Desenvolvimento de novos dispositivos Fotônicos

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Photonics Groups

- developing novel nonlinear optical materials
- novel methods in nonlinear optics
- control of light matter interaction with fs-pulses
- fs-laser microfabrication of photonic devices

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Prof. Leonardo De Boni
Prof. Lino Misoguti

Laser pulse

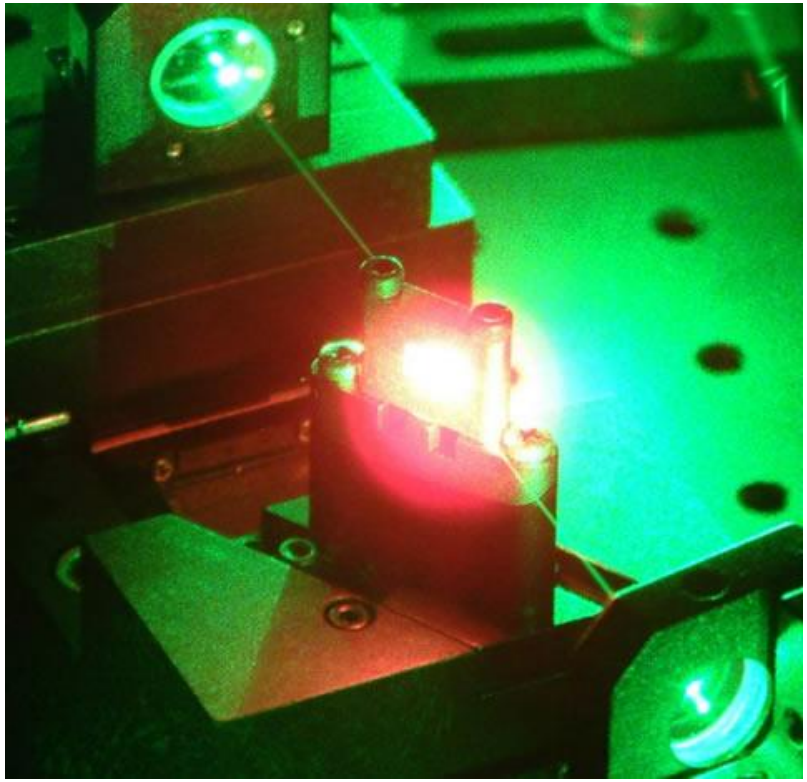
U.S.S Entreprise NCC-1701-E
Length: 685. 3 m
Width: 250.6 m
Height: 88.2 m

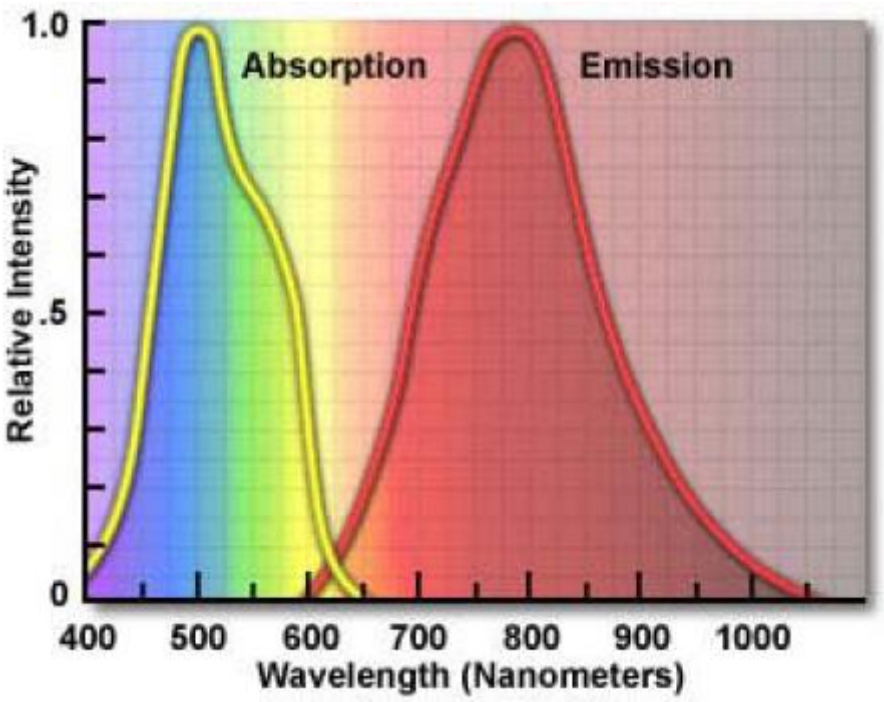
Lenght of light pulse: l ~ 15 m

T = l/c = 50 ns

Ti:sapphire laser

cristal Ti:safira

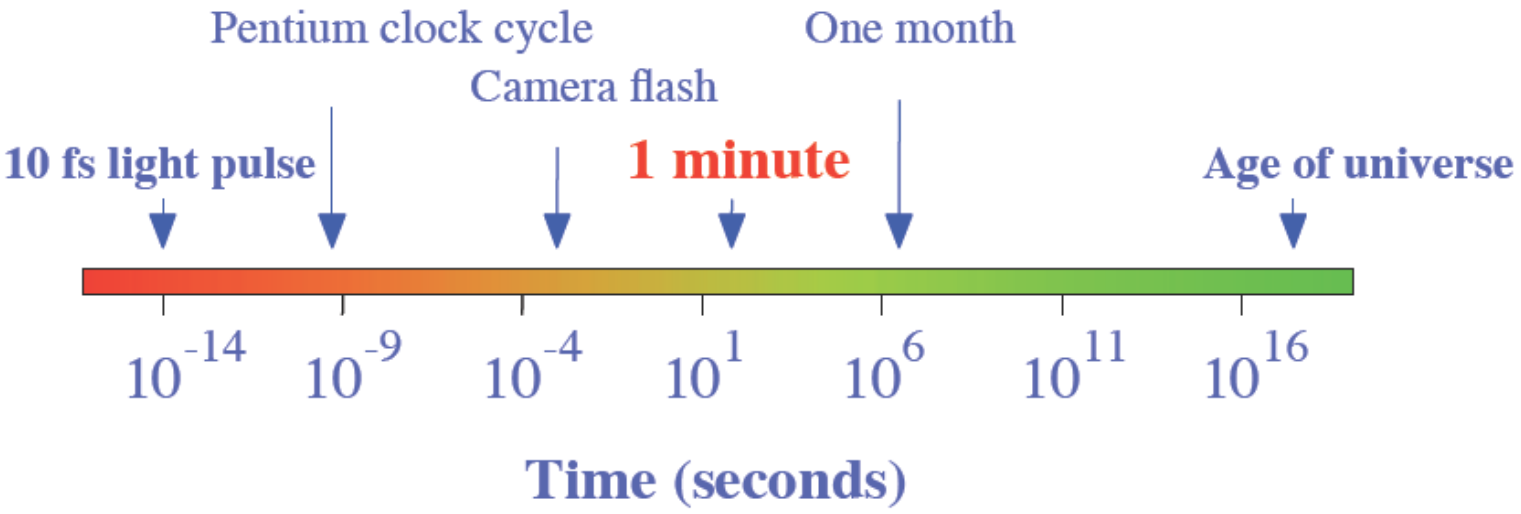




Duration from 20 – 100 fs.

Time scale of ultrashort pulses

1 fs = 10^{-15} s

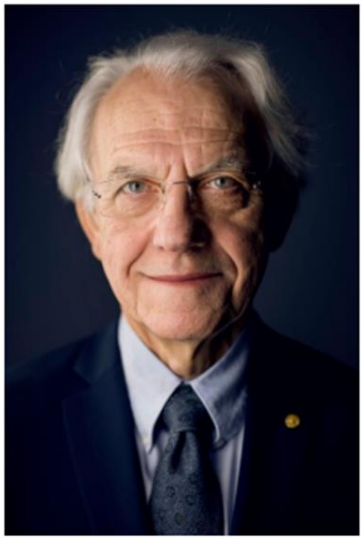


ultrashort pulses amplification

The Nobel Prize in Physics 2018

Ill. Niklas Elmehed. © Nobel Media

Arthur Ashkin



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Gérard Mourou

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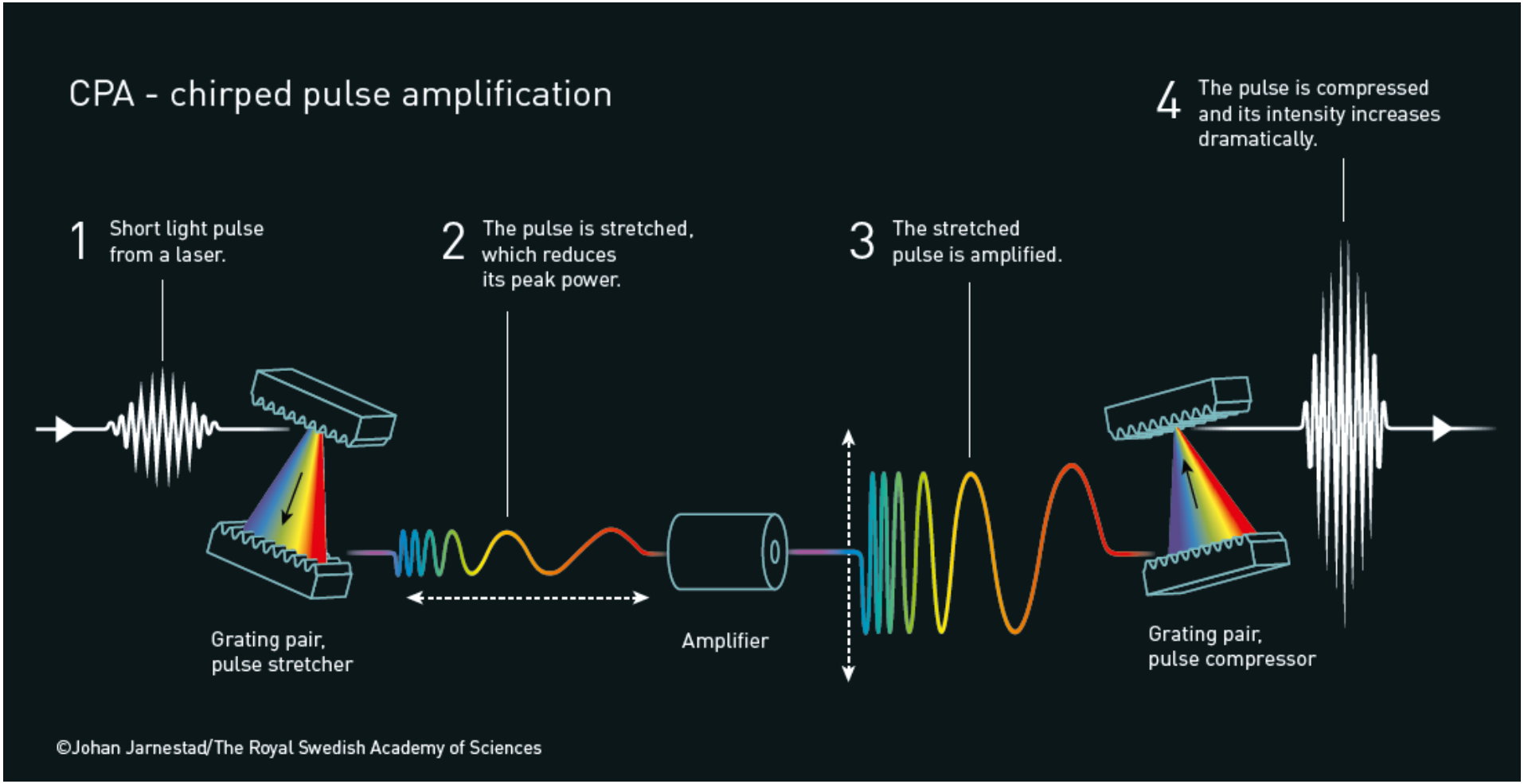
Donna Strickland

for their method of generating high-intensity, ultra-short optical pulses

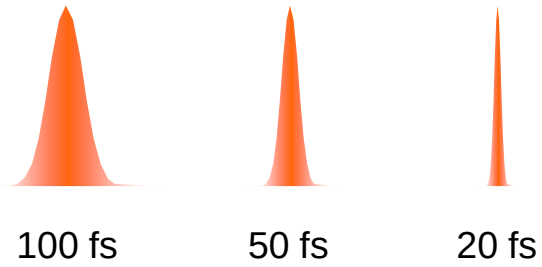
Chirped Pulse Amplification - CPA

Chirped pulse amplification



Microfabrication

Ti:Sapphire lasers



Very intense light

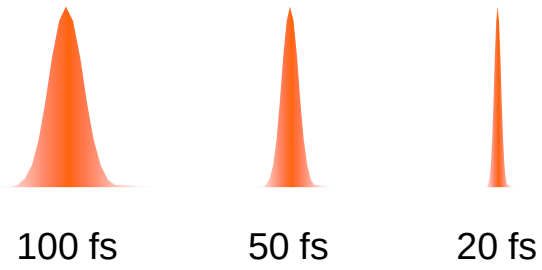
Laser intensities ~ 100 GW/cm²

1 x 10^{11} W/cm²

Laser pointer: 1 mW/cm² (1 x10^{-3} W/ cm²)

