UNIVERSITY OF Southampton

Digital multimirror devices for precision laser micromachining

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Light

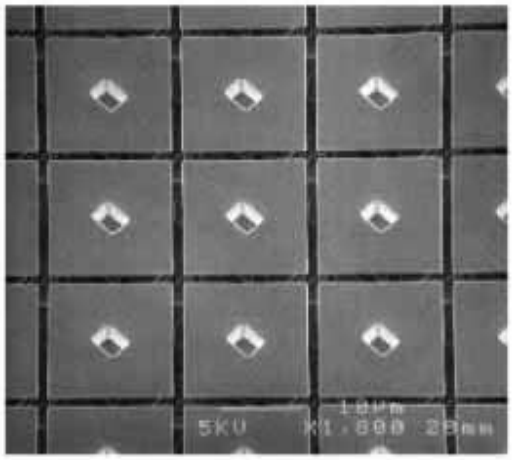
Content

- **DMD devices for laser processing**
- Laser:
  - Ablation
  - Multiphoton polymerisation (MPP)
  - Laser-induced forward transfer (LIFT)
  - *all within the context of **microscale** materials processing*
- Summary

Digital Micromirror Devices (DMD)

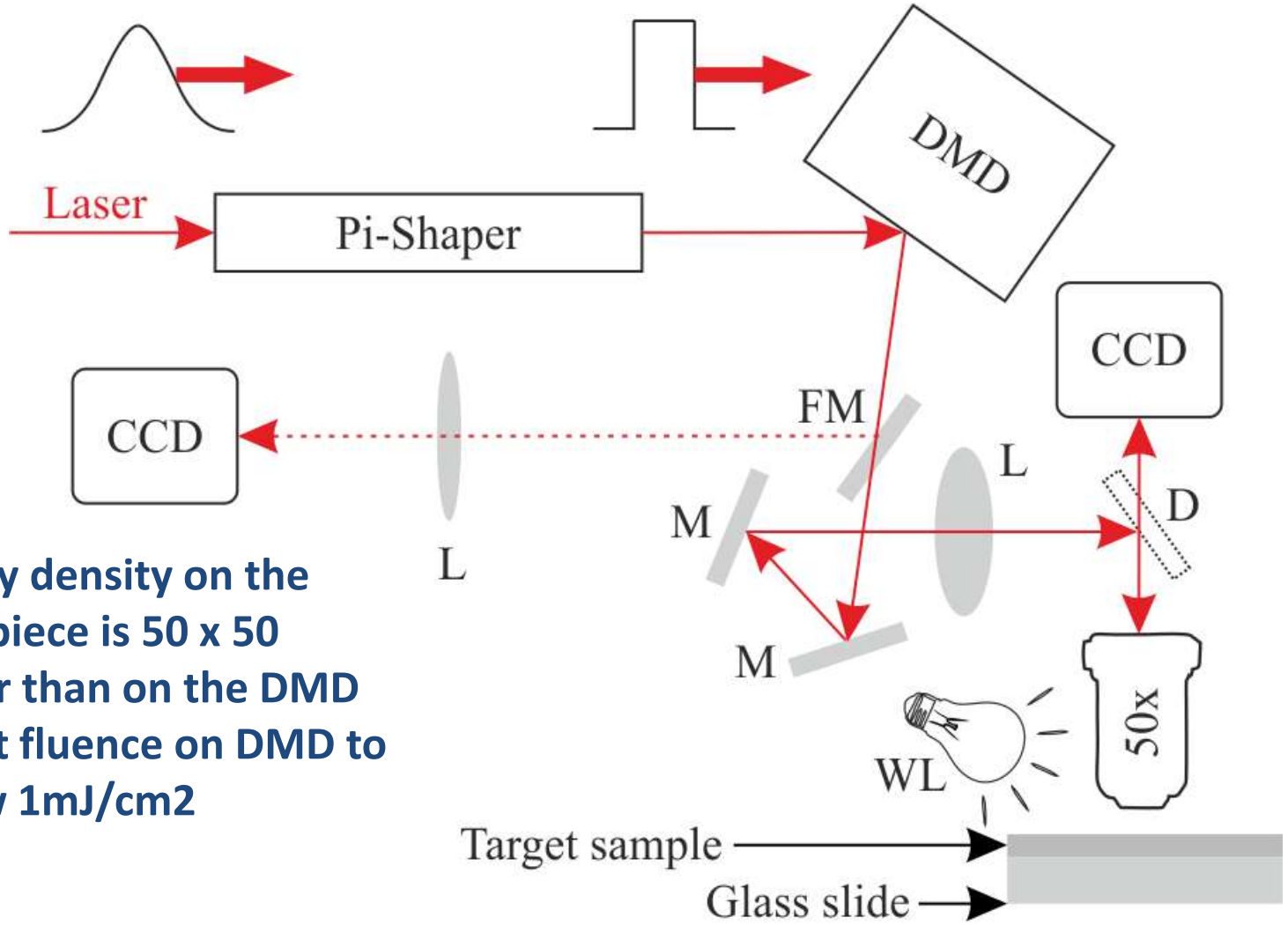
- Used in majority of projectors
- Array of individually controlled ~7µm wide mirrors
- Operates across the visible and NIR region
- Can be used as an ***intensity*** spatial light modulator (SLM)
- Cheap (~£200) and fast switching speed (>1Khz)

Schematic of a section of the digital mirror device (actual model used: Texas Instruments DLP3000, 608 x 684 mirrors)



