Two-photon polymerized microstructures doped with MEH-PPV

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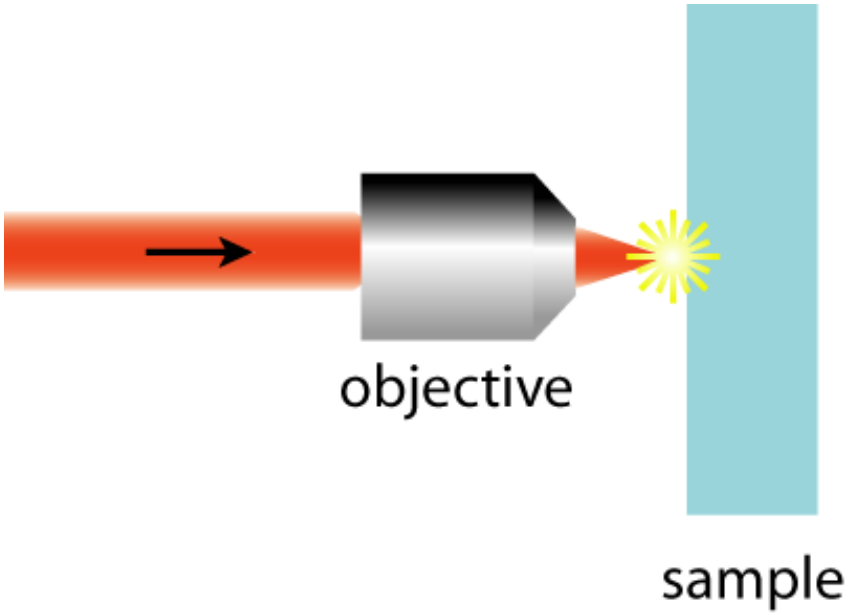
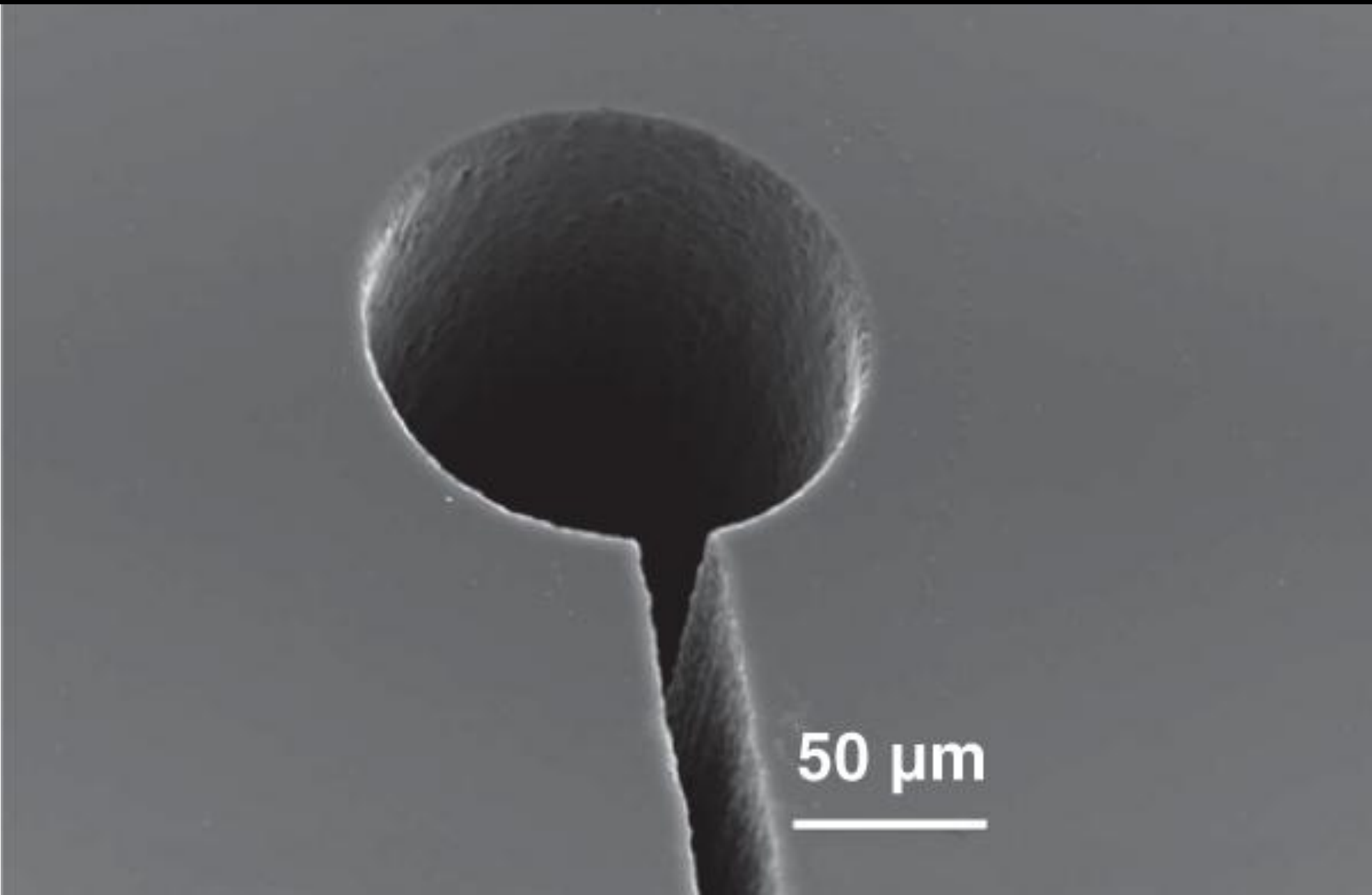
Eric Mazur, Cleber R. Mendonca

