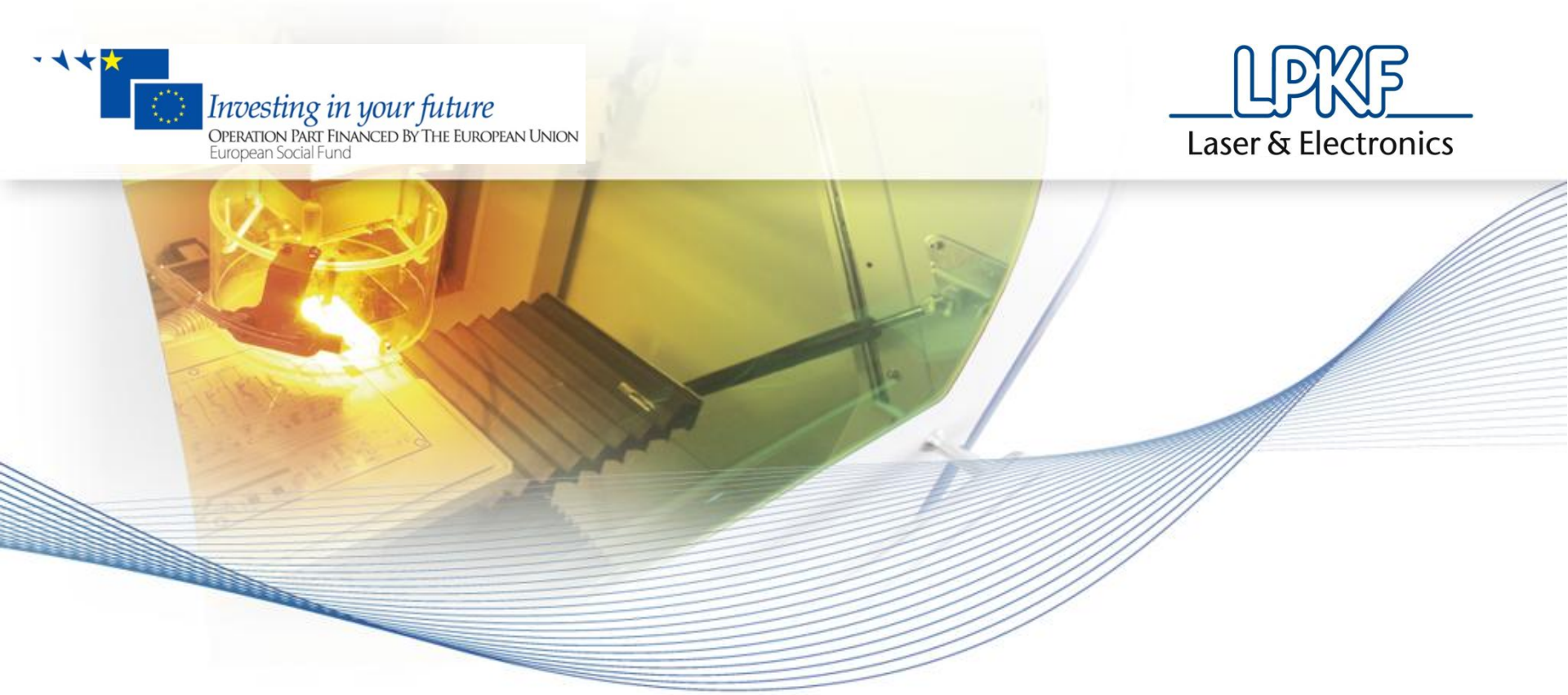
Investing in your future
Operation Part Financed By The European Union
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LPKF
Laser & Electronics



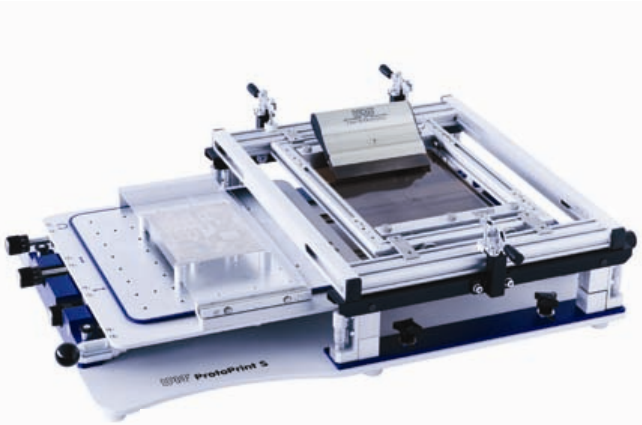
Optical Nanolithography

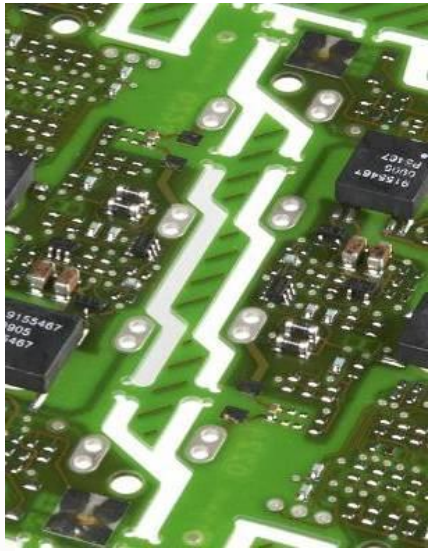
Blaž Kavčič
LPKF Laser & Elektronika d.o.o., Naklo, Slovenia

Company

Equipment for fast prototyping in electronics (PCBs, SMT)











Company

Laser micromachinning systems for electronic and photovoltaic industry









Company

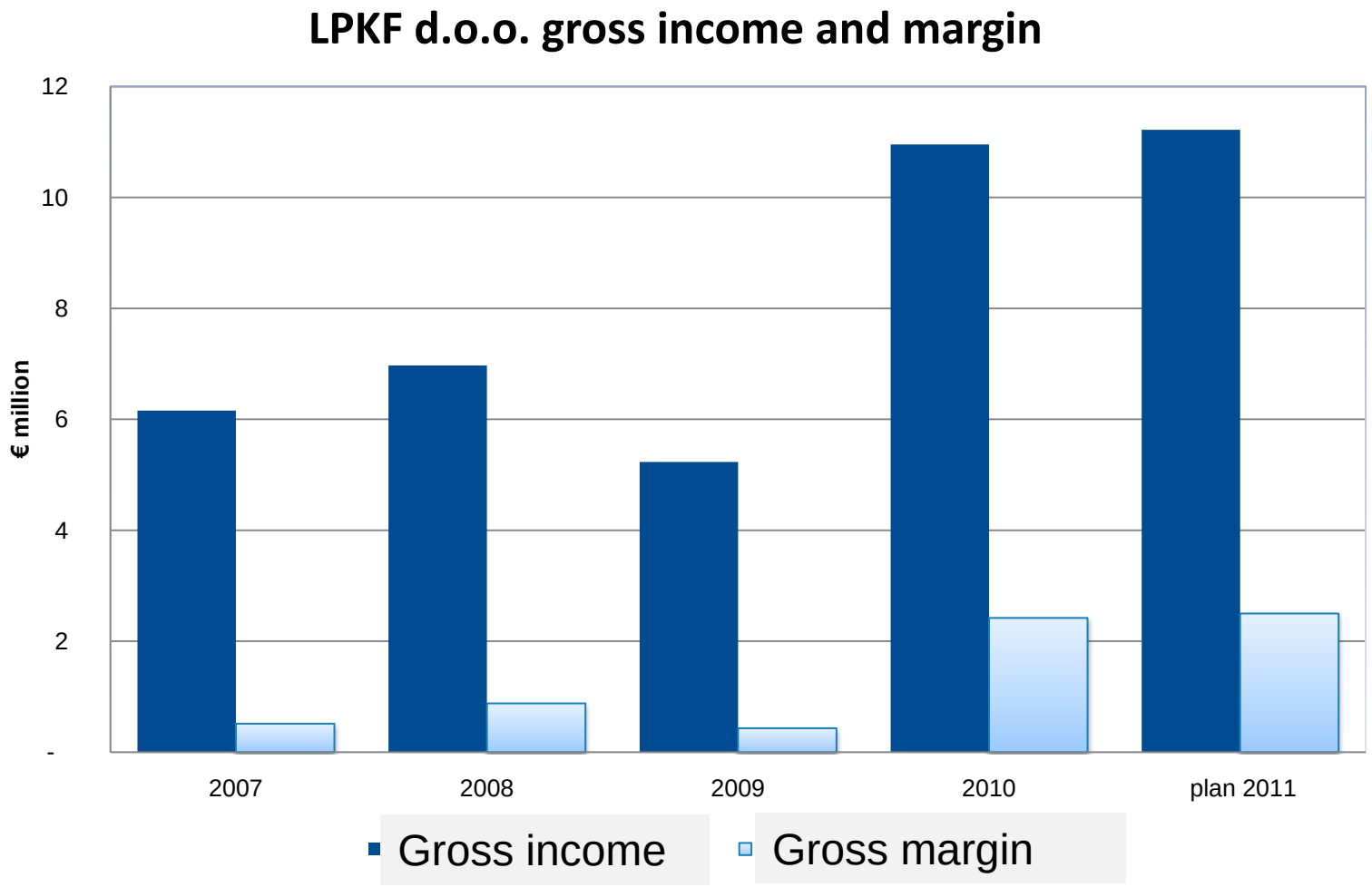
- Since 1994
- Slovenian ownership: 25%
- New office building: Naklo, 2007
- Development, production, sales



	2008	2009	2010
Income	6,7 M€	4,9 M€	10,2M€
EBIT	880k€	432k€	2.420k€
Exports	97%	94%	92%
Employees	48	47	53

© 2009

Company



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Seminar overview

LPKF Laser & Electronics

- Introduction to optical lithography
- Maskless nanolithography
  - laser direct imaging (LDI)
  - acousto-optic deflector
  - LPKF ProtoLaser LDI
- LDI sample microstructures, applications
- Summary

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Introduction

- Microstructuring important in industry, research, development...