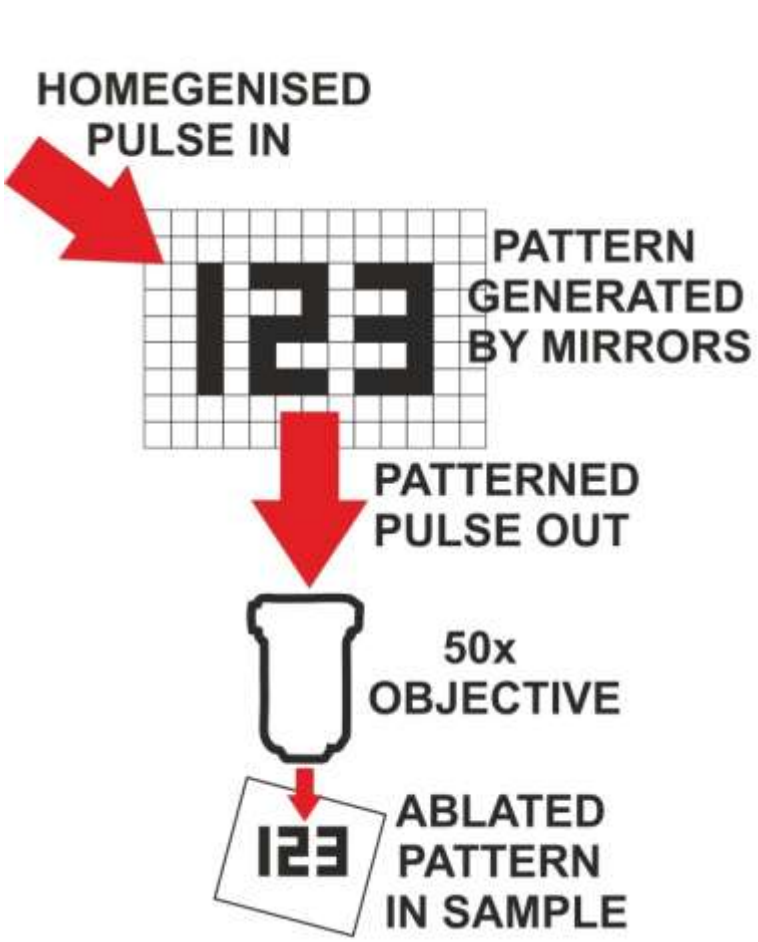
Experimental schematic

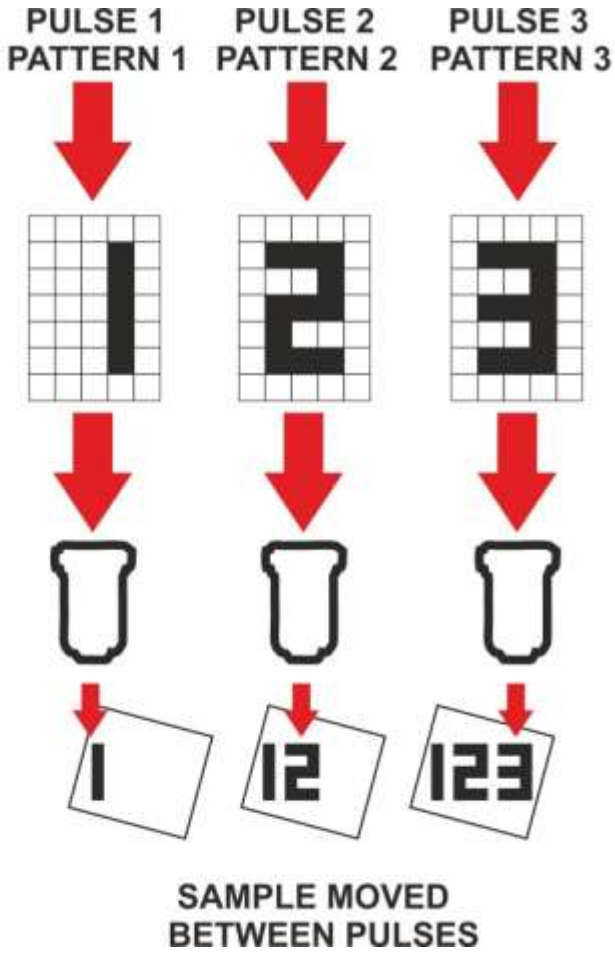
Ti: sapphire, 2mJ max, 1kHz, 800nm



Energy density on the workpiece is 50 x 50 higher than on the DMD
- Limit fluence on DMD to below 1mJ/cm2

Pattern updating





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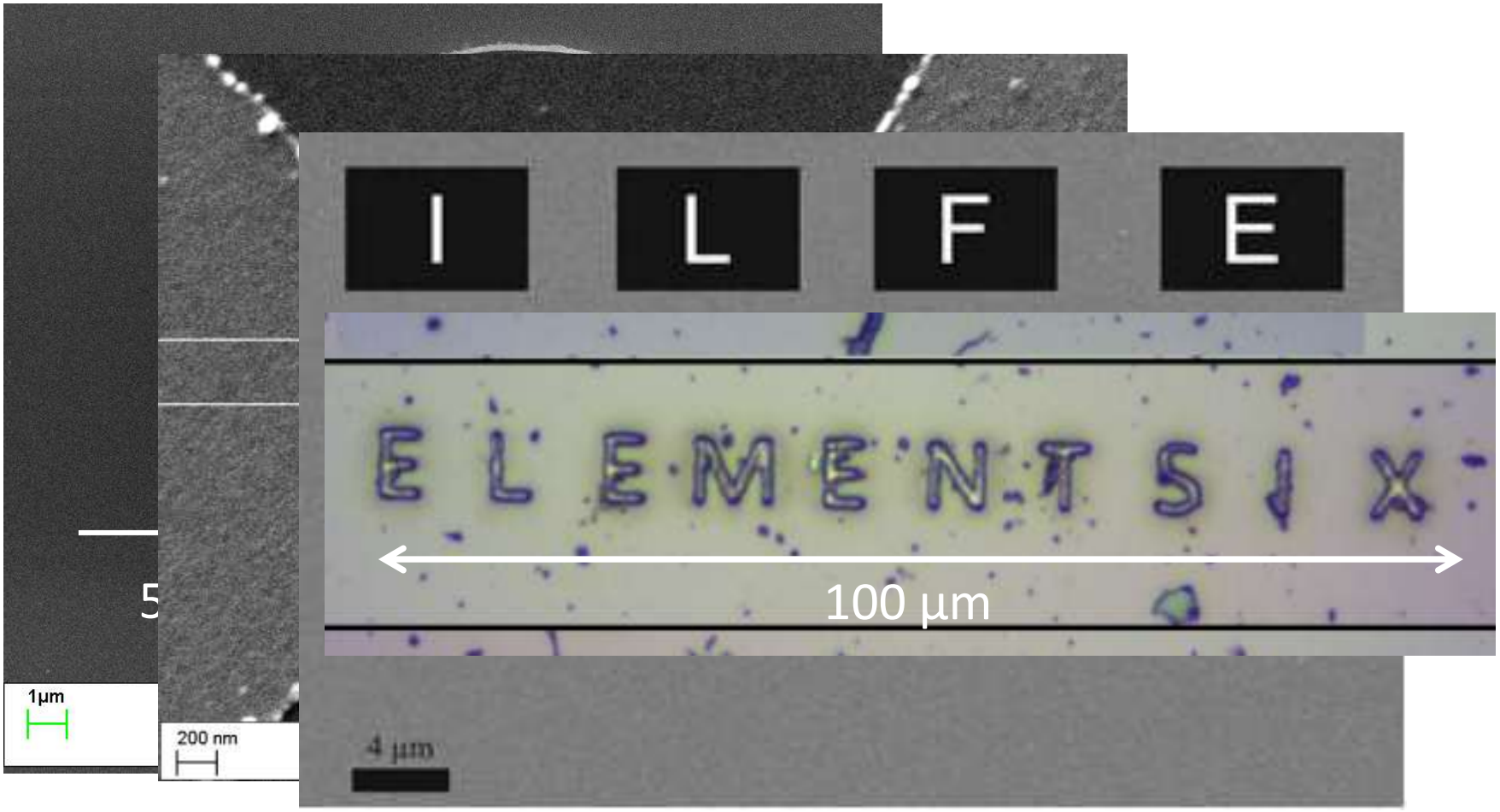
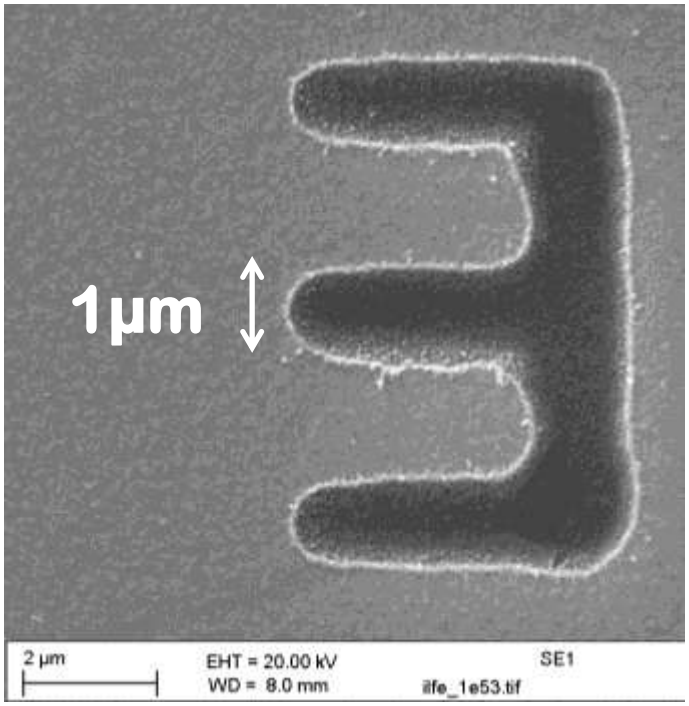
1 Ablative removal:

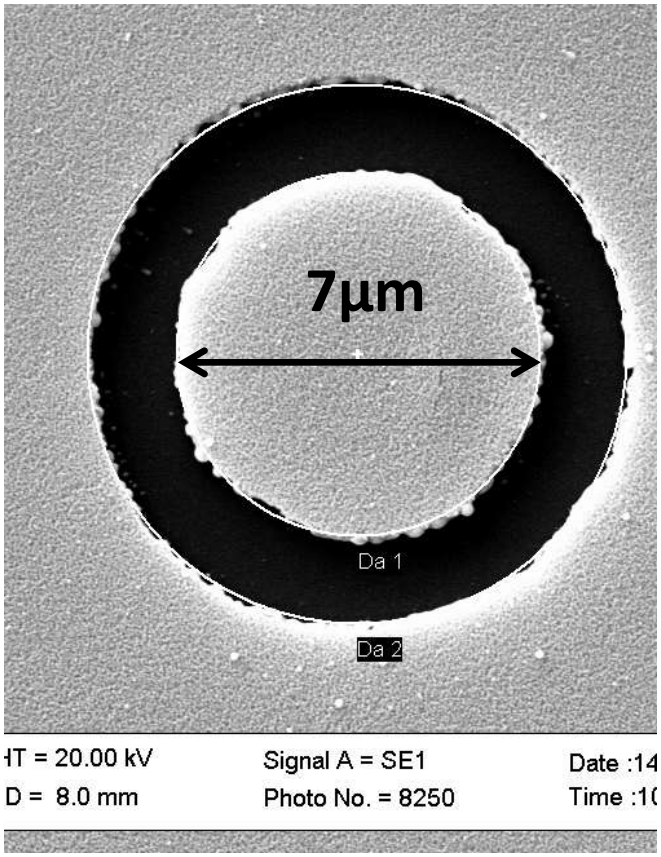


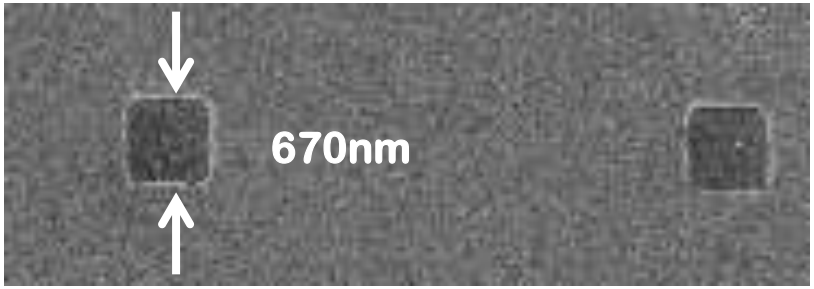
Semiconductors **Metals/alloys** **Diamond**

Close-ups:



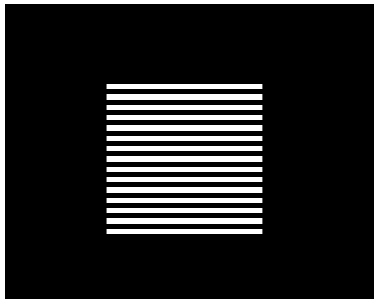
These all took 150 fs



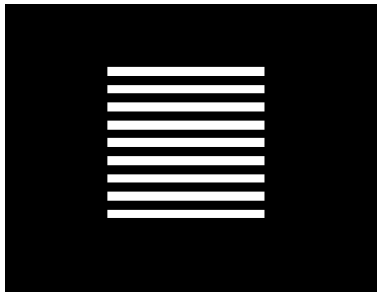


Direct writing of gratings: 6300 Gratings, Actual time = ~4 minutes, best possible time = 6.3 seconds