fs-laser micromachining

Ti:Sapphire lasers



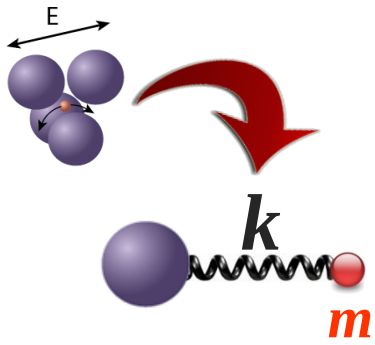
Very intense light

Nonlinear Optical Phenomena

Nonlinear optical response

hihg intensities

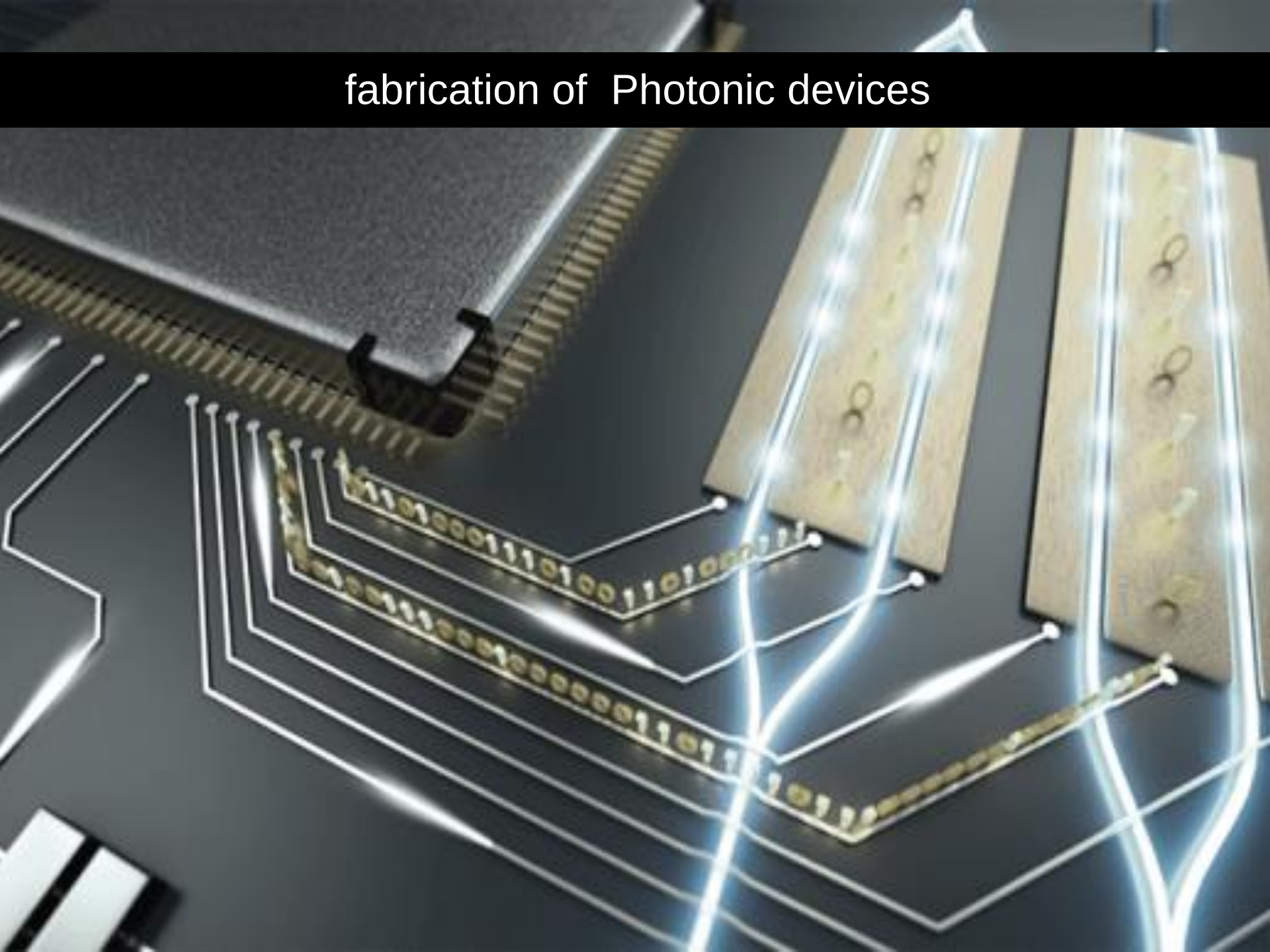
$E_{rad.} \sim E_{inter.}$



Nonlinear polarization

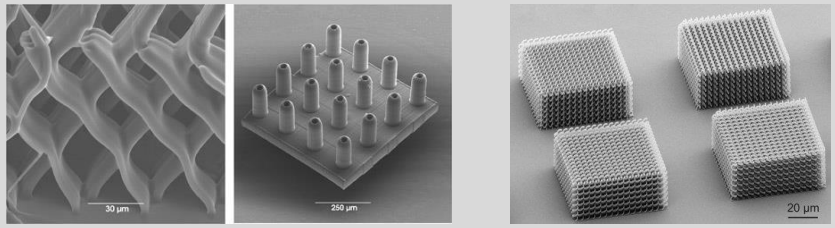
$$P = \varepsilon_0(\chi^{(1)}E + \chi^{(2)}E^2 + \chi^{(3)}E^3 + \ldots)$$

fabrication of Photonic devices



fabrication of Photonic devices

Fabrication:
capable of obtaining complex 3D structures

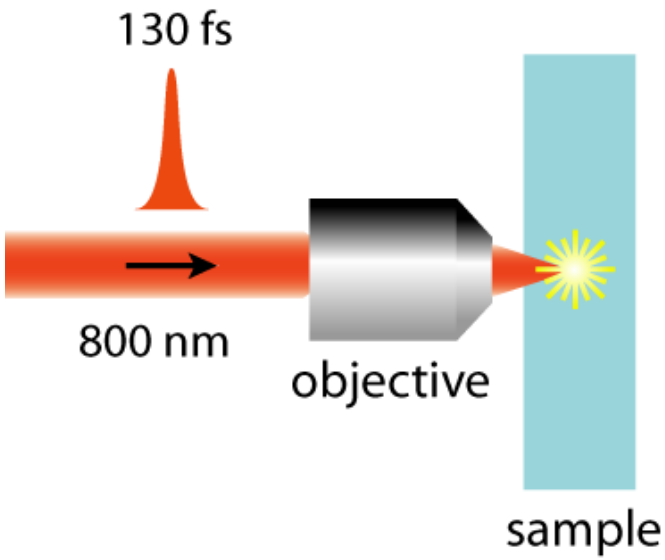


Materials:
expand the capabilities of devices

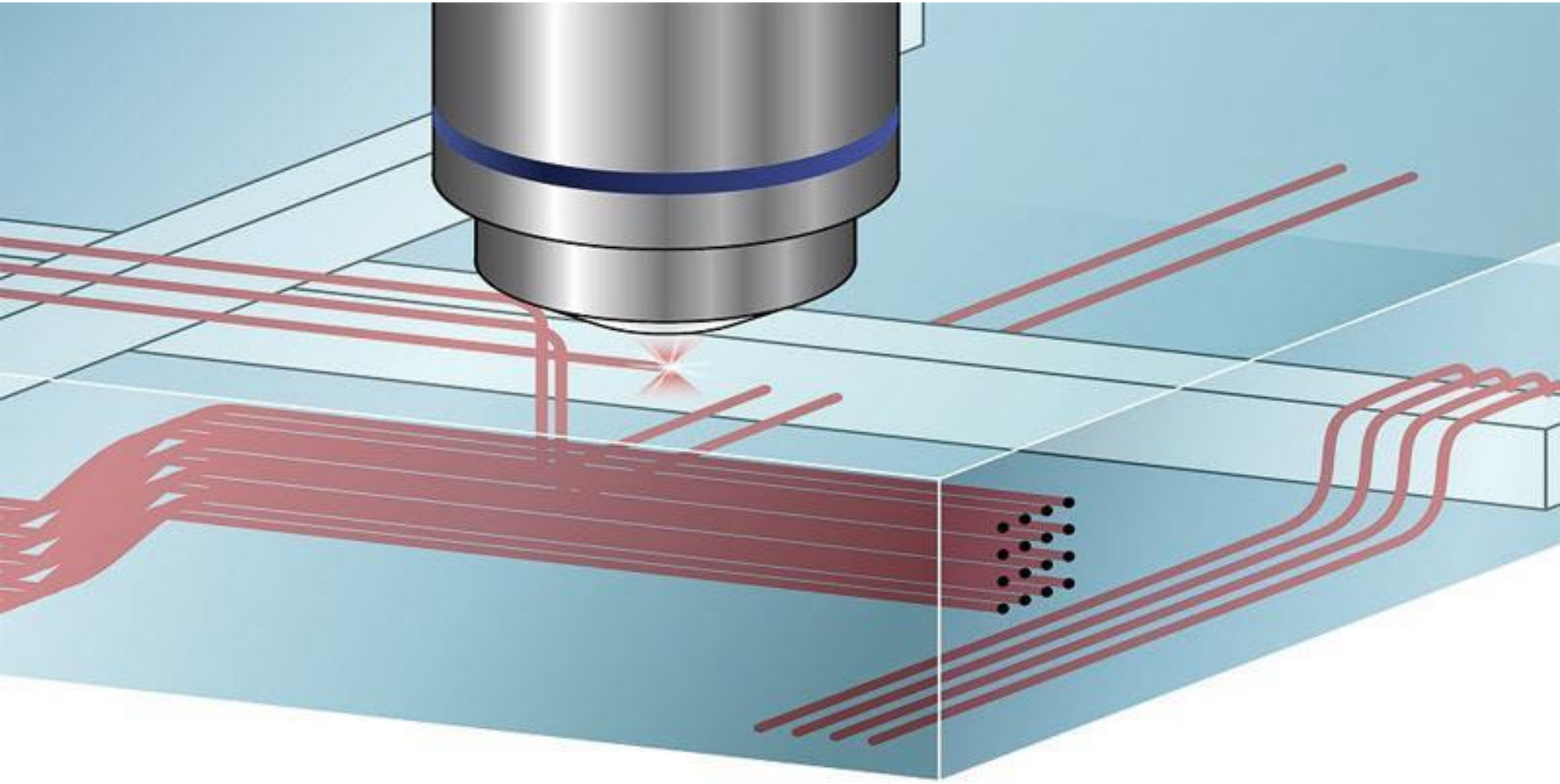
Strategies for obtaining fs-laser microfabrication of functional materials

Microfabrication

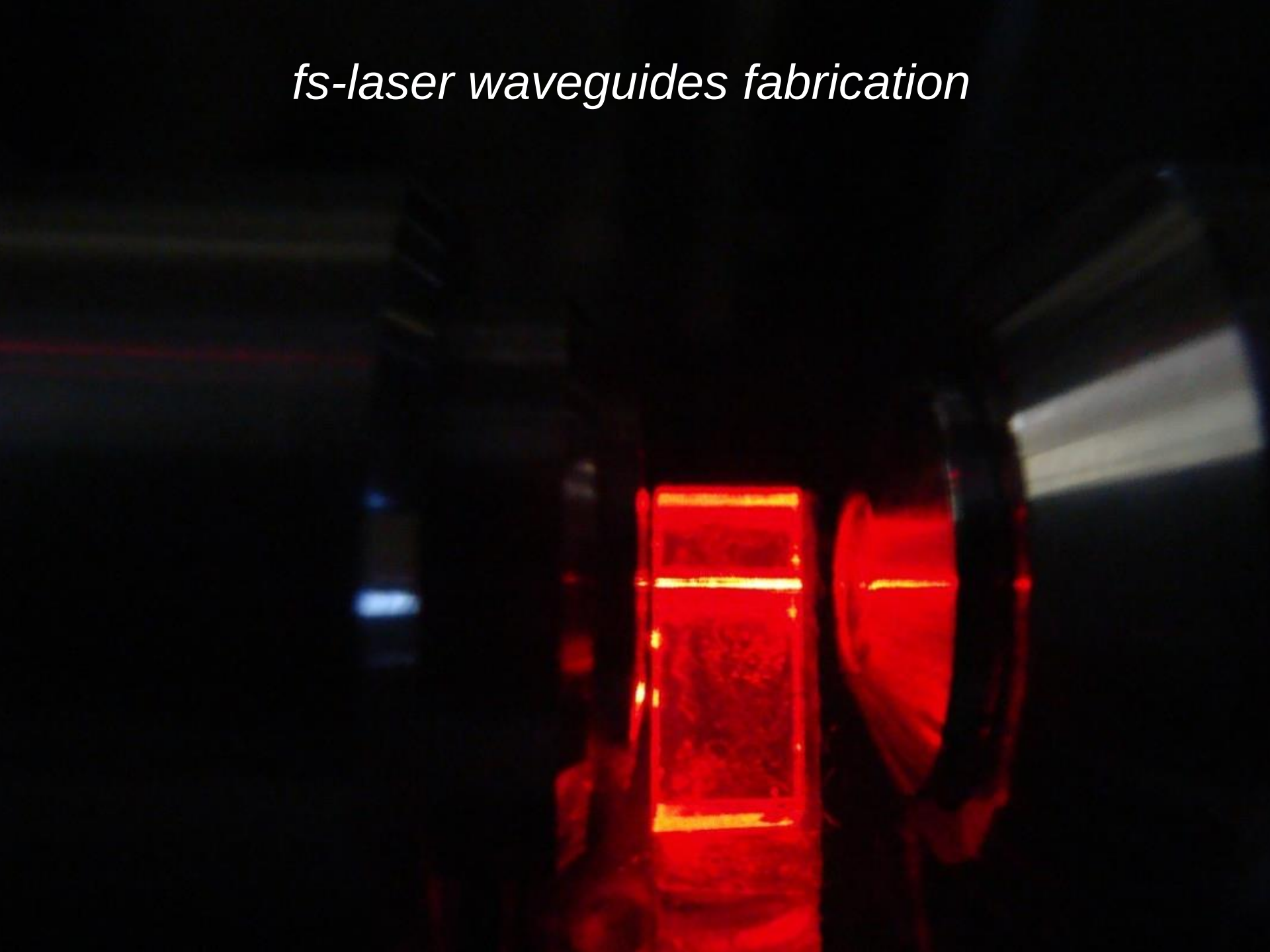
Microfabricate and microstructure materials using fs-laser and nonlinear optical processes



