Direct laser writing of micropillars on Siloxane moulds for microrreplication

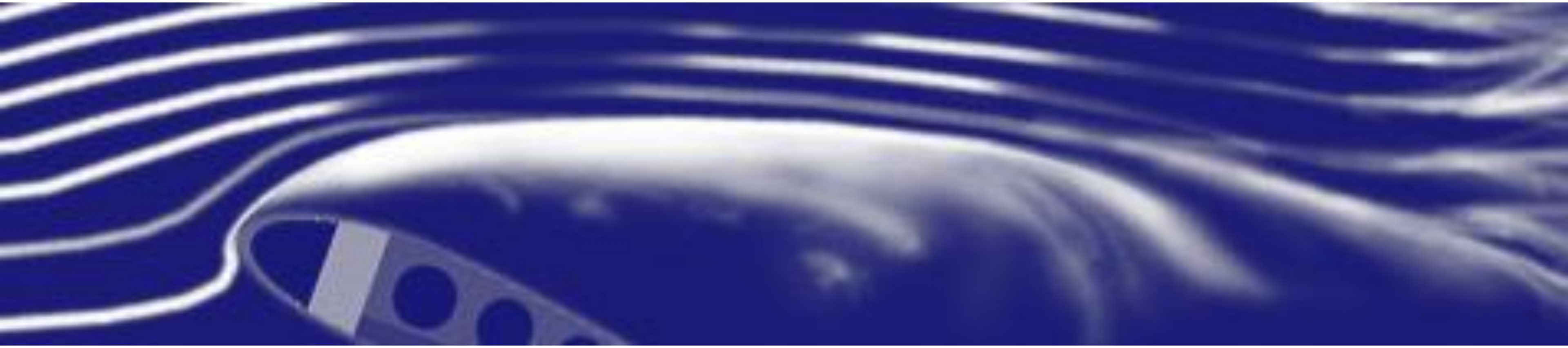
Nerea Otero I notero@aimen.es

Outlook

- Motivation
- Laser direct writing of micromoulds in PDMS
- Replication results
- Conclusions and further work

notero@aimen.es

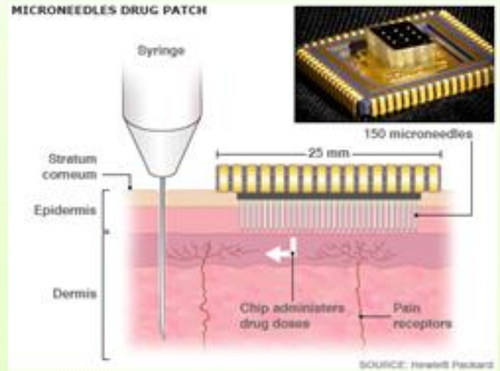
Motivation

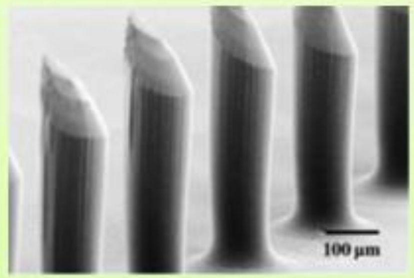


Motivation

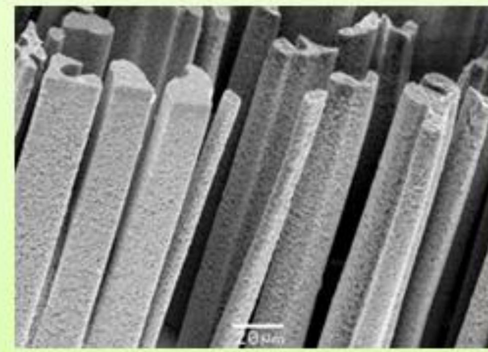
THREE INNOVATIVE PRODUCT DESIGNS: Microfluidics, microneedles, piezotransducers.

Handheld analyzer and Microfluidic chip (SensLab)





Drug Patch Chip and microneedle array (Crospon)



IntraVenous US Catheter and microPTZ transducer(AFM)

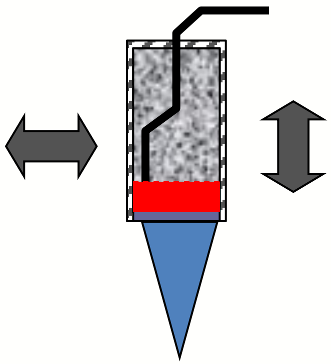
Manufacturing challenges:

- Integration of functional and disposable parts: need for *"functional materials and geometries"*
- Manufacturing cost and flexibility: Disposable part of the device need very low cost. Patient sp.