How they appear on the DMD

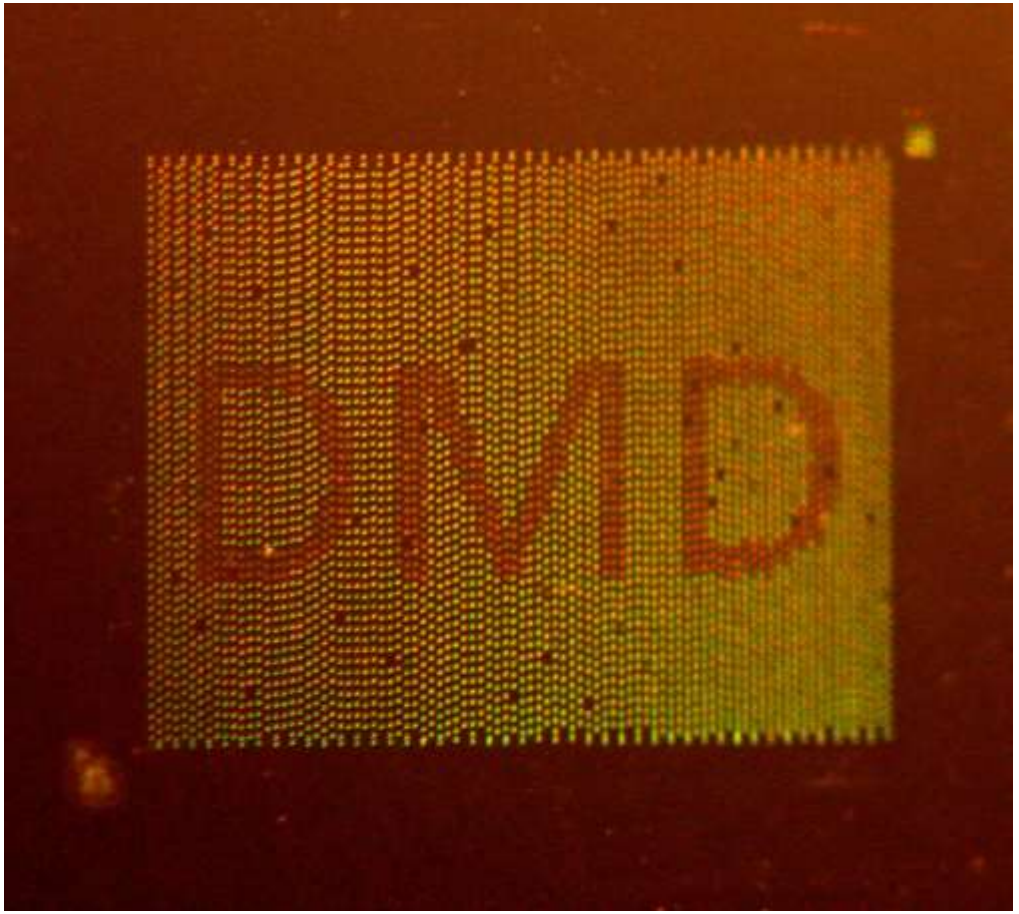


Each line 10 pixels wide

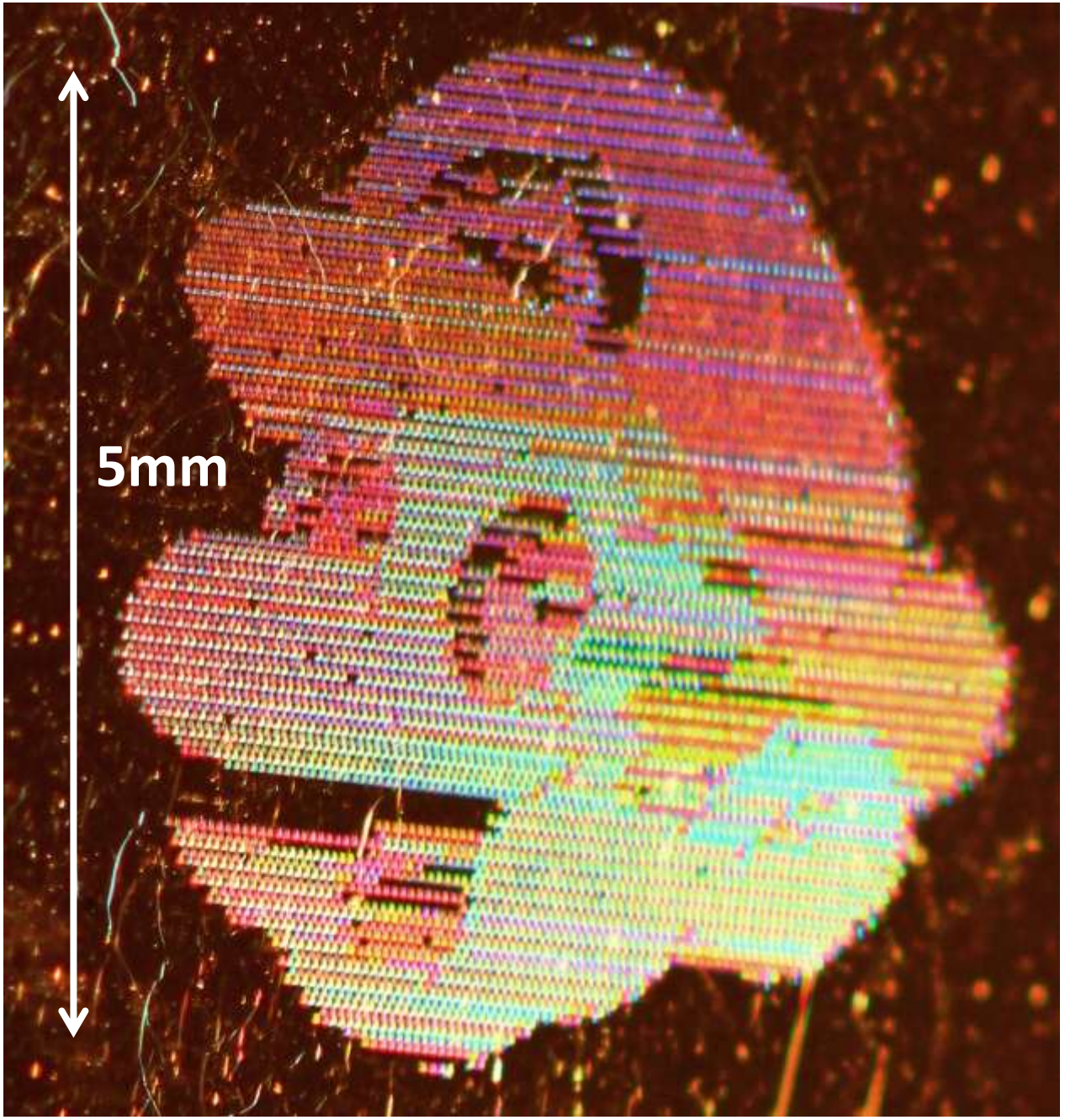


Each line 17 pixels wide

4.5x3.5mm total area, each pixel in image a grating of 30x30µm



Any image can be displayed on DMD for each pixel of course, not just gratings (though they look macroscopically attractive).



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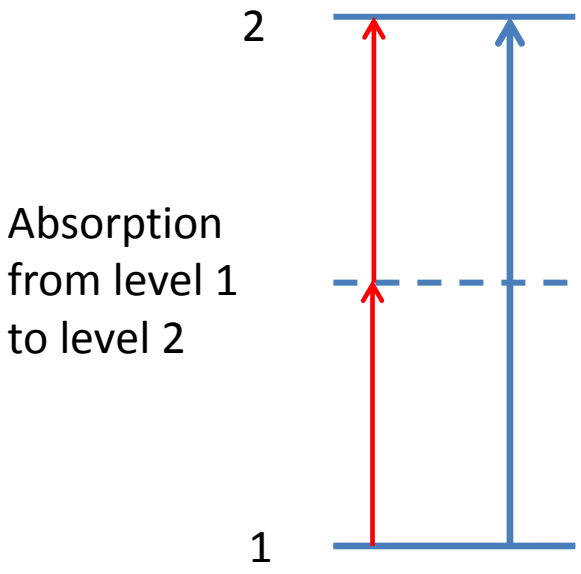
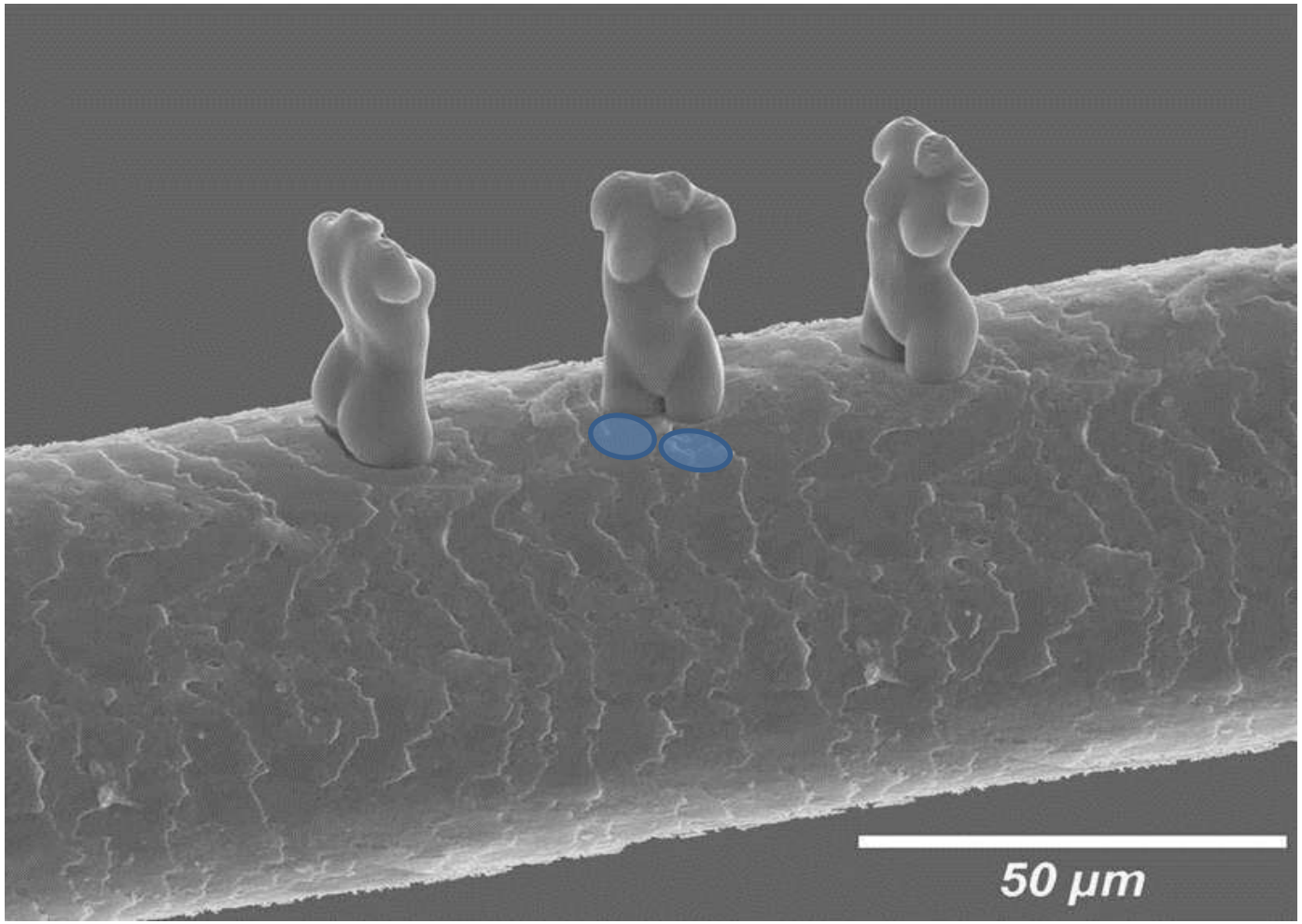
MPP