fabrication of 3D waveguides

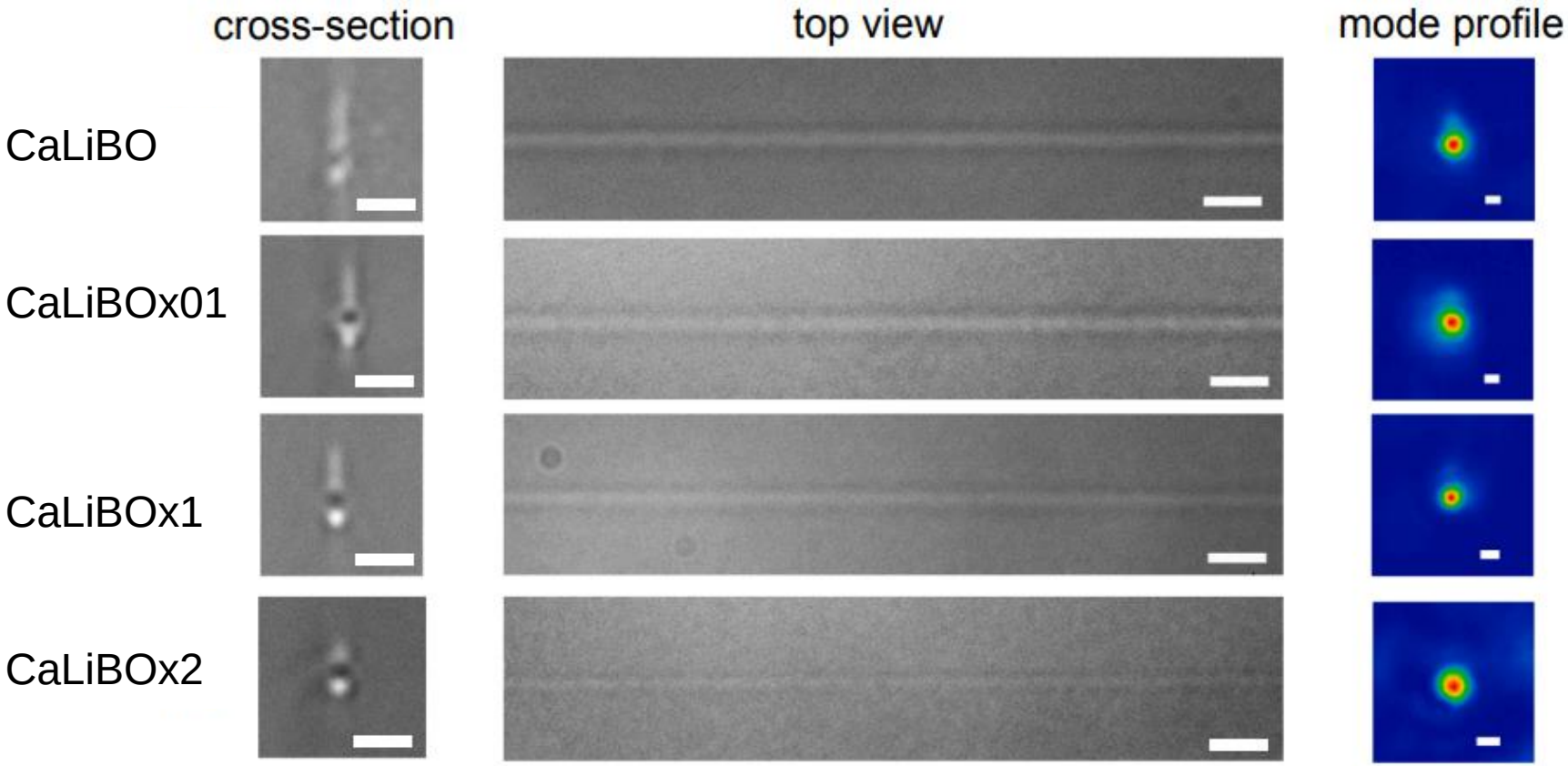


fs-laser waveguides fabrication

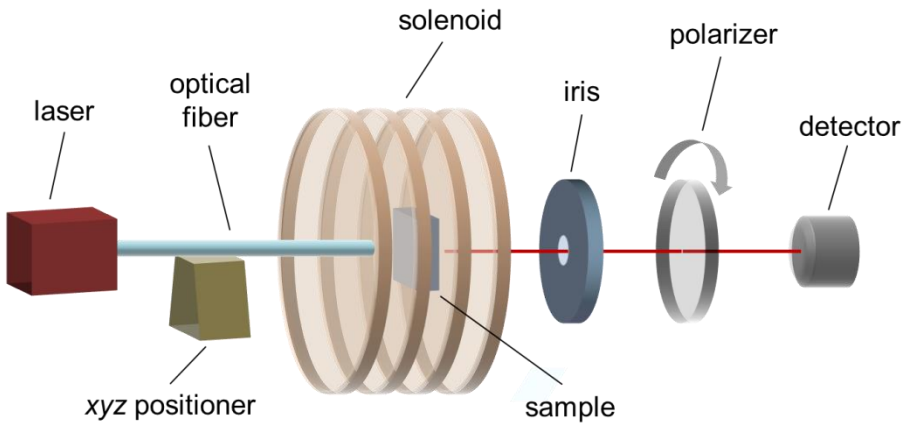


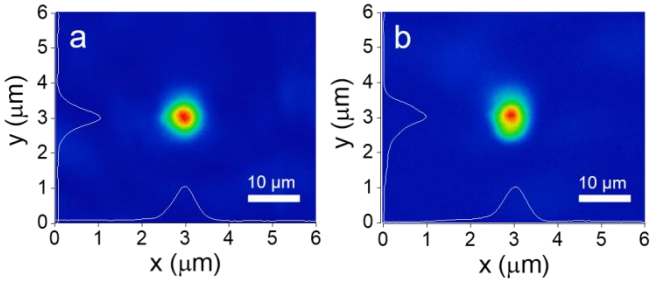
waveguides in CaLiBO glass

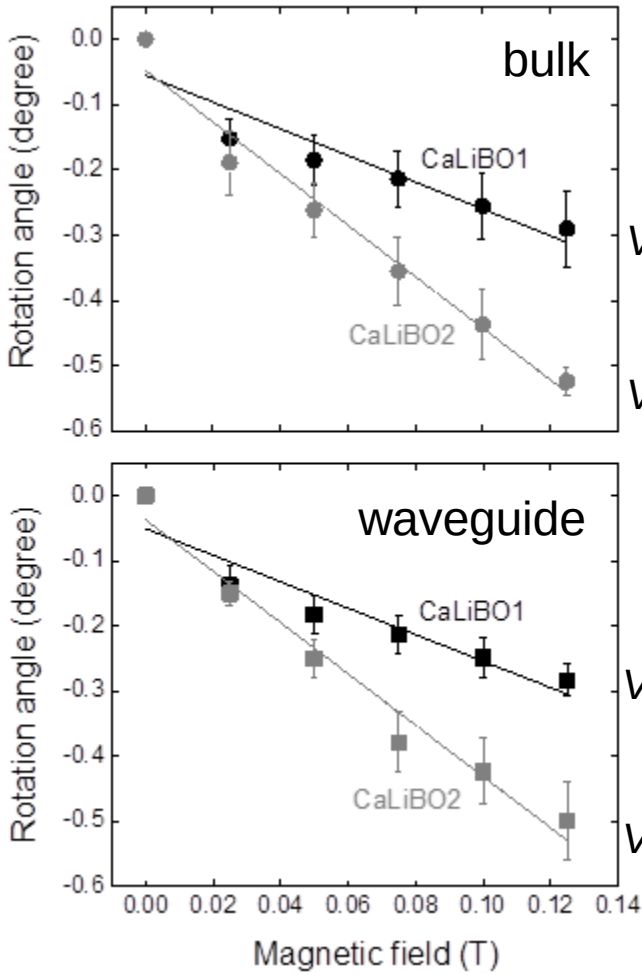
Waveguide microfabrication performed at 800 nm with 50 fs pulses at 5 MHz



Magneto-optical waveguides in CaLiBO glass







$V = -292\ °T^{-1}m^{-1}$

$V = -560\ °T^{-1}m^{-1}$

$V = -290\ °T^{-1}m^{-1}$

$V = -561\ °T^{-1}m^{-1}$

Gorilla® Glass

- huge popularity (~4.5 Bi devices)
- commercial impact
- wide transparence
- mechanically resistant
- excellent matrix to host femtosecond waveguide fabrication

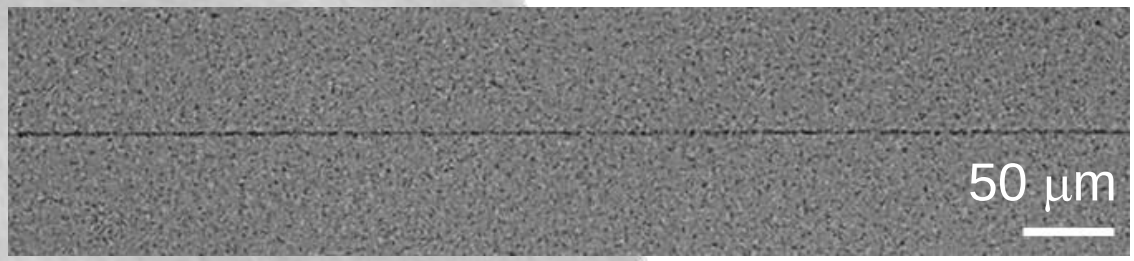
Study of Gorilla Glass nonlinearities: bulk and fs-laser inscribed waveguides

waveguides in Gorilla glass

Waveguide microfabrication performed at 775 nm with 150 fs pulses at 1 kHz

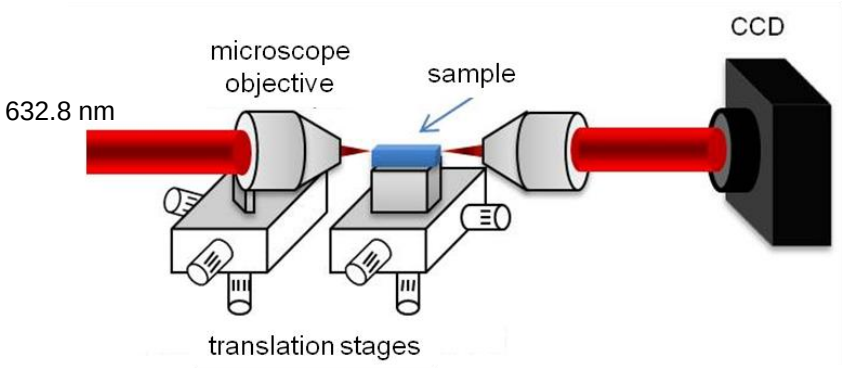
15 mm long
100 μm bellow surface

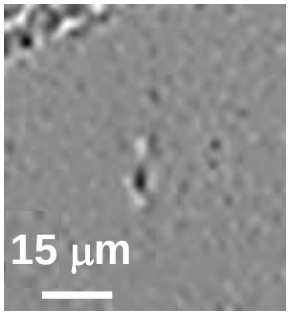
E= 250 nJ

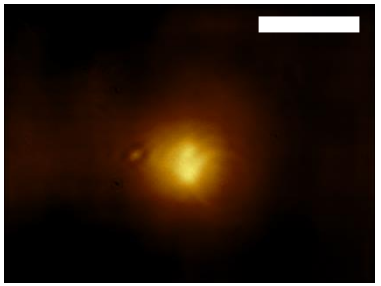


waveguides in Gorilla glass

Coupling light into the waveguides





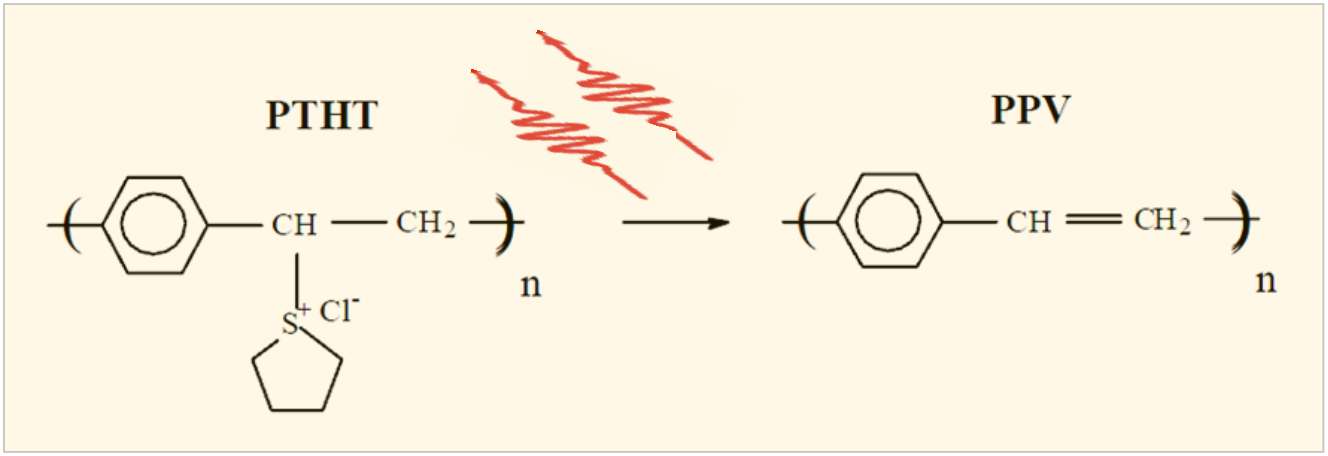


Coupling cw light at 775 nm and 632.8 nm

Guided modes intensity distributions

Total losses

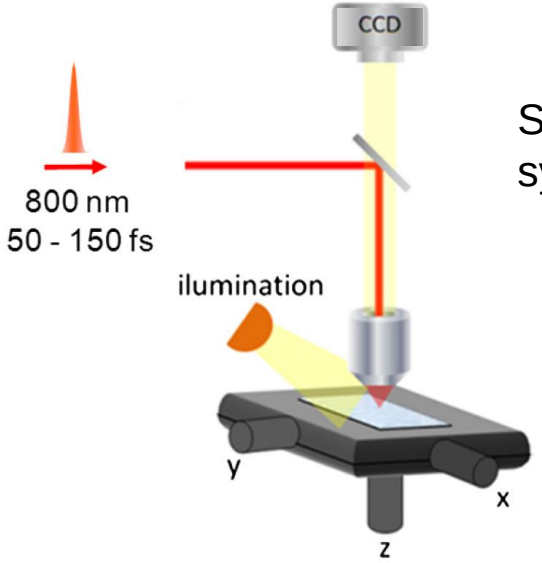
fs-laser synthesis of PPV



800 nm, 50-150 fs

5 MHz
v = 5 - 100 µm/s
E = 15 - 35 nJ

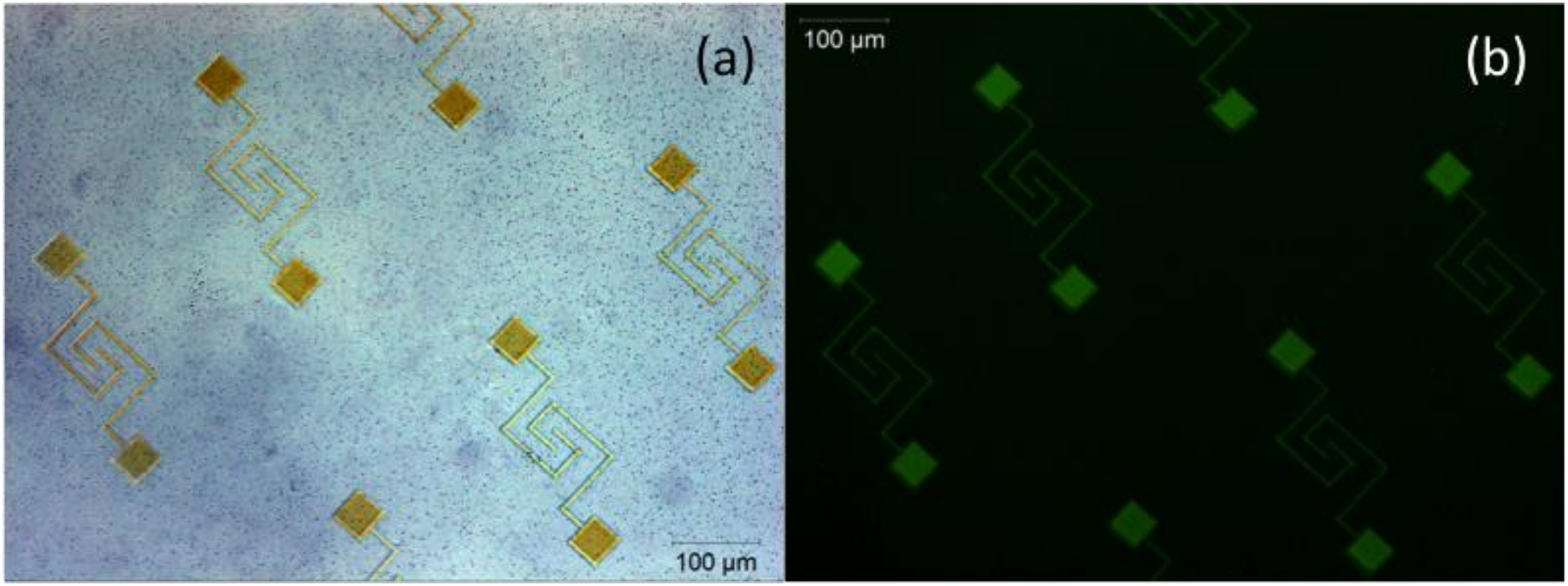
86 MHz
v = 50 µm/s
E = 0.44 - 0.8 nJ



Spatial localized PPV synthesis

fs-laser synthesis of PPV

Bright field **Fluorescence**



microcapactitors

Production of color centers in diamond

Quantum information technology needs physical systems capable of processing quantum information.

Solid-state qubits have being considered promising candidates due to its capacity of hosting isolated and optically accessible quantum structures at room temperature.0

Diamond

Diamond stands out for its optically active defects, specially negatively charged nitrogen-vacancy (NV^-) color center.