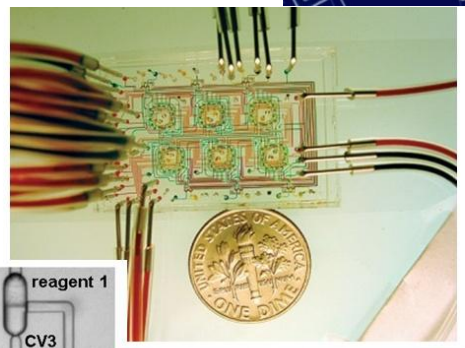
Introduction

- Microstructuring important in industry, research, development...

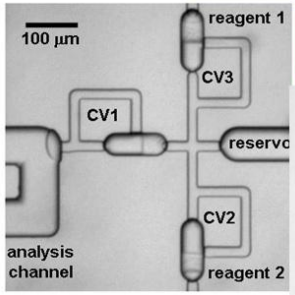
- Micro-scale devices:
  - integrated circuits, PCB
  - microfluidics, lab-on-a-chip
  - MEMS, nanotechnology

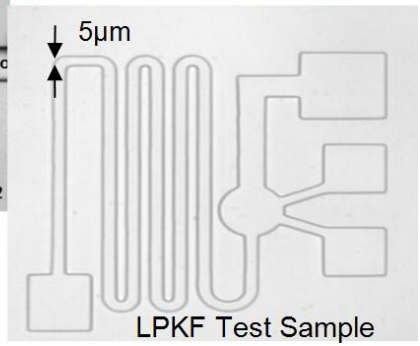
- Demand for higher resolution, speed, simplicity, lower costs...





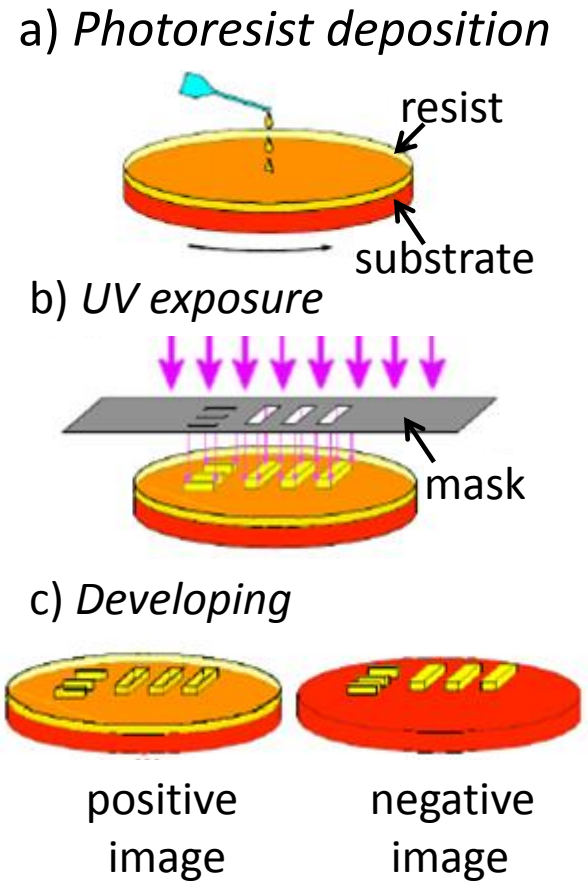






Optical lithography

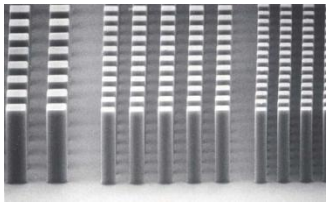
- Widely used method, similar to photography



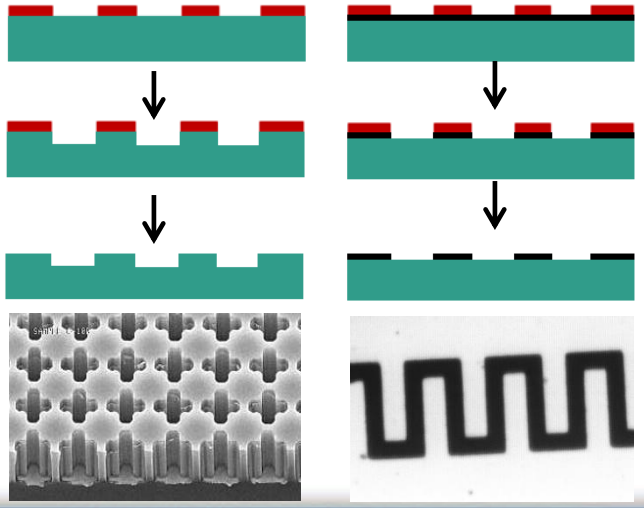
Optical lithography

- Widely used method, similar to photography
- Microstructures are used:

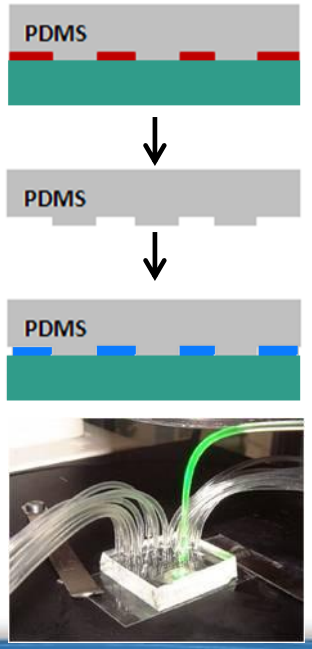
directly:



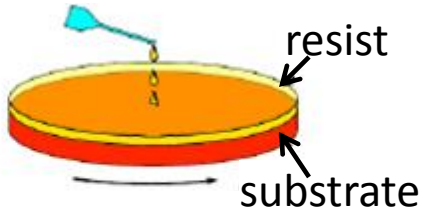
further substrate processing:



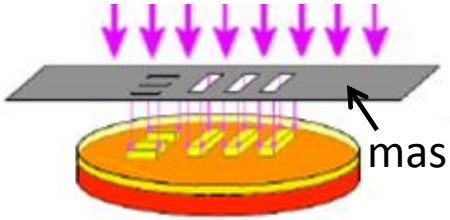
replication:



a) *Photoresist deposition*



b) *UV exposure*



c) *Developing*



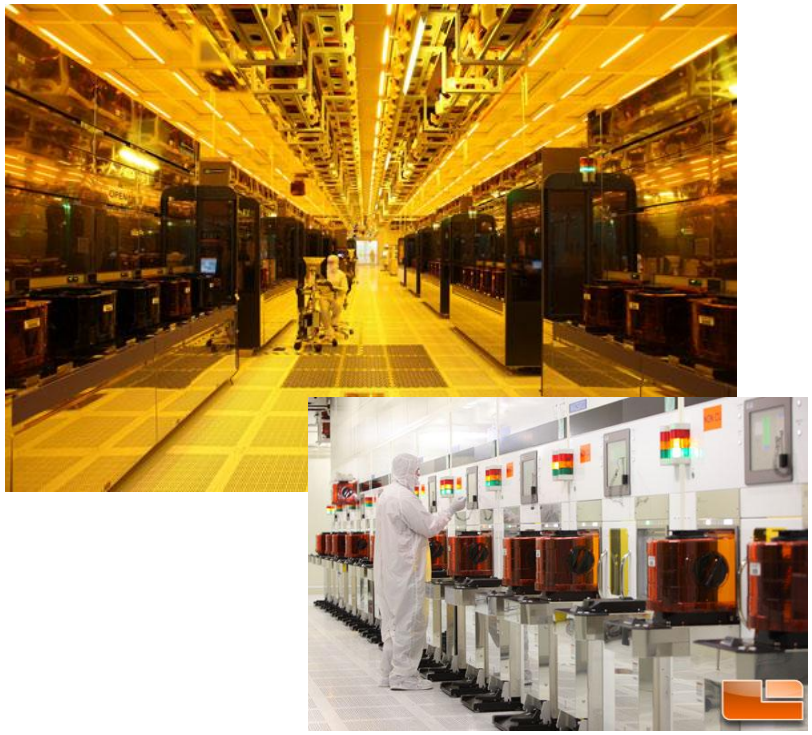
positive image

negative image

Lithography in industry and prototyping

LPKF Laser & Electronics

- Industrial use:
  - mask lithography
  - high throughputs

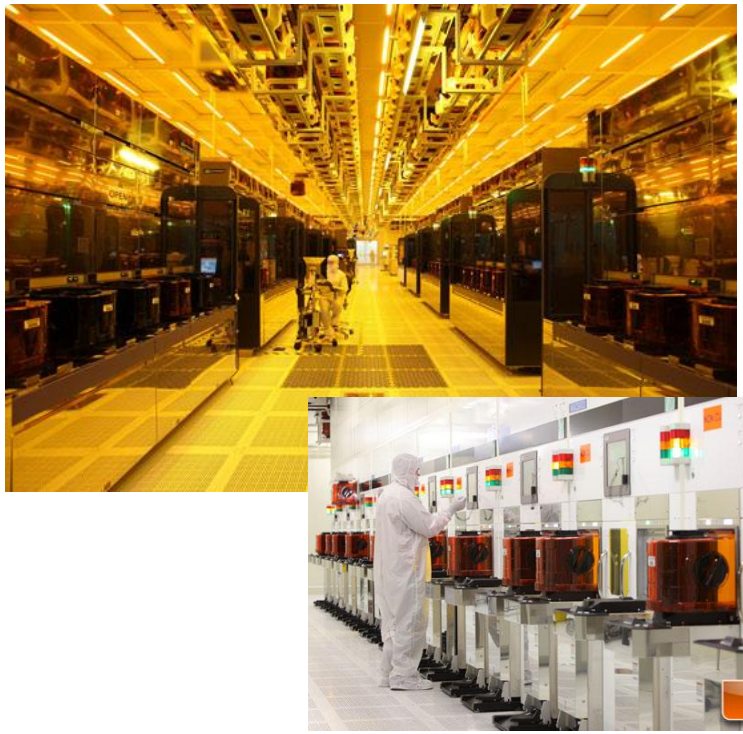


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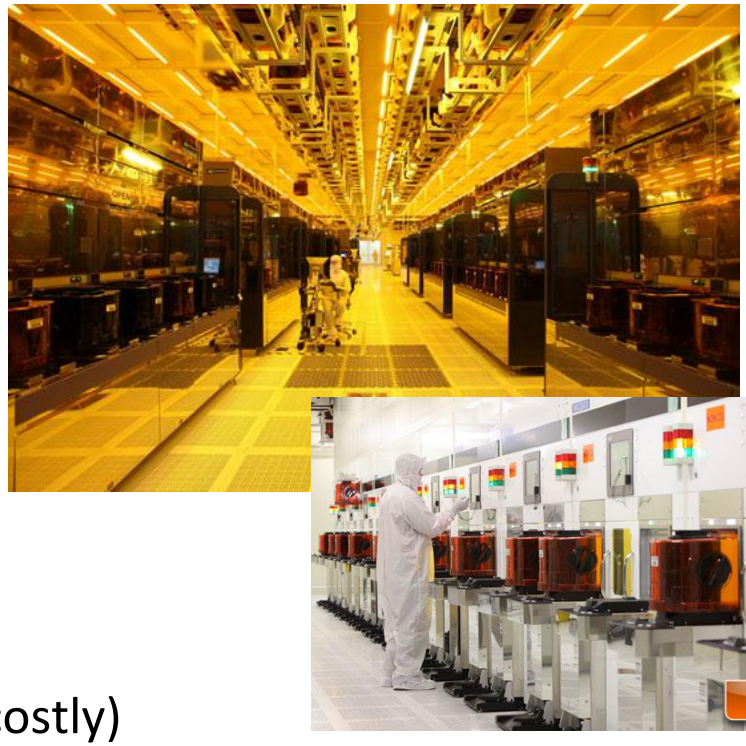
- Prototyping, experiments:
  - frequent design changes - flexibility
  - small numbers of samples
  - low costs



Lithography in industry and prototyping

LPKF Laser & Electronics

- Industrial use:
  - mask lithography
  - high throughputs



- Prototyping, experiments:
  - frequent design changes - flexibility
  - small numbers of samples
  - low costs

- Drawbacks of using masks:
  - mask fabrication (time-consuming, costly)
  - inflexible
  - clean rooms, flat surfaces

Maskless lithography

- Two “maskless” alternativnes:

  1. Electron beam lithography
     - direct exposure (no contact)
     - small features (20-30 nm)
     - slow, costly, vacuum, conductive substrates
     - beam instability



Maskless lithography

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     - similar, but uses laser
     - beam positioning precision
     - lower cost, desktop size
     - useful for micro-scale

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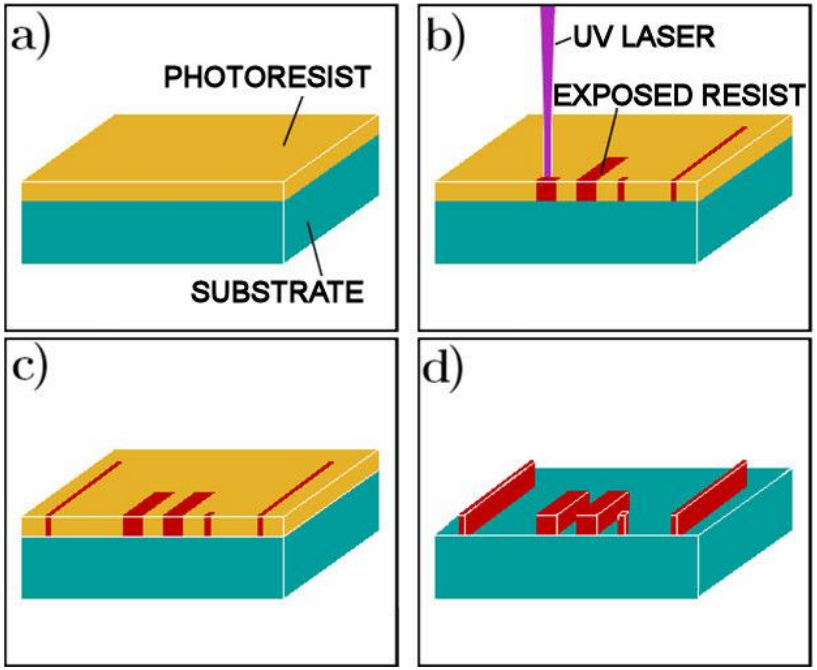
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     → suitable for prototyping → LPKF ProtoLaser LDI

Laser Direct Imaging (LDI)

LPKF Laser & Electronics

- LDI technique:
  - focused UV laser
  - beam steering



→ direct photoresist exposure

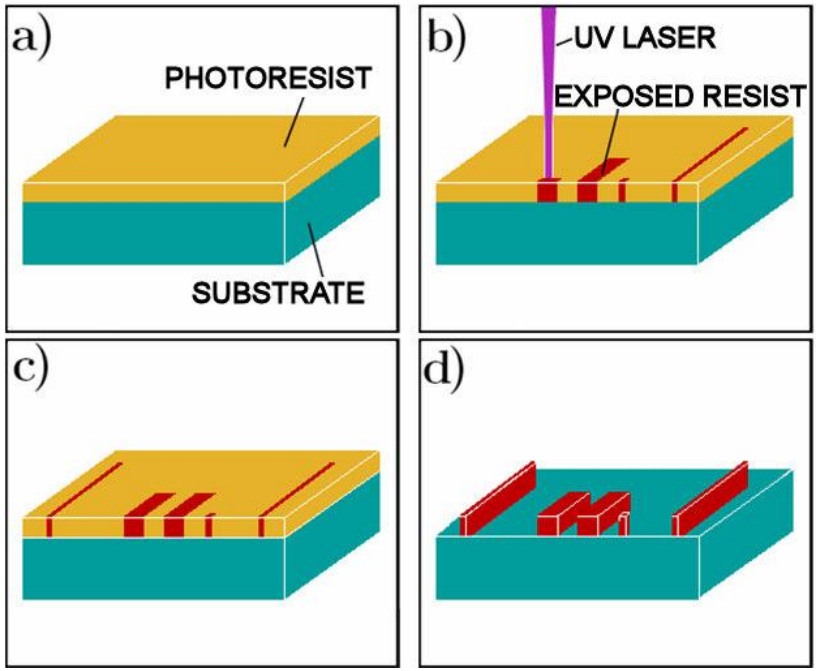
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Laser Direct Imaging (LDI)

LPKF Laser & Electronics

- LDI technique:
  - focused UV laser
  - beam steering

- Advantages:
  - no masks (flexible)
  - desktop device
  - suitable for micro-scale designs