- With very fast laser pulses, materials can absorb at wavelengths they are '***not supposed to***'!
- Using light at 800nm wavelength, a material can simultaneously absorb 2 photons, equivalent to an absorption in the blue (400nm).



2 photons at 800 nm can have the same effect as 1 photon at 400nm…..very clever trick!

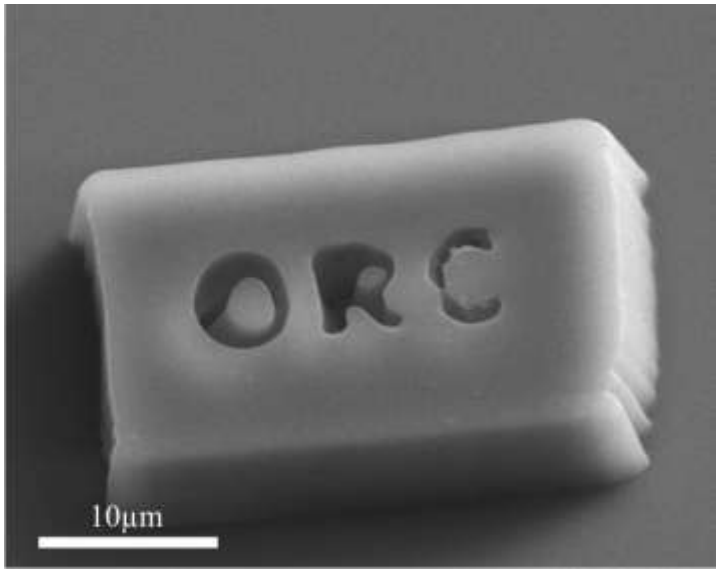
Multiphoton writing (serial printing)



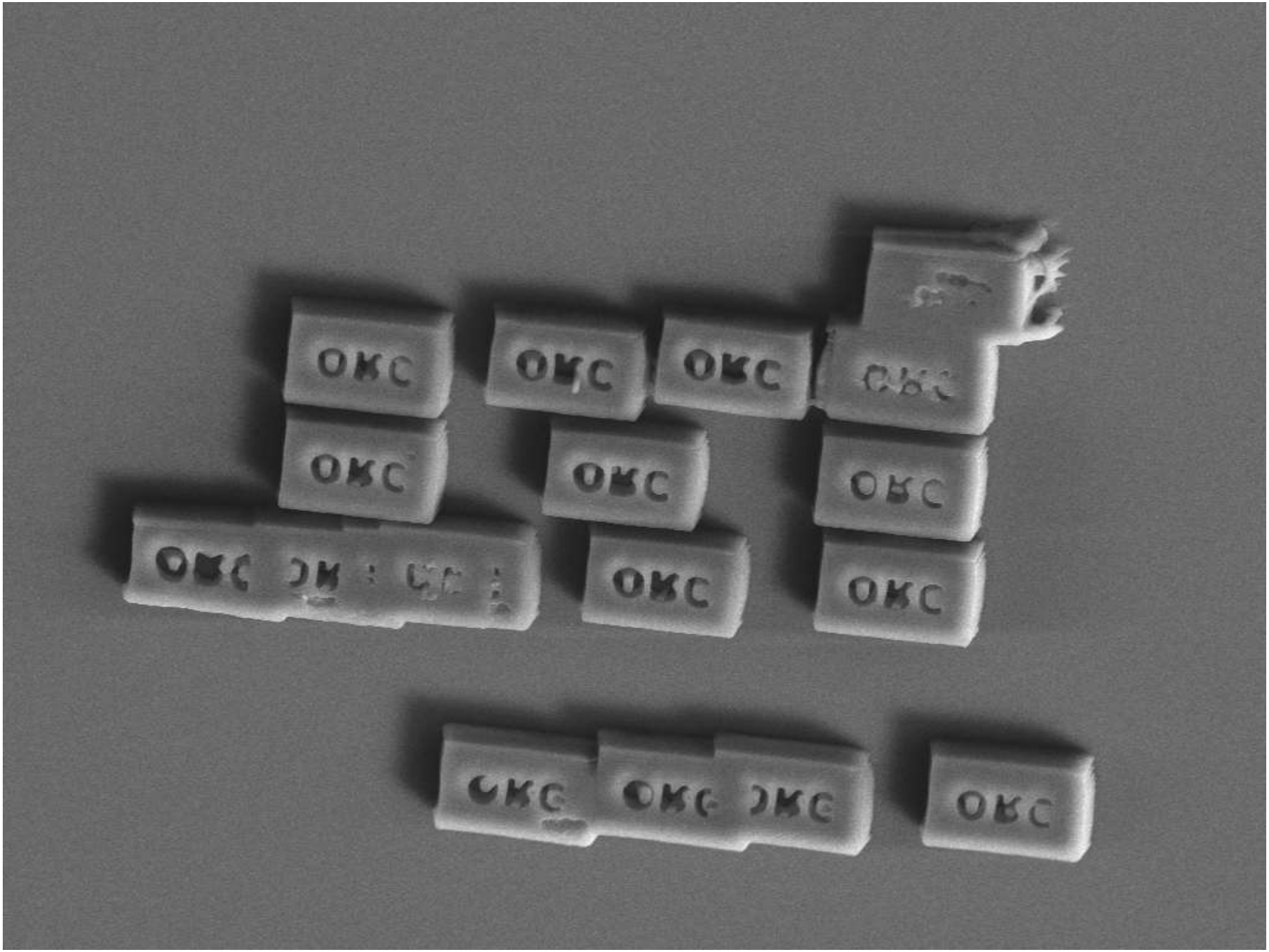
Laser Zentrum, Hannover, + Nanoscribe….many others

