts that were not possible previously. More importantly, objects printed by the FP NanoPrinter will have improved structural strengths owing to the enhanced voxel aspect ratio of 1:1.25. By substantially saving the laser operation time, the FP NanoPrinter effectively reduces the printing cost per part by 90%.

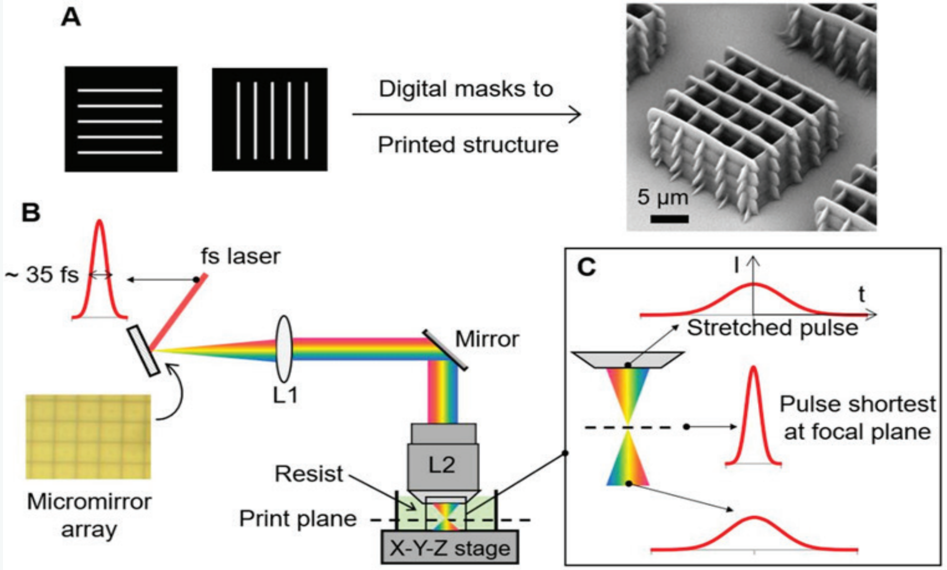


Figure 1. Principle of Femtosecond Projection [1]. (A) Design of 2D digital masks. (B) Generation of a patterned femtosecond light sheet via temporal focusing. (C) Schematic of the temporal focusing effect that in the focal plane, a light sheet with the shortest pulse duration is formed by recombining all the dispersed laser spectral components.

By exploiting the ultrahigh peak power of the femtosecond light sheet, the FP NanoPrinter can create complex 3D structures with a wide selection of materials (including metals, alloys, semiconductors, polymers, ceramics, biomaterials) on custom-developed swellable hydrogel substrates. By shrinking the gel substrate 3D structures made of different materials can achieve a minimum feature size with 30 nanometers, which enables the design and fabrication of many functional nano-devices for applications in photonics, health, automobile and even aerospace [2].

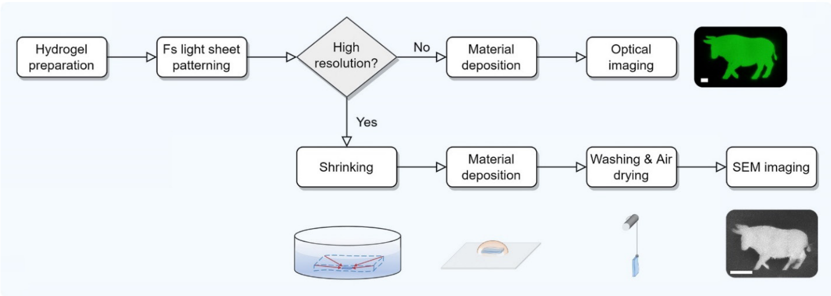
PRODUCT CAPABILITIES

FP NanoPrinter™

Multi-material Nanofabrication using Hydrogel Substrate

- Kinetically controlled material assembly + shrinking to go beyond diffraction limit
- Resolution: up to 30 nm
- Materials: →17 - metals, alloys, oxides, salts, semiconductors, polymers, crystals, dyes, biomaterials, inks, etc.

FABRICATION WORKFLOW FOR HYDROGEL SUBSTRATE



Schematic that illustrates the overall fabrication process via the hydrogel platform.
Scale bars:10 μm for the optical image (top); and 1 μm for the SEM image (bottom) [2].