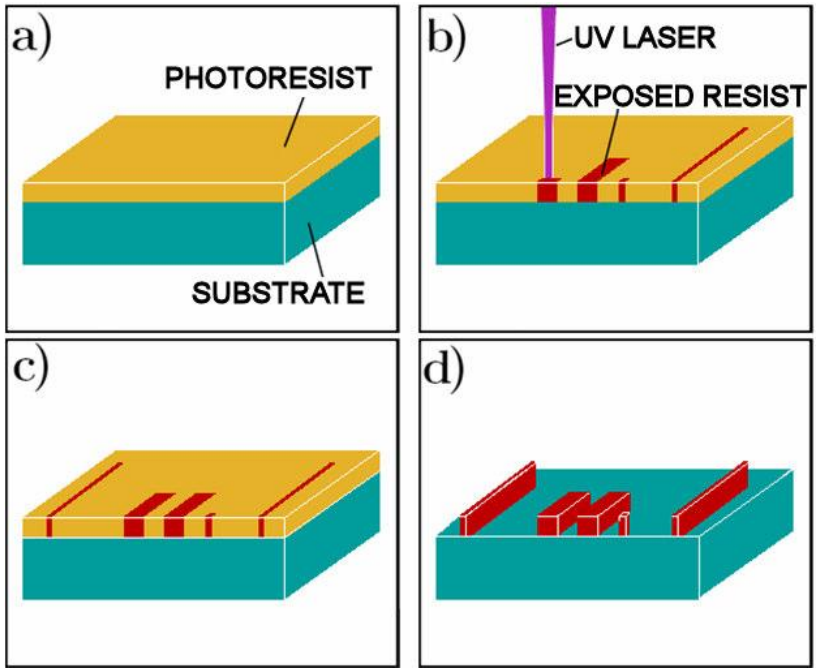
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Laser Direct Imaging (LDI)

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- Advantages:
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  - desktop device
  - suitable for micro-scale designs



→ direct photoresist exposure

Beam steering?

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Acousto-optic deflector

LPKF ProtoLaser LDI - acousto-optics for beam positioning

Acousto-optic deflector

LPKF Laser & Electronics

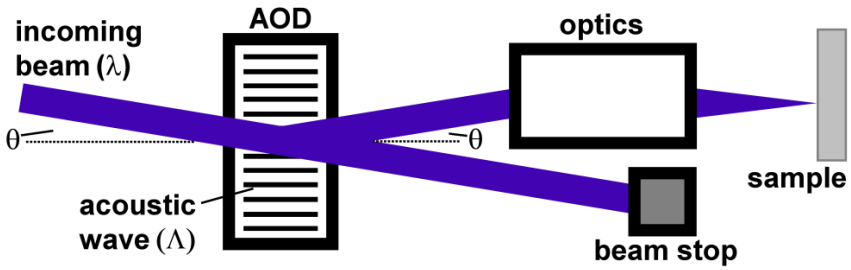
LPKF ProtoLaser LDI - acousto-optics for beam positioning

- Acousto-optic deflector (AOD):
  - beam deflection (Bragg)

    $\sin\theta = \lambda/2\Lambda$

  - exposure (intensity) control

    $I/I_0 \alpha \sin^2 P_{ac.}$



Acousto-optic deflector

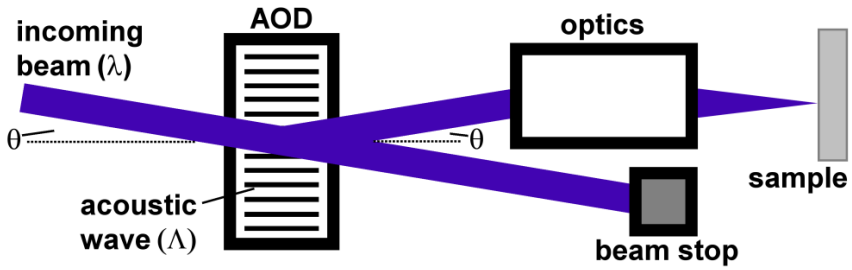
LPKF Laser & Electronics

LPKF ProtoLaser LDI - acousto-optics for beam positioning

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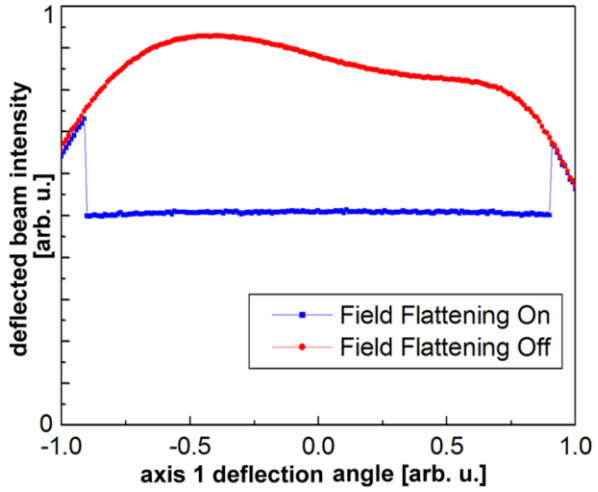


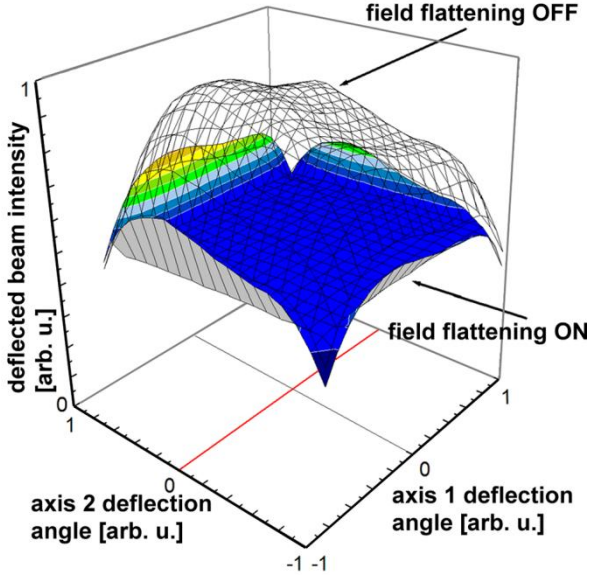
  - fast (100 kHz position switching, no moving parts)
  - sub-nm positioning precision
  - smooth sidewalls (nm possible)

  - tested technology (optical tweezers, Aresis Tweez)