Ultrasound Technology

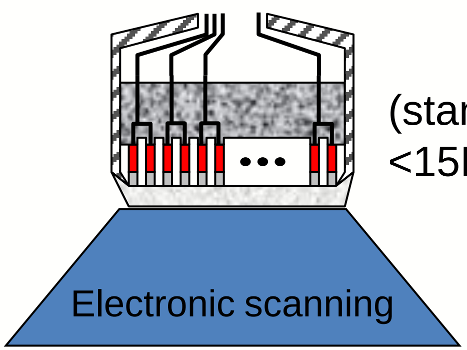
- Safe, inexpensive, real time - >20% of all clinical scans ($5bn).
- Widely used in Fetal imaging, Cardiac imaging, Blood flow measurement, Intra-operative guidance.
  - Utilises machined piezoelectric ceramic element
  - Minimum image feature size 150um at 10MHz
  - Current commercial limit ~15MHz.
- For imaging:

Mechanical scanning



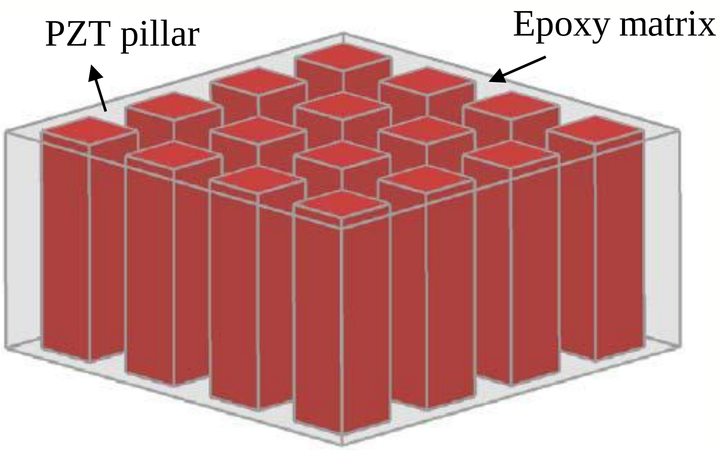
Single element transducer

(standard for frequencies <15MHz)



Array transducer

1-3 piezocomposites

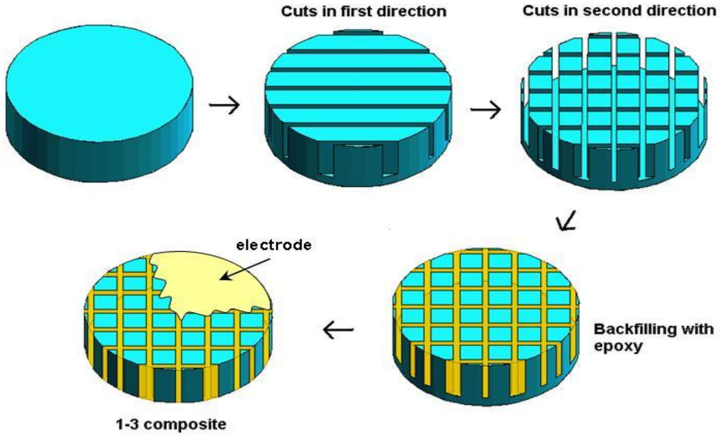


1-3 piezocomposite

Dimension requirements

Frequency	20 MHz	40 MHz
Pillar width	24 µm	14 µm
Kerf	20 µm	8 µm
Thickness	80 µm	40 µm

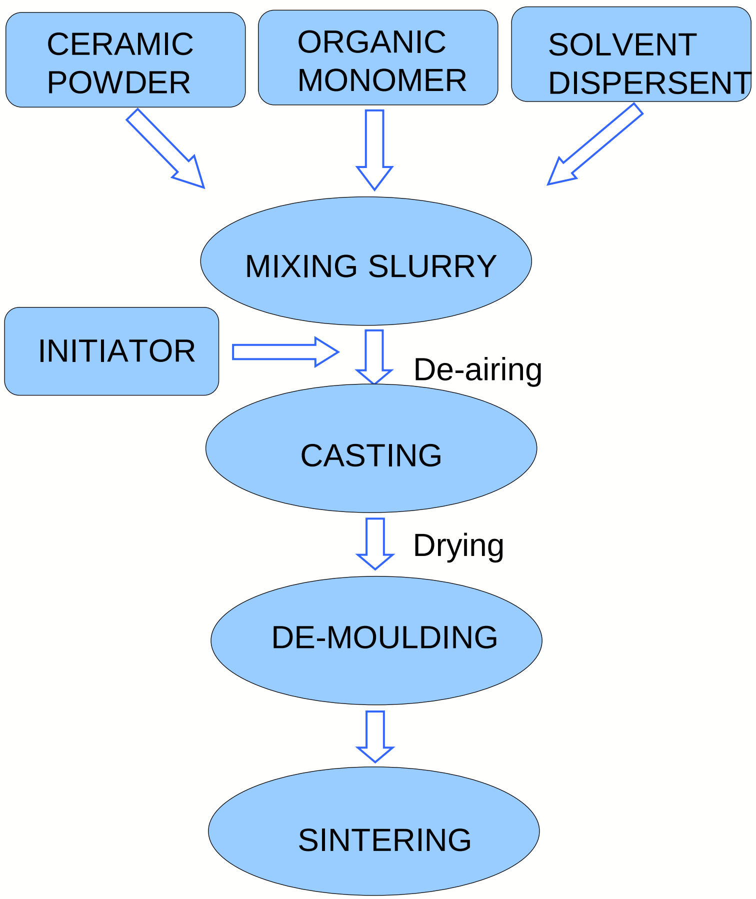
- Piezocomposites made almost exclusively by the dice-and-fill technique for f<20MHz
- Impossible to fabricate high frequency arrays by dice and fill because of the ultrafine feature size required.