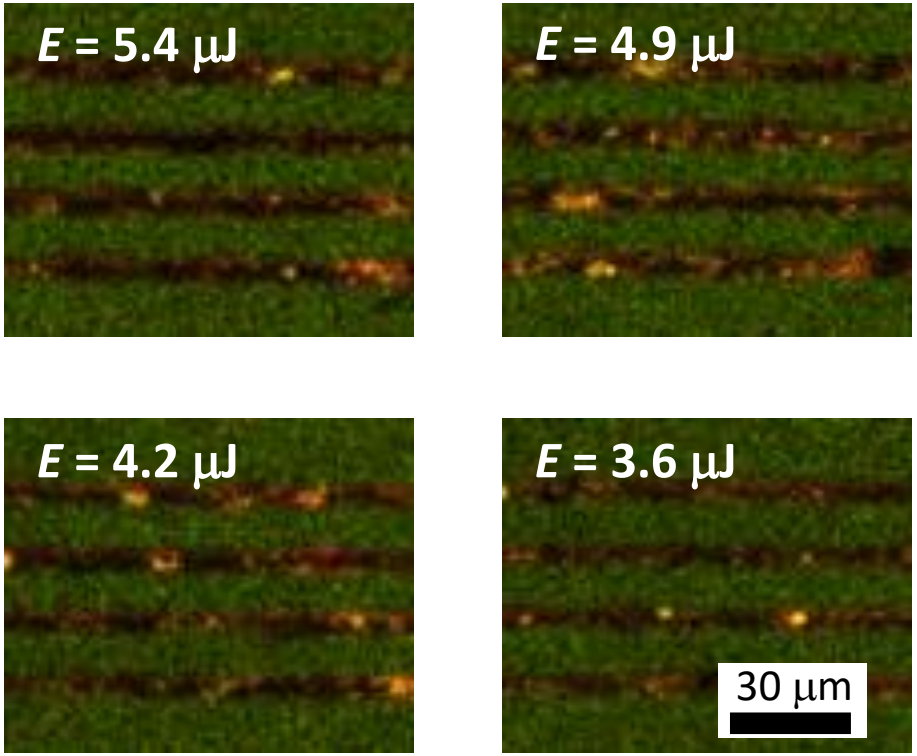
Diamond

- wide transparency
- high refractive index of ~2.4 (visible)
- 5.45 eV energy gap
- high hardness
- excellent host for color centers
  - **NV^-**

Localized production of NV^- centers in diamond

Fluorescence microscopy

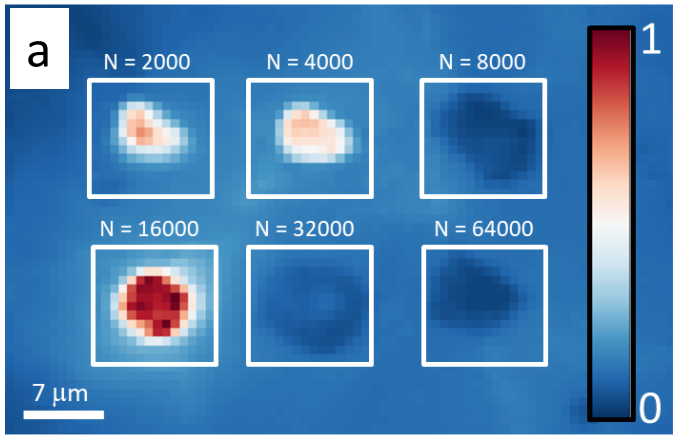
Zeiss LSM- 780 with excitation at 543 nm

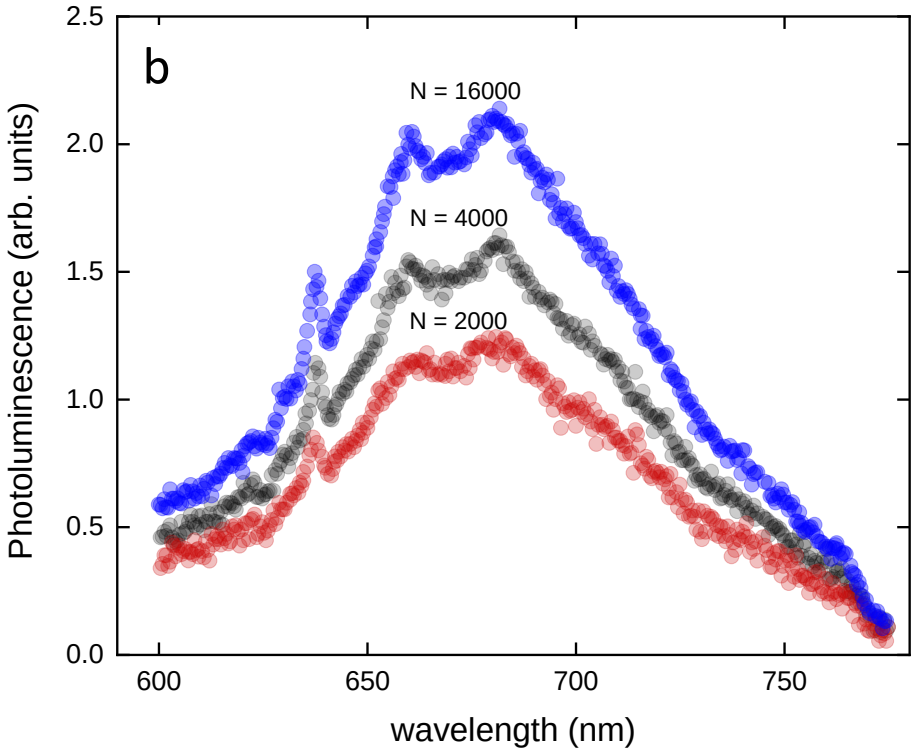


We observe many optically active deffects emitting fluorescence

Production of NV centers

- positioning the beam focus 15 µm above sample surface
- irradiating with 2.5 µJ with different number of pulses

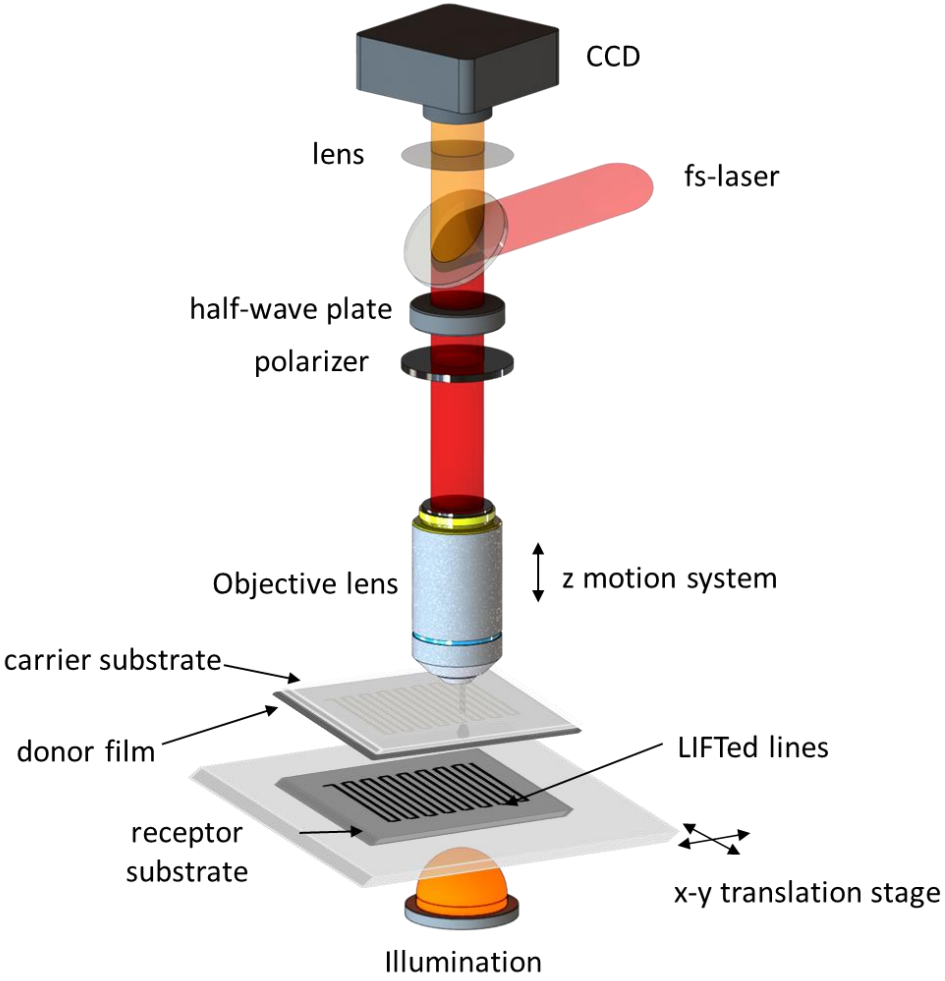




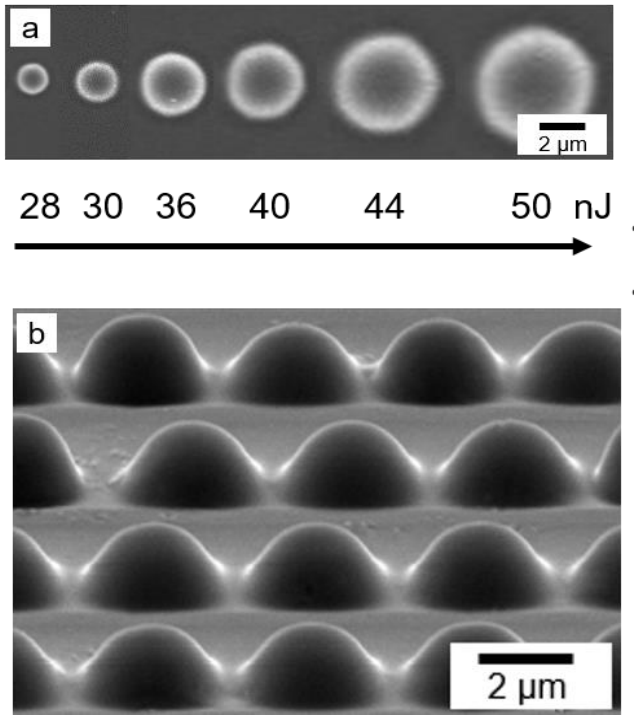
Photoluminescence images
Excitation at 532 nm

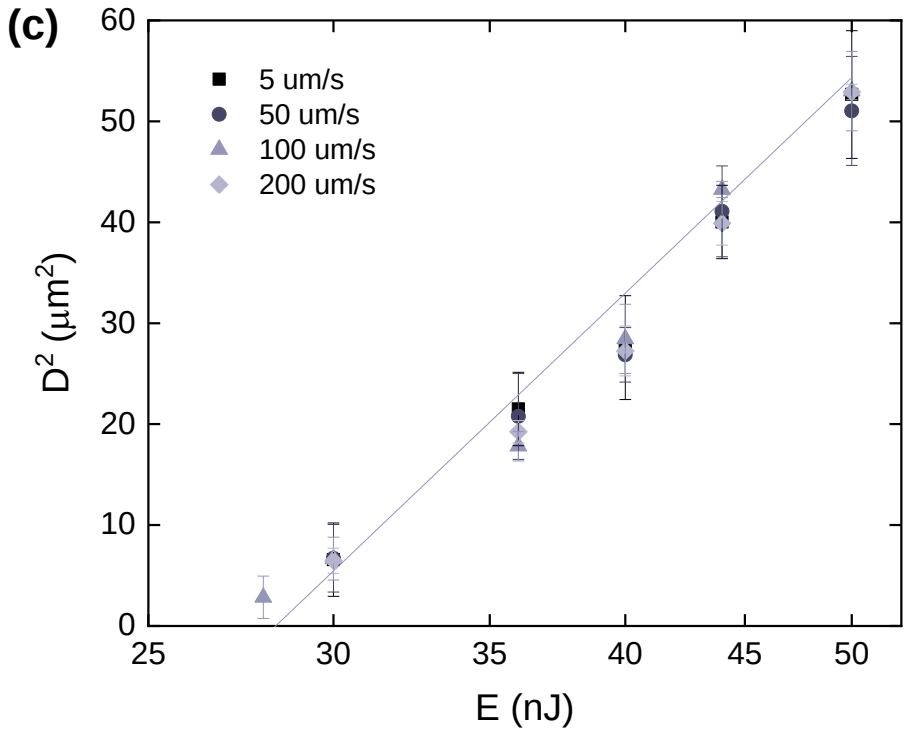
LIFT: Laser induced forward transfer

A transfer process allowing the deposition of a small amount of material in solid or liquid phase with high resolution.