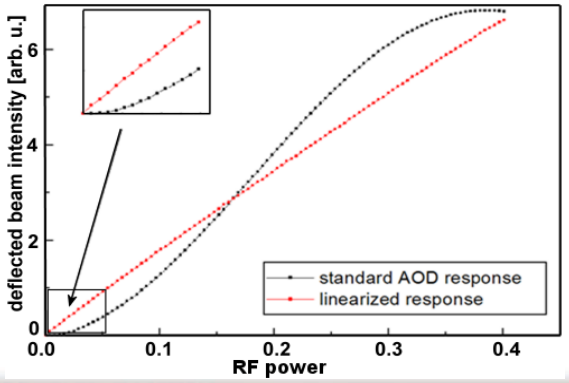
Acousto-optic deflector

- Intensity of deflected beam (I) is uniform accross the AOD field



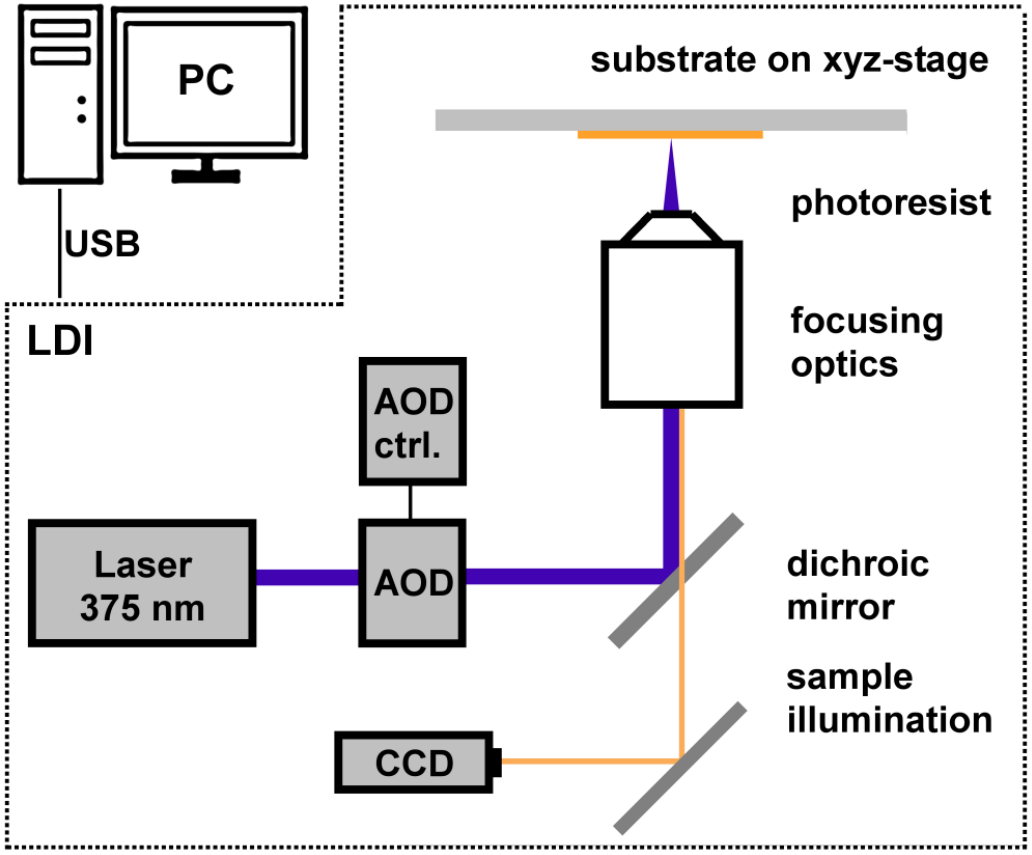


- I is proportional to AOD driving RF power



System diagram

- Main components of ProtoLaser LDI system



LPKF Protolaser LDI

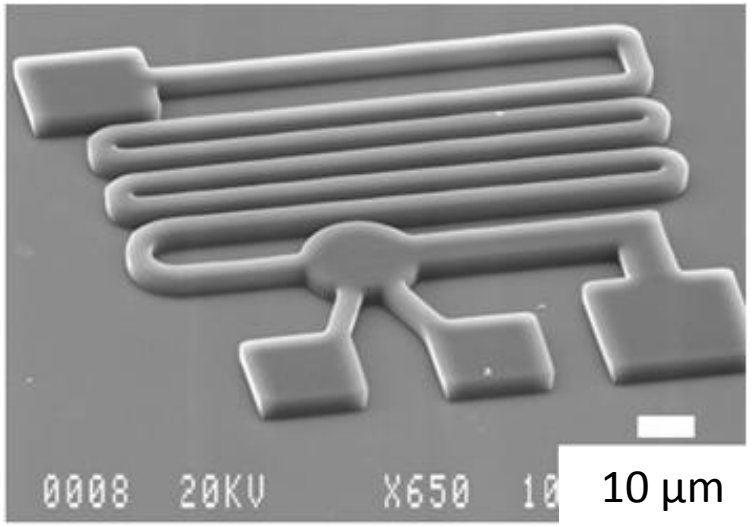
- Desktop LDI system, LPKF ProtoLaser LDI



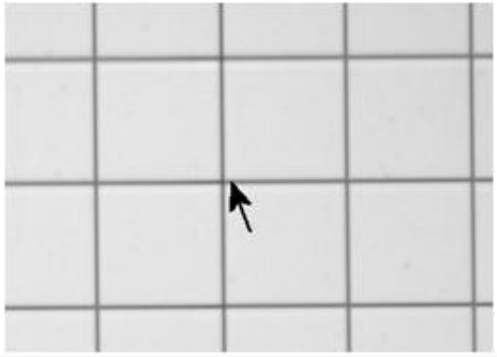
LPKF ProtoLaser LDI characteristics

Specifications:

- UV laser: 375 nm
- standard UV resists (SU-8, AZ,...)
- spot size: 1 and 3 µm
- Rayleigh length: 2 and 19 µm
- Beam positioning: < 1 nm
- address grid: user-selectable
  100 to 1000 nm typically
- Substrate: max. 100 X 100 mm²



grid of 800 nm lines in AZ



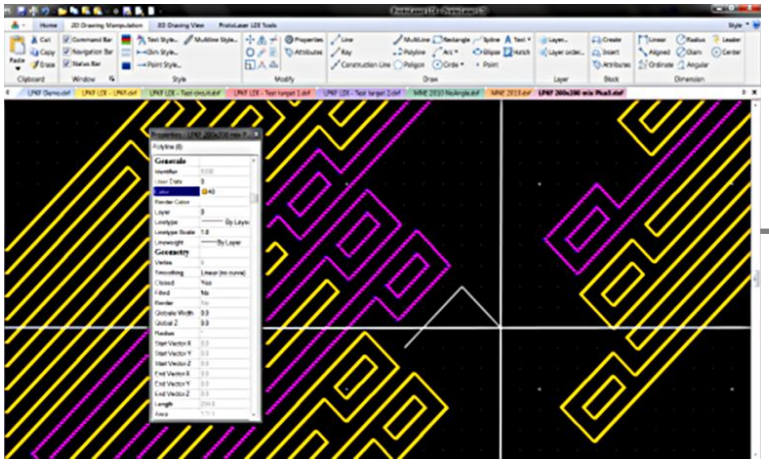
Automation, other features:

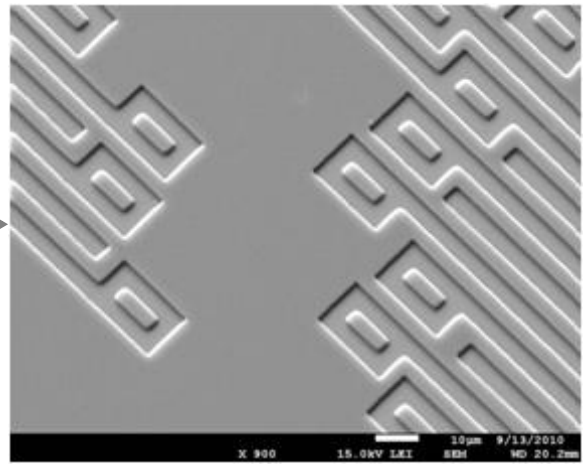
- Self-calibration, auto focusing
- Large area: mechanisms for seamless field stitching
- Miscroscope

Control software

- PC control via standard USB interface

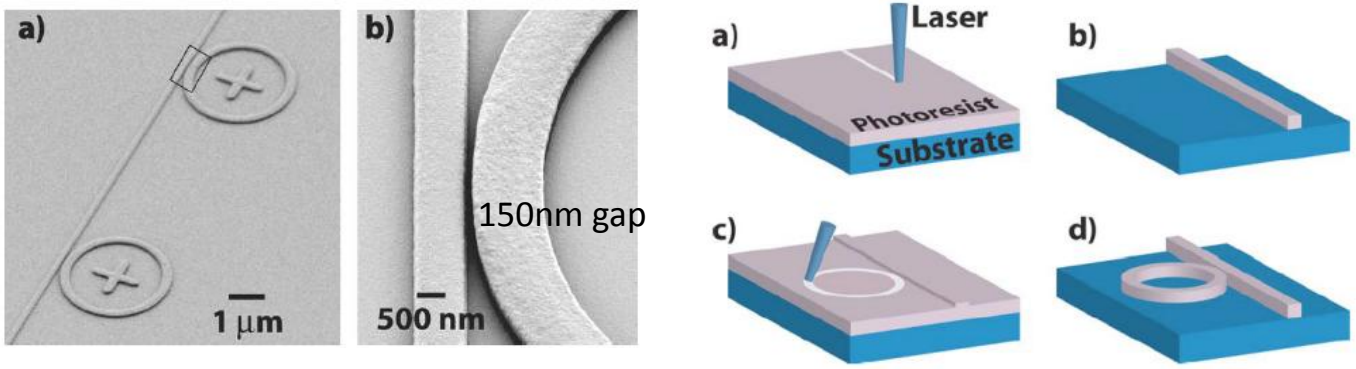
- LPKF ProtoLaser LDI software:
  - CAD design (native format or DXF/DWG)
  - exposure parameters setting
  - sample inspection microscope
  - sample alignment





Feature size vs. resolution

- Ring micro-resonator: needs smooth side-walls

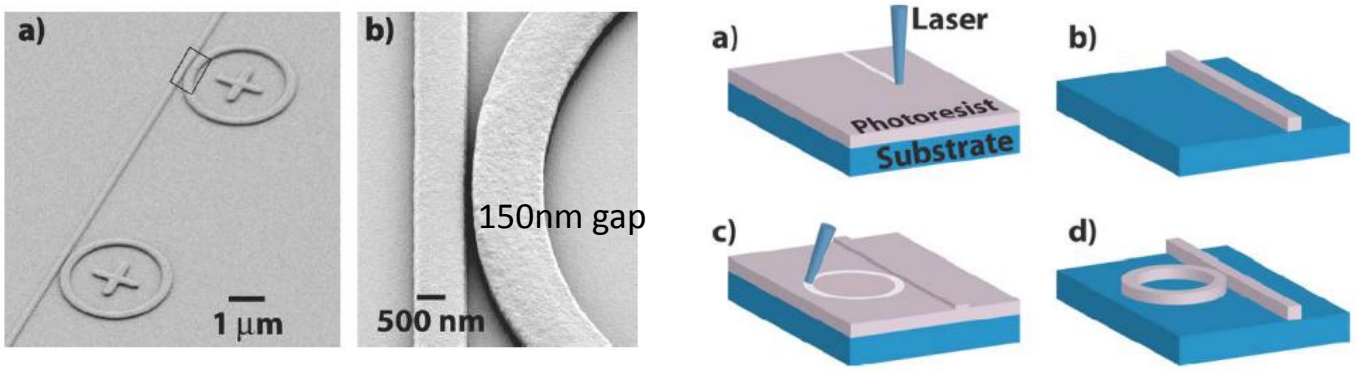


Koechlin et al., ***Rev. Sci. Inst.*** (2009)

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Feature size vs. resolution

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Koechlin et al., ***Rev. Sci. Inst.*** (2009)