laser microfabrication

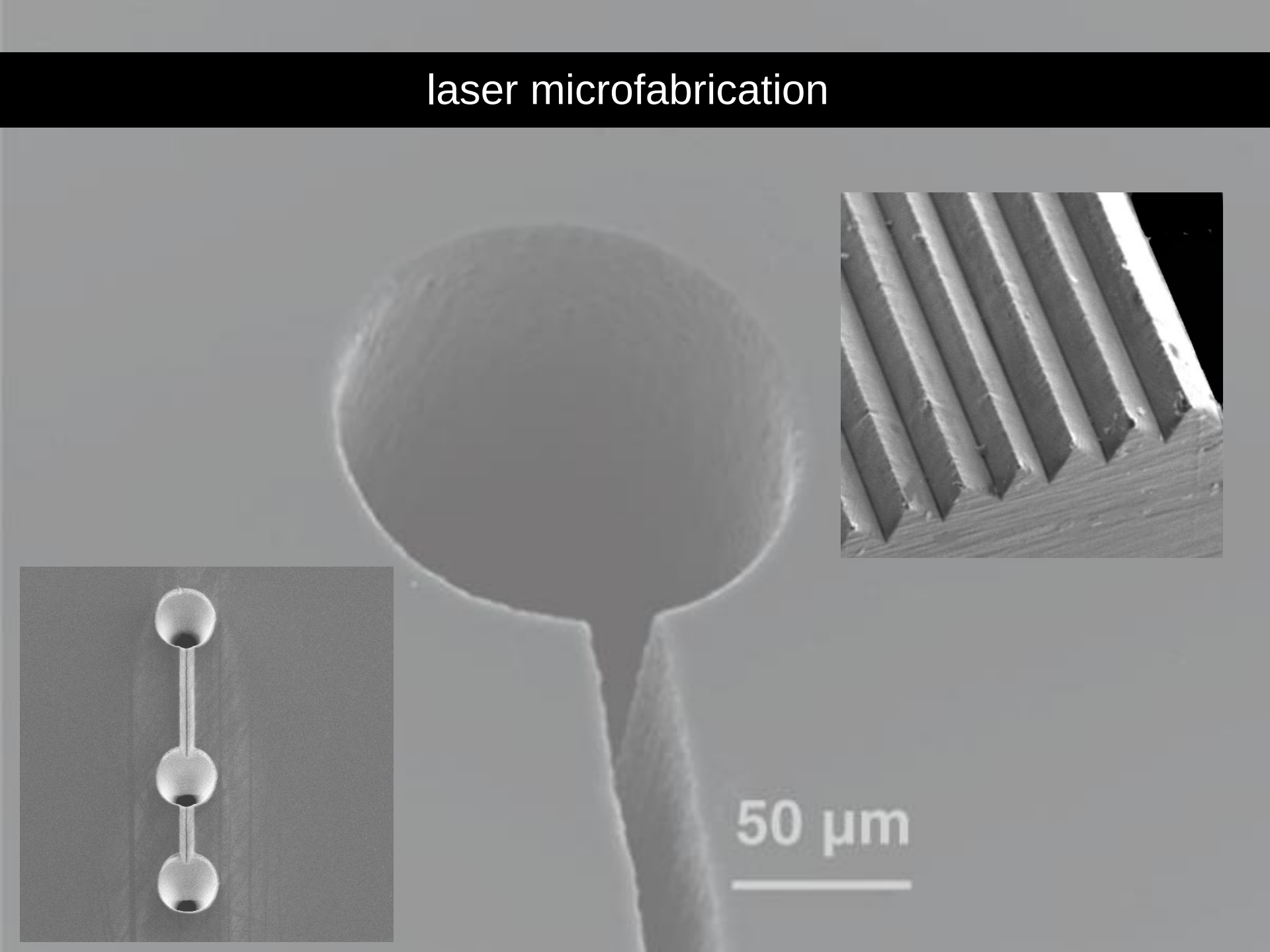
focus laser beam on material's surface



laser microfabrication

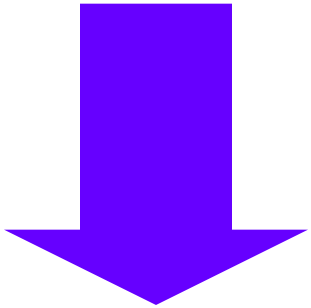


laser microfabrication



fs-laser microfabrication

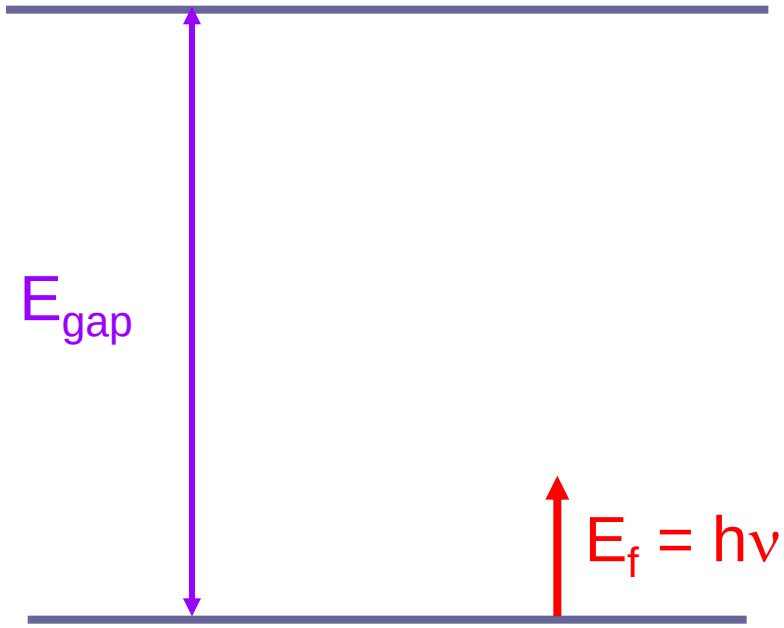
photon energy < bandgap



nonlinear interaction

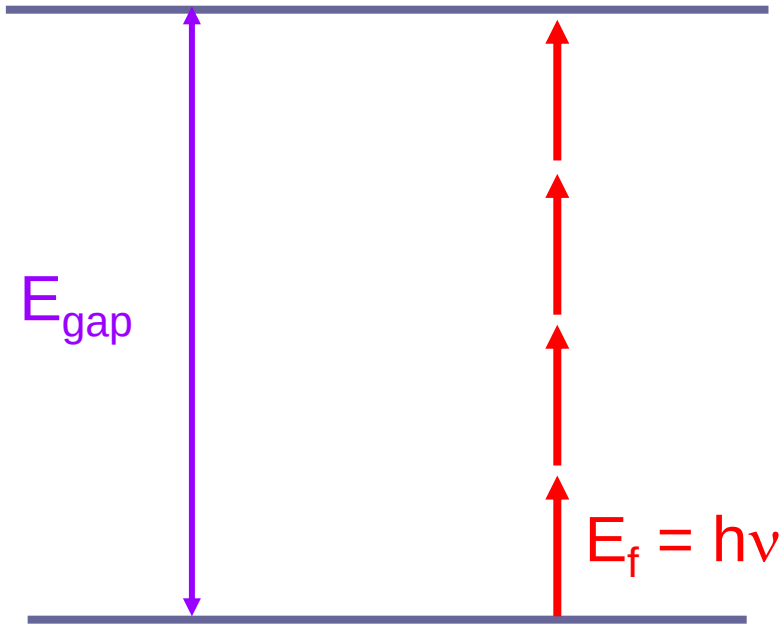
fs-laser microfabrication

nonlinear interaction



fs-laser microfabrication

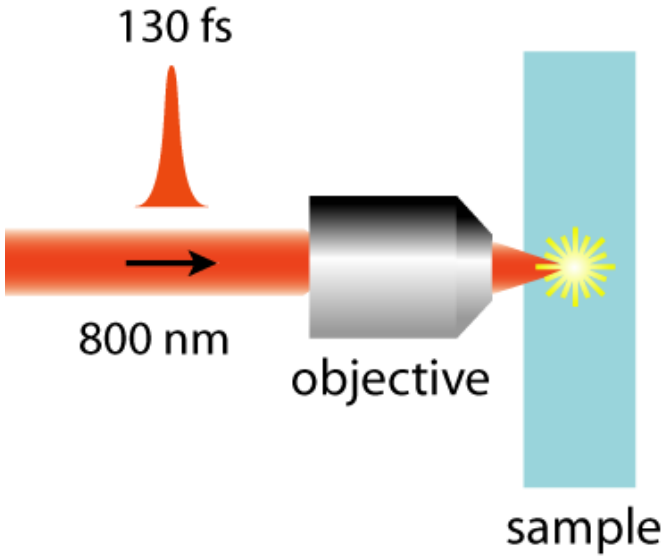
nonlinear interaction



multiphoton absorption

fs-laser microfabrication

focus laser beam inside material

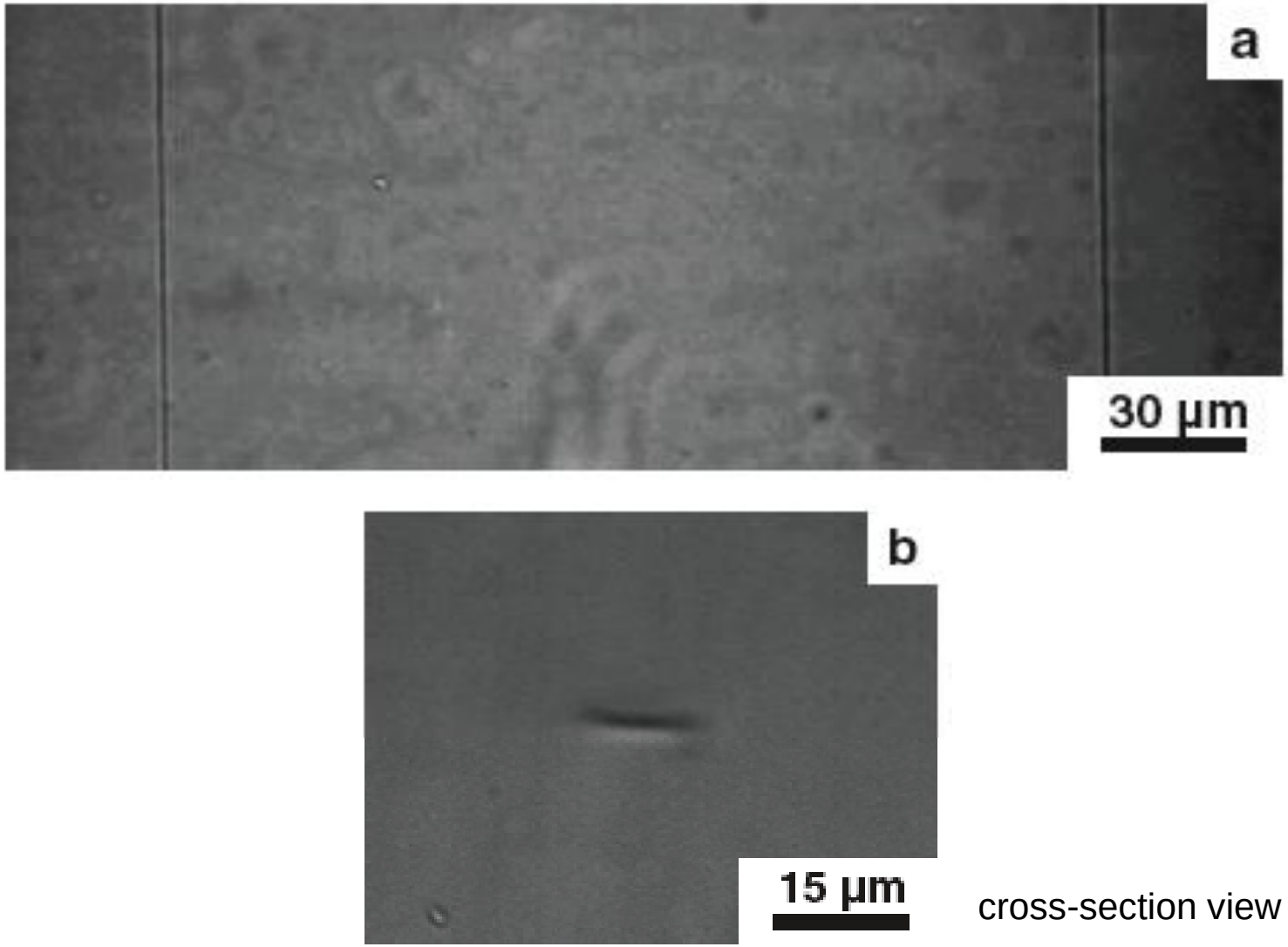


fs-laser microfabrication

curved waveguides inside glass

fs-laser microfabrication

3D waveguides in PMMA



cross-section view

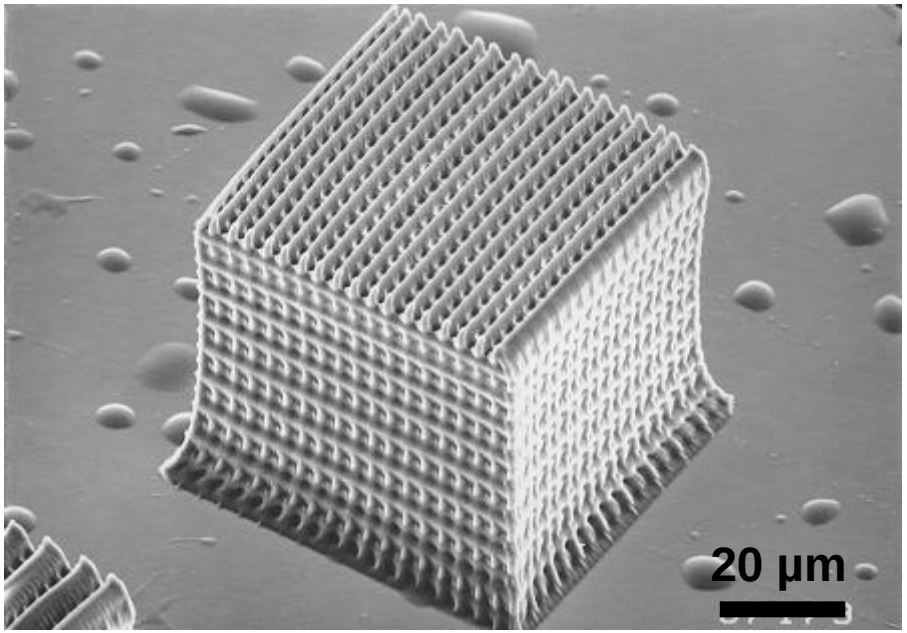
fs-laser microfabrication

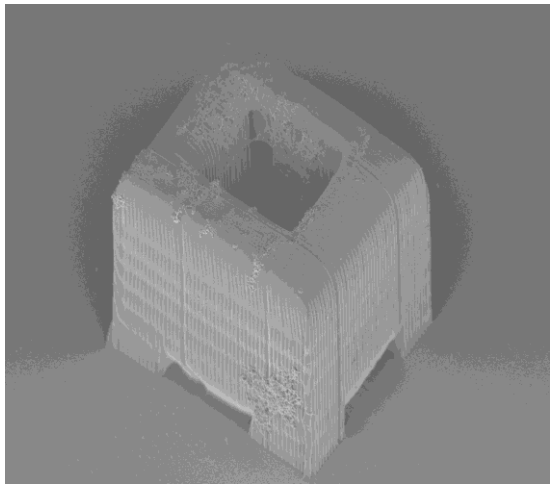
Novel concept:

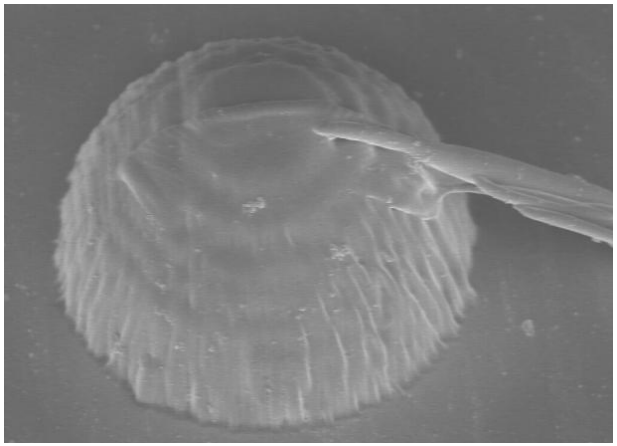
build a microstructure using fs-laser and nonlinear optical processes

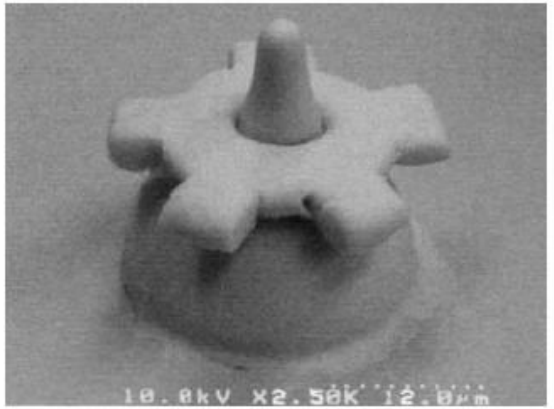
two-photon polymerization

photonic crystal – J. W. Perry









two-photon polymerization

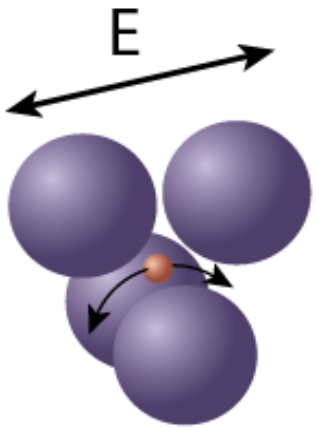
applications

- micromechanics
- waveguides
- microfluidics
- biology
- optical devices

Outline

- two-photon polymerization microfabrication
- microstructures containing MEH-PPV
- waveguiding the MEH-PPV emission
- summary