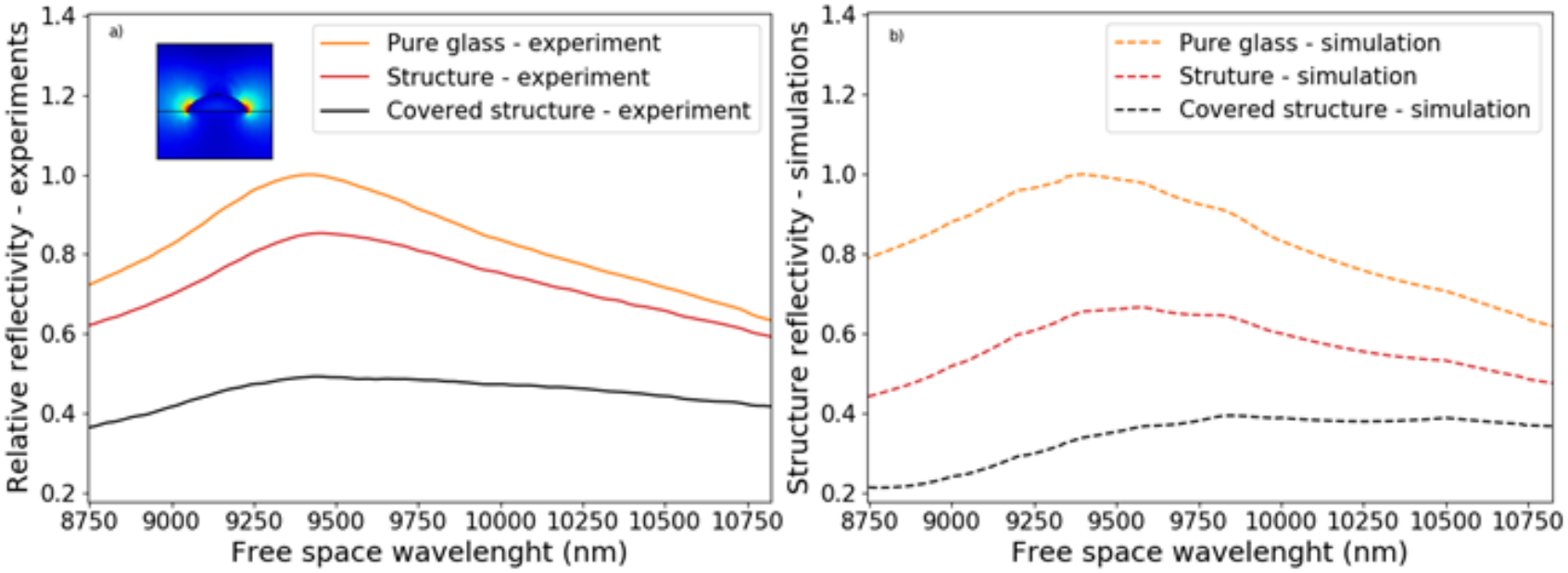


Fibroin LIFT

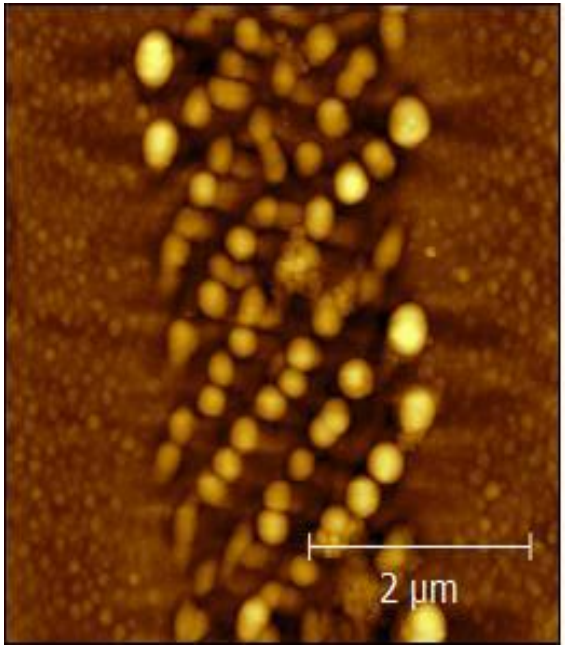


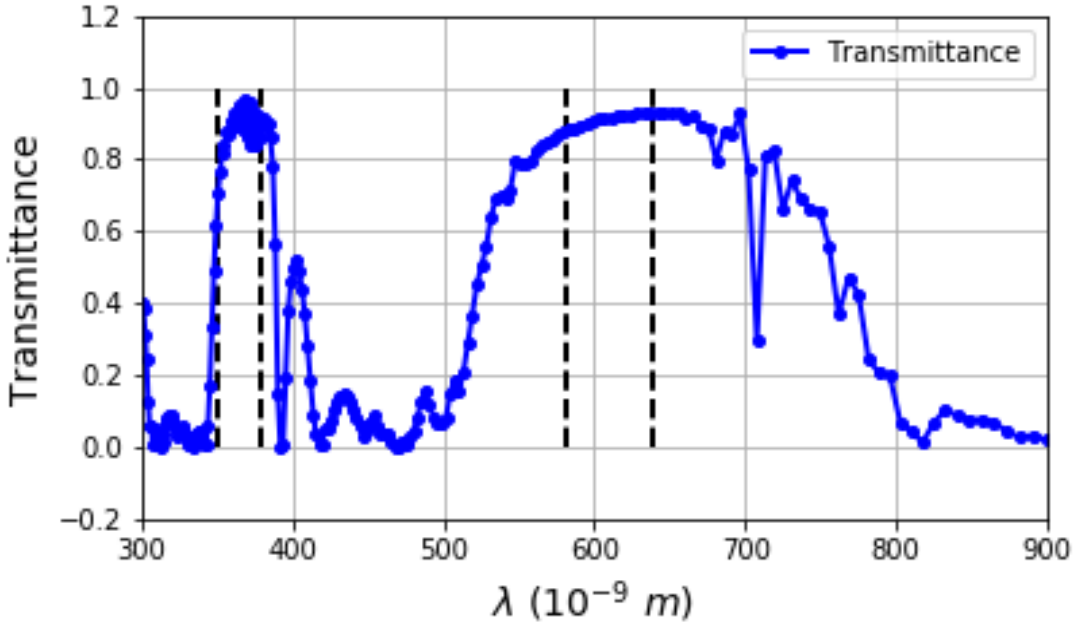


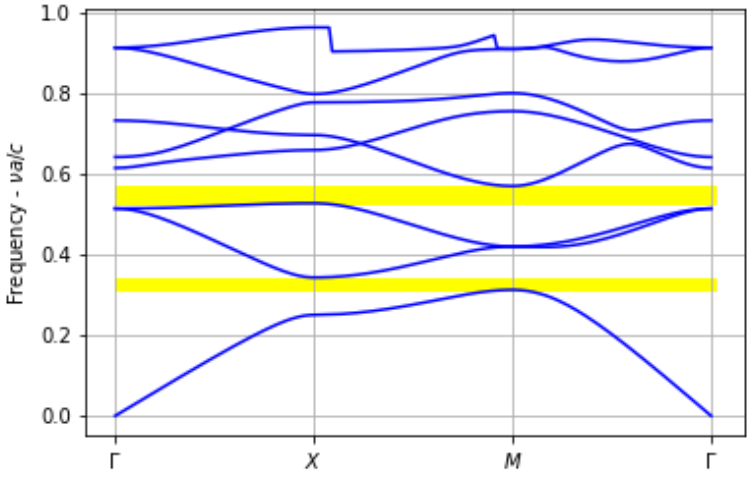
Fibroin Periodic Structures



Photonic crystal structures







Photonic crystal waveguide !

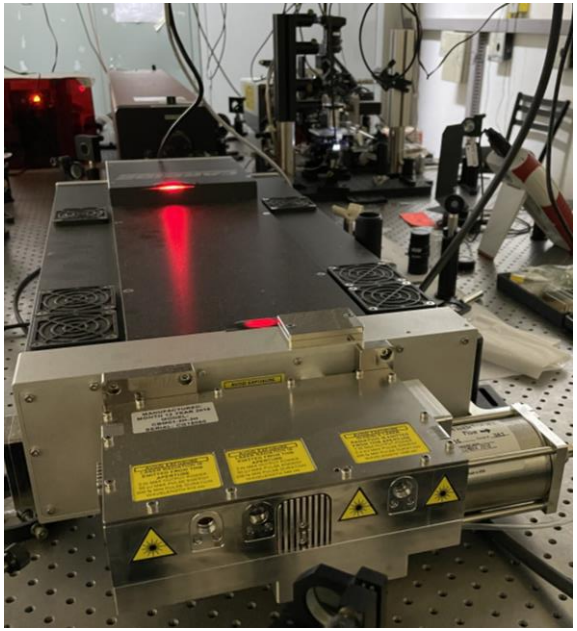
As2S3

LIFT of Platinum

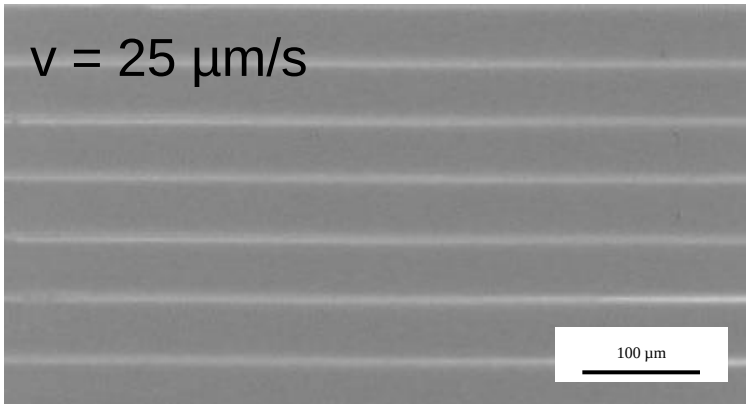
Platinum:

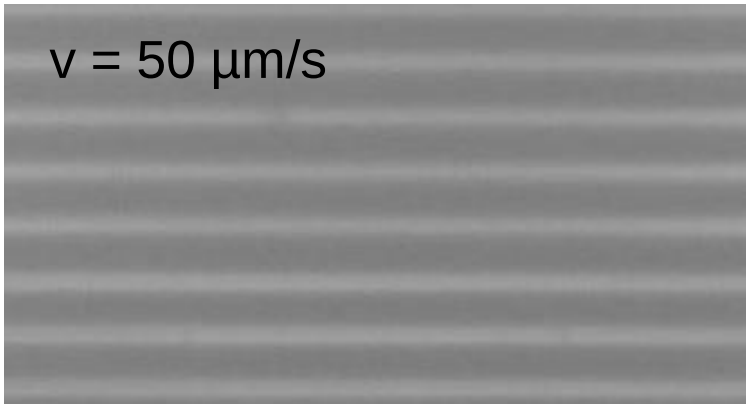
Many applications;
Low reactivity;
High melting temperature;
Optical/photonic devices

LIFT of Platinum

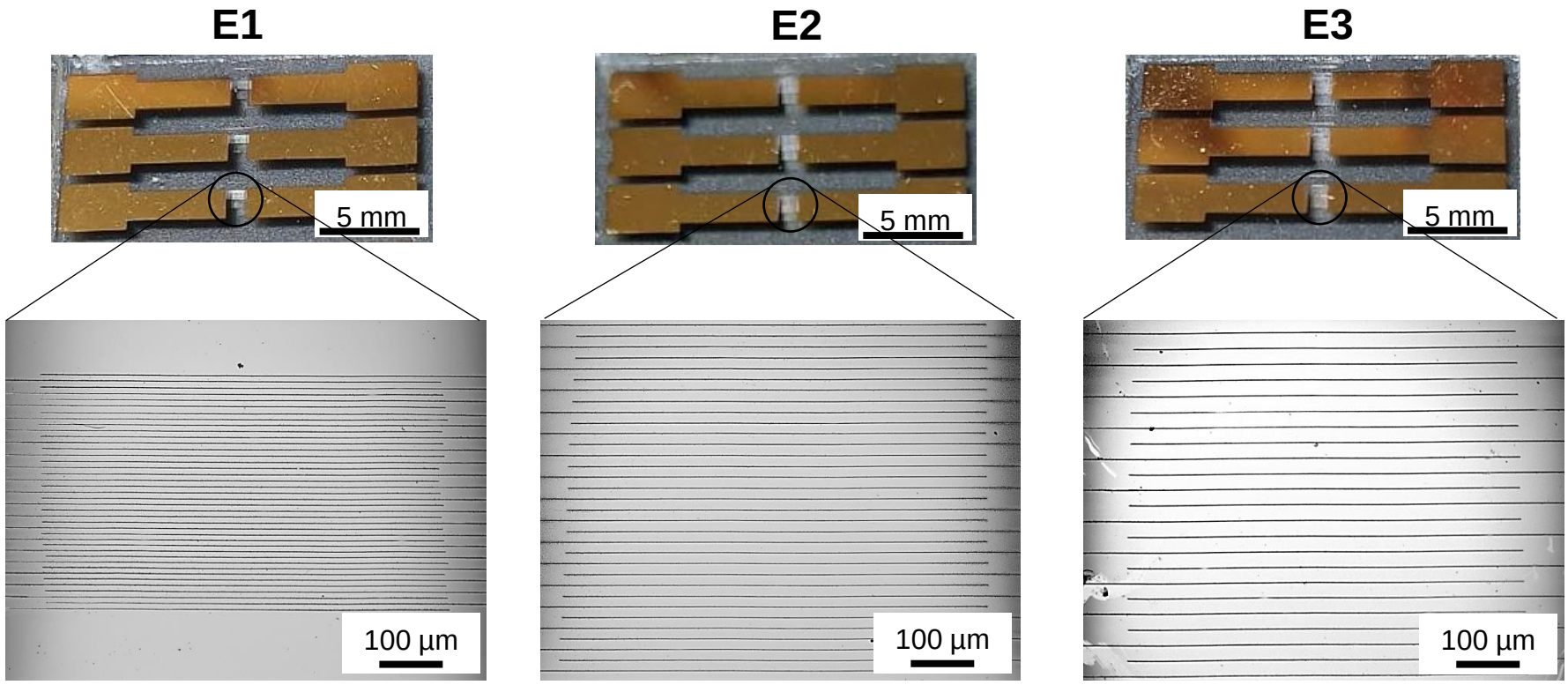


- Diode-pumped Yb:KGW;
- Centered at 1030 nm;
- Repetition rates from 1 to 12 kHz;
- Pulse energies from 0.2 to 15 µJ;
- Scanning speeds: 25 and 50 µm/s.