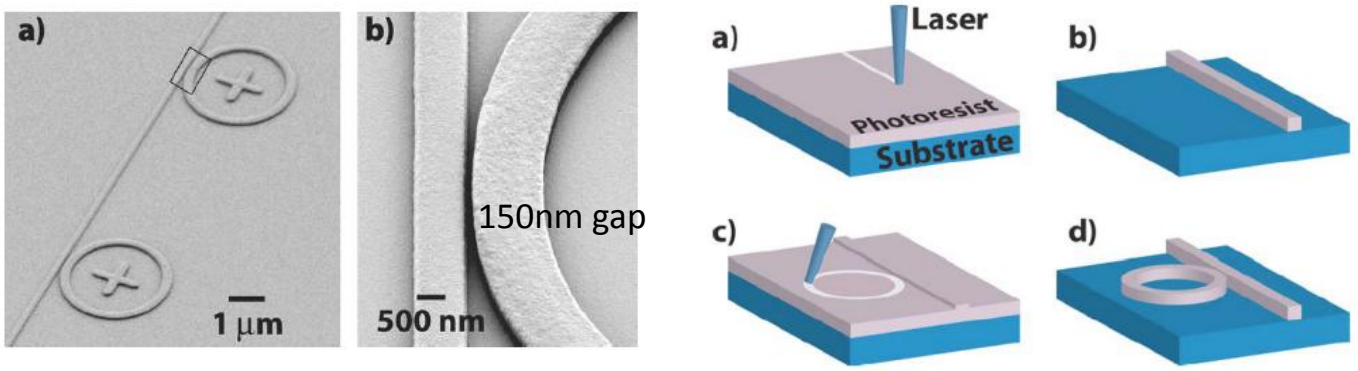
→ needs alignment and precision, smooth sidewalls
→ beam spot can be > 1 µm
→ nm-sized features not needed

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Feature size vs. resolution

LPKF Laser & Electronics

- Ring micro-resonator: needs smooth side-walls



Koechlin et al., ***Rev. Sci. Inst.*** (2009)

→ needs alignment and precision, smooth sidewalls
→ beam spot can be > 1 µm
→ nm-sized features not needed

- Microfluidics, biotechnology, nano experiments: similar considerations

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Sample images

Annulus in AZ, spot spacing 250 nm

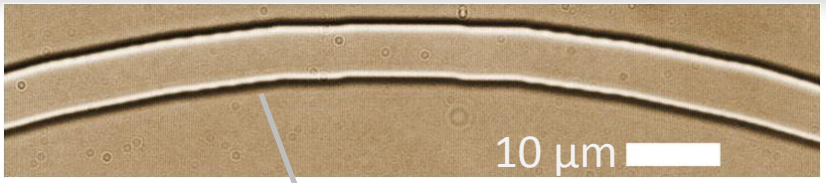


10 µm

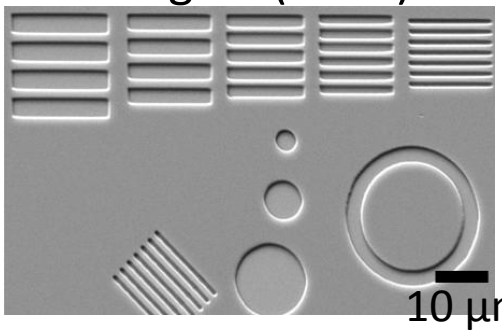
visible rasterisation!

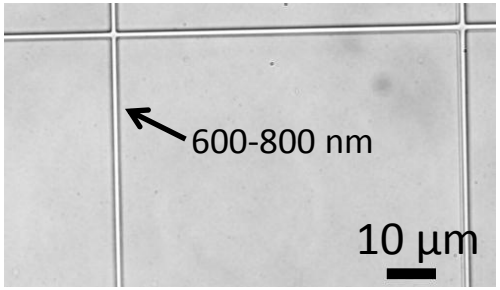
Sample images

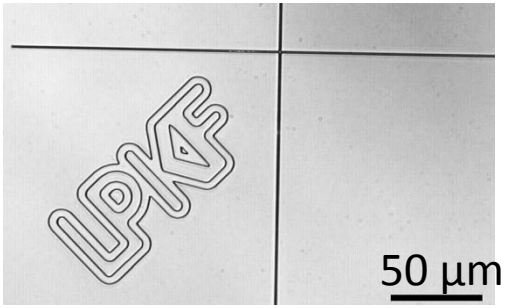
Annulus in AZ, spot spacing 250 nm



Test targets (in AZ)

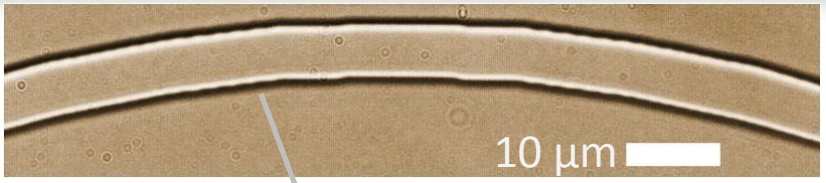






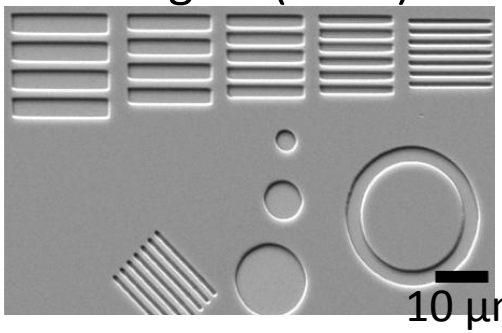
Sample images

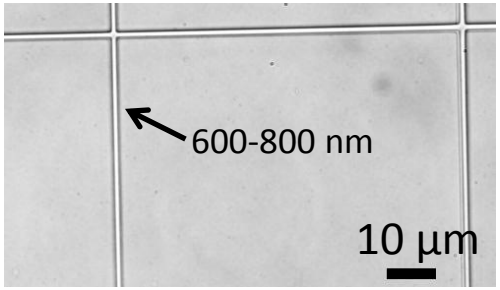
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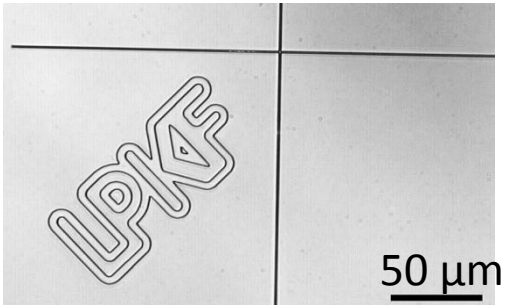


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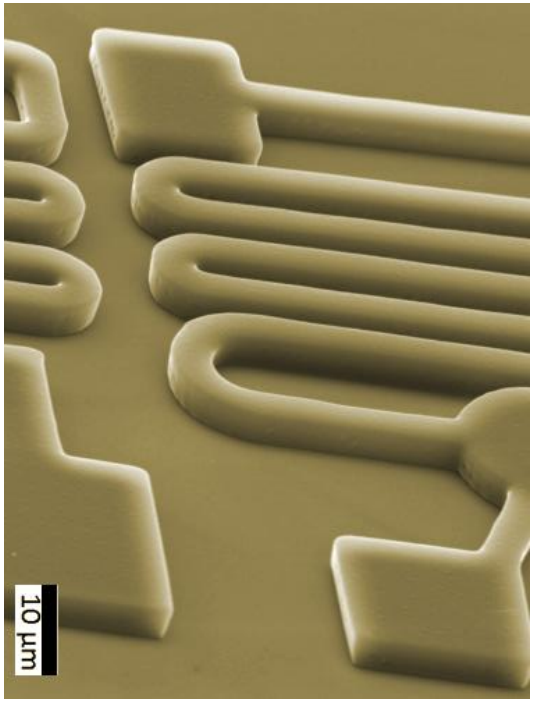
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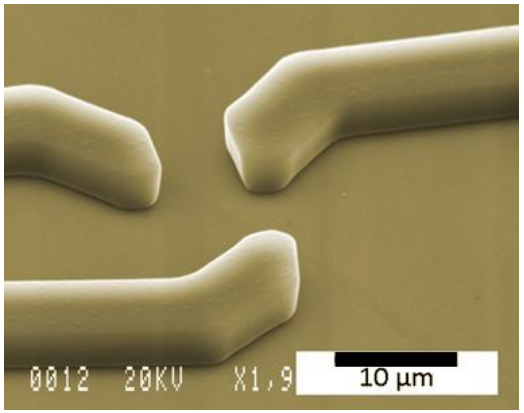