Conventional dice-and-fill technique

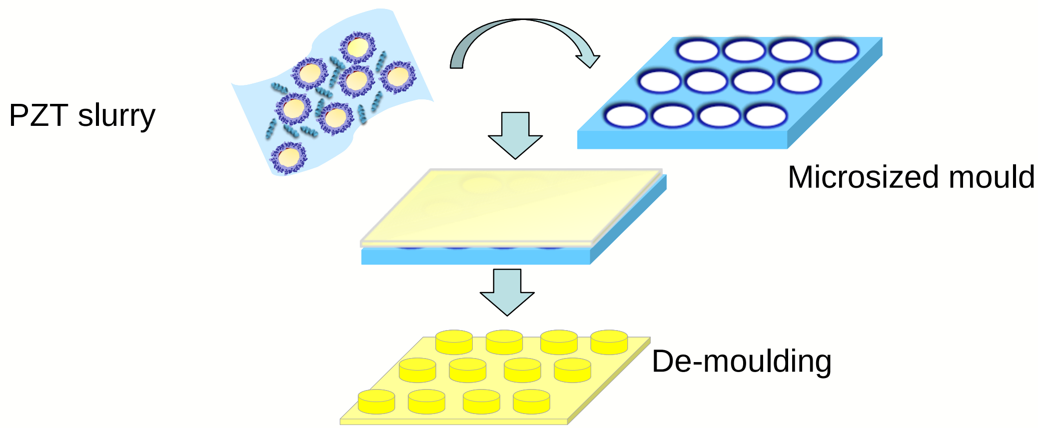
Current transducer manufacturing techniques limit frequency to <15MHz, thus limited resolution.

Alternative Fabrication Technology: Gel casting

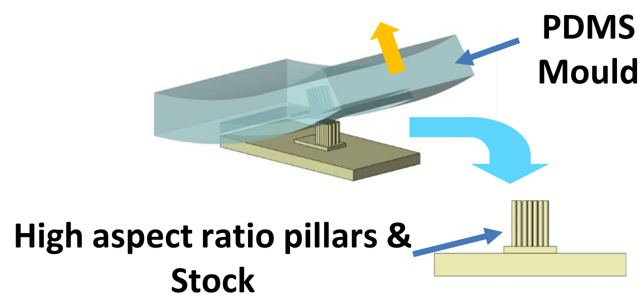


Flow chart of gel casting process.

- Capability of producing complex parts
- Homogeneous material properties
- Rapid forming circle
- Low capital equipment cost.