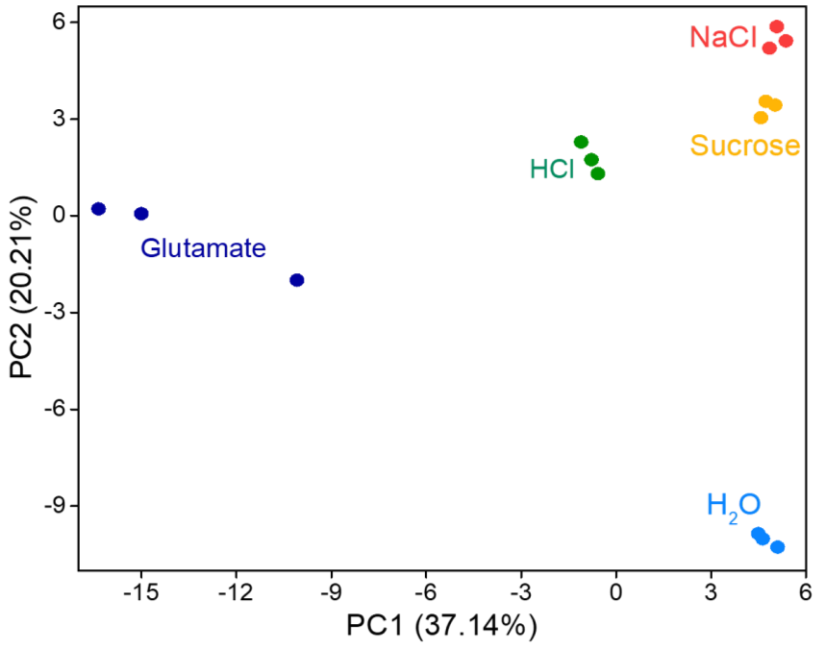
LIFT GO-Si Xerogel

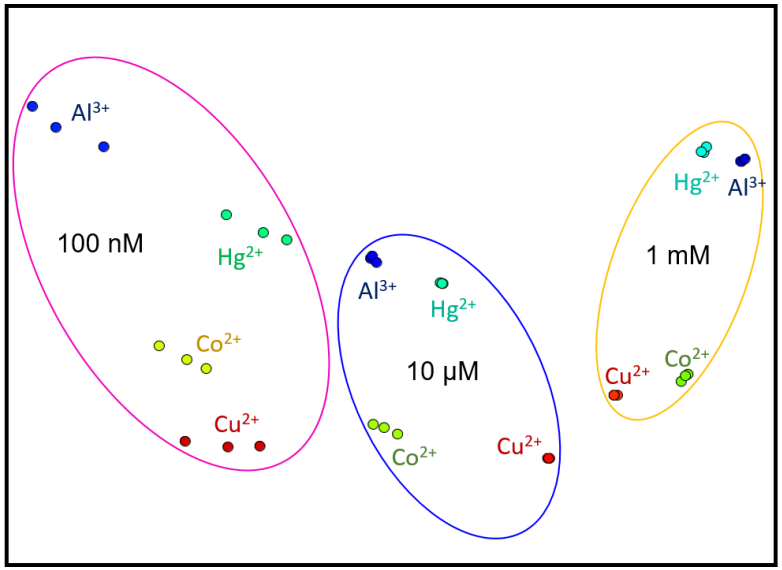


LIFT GO-Si Xerogel

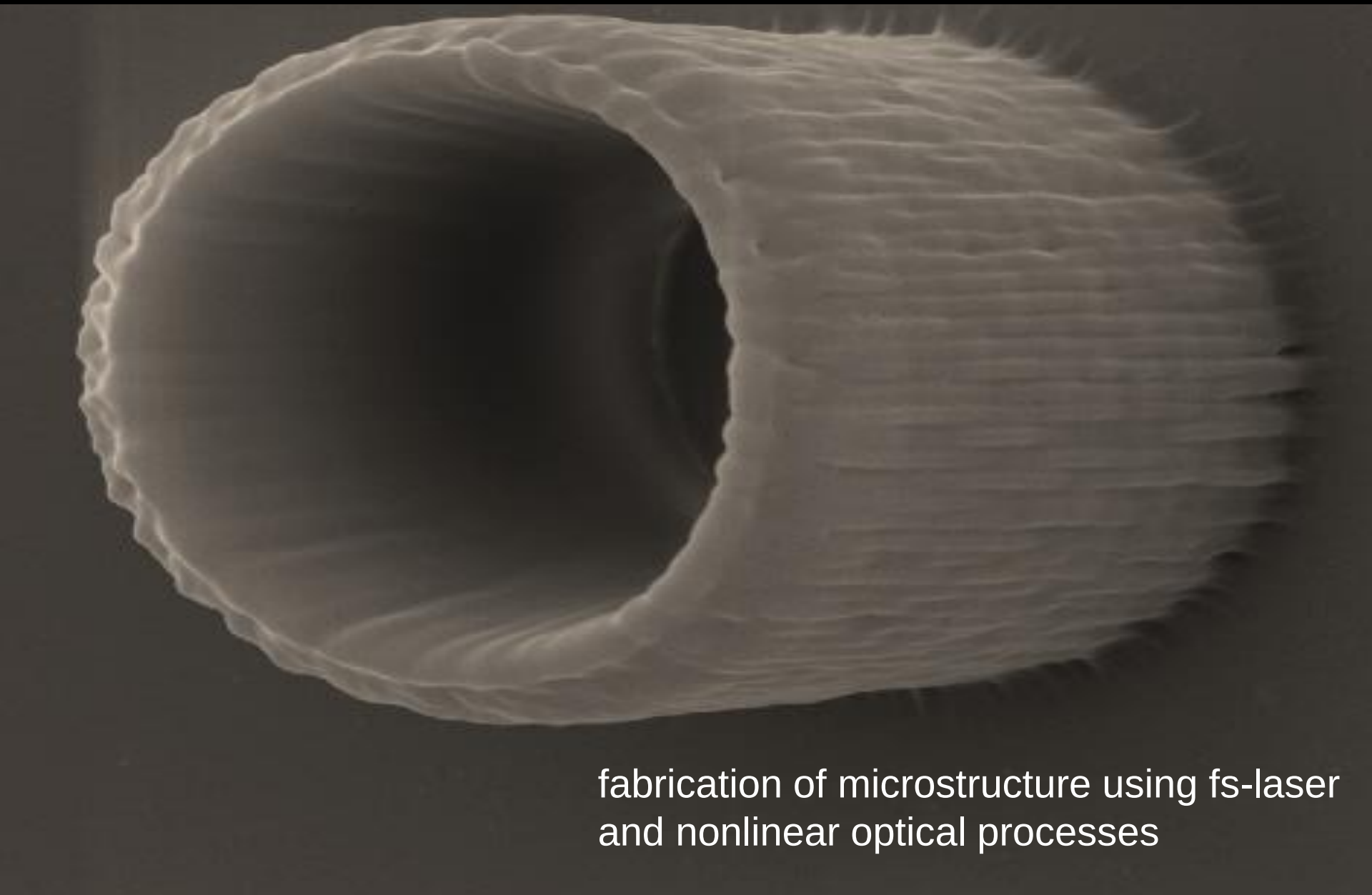
- *Flavor separation (classic application for electronic tongue) using the three electrodes and impedance measurements (Z' and Z").*
- *It demonstrates the potential of electrodes for use in an array sensor.*

- *The electrodes were able, through the impedance data (Z' and Z"), to separate the different heavy metals in terms of concentrations.*





fs-laser microfabrication



fabrication of microstructure using fs-laser and nonlinear optical processes

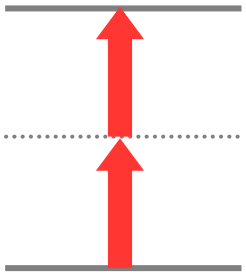
Two-photon polymerization

Monomer + Photoinitiator $\rightarrow$ *Polymer*

laser pulse

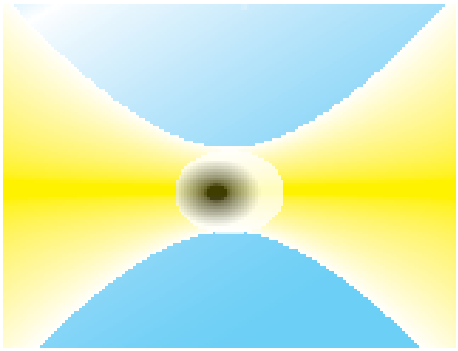
100 fs

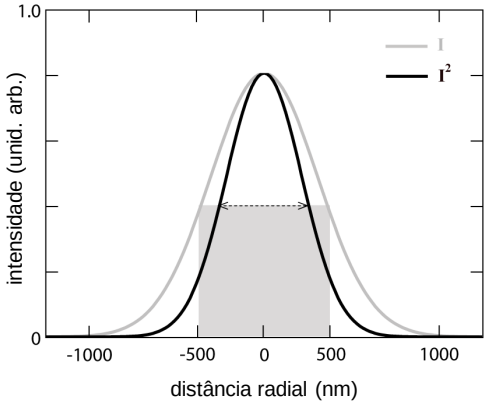
Photoinitiator is excited by ***two-photon absorption***



$$R \propto I^2$$

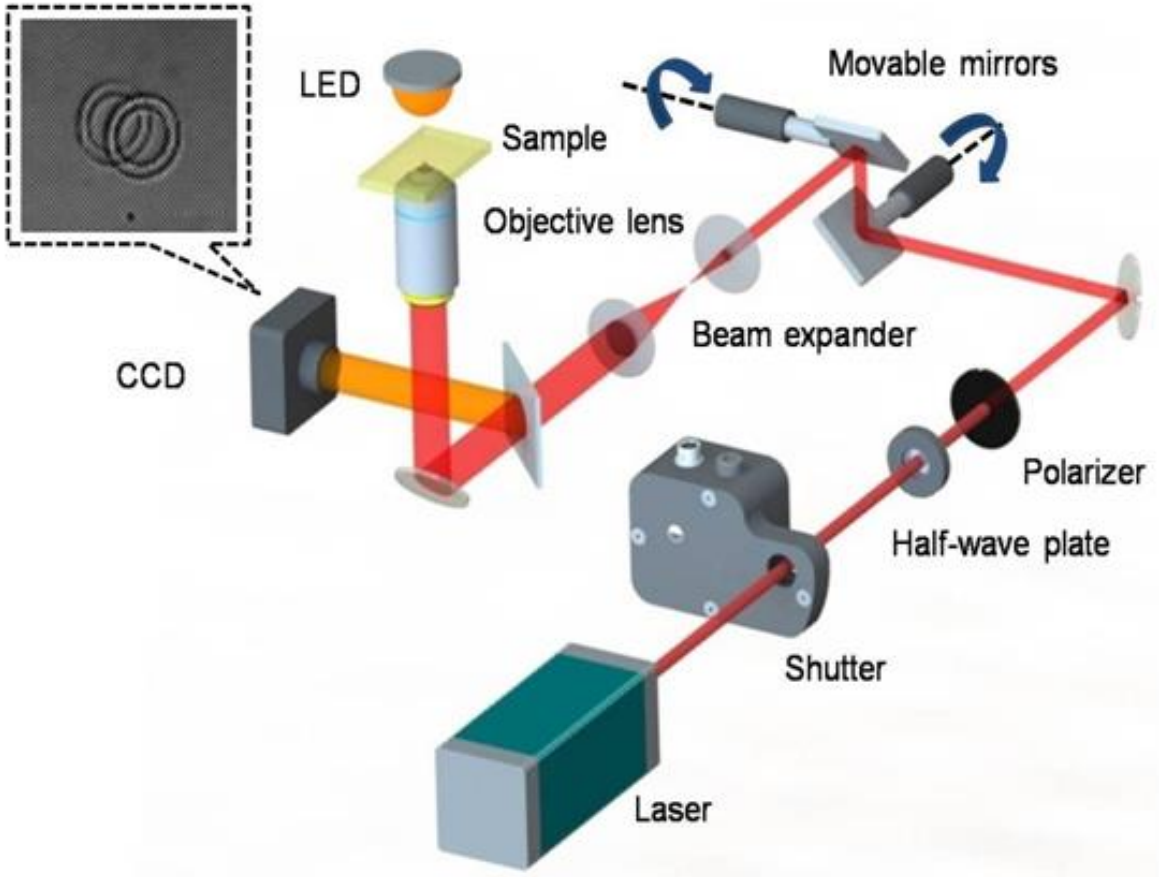
The polymerization is confined to the focal volume.