Nonlinear Optics



anharmonic oscillator

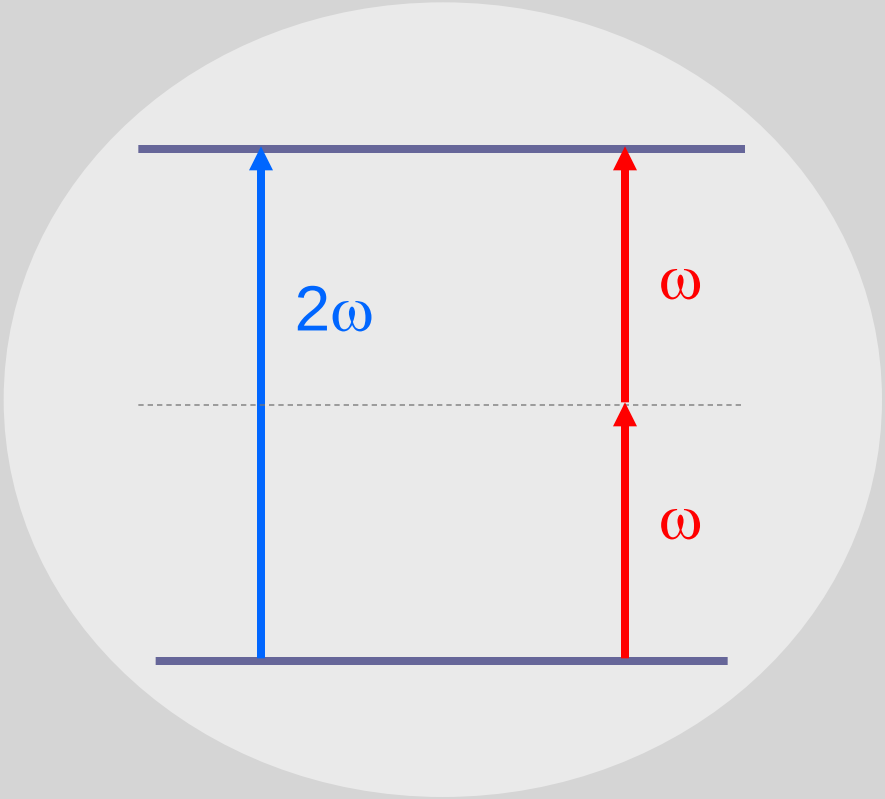
high light intensity

$$E_{rad.} \sim E_{inter.}$$

nonlinear polarization response

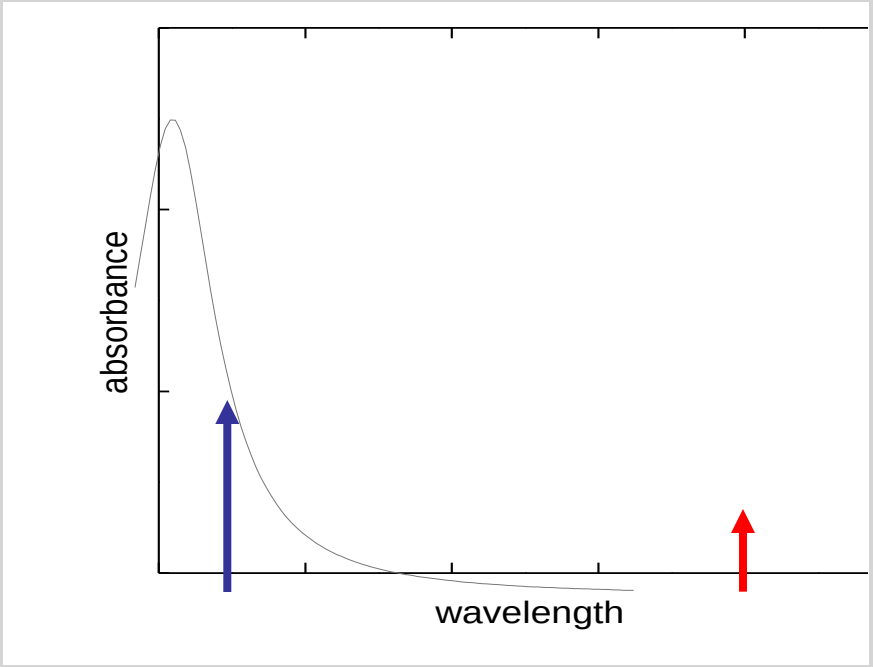
$$P = \chi^{(1)}E + \chi^{(2)}E^2 + \chi^{(3)}E^3 + \ldots$$

Two-photon absorption



$$\alpha = \alpha_0 + \beta I$$

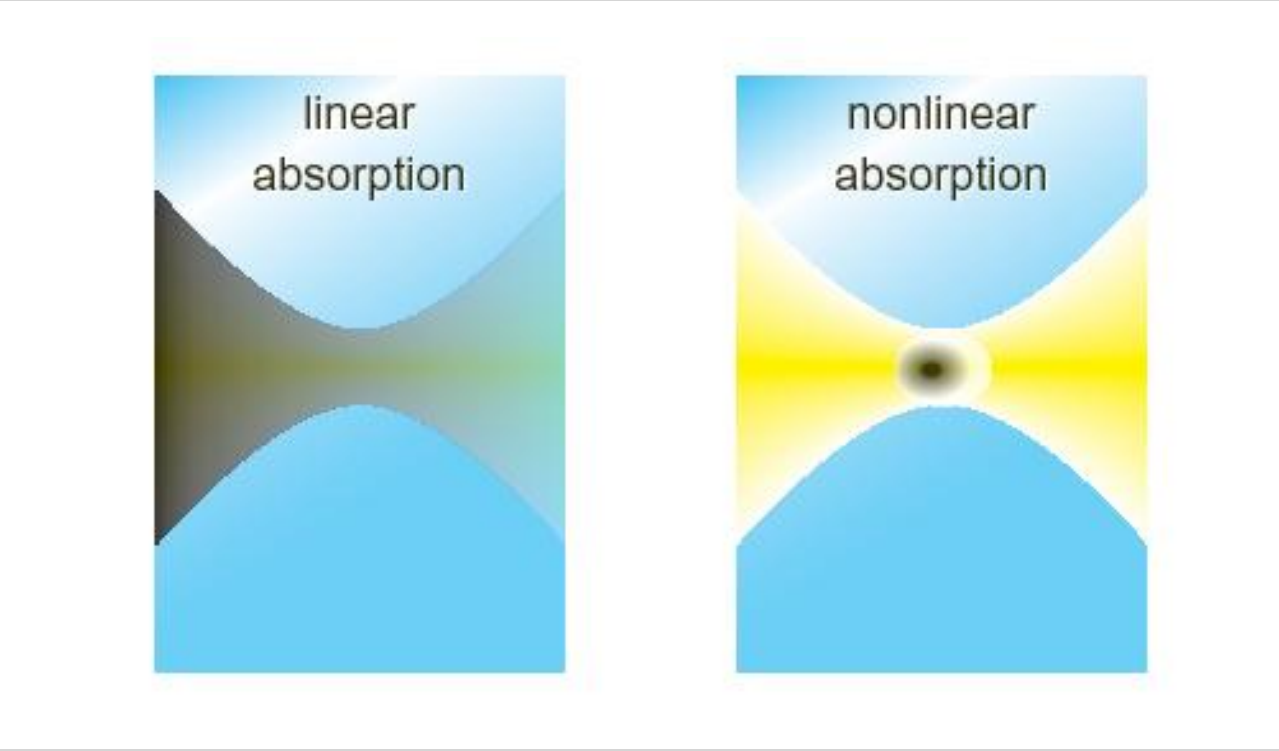
Third order processes $\chi^{(3)}$



Two-photon absorption

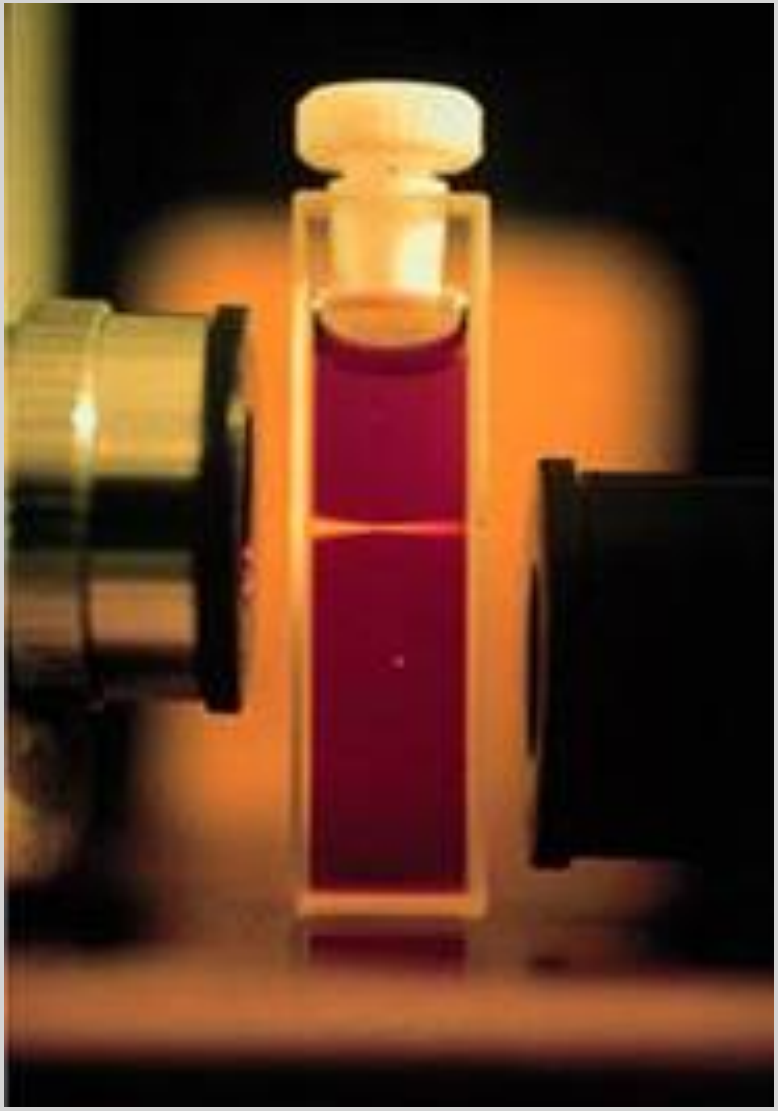
Nonlinear interaction provides spatial confinement of the excitation

fs-microfabrication



$$\alpha = \alpha_0 \qquad \alpha = \alpha_0 + \beta I$$

Two-photon absorption



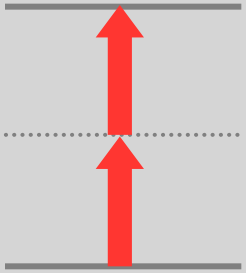
spatial confinement of excitation

Two-photon polymerization

Monomer + Photoinitiator $\rightarrow$ *Polymer*

light

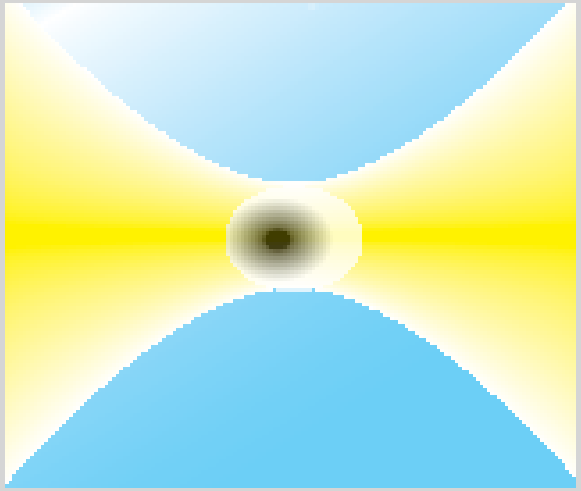
Photoinitiator is excited by ***two-photon absorption***