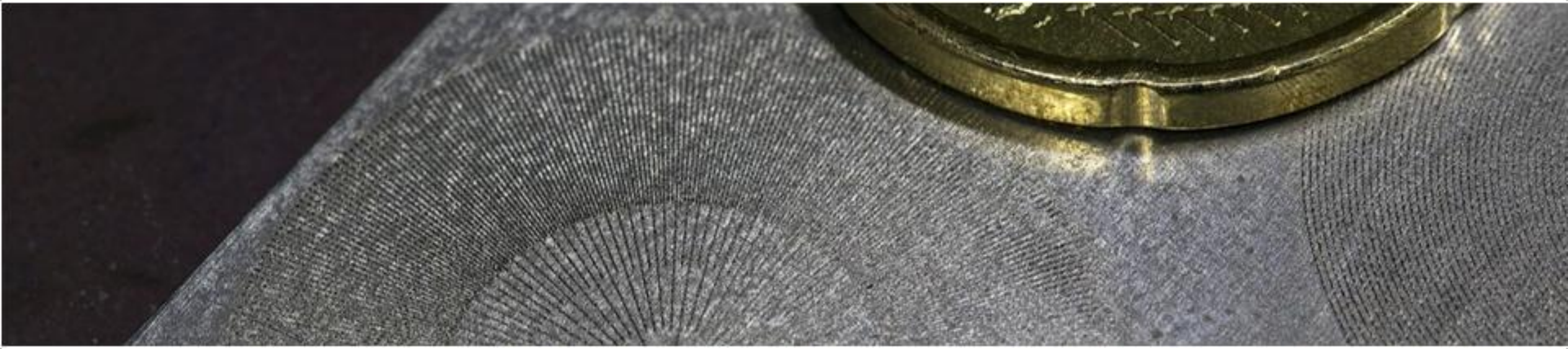


Gel casting for 1-3 piezocomposite fabrication.



- **Material:** Etched silicon master pattern is replicated on PDMS (later used to cast the ceramic slurry);

Direct laser fabrication of PDMS moulds



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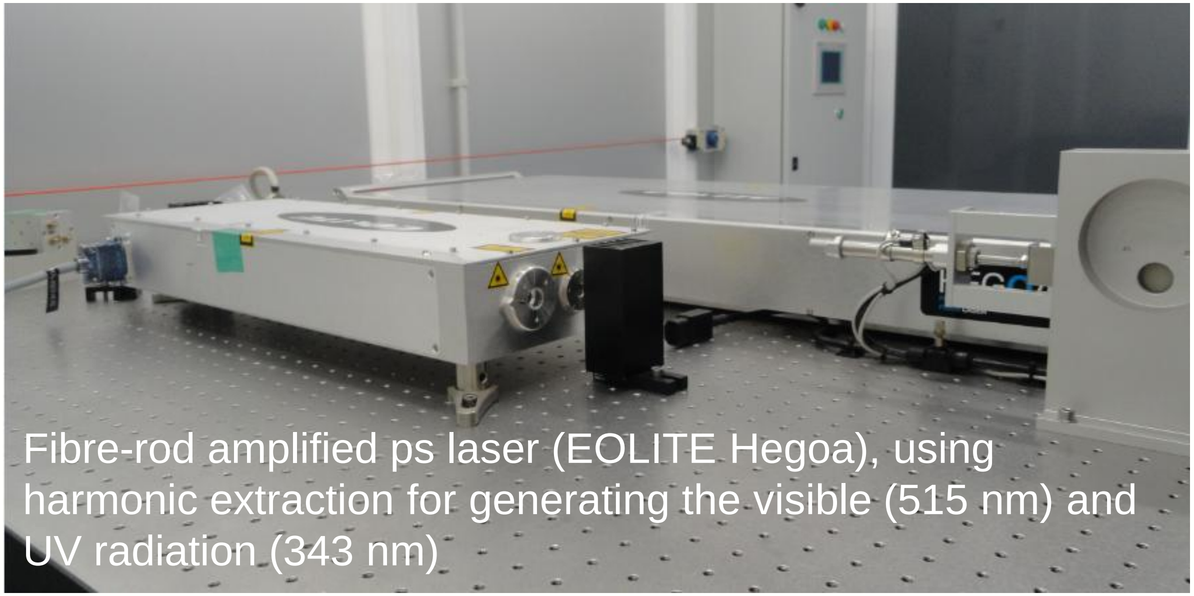
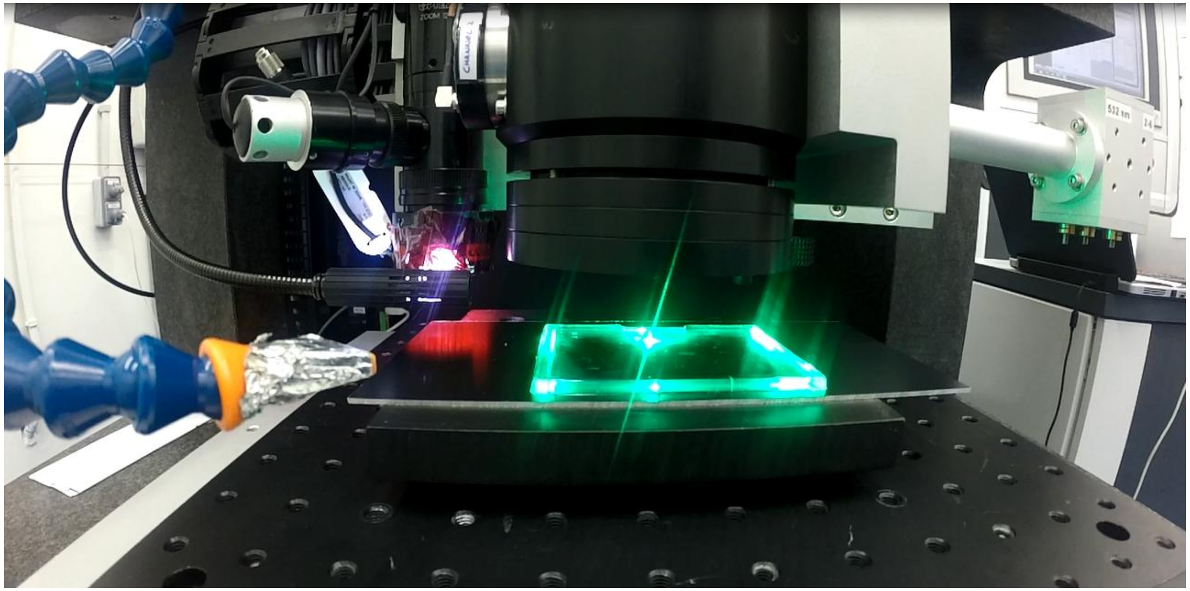