Two-photon Polymerization (high throughput and high resolution simultaneously)

- Resolution: 140 nm lateral, 175 nm axial
- Throughput: 100 - 1000 mm^3/hour
- Volume printing cost: US$ 1.5/mm^3

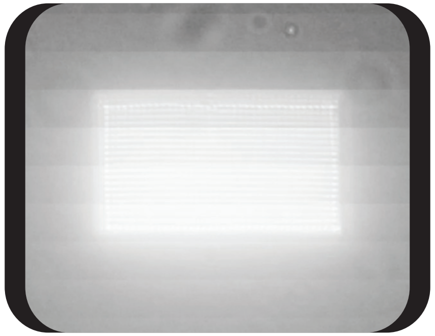
3D FABRICATION WORKFLOW

CREATING PRINTING PROCESSING

SOFTWARE

AstraWrite™

AstraWrite™ offers an intuitive and comprehensive user interface to control and monitor the printing process in real-time. AstraWrite controls the FP NanoPrinter to fabricate the designed 2D or 3D structures by loading the DMD patterns converted from the custom-designed CAD files. AstraWrite also allows advanced users to control and directly interface with the sub-systems in the FP NanoPrinter, including the DMD, XYZ stage, and laser system.



KEY FEATURES

- Automated 3D TPP fabrication
- 3D stitching for large structures
- In situ monitoring of TPP fabrication
- Direct interface/control of FP NanoPrinter sub-systems

APPLICATIONS

The FP NanoPrinter is a revolutionary tool at the forefront in many different fields including

- Cell/Tissue Scaffolds
- Drug Delivery Devices
- Bio-inspired Structures
- Micro-/nano-fluidics

- Rapid Prototyping
- Micro-/nano-structures
- Micro-/nano-machines
- Metamaterials

- Diffractive Optical Elements
- Photonic Devices
- Micro-/nano-optics
- Micro-structured Fibers

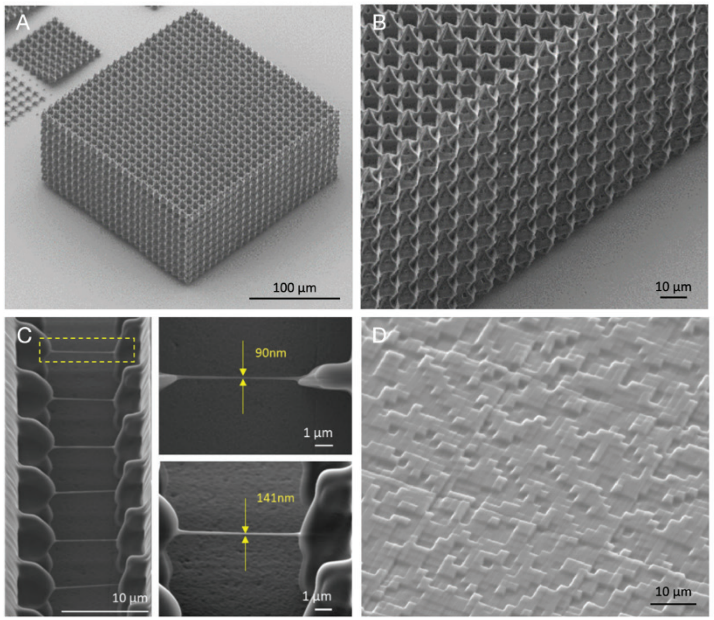


Figure 2. Printing of complex 3D structures with submicron resolution via FP NanoPrinter. (A to B) Metamaterial structures and their enlarged view. (C) Nanowire arrays demonstration a lateral and axial resolution of 90 nm and 141 nm respectively. (D) 3D diffractive optical element (DOE) device.