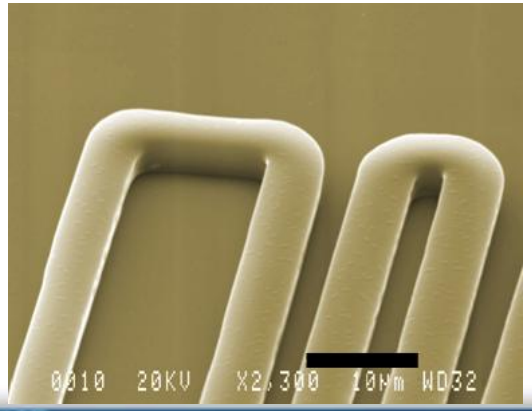




SU-8 on glass microchannel master

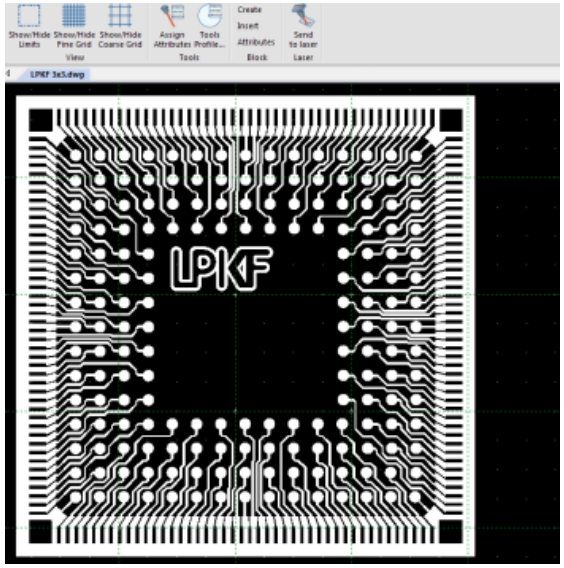


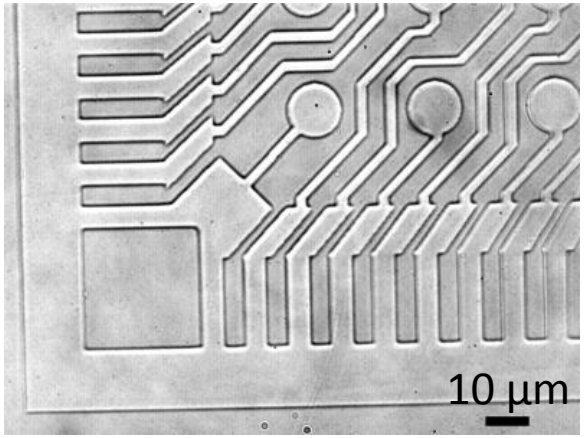


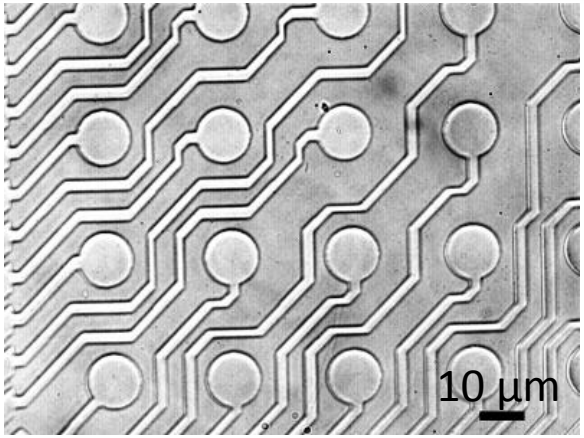


Sample images

Fine tool (1 µm spot) “BGA chip”

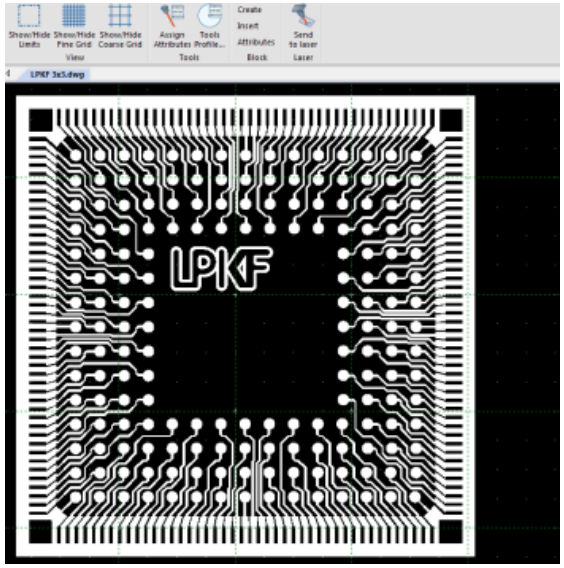


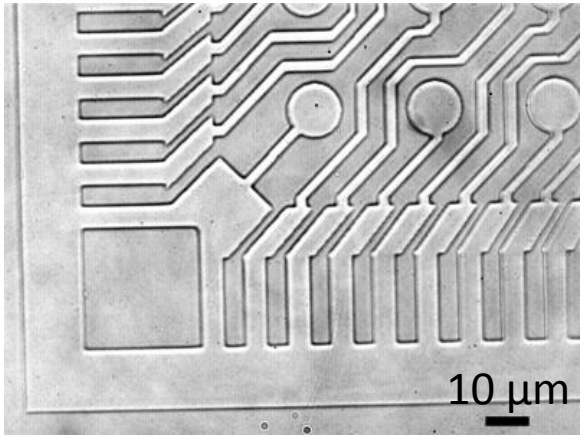


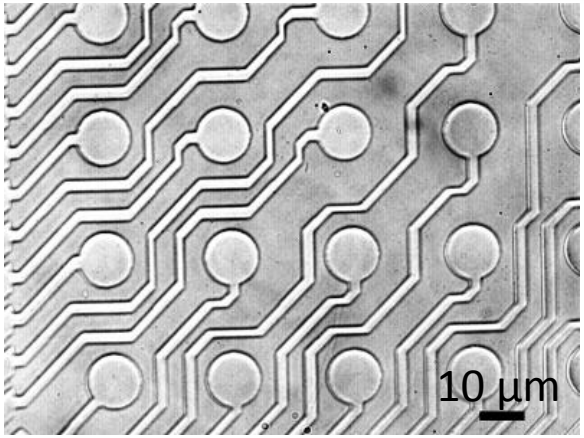


Sample images

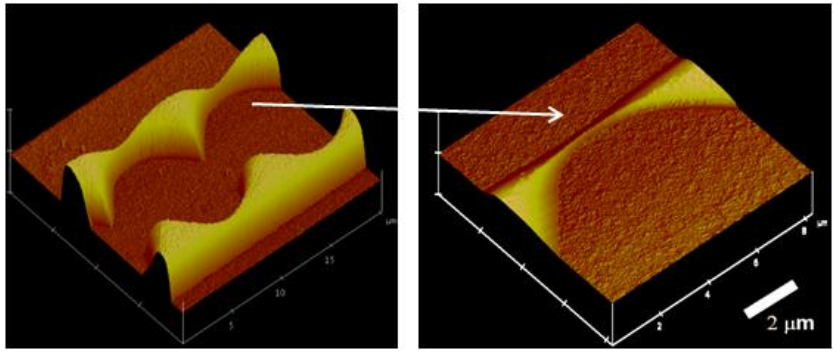
Fine tool (1 µm spot) “BGA chip”