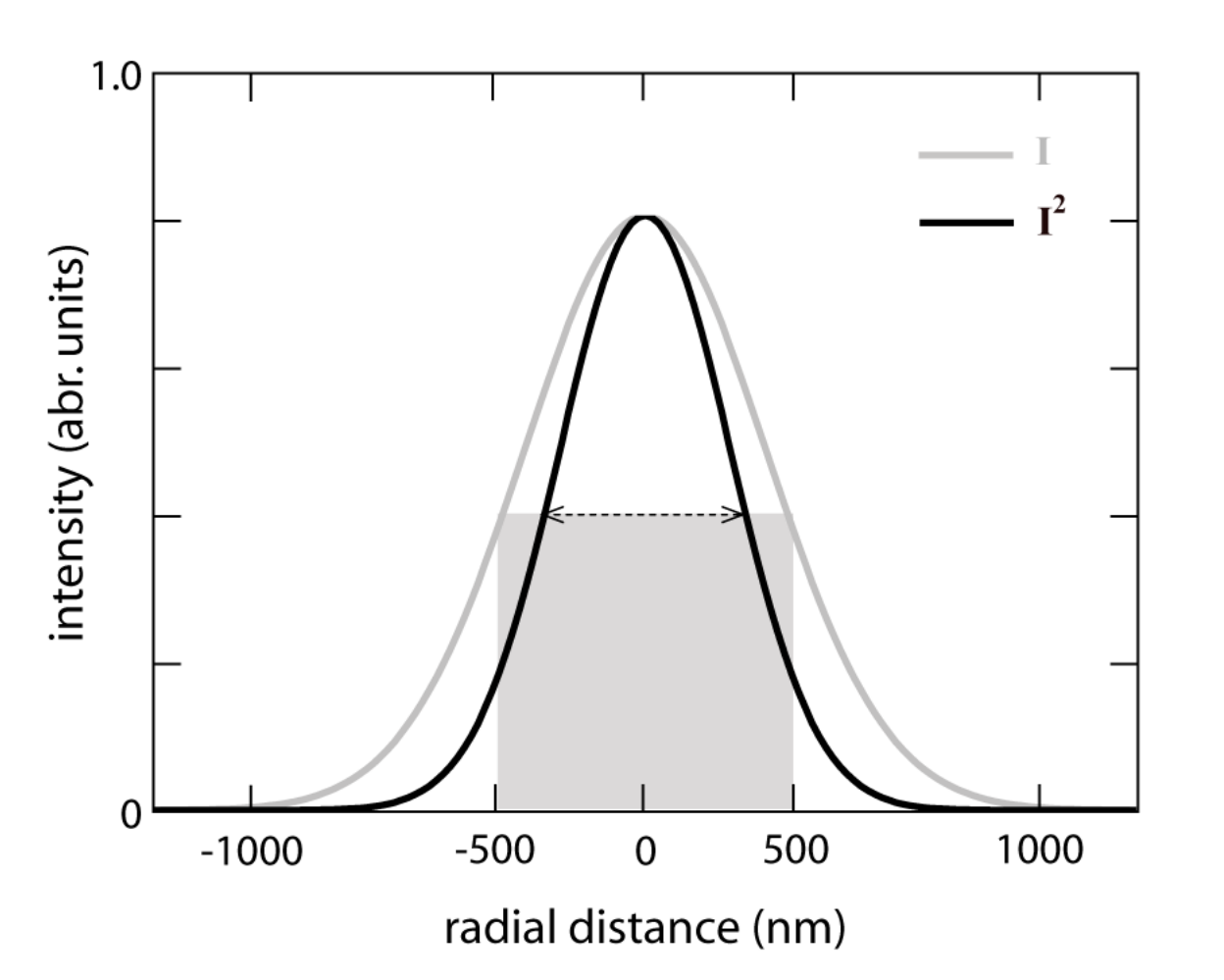
$$R_{2PA} \propto I^2$$

The polymerization is confined to the focal volume.