Fibre-rod amplified ps laser (EOLITE Hegoa), using harmonic extraction for generating the visible (515 nm) and UV radiation (343 nm)

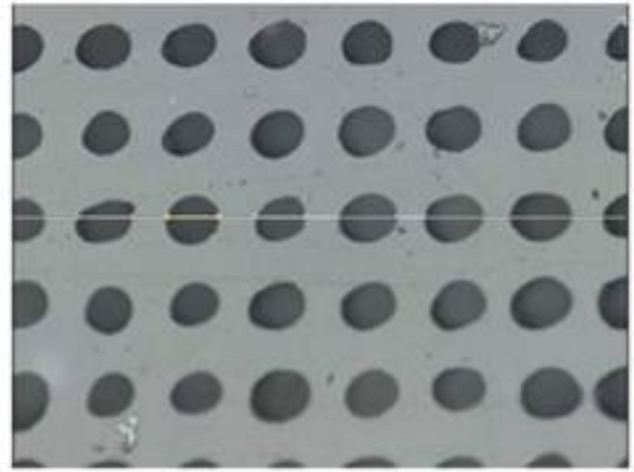


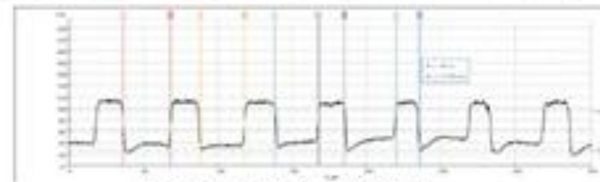
The laser beam is focused with:

- Microscope objective lens (20x with NA=0.4).
- 35 mm focal length flat field optics (Theta-lens), NA=0.15.

Micromachining with green laser

Patterned moulds on 2mm x 2mm area





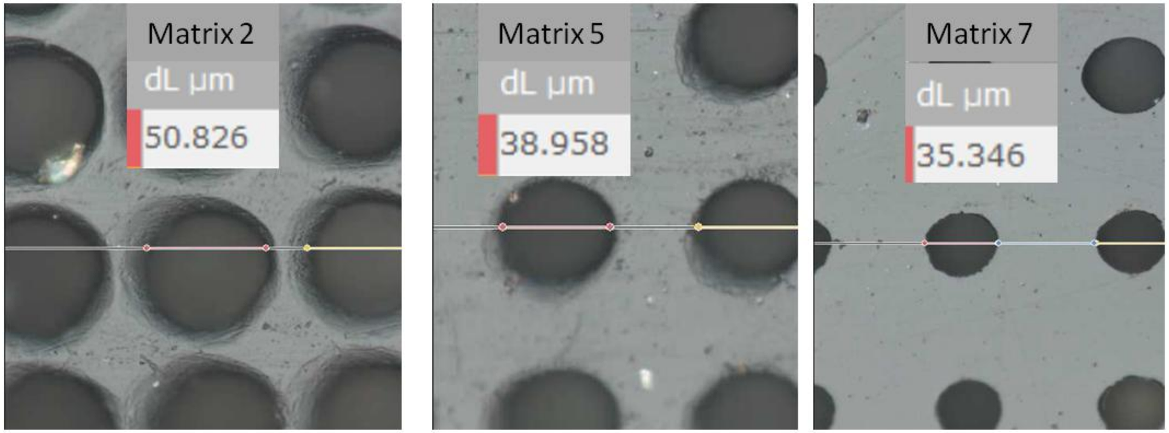
Repetition rates around 1 MHz provide good quality and well controlled hole diameter.