DMD MPP but **single shot** exposure

Image file that was displayed on the DMD during the period of the pulse



SEM image of structure fabricated using a single pulse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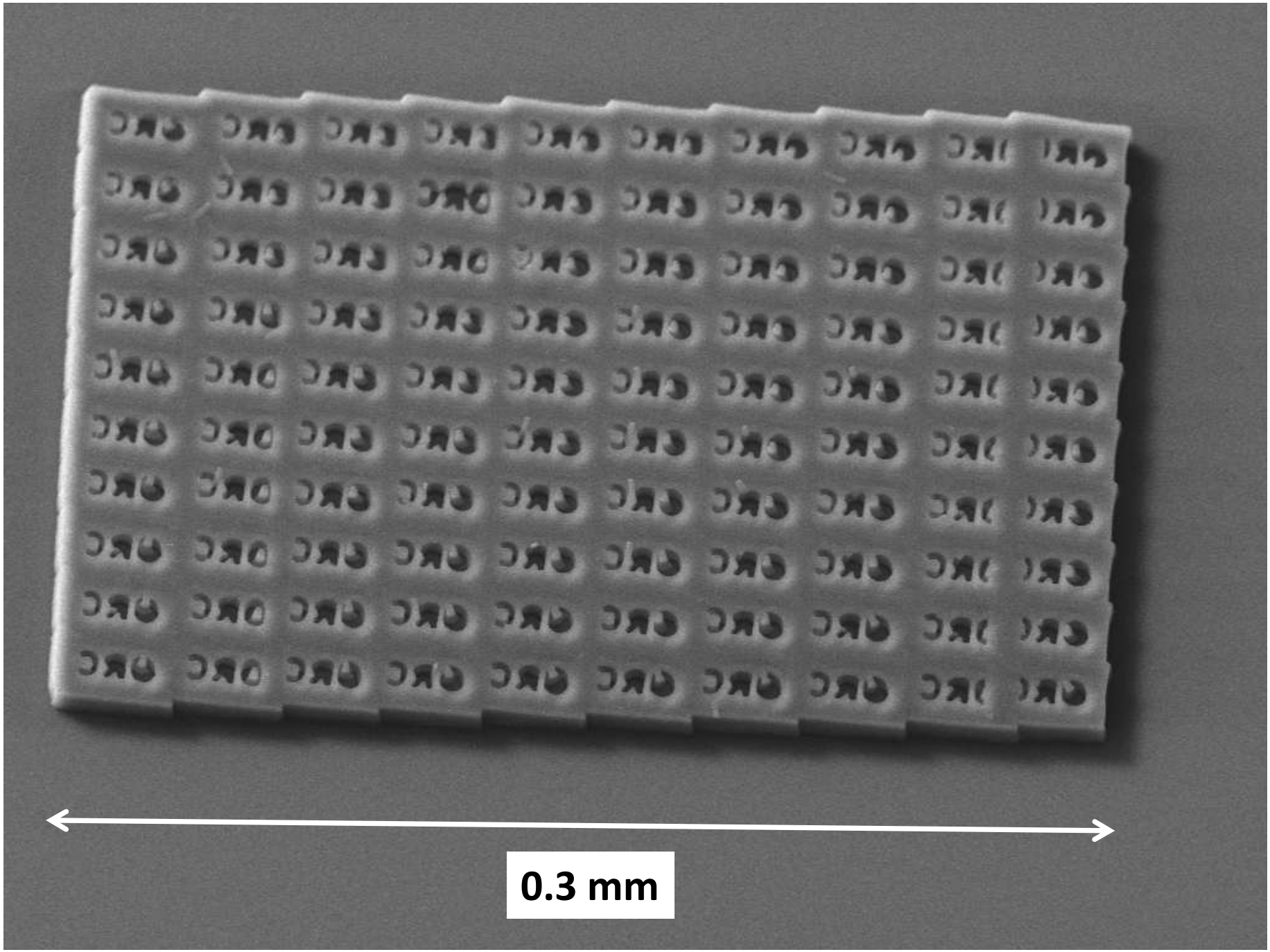
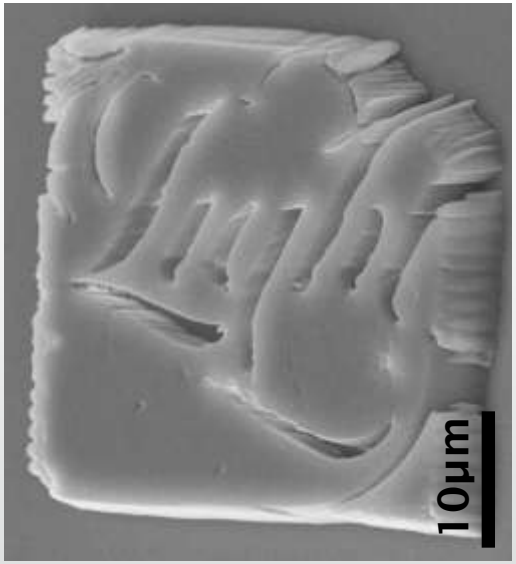
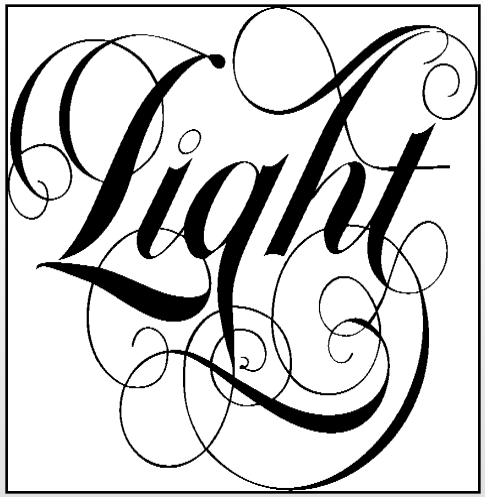

0.3 mm

DMD-based approach

- For larger areas, maybe 10 shots is required for optimum definition:
- Feature size can be ~400nm (~λ/2)