High spatial resolution

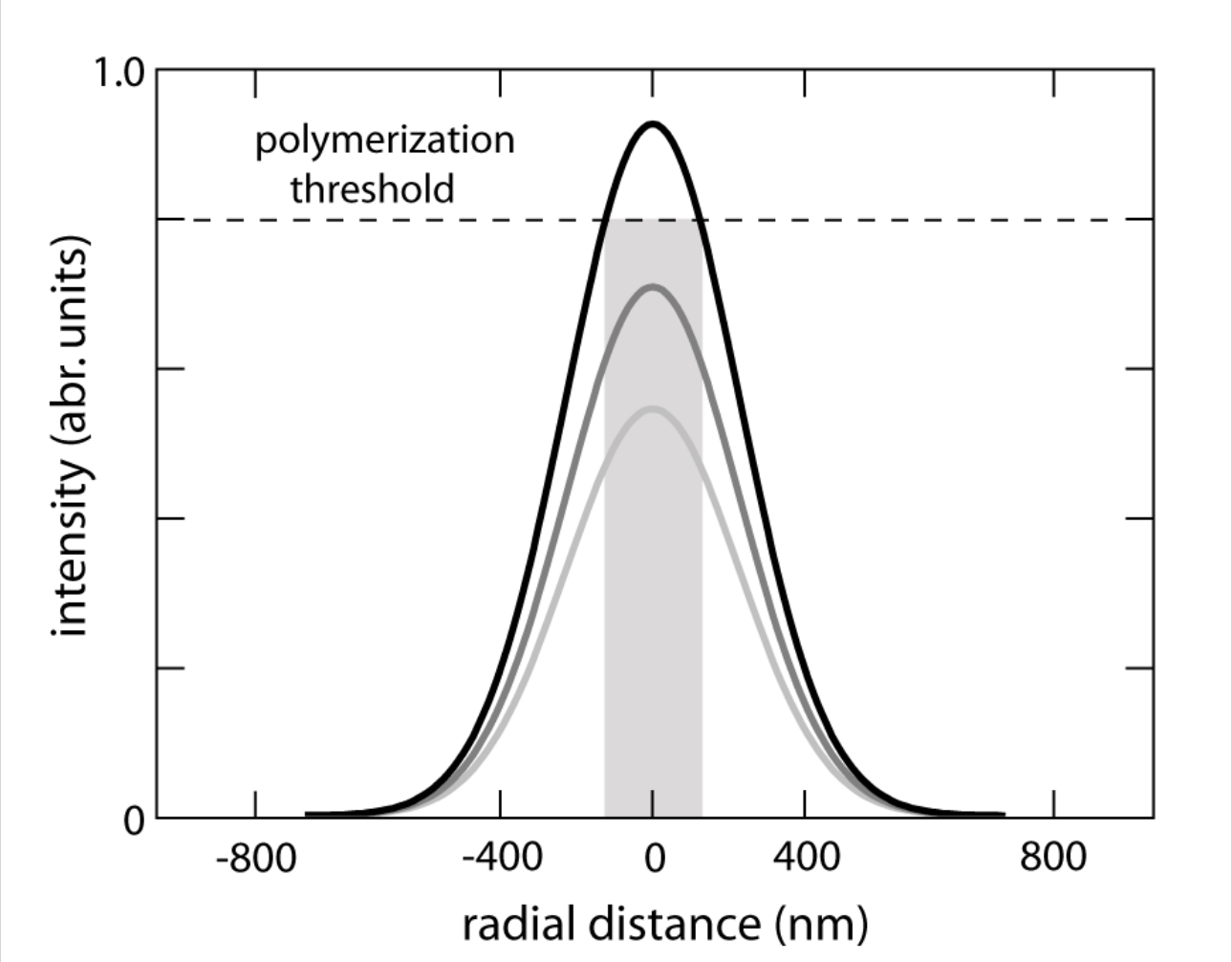


Two-photon polymerization



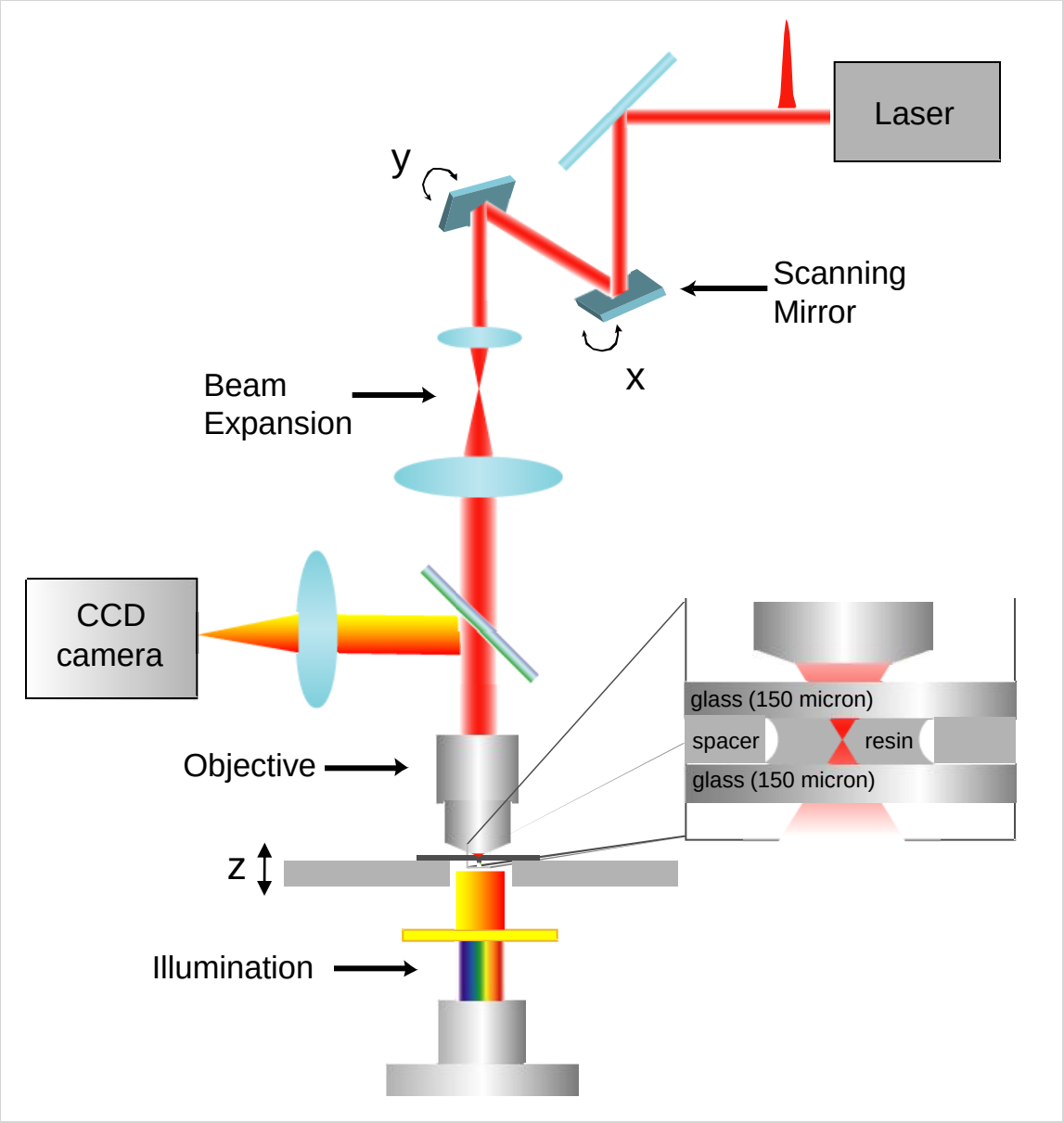
bellow the diffraction limit

Two-photon polymerization



even higher spatial resolution

Two-photon polymerization setup



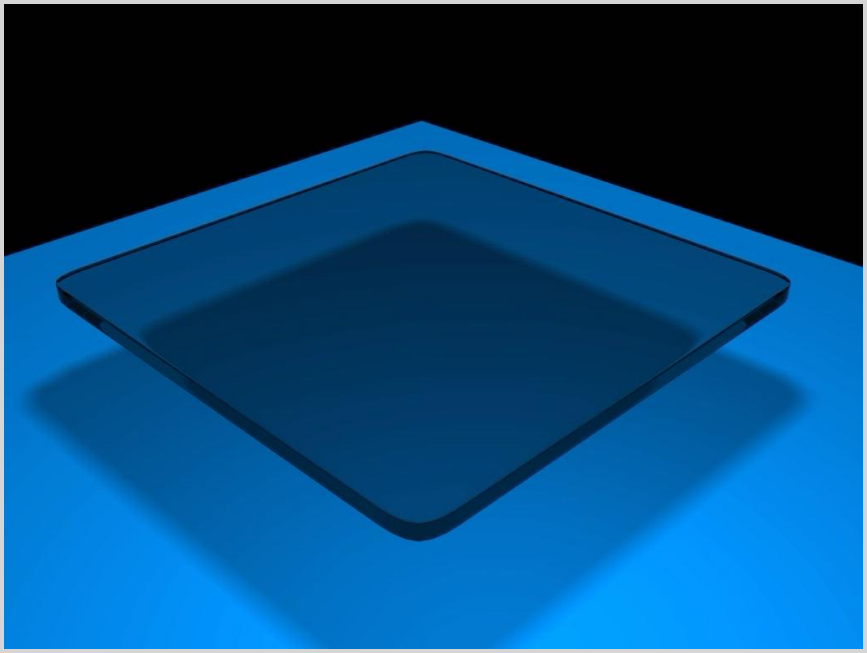
Ti:sapphire laser oscillator

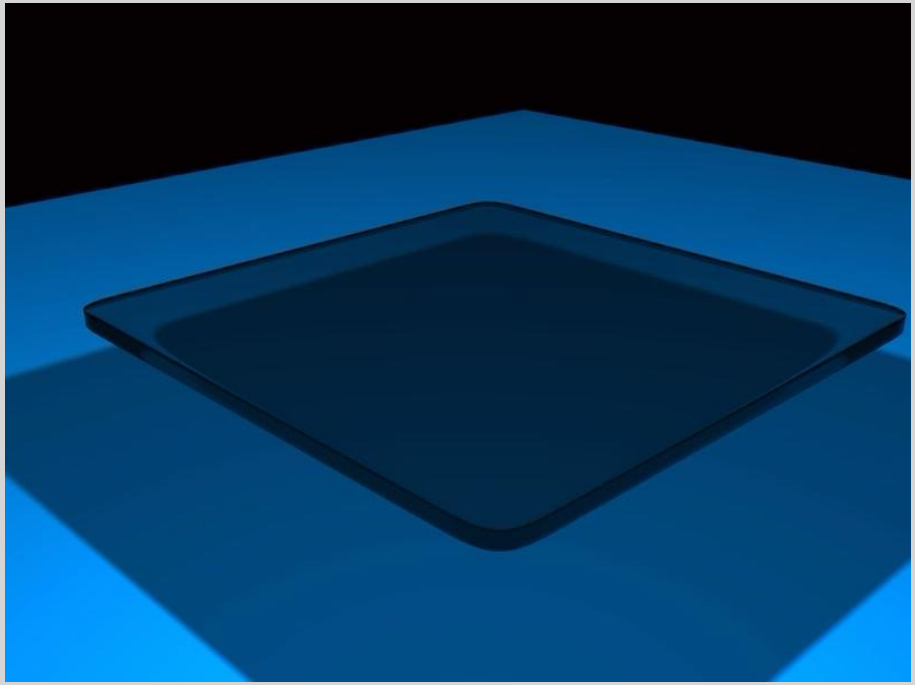
- 130 fs
- 800 nm
- 76 MHz
- 20 mW

Objective

40 x
0.65 NA

Two-photon polymerization

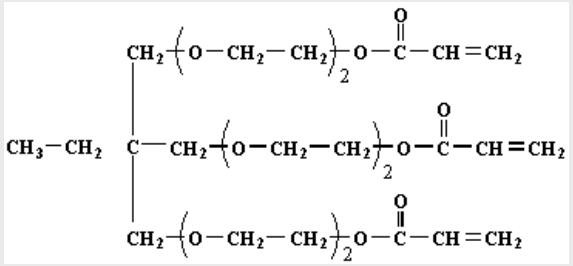




Resin preparation

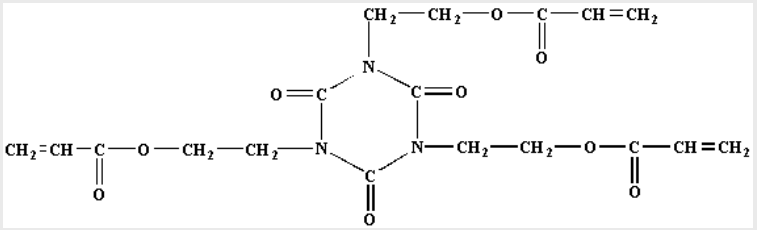
Monomers

Monomer A



reduces the shrinkage upon polymerization

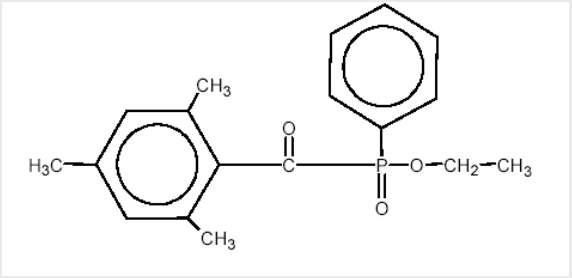
Monomer B



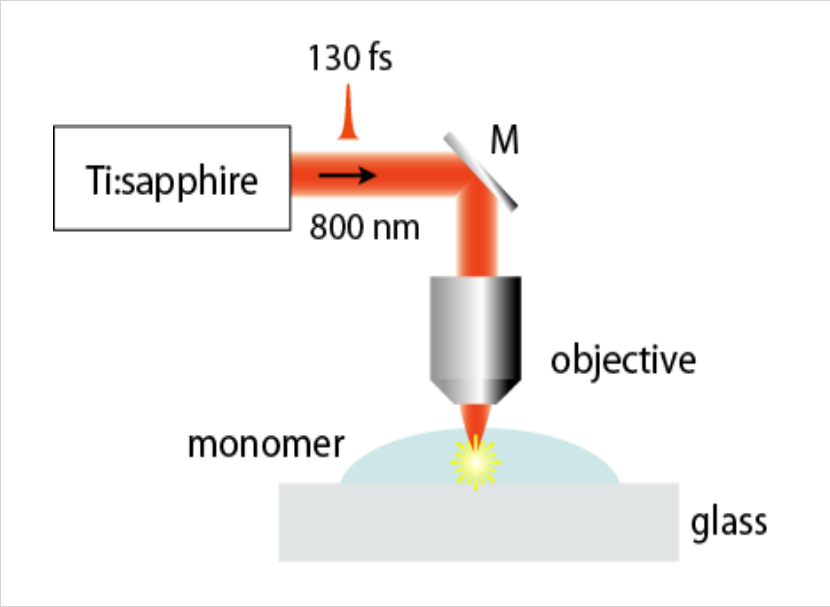
gives hardness to the polymeric structure