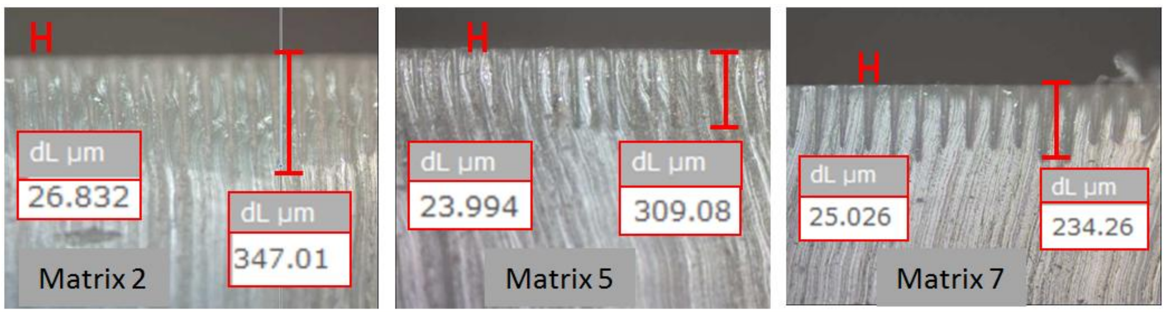
10 µJ per pulse,
focal spot of 15 µm
30 ps of pulse duration

For higher repetition rates, or higher pulse energies, the laser produces widening of the micro-channel diameter, and particularly larger distortion and widening of the entrance diameter.

Below 1 MHz did not improve the process with either poor or no PDMS ablation.

Micromachining with green laser





	Energy (µJ)	Avg. Depth (µm)	St. Dev. (µm)	Diam (µm)
Matrix: M5	8.4	289.5	15.0	38.4
Matrix: M2	9.6	358.7	54.5	52.5

Hole highly dependent on laser pulse characteristics.

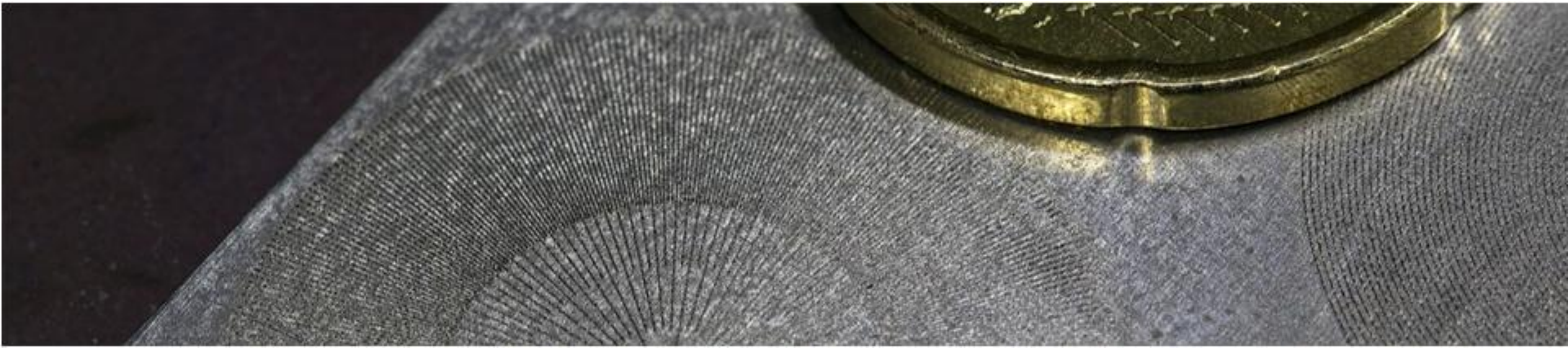
7 % increase in the pulse energy results in a considerable increase in the drilled depth and larger dispersion