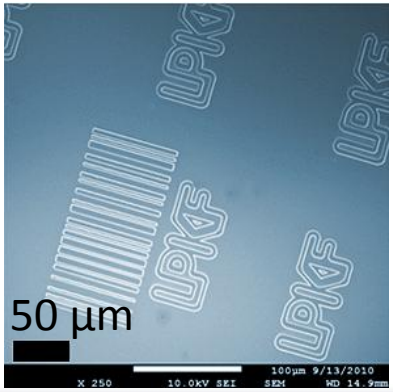






AZ pattern for electrodes, submicron spacing

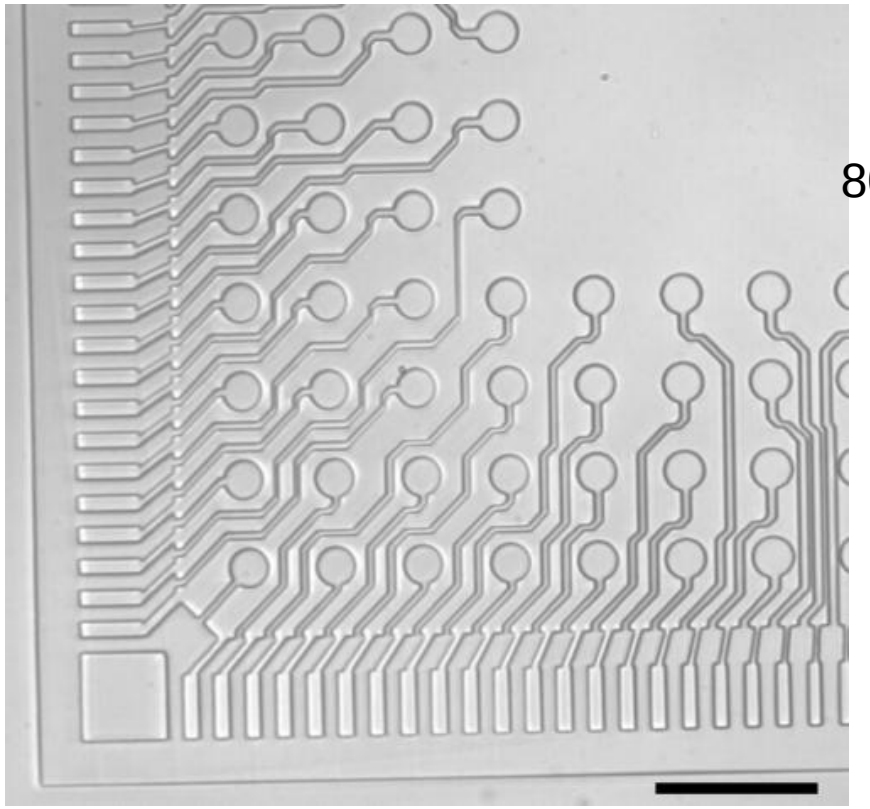




“LPKF” barcode

Sample images

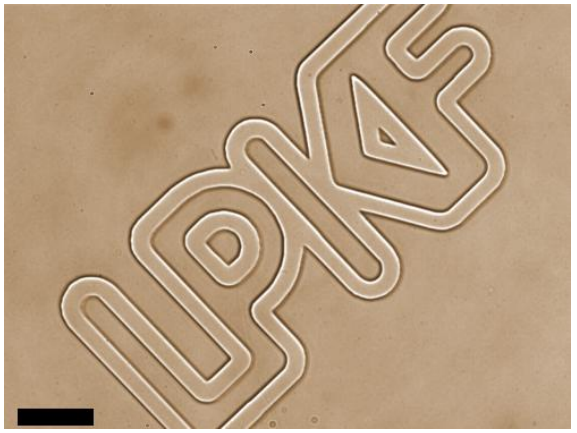
Coarse tool (3 µm spot) – for thicker resists and larger elements with less detail at greater speed



800 nm spot spacing

150 µm

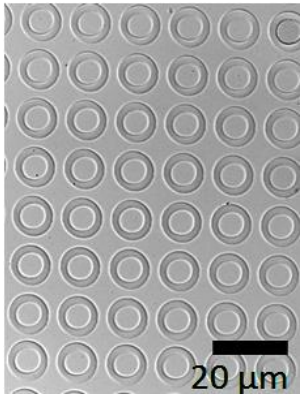
“LPKF” in AZ



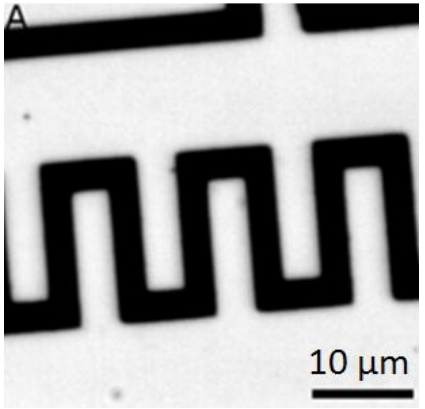
50 µm

Sample applications

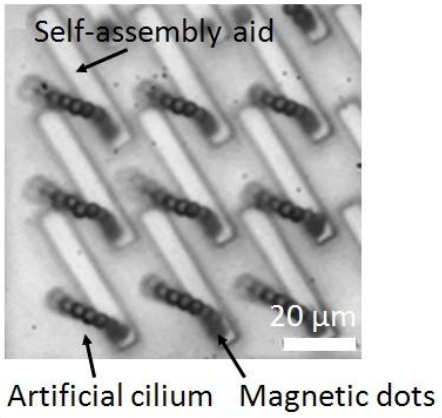
Patterned surface for shallow particle trapping potentials



Chromium electrodes on glass substrate by metal layer etching

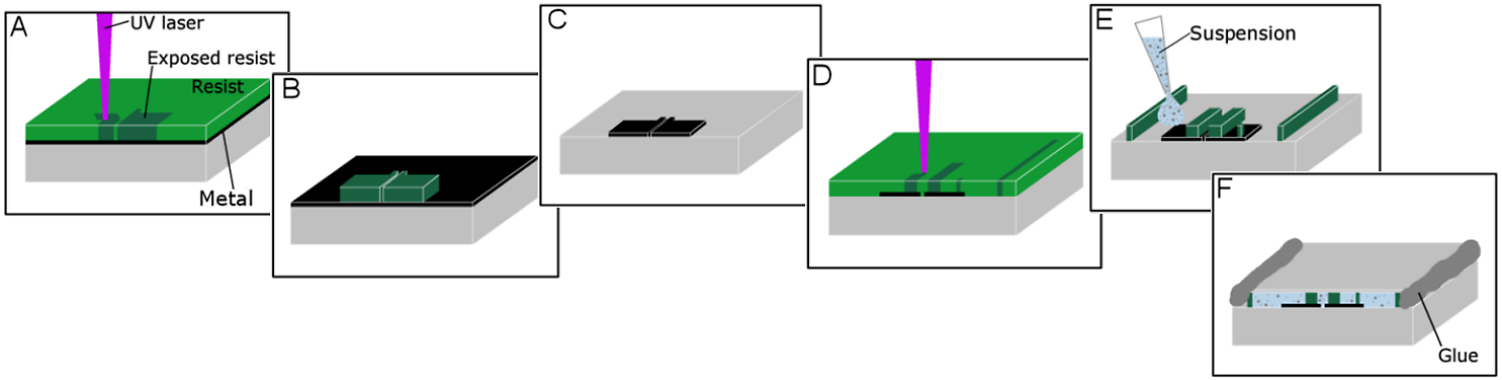


Metal and resist 2-layer structure for **artificial cilia** assembly and anchoring



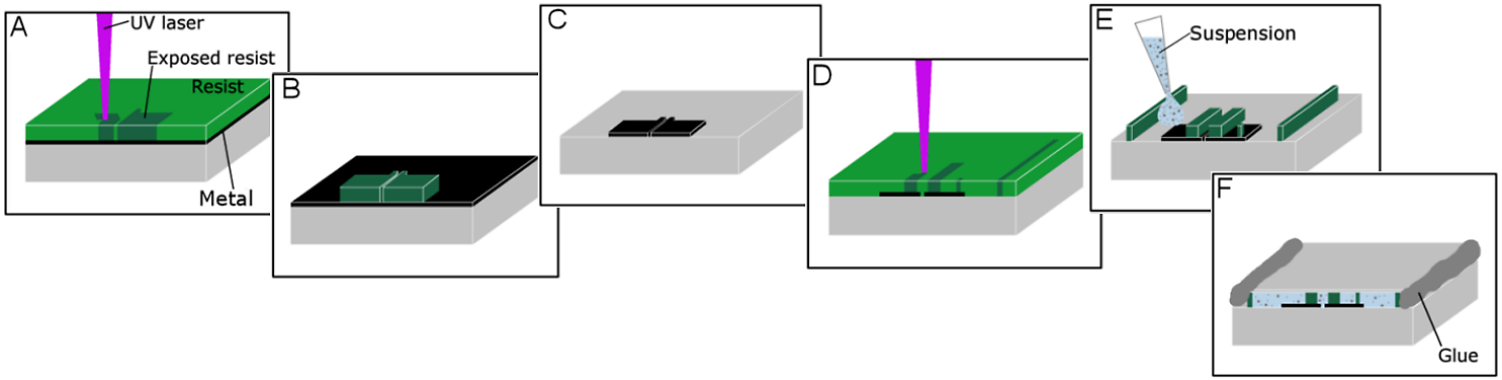
Sample applications

- Two-layer structures in two steps

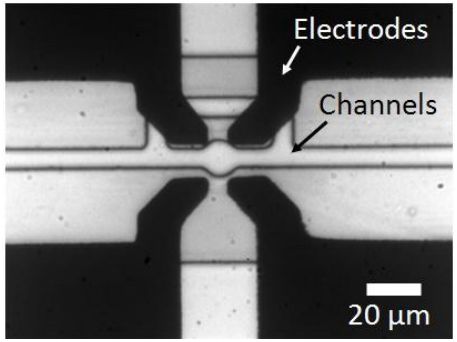


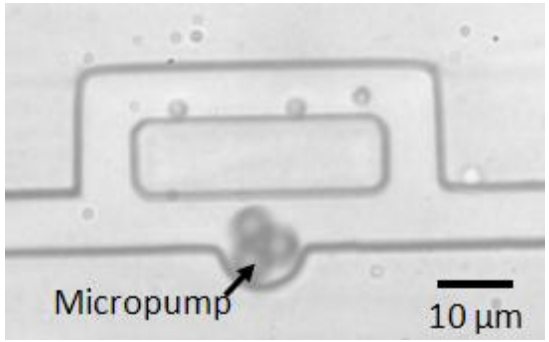
Sample applications

- Two-layer structures in two steps



Individually addressable
microfluidic pump





Summary, future steps

- LDI: flexible, fast, simple to use, full user control
  Precise beam positioning (sub-nanometer)
  Widely used, known process, but more experimenter-friendly

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Summary, future steps

- LDI: flexible, fast, simple to use, full user control
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- LPKF ProtoLaser LDI for the Nanocenter undergoing final software tests
  The system is in daily use at FMF

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- Cooperation with Nanocenter on future development of PL LDI and new generation two-color nanolithography system (~ 200 nm structures)

LPKF ProtoLaser LDI is a project of:

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