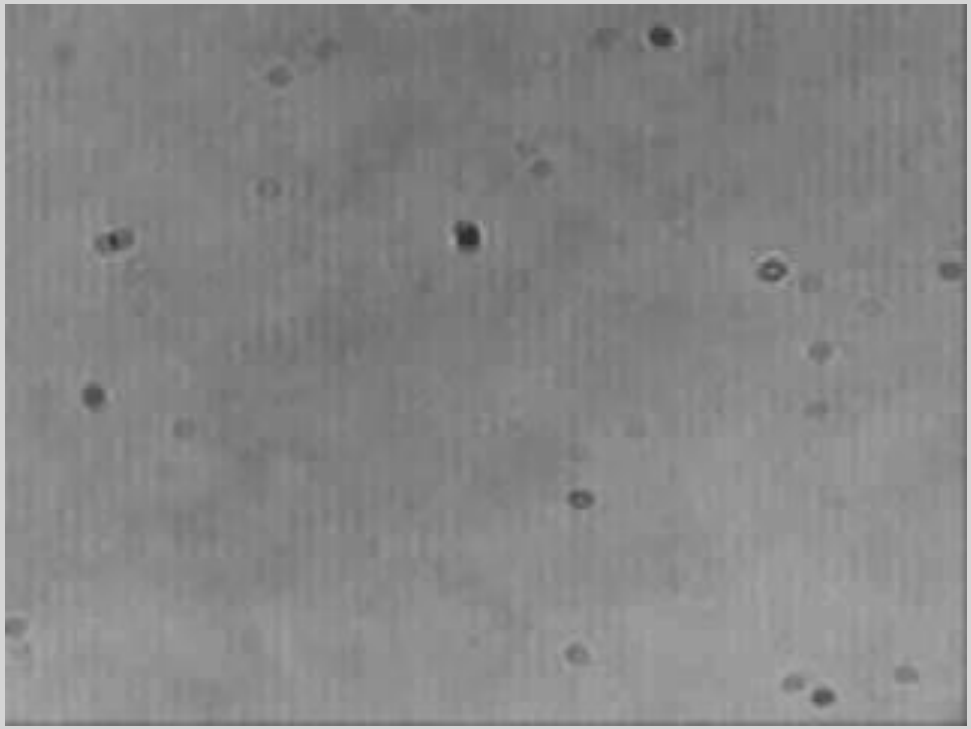
Photoinitiator

Lucirin TPO-L

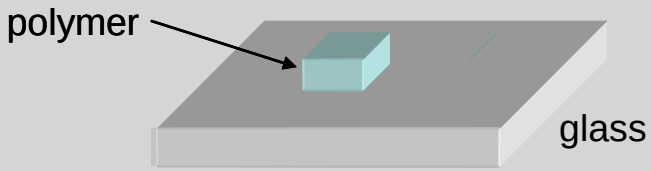


Two-photon polymerization

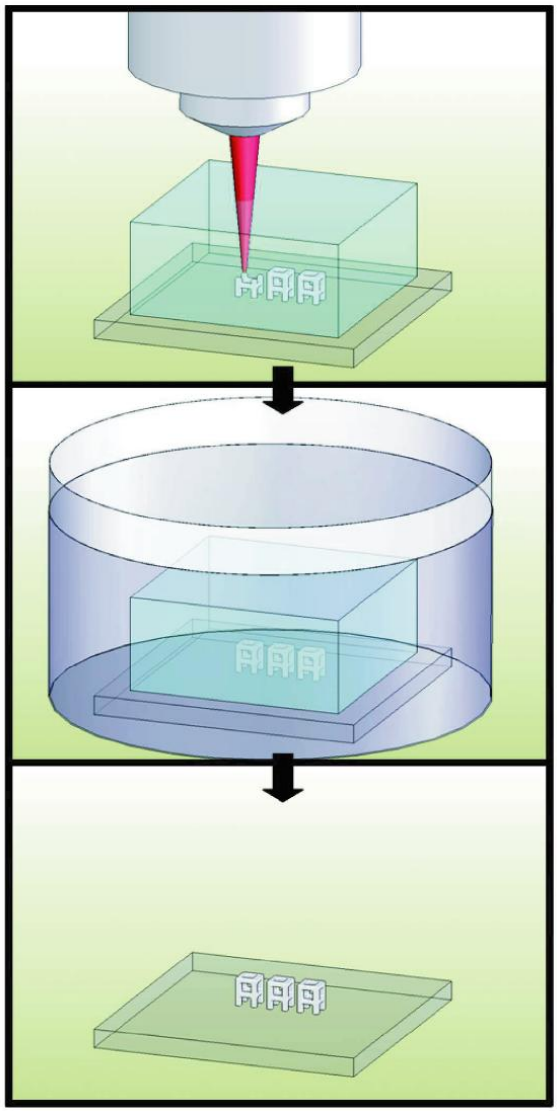




30 µm x 30 µm x 12 µm cube



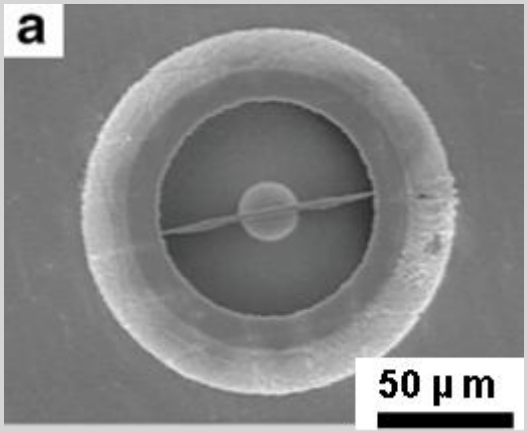
Two-photon polymerization

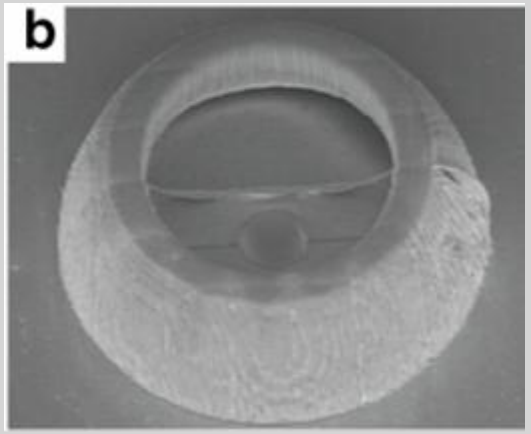


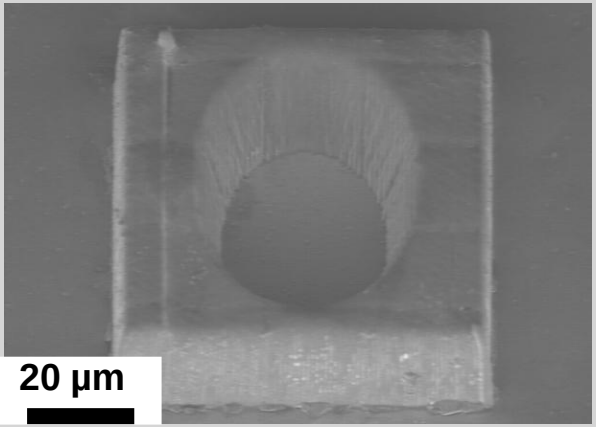
After the fabrication, the sample is immersed in ethanol to wash away any unsolidified resin and then dried

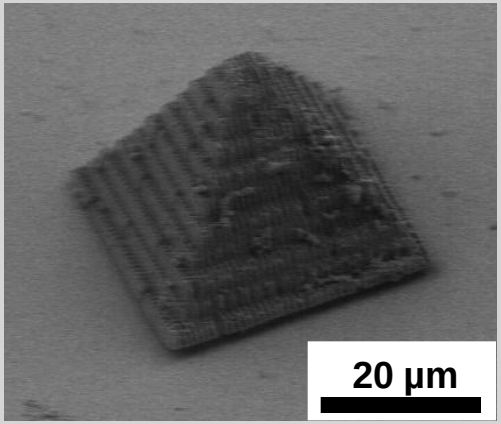
Two-photon polymerization

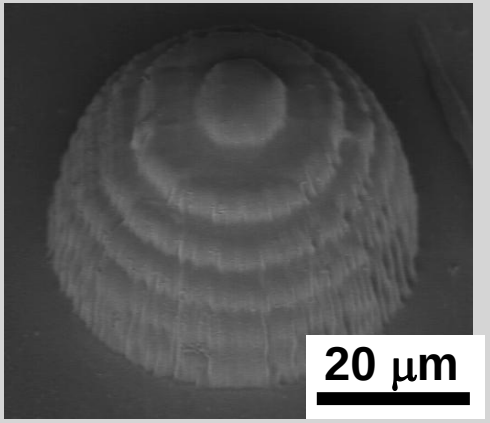
Microstructures fabricated by two-photon polymerization



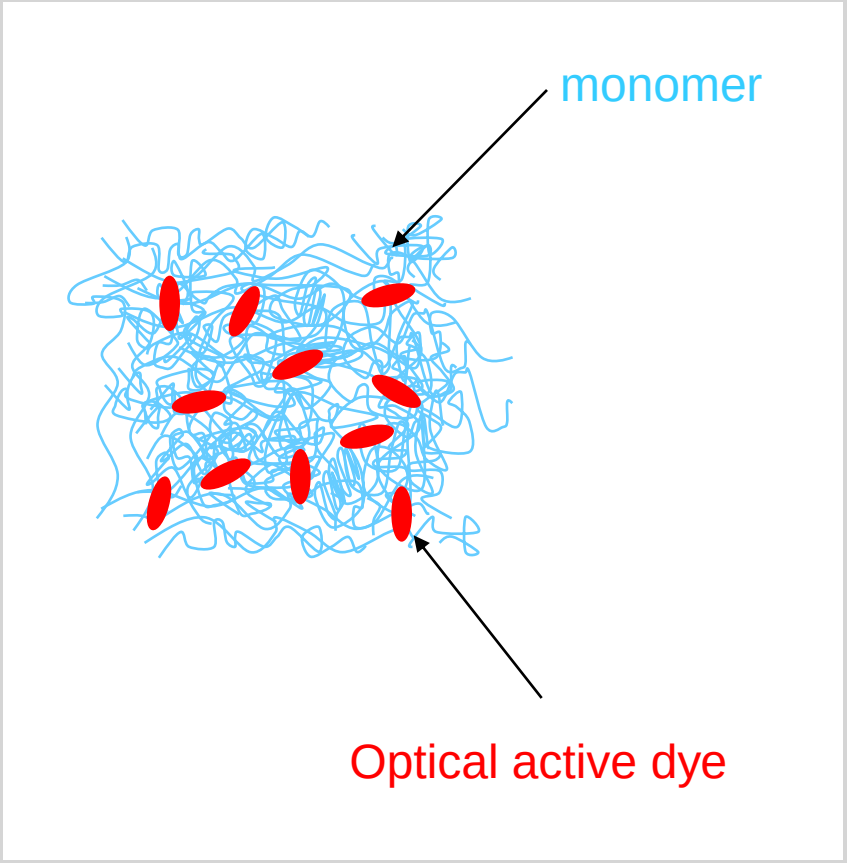


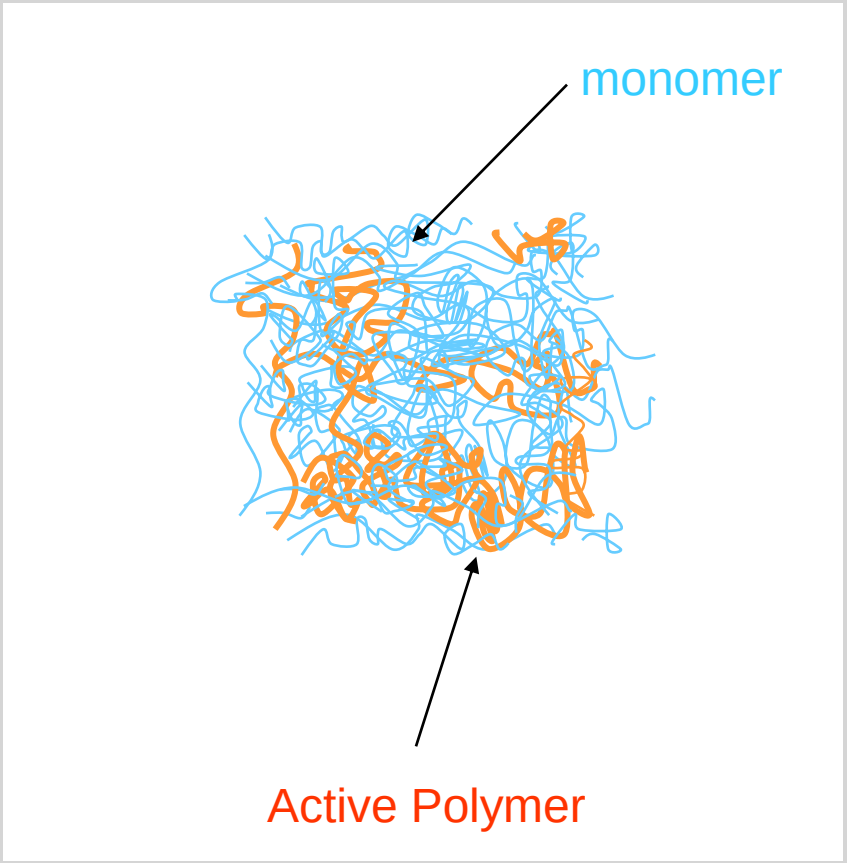






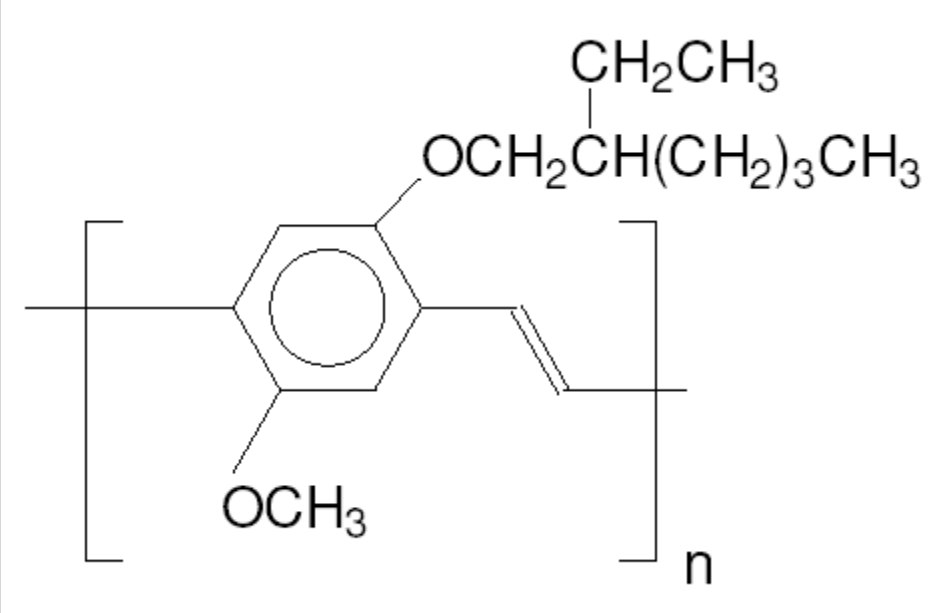
Microstructures containing active compounds