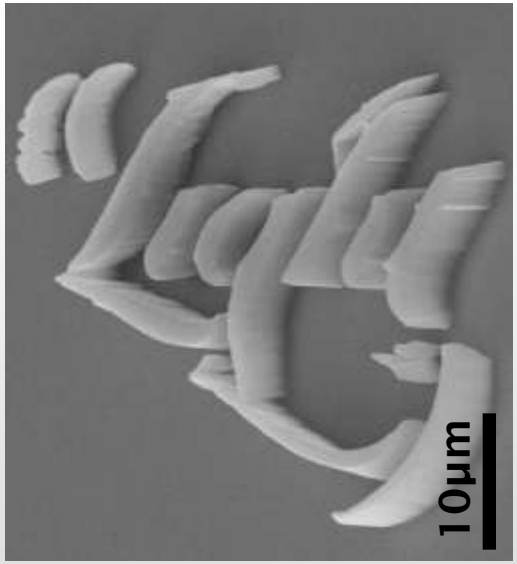
+ contrast



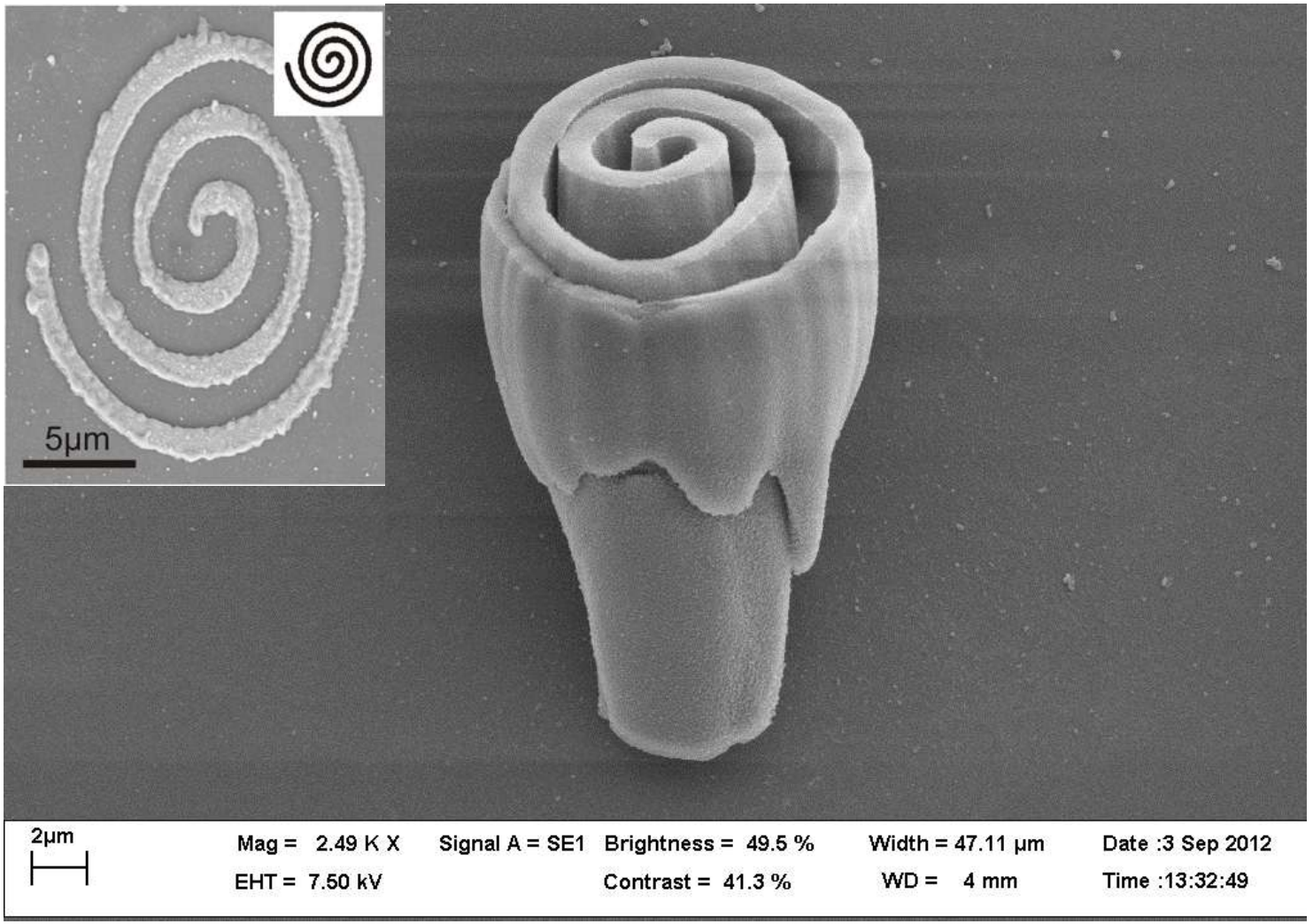


Pattern used on DMD

- contrast



But need to consider depth of field



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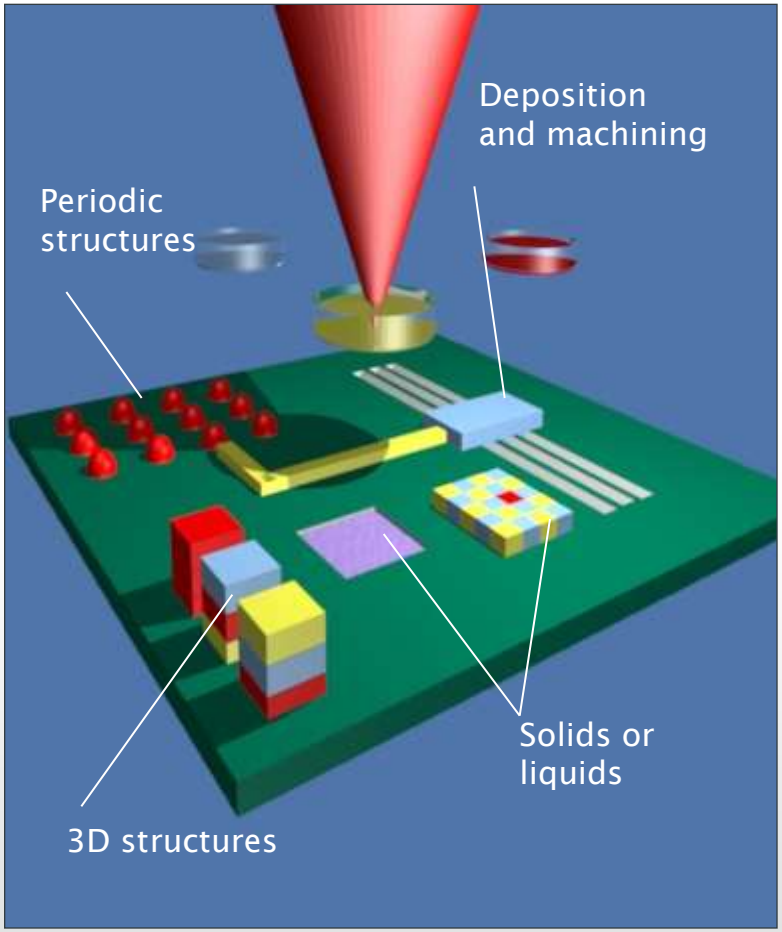
LIFT basics:

Laser-**I**nduced **F**orward **T**ransfer = Laser printing

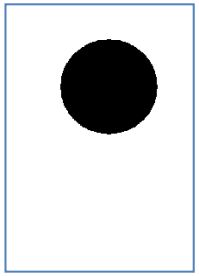
Typewriter	LIFT
Key	Laser
Ribbon	Carrier
Ink	Donor
Paper	Receiver

LIFT – The Potential

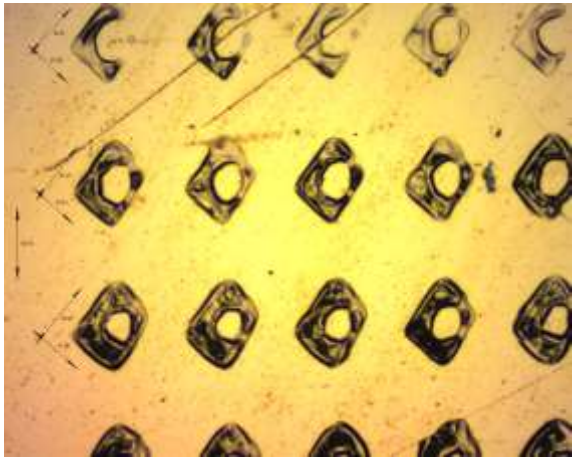


- Ultrashort regime → can ablate most source film materials.
- Deposition onto wide range of receiver materials and geometries.
- Fast and relatively simple.