Diameter enlarged with higher power

Processing window relatively narrow

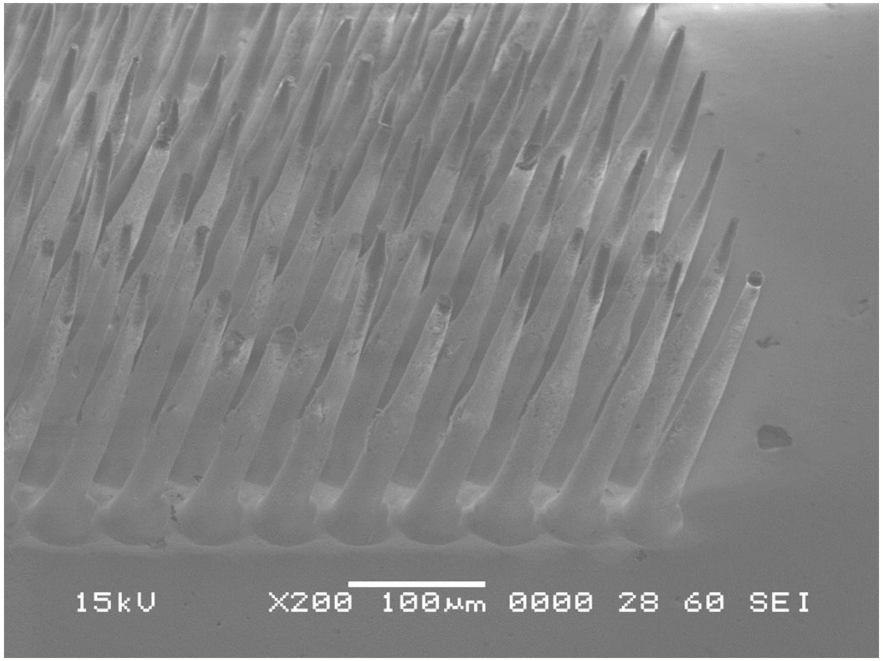
35 – 40 micro channels per second

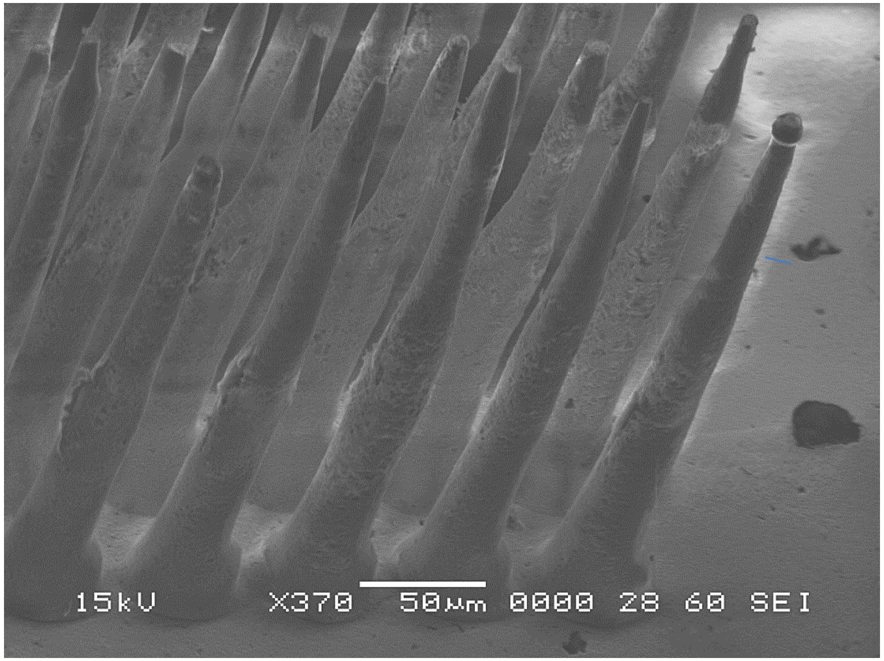
Replication results



De-moulded green pillar structure

For assessment of the channel matrix quality and correct geometry, the fabricated moulds were used for replication via epoxy gel casting of PZT slurry (0.8 µm particle size, 45% vol. solid fraction, 40% epoxy).





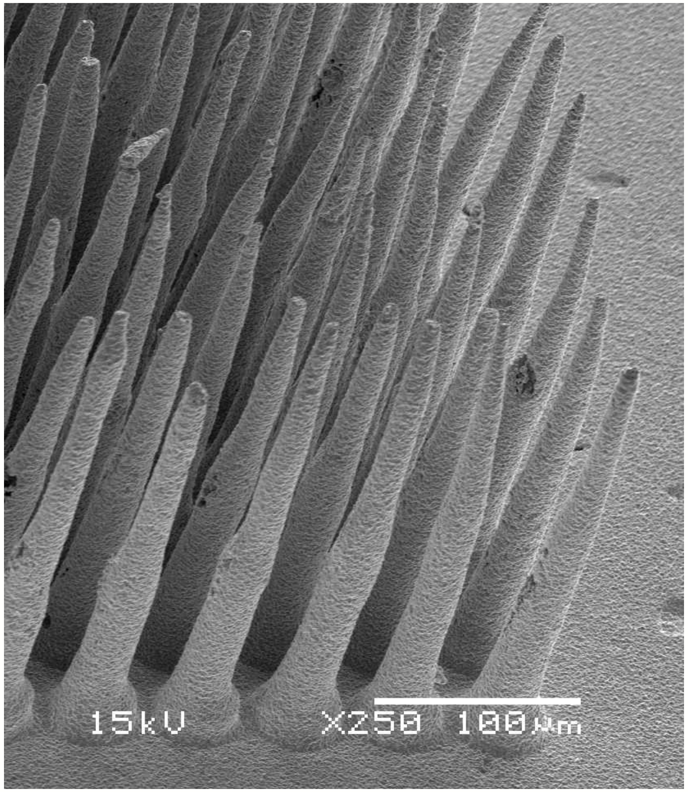
Pillar geometry:

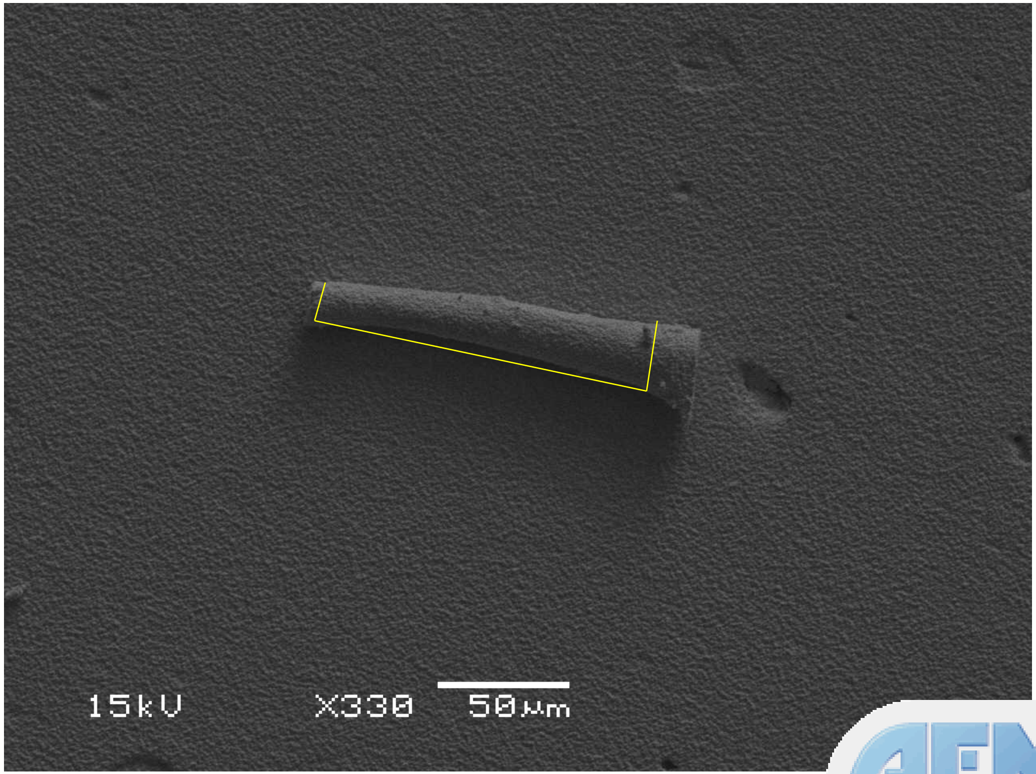
Fine tips (bottom of the laser drilled channel, diameter ~32micron)
Cylindrical section (base: opening of the hole in the surface, ~43micron diameter
Pillar height: >180 microns

Sintered pillar structure

Tips irregular and with inconsistent height → structures encapsulated in polymer and lapped

→ 125 microns of usable portion, cylindrical, with 5 degrees taper





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FABIMED PROJECT

FABRICATION AND FUNCTIONALIZATION OF BIOMEDICAL MICRODEVICES

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LASER APPLICATIONS CENTRE
Polígono Industrial de Catoboi
SUR-PI-2 (Sector 2) Parcela 3
E36410 O PORRIÑO
Pontevedra – España
Telf. +34 986 344 000
Fax +34 986 337 302

Laboratories
AIMEN
Relva 27 A – Torneiros
E36410 O PORRIÑO
Pontevedra – España
Telf. +34 986 344 000
Fax +34 986 337 302

Delegación A Coruña
Polígono Industrial de Pocomaco
Parcela D-22 Oficina 20
E15190 A CORUÑA
Telf. +34 617 395 153

Delegación Madrid
Avda. General Perón 32 8º H
Edificio Torre Castellana
E28020 MADRID
Telf. +34 687 448 915

Thank you!

Nerea Otero | ***CAL – Laser Applications Centre***
T +34 986 344 000 | @ notero@aimen.es