Microstructures containing MEH-PPV

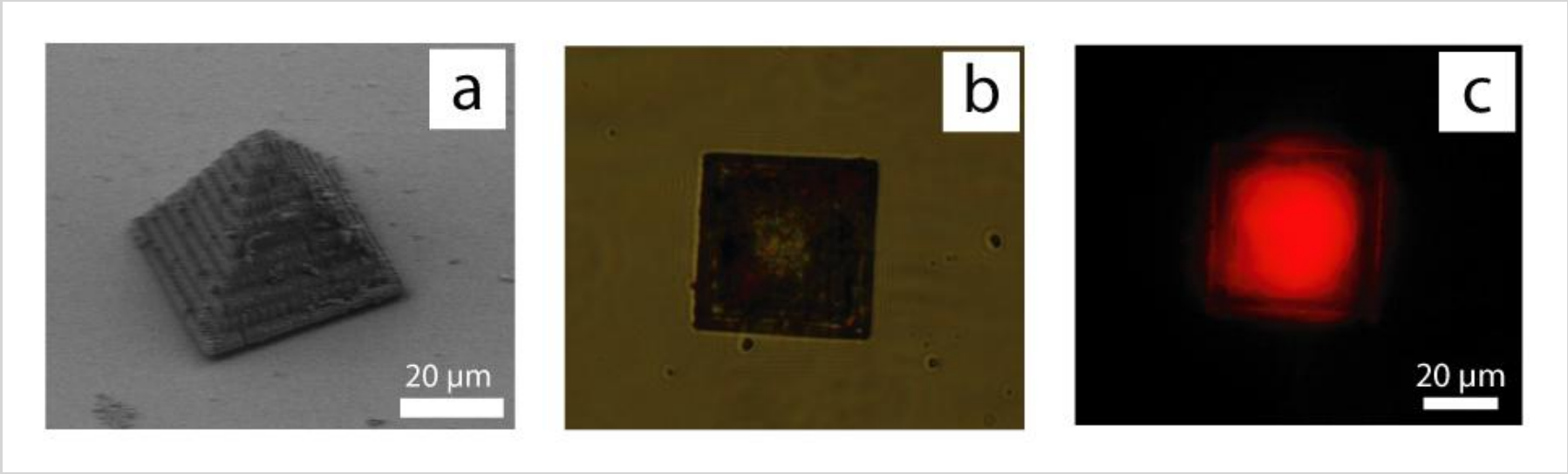
MEH-PPV



Fluorescence
Electro Luminescent
Conductive

Microstructures containing MEH-PPV

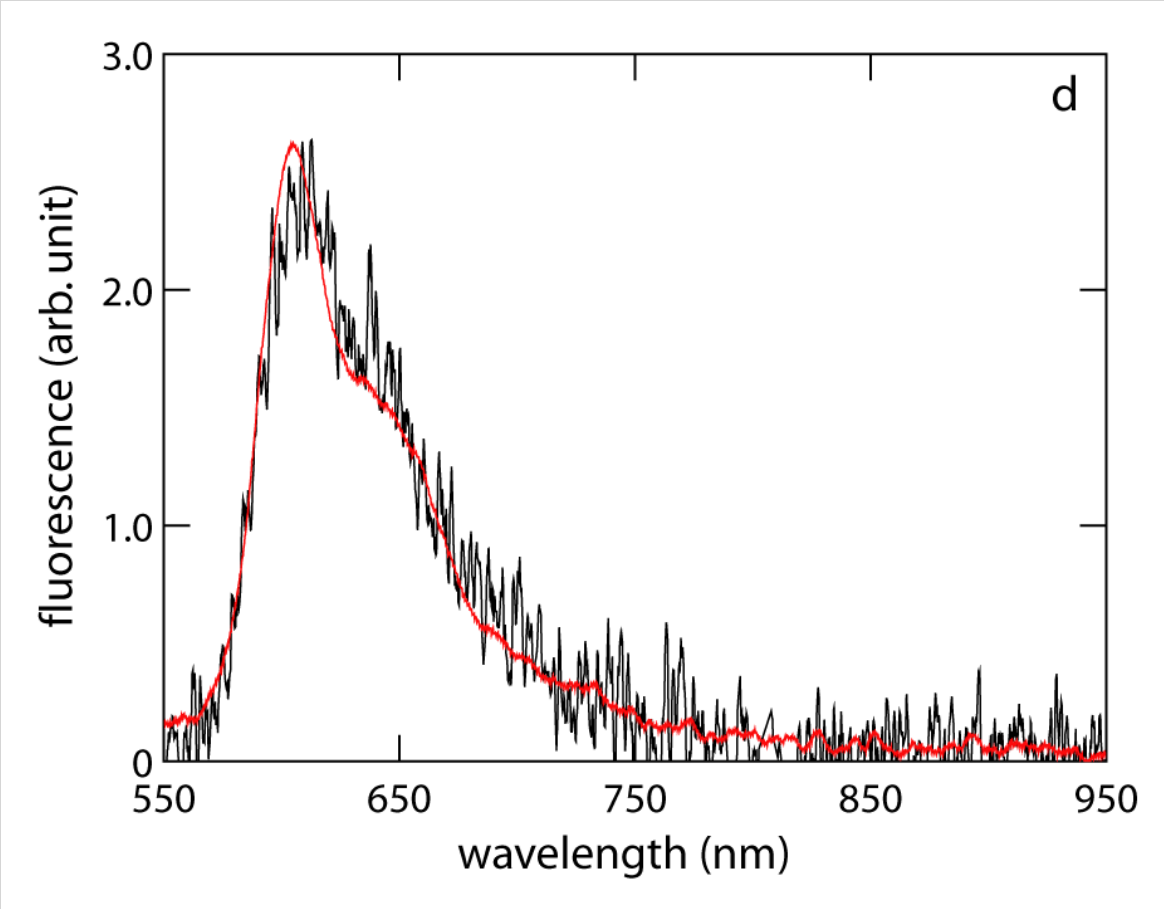
MEH-PPV: up to 1% by weight
laser power 40 mW



a - Scanning electron microscopy

b,c - Fluorescence microscopy of the microstructure with the excitation OFF (b) and ON (c)

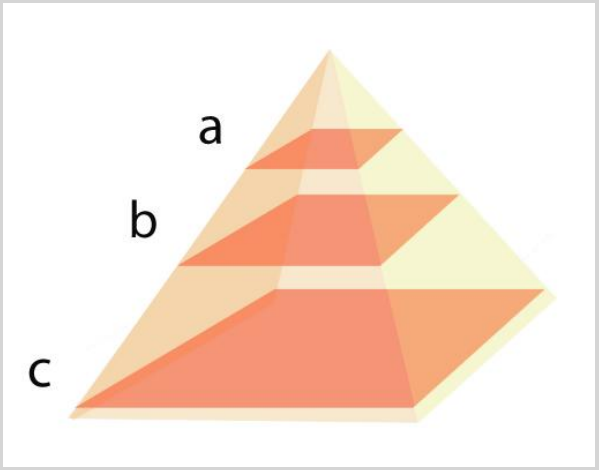
Microstructures containing MEH-PPV

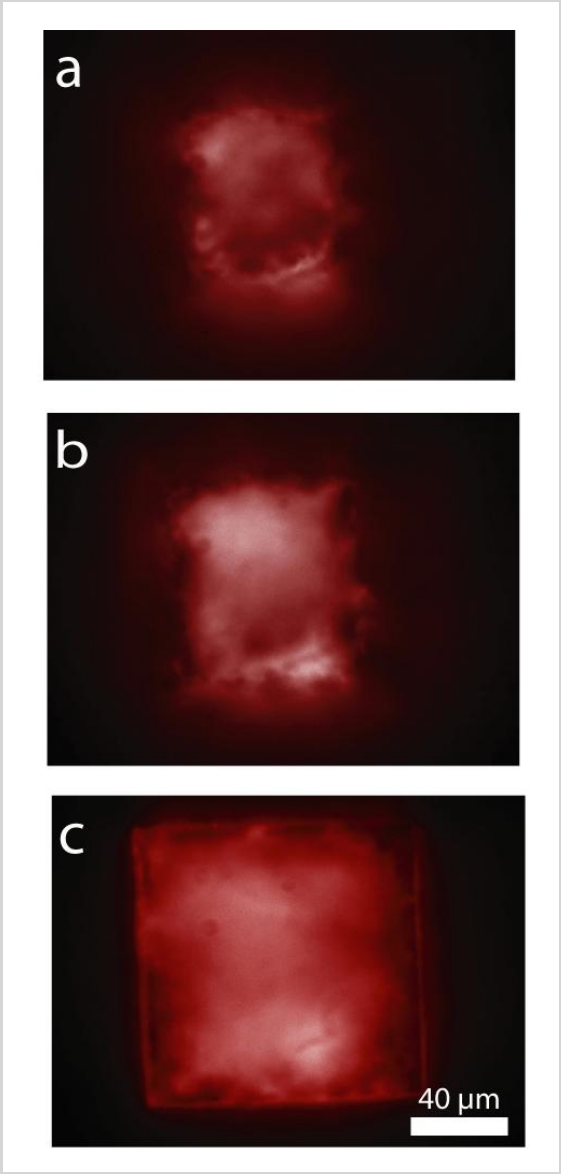


d - Emission of the microstructure (black line) and of a film with the same composition (red line)

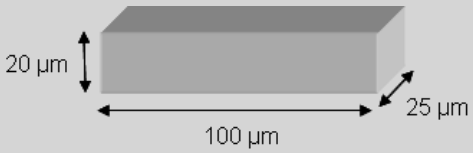
Microstructures containing MEH-PPV

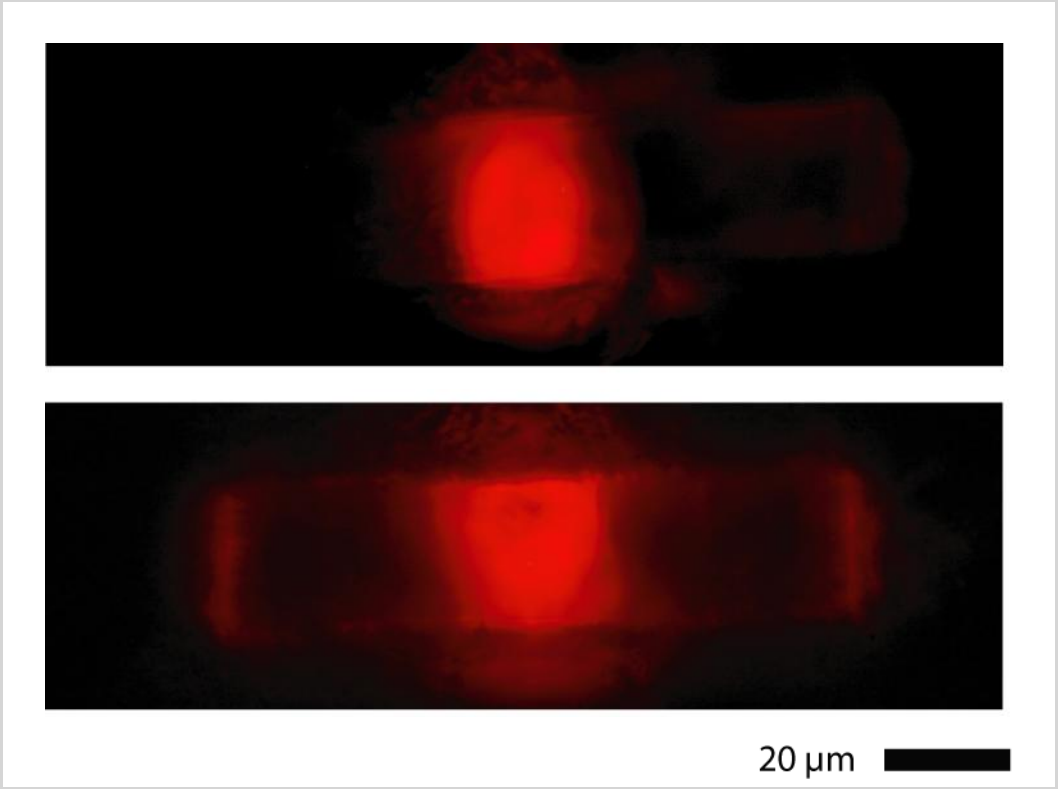
Fluorescent confocal microscopy images in planes separated by 16 μm in the pyramidal microstructure.