High spatial resolution

Two-photon polymerization setup



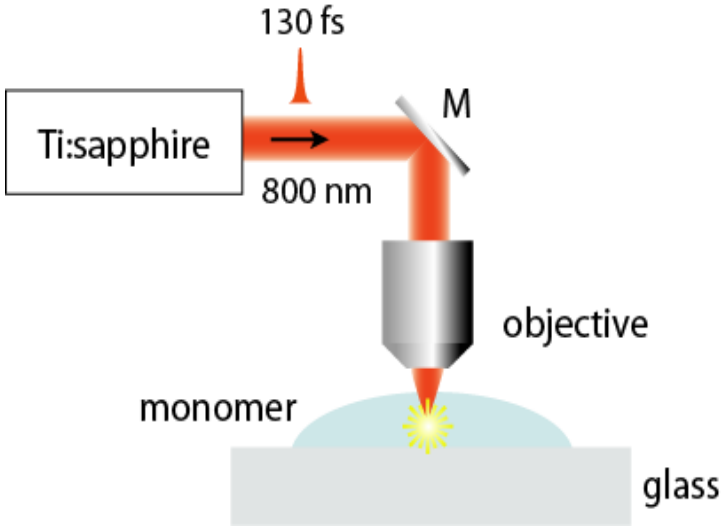
Ti:sapphire laser oscillator

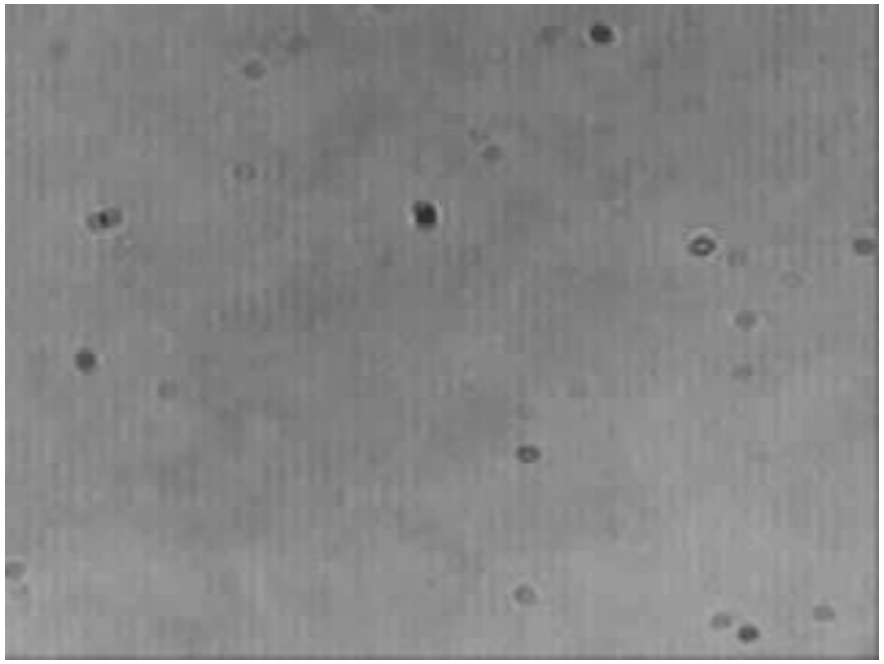
- 50 fs
- 800 nm
- 80 MHz
- 20 mW

Objective

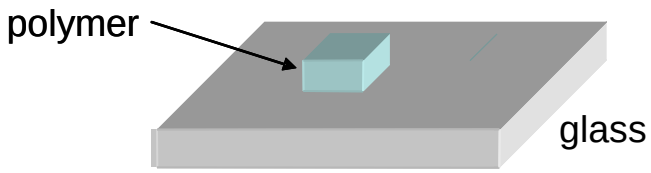
40 x
0.65 NA

Two-photon polymerization



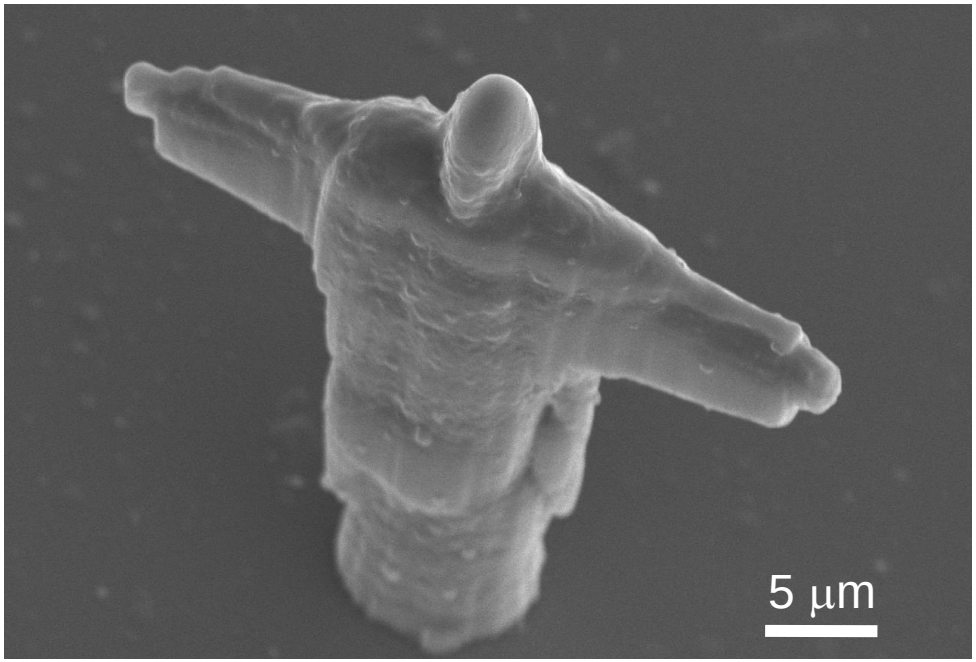


30 µm x 30 µm x 12 µm cube



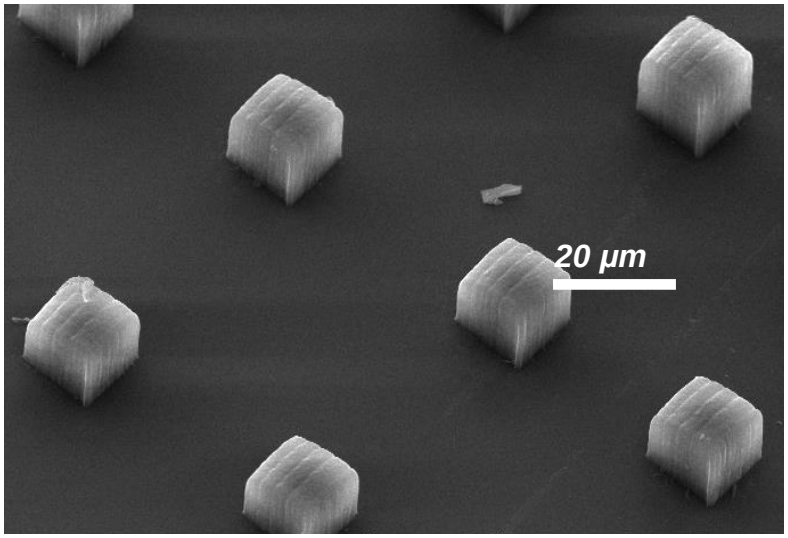
two-photon polymerization

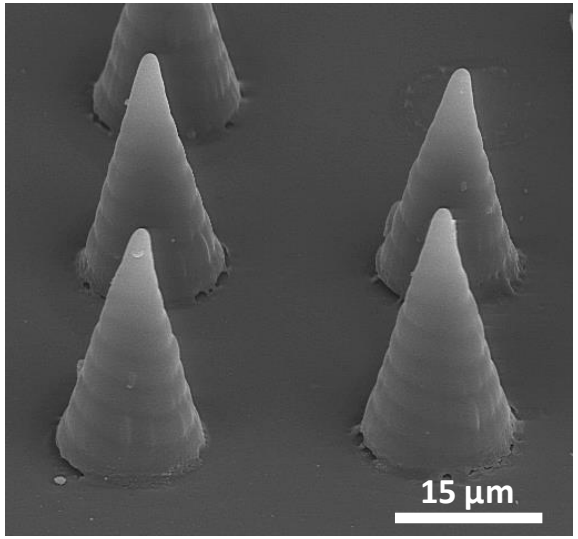
Microstructure fabricated by two-photon polymerization

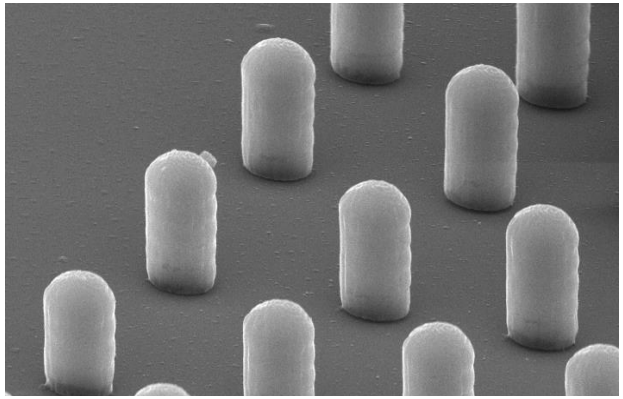


Two-photon polymerization

Microstructures fabricated by two-photon polymerization

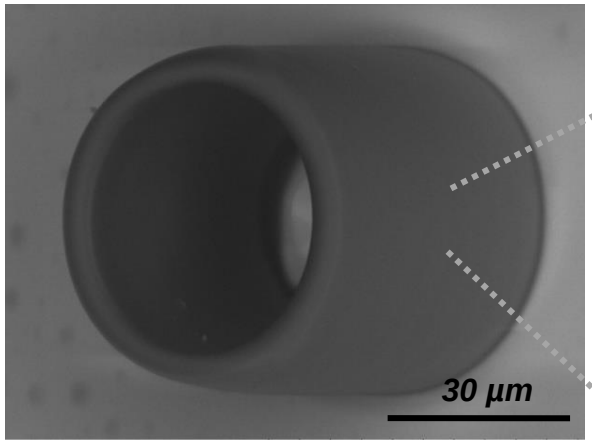


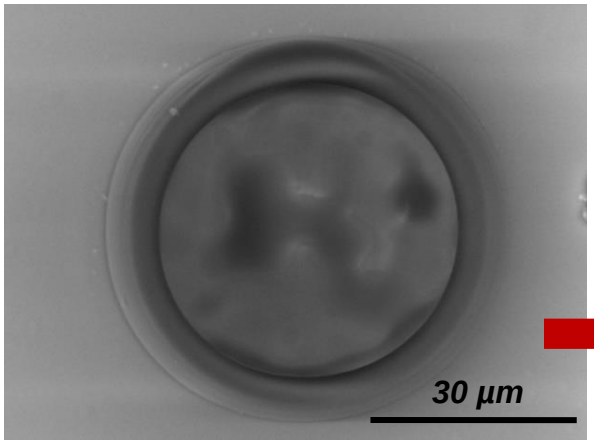


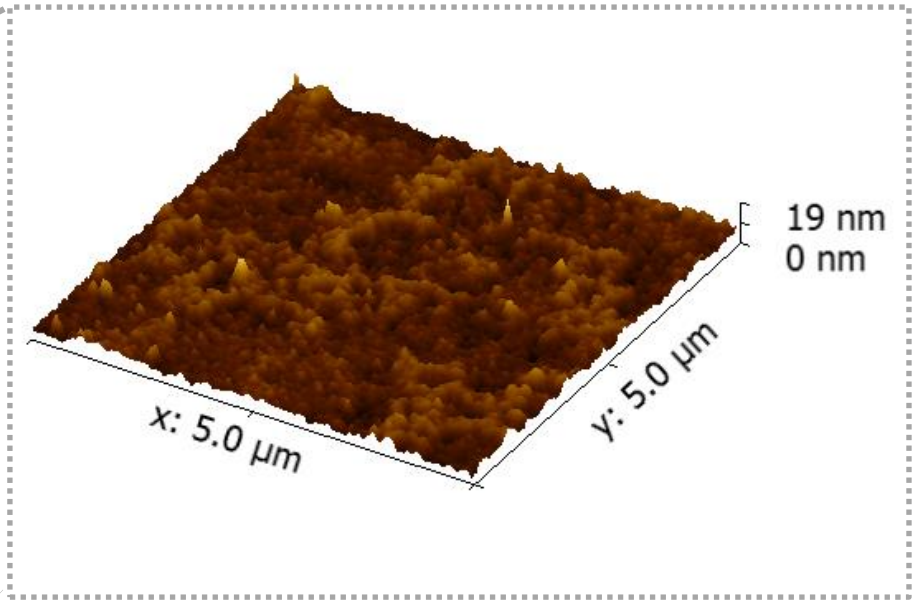


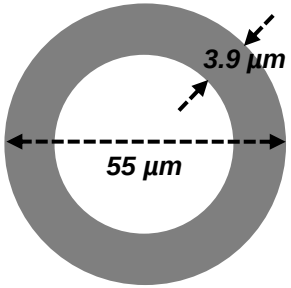
Microresonator - roughness

Good structural integrity and great optical quality





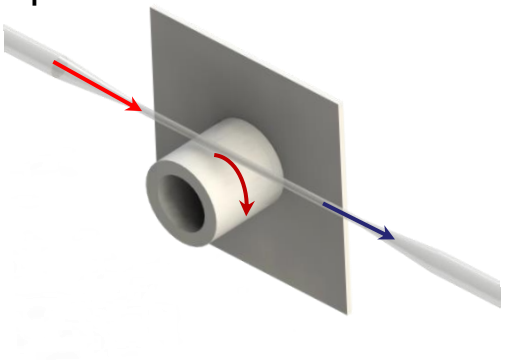


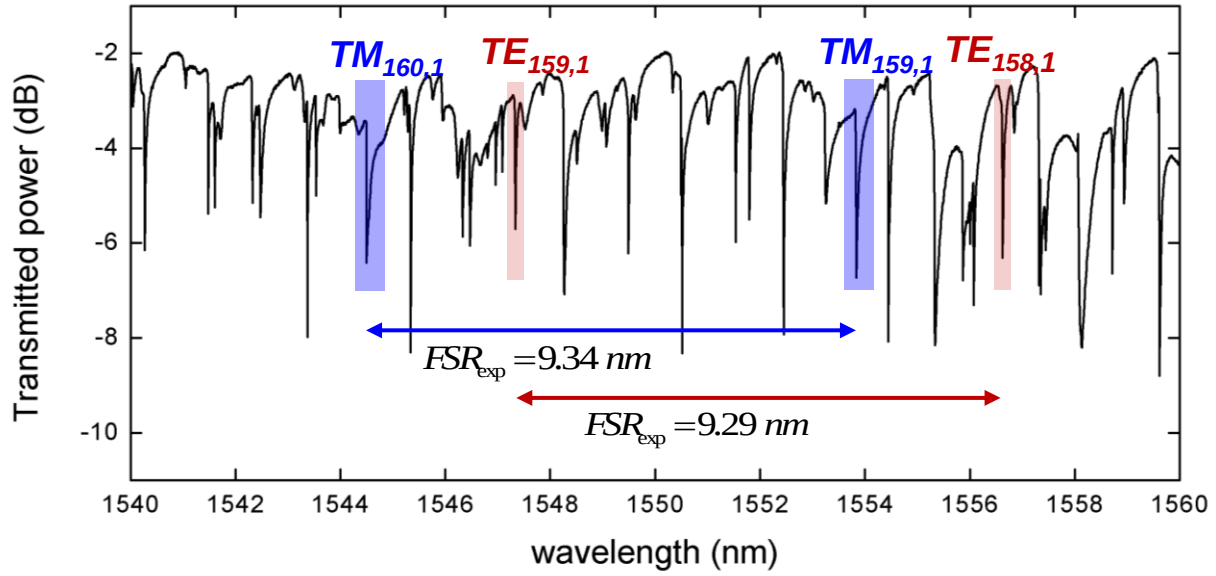


1.9 nm rms roughness (σ_{rms})

Microresonator - modes

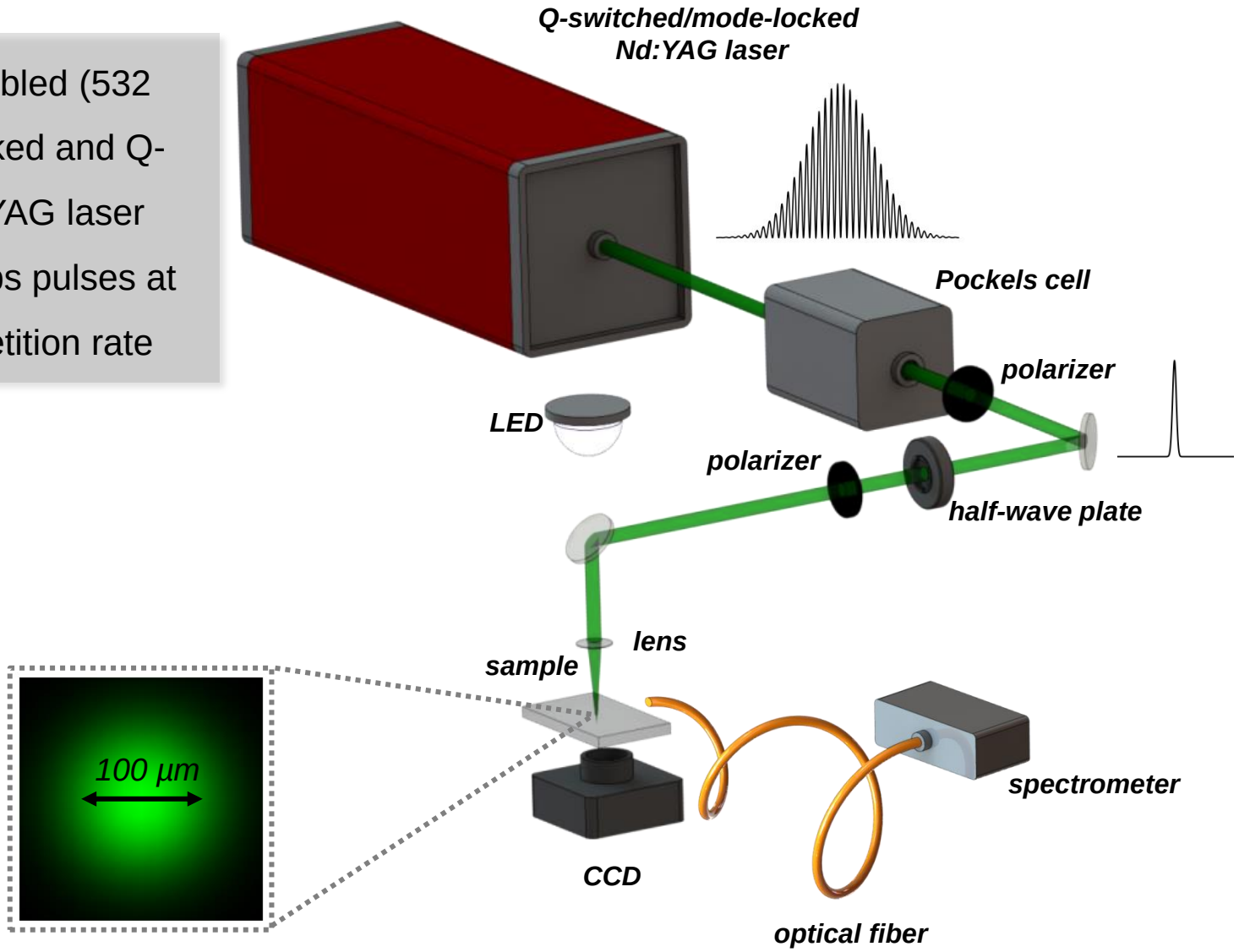
Coupling based on evanescent wave with tapers