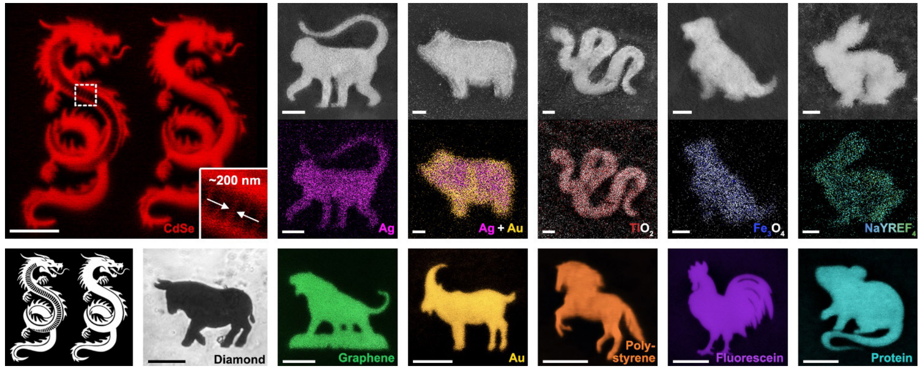


Figure 3. Demonstration of material variety via 12 Chinese zodiac animals, including fluorescent image of two dragons of CdSe quantum dots (QDs) without shrinking (the inset shows a resolution of ~200 nm); SEM (top) and EDX (bottom) images of a monkey of Ag; pig of Au-Ag alloy; snake of TiO2; dog of Fe3O4; rabbit of NaYREF4; optical microscopy image of an ox of diamond; fluorescent images of a tiger of graphene QDs; goat of fluorescent Au; horse of polystyrene; rooster of fluorescein; and mouse of fluorescent protein.

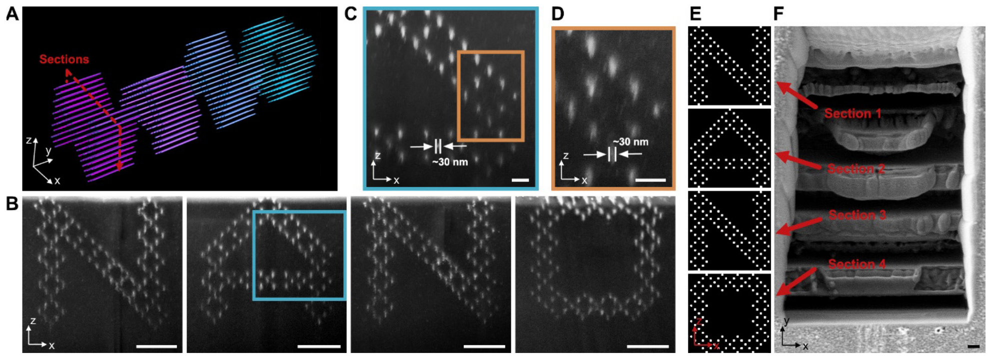


Figure 4. Nanostructures demonstrating minimum feature sizes. (A) 3D model of a nonconnected "NANO" structure comprised of arrays of parallel nanowires. (B) SEM cross-sectional images of the "NANO" structure cut by focused ion beam (FIB); (C) zoom-in view of the letter "A" in (B); and (D) zoom-in view (C). (E) Four cross-sectional patterns of the "NANO" structure (in the x-z plane of (A)). (F) SEM images showing the trenches of the gel sample opened by the FIB-cut, where the positions of each letter are labelled. All cross-sectional images were taken at a substrate tilt angle of 52°

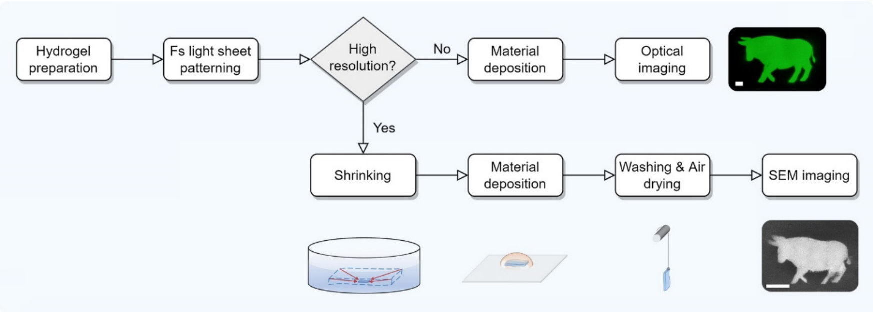


Figure 5. Fabrication of large-scale woodpile structures: (A) 12-layer woodpile structure of fluorescent polystyrene (top view, stitched from 16 sub-images due to the limited microscope field of view.); (B) zoom-in view of (A), where the inset shows a 3D fluorescent image of the structural details in the selected area; (C) cuboid woodpile structure of fluorescent protein; (D) O-shaped 3D woodpile structure of CdSe.