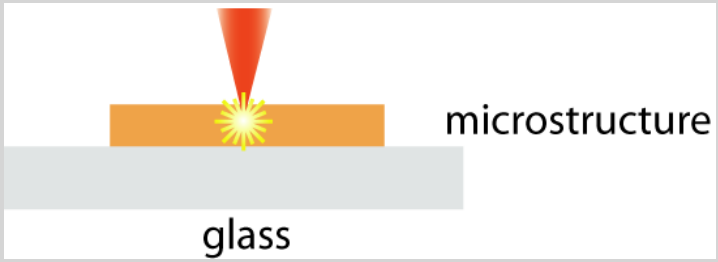


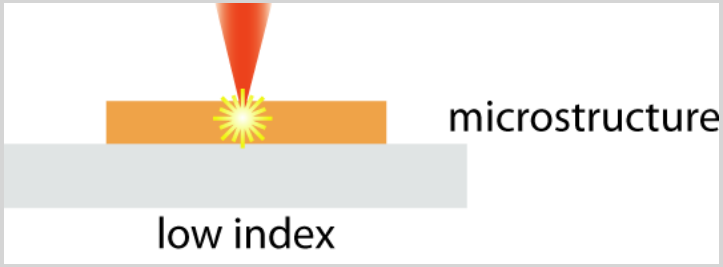


Microstructures containing MEH-PPV





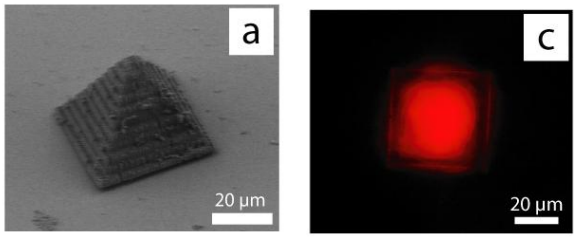


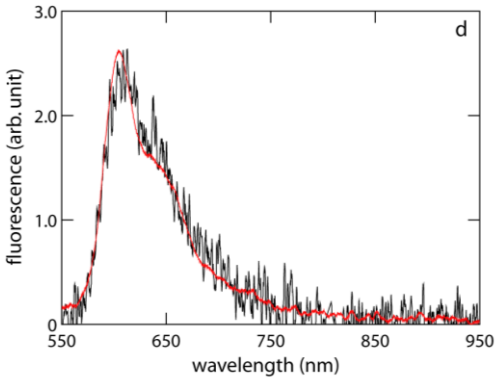


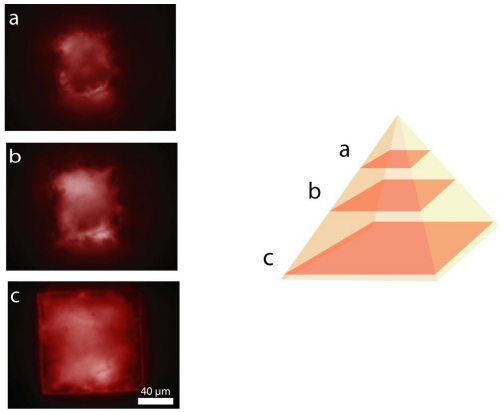
waveguiding of the microstructure fabricated on porous silica substrate (n= 1.185)

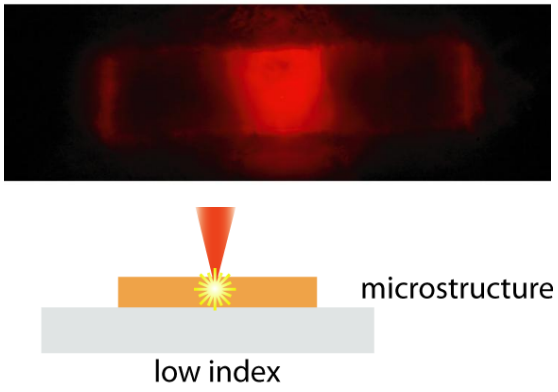
Applications: micro-laser; fluorescent microstructures; conductive microstructures

Summary


a
20 µm
c
20 µm

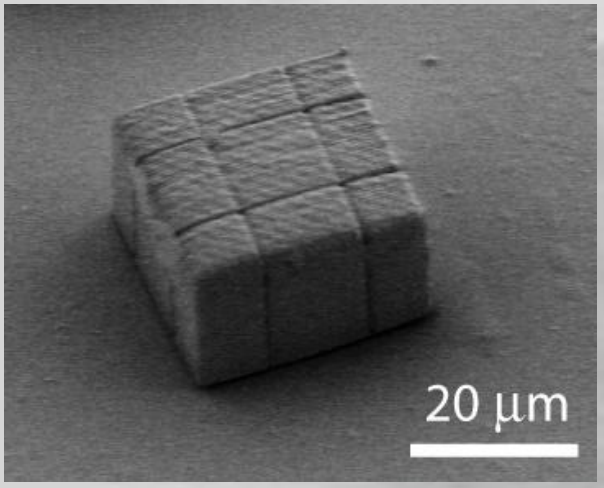

d
fluorescence (arb. unit)
3.0
2.0
1.0
0
550
650
750
850
950
wavelength (nm)

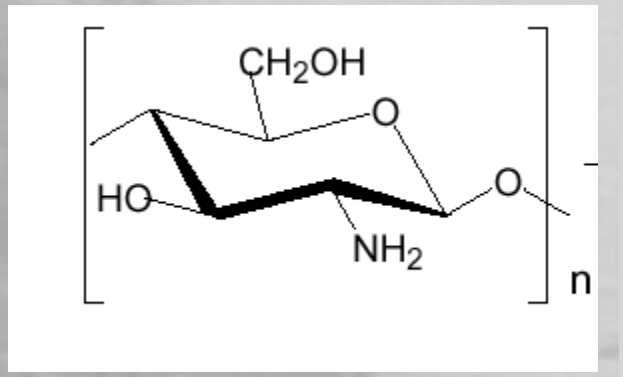

a
b
c
40 µm
a
b
c

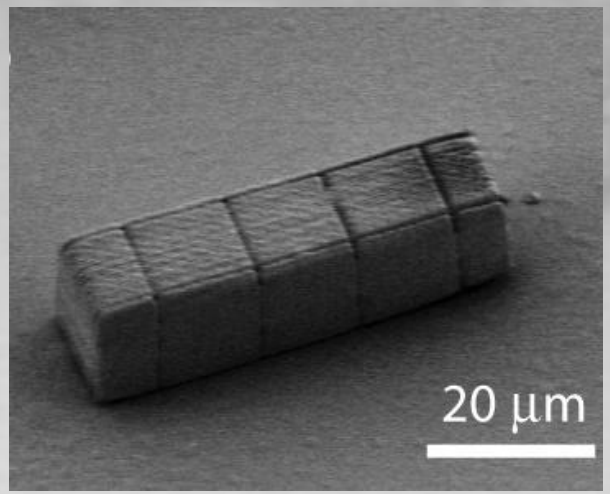

microstructure
low index

Other studies

- microstructures containing biopolymer - chitosan

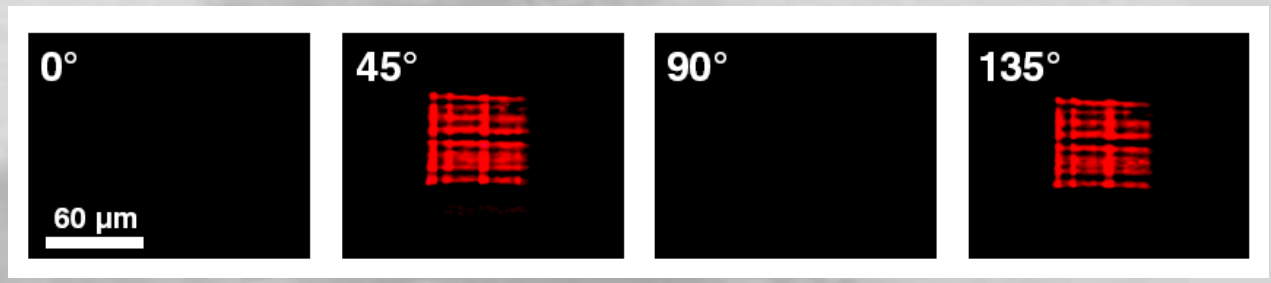


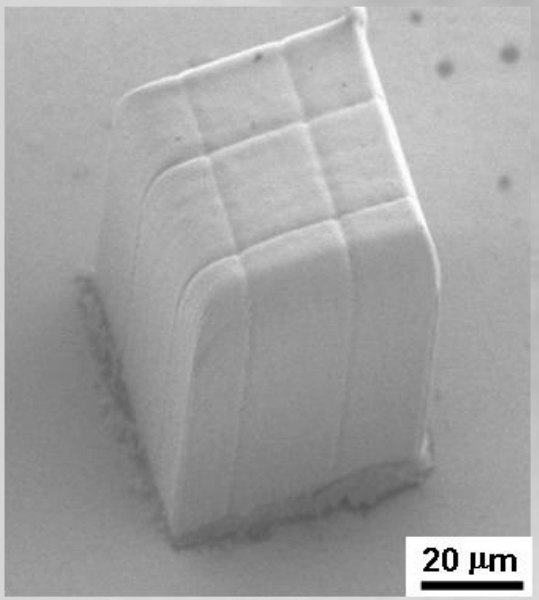


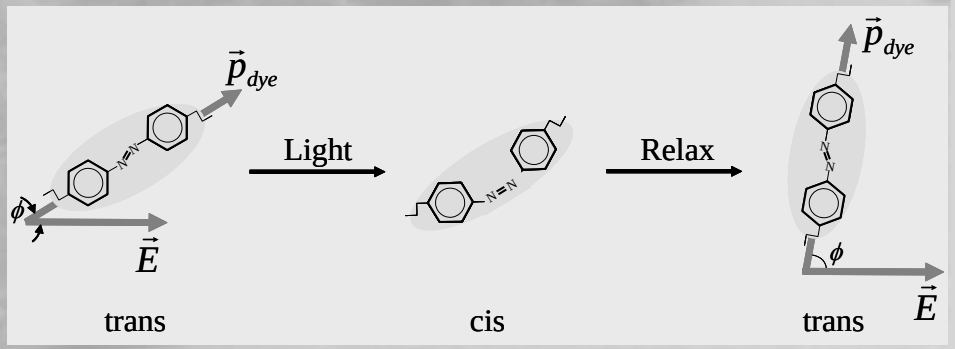


Other studies

- microstructures for optical storage – birefringence

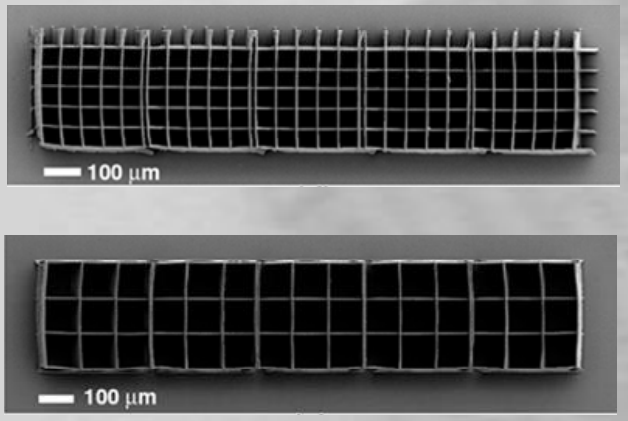


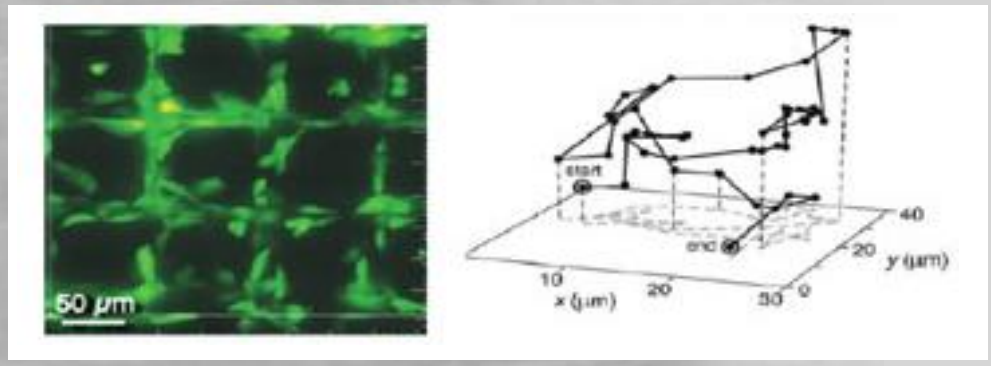




Other studies

- 3D cell migration studies in micro-scaffolds





Acknowledgments

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Thank you !
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