Using DMD patterning for incident laser field

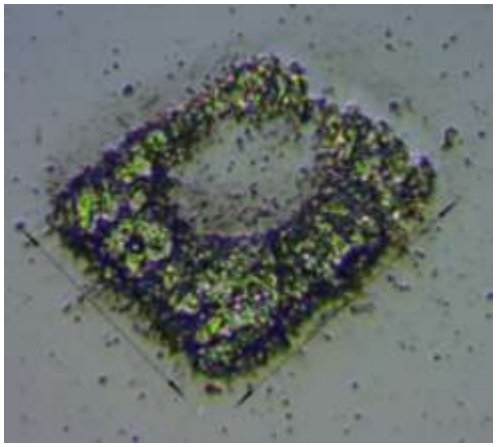


Pattern on the DMD



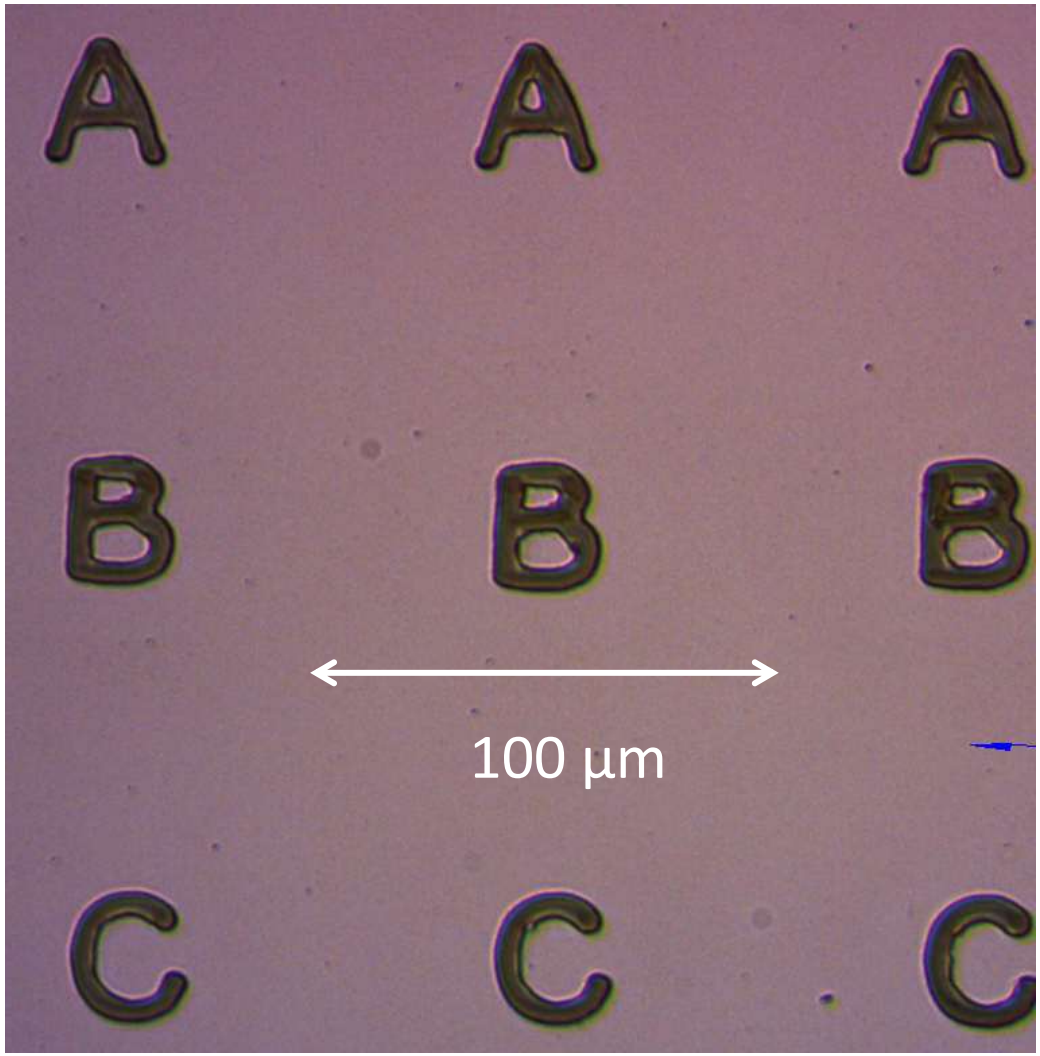
Pattern on the donor film

40µm x 40µm



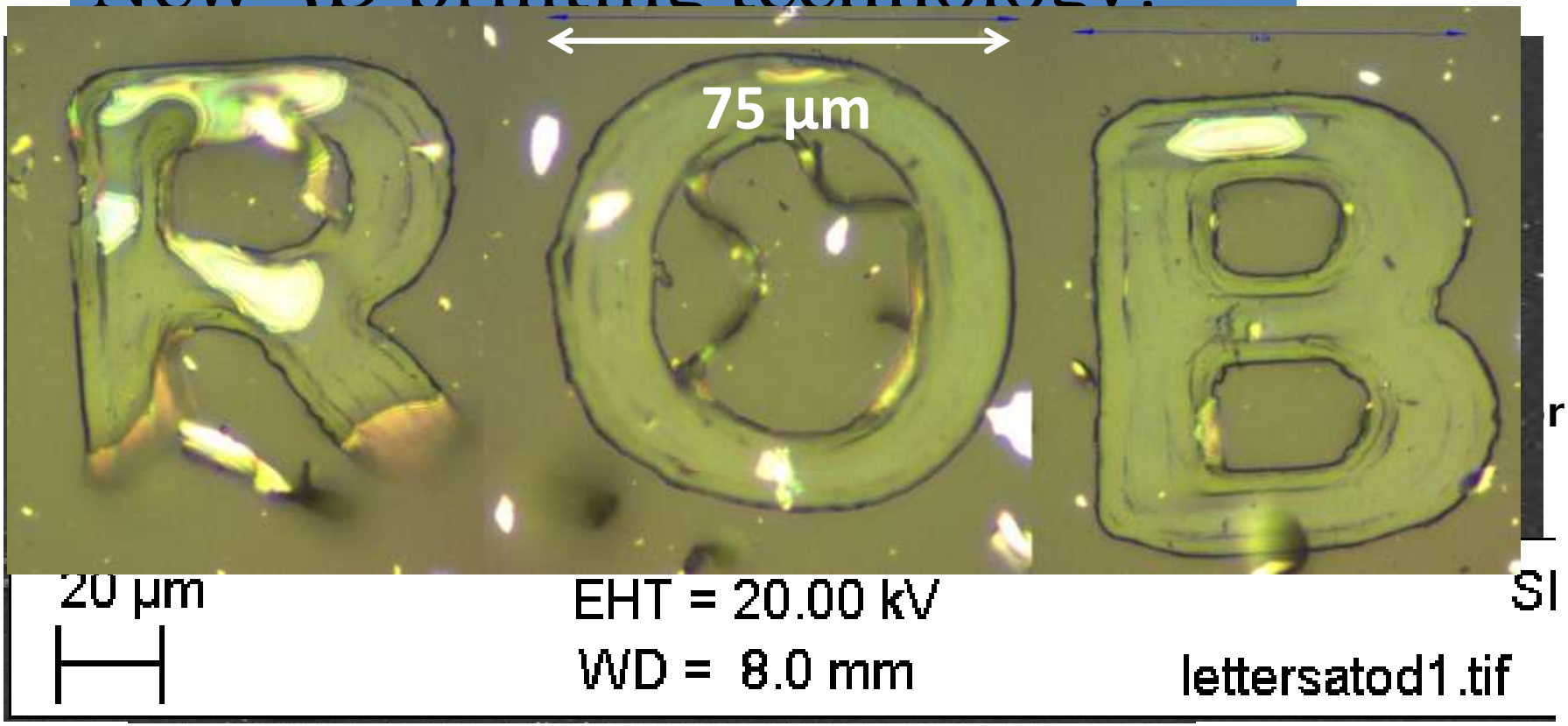
Final LIFTed feature (Au on Si).

700nm thick Si films: the donor



Most recent DMD LIFT results

New 3D printing technology!



Summary

- DMDs are very useful for precise ablation, multiphoton polymerisation and LIFT and can produce µm-mm scale features.
- Single-shot processing and areas up to ~50 μm^2
- Step and repeat for larger areas.

Recent EPSRC grant announcement

- EP/L022230/1 : 2014/2015
- Digital Multimirror Devices for laser-based Manufacturing
- Under the ***Manufacturing with light*** scheme
- Please make contact with me via:

rwe@orc.soton.ac.uk