SPECIFICATIONS

Technical Specifications		
Application	**Hydrogel platform**	**Two photon polymerization**
Printing Technology	Femtosecond Light Sheet	Femtosecond Projection Two Photon Lithography (FP-TPL)
Minimum feature size (XY / Z)	30 nm* / 50 nm* after shrinkage 400 nm* / 600 nm* before shrinkage	140 nm* / 175 nm*
Shrinkage ratio	1x - 15x on each dimension	N/A
Resolution (Diffractive limit, XY / Z)	340 nm* / 500 nm*	340 nm* / 500 nm*
Layer distance	0.1 - 5 µm	0.1 - 5 µm
Printing rate	0.1 - 100 mm^3/hr, dependent on shrinkage ratio	100 mm^3/hr
Minimum surface roughness	⩽ 5 nm	⩽ 20 nm
Field of view (on 40x objective lens)	180 µm × 100 µm	180 µm × 100 µm
Build volume	20 mm × 20 mm × 0.5 mm (before shrinkage)	250 mm × 250 mm × 10 mm (travel of XYZ stage)
Substrate types	Glass	Glass
Compatible material	Metals, metal alloys, 2D materials, semiconductors, oxides, diamond upconversion materials, polymers biomaterials, molecular crystals	Photoresin

Light Source Requirements	
Light Source	NIR femtosecond laser (800 nm, > 5 mJ@1 kHz, < 35 fs)
Laser safety	Class 4
Beam diameter	10-15 mm
Software	
AstraWrite	Proprietary GUI
Data input	Various image files (.bmp, .stl)
Dimensions	
Printer (w/o desktop)	1400 mm × 1650 mm × 450 mm (550 mm × 1550 mm × 450mm w/o laser)
Total weight (w/o desktop)	350 kg (50 kg w/o laser)
Site requirements	
Operating temperature	23 ± 1 ℃
Relative humidity	< 50% (< 35% recommended)
Room lighting	≥ 590 nm lighting at operation
Particles	Class 10000
Power supply	220V, > 35 A current supply
Vibration level	Vibration isolation & damping required; no vibration source in the room
Compressed air supply for optical table	required
Ambient air requirement	No significant airflow within 20 cm of the printer
Altitude	Up to 2500 m

*Determined by system settings, printing parameters, objective lens, site temperature and conditions.

Astra Optics Limited follows a policy of continuous product improvement. Specifications are subject to change without notice. Astra Optics Limited offers a limited warranty for all NanoPrinter Systems. For full details of this warranty coverage, please contact your local sales or service representative.

References:
[1] S.K. Saha, D. Wang, V.H. Nguyen, Y. Chang, J.S. Oakdale, S. Chen, "Scalable Submicrometer Additive Manufacturing," Science, Vol. 366, No. 6461, pp. 105-109, 2019.

[2] F. Han, S. Gu, A. Klimas, N. Zhao, Y. Zhao, and S. Chen, "3D Nanofabrication via Ultrafast Laser Patterning and Kinetically-regulated Material Assembly," Science, Vol. 378, No. 6626, pp. 1325-1331, 2022.

ABOUT ASTRA OPTICS LIMITED

Astra Optics Limited, founded by a team of experts in optical engineering, material science, and nanomanufacturing, is a spin-off company from the Chinese University of Hong Kong.

Our ground-breaking 3D nanofabrication technology, i.e., femtosecond projection laser patterning system and hydrogel-based multi-material fabrication platform, has proven records to revolutionize the micro-additive manufacturingindustry by overcoming the critical bottlenecks in current state-of-the-art solutions, namely, low-throughput (~0.1 mm^3/hr) and high fabrication cost ($20/$mm^3$). The FP NanoPrinter is the only truly scalable nano-printing solution that simultaneously demonstrates record resolution (20 nm), throughput (100s mm^3/hour), and substantially reduced cost ($1.5/$mm^3$), which is three orders of magnitude faster than existing commercial methods.

Our records have been internationally recognized by our 2019 and 2022 publications in the **Science Magazine** (Saha et al., **Science**, 366(6461): 105-109, 2019 & Han et al., **Science**, 378(6626) :1325-1331, 2022) with multiple U.S.patents.

By substantially lowering the cost of micro-additive manufacturing, our product enables industrial scale application of TPL and multi-material 3D nanofabrication at 20-nm resolution for the first time. Our product will generate impact in different industries such as nanotechnology, biotechnology, healthcare, renewable energy, and electronics.