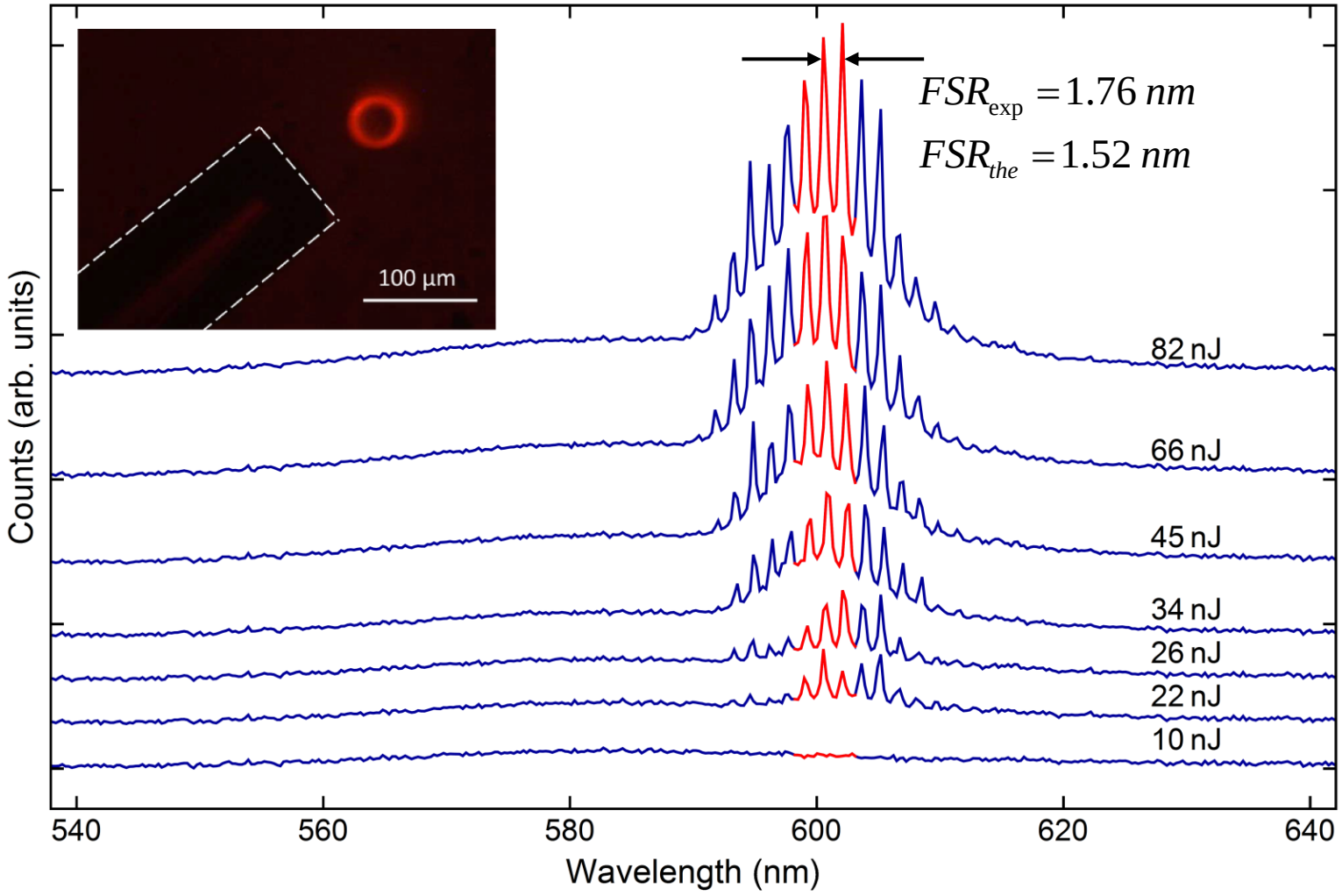


Pumping the microresonators

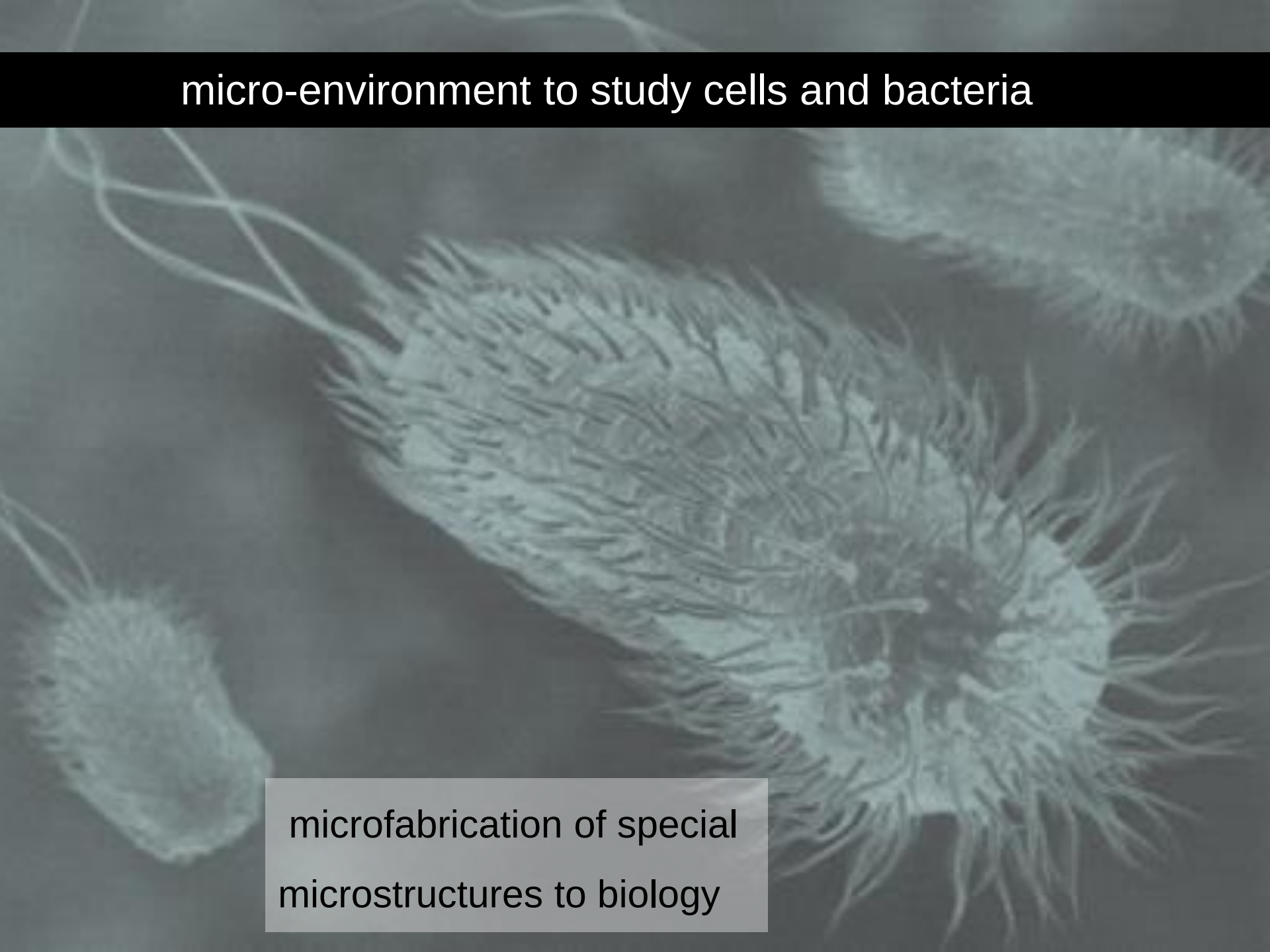
frequency-doubled (532 nm), mode-locked and Q-switched Nd:YAG laser producing 100 ps pulses at 100 Hz of repetition rate



Microresonators emission



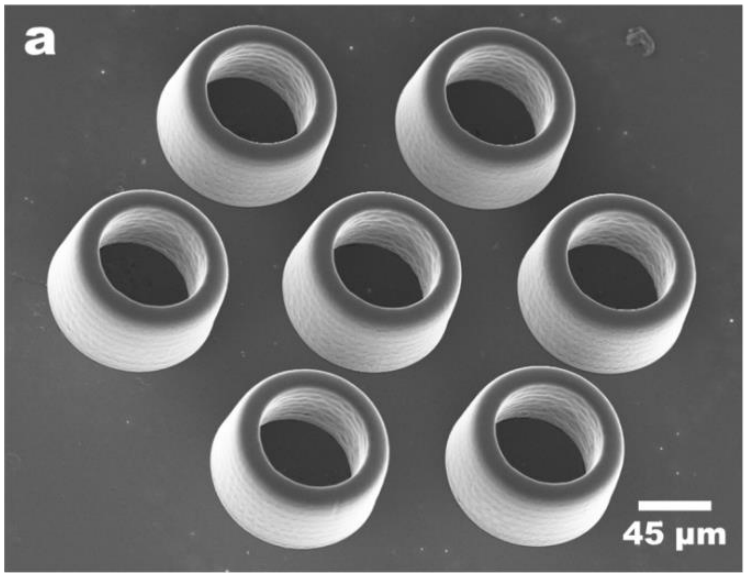
micro-environment to study cells and bacteria



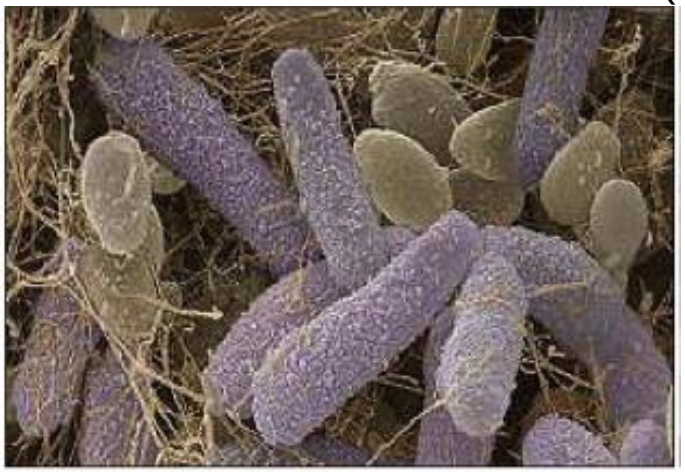
microfabrication of special microstructures to biology

Bacterial cellulose growth on 3D micro-environments

Miniaturized environments have emerged as an excellent alternative to evaluate and understand biological mechanisms.



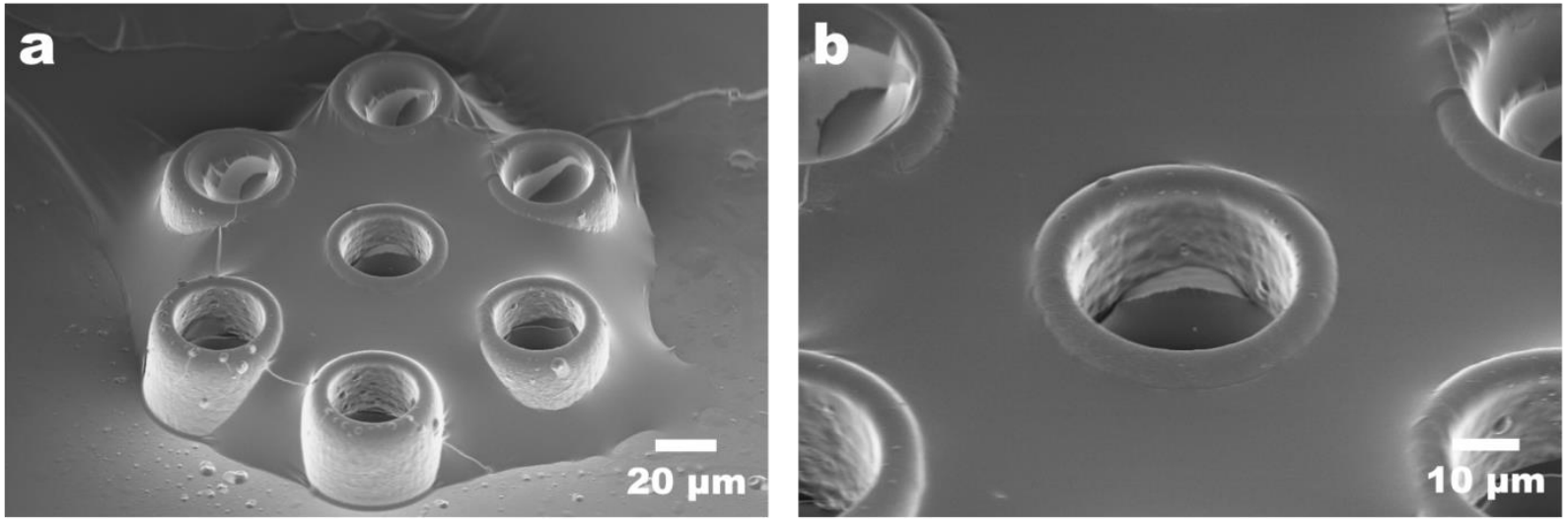
Komagataeibacter xylinus → bacterial cellulose (BC) growth



- BC is a natural polymer with several biological applications
  - Completely biocompatible
  - Tissue engineering
  - Drug delivery

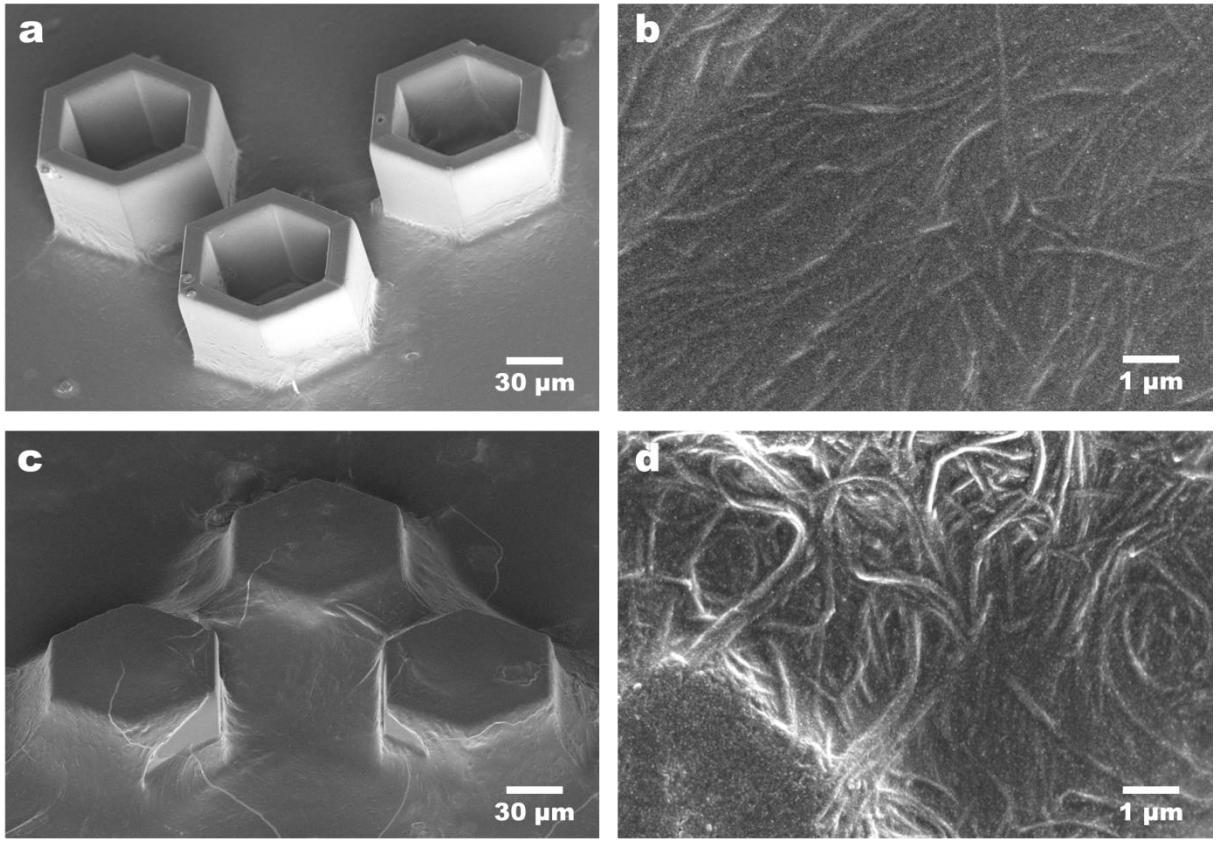
Bacterial cellulose growth on 3D micro-environments

Bacterial cellulose grown on the microstructures fabricated with hybrid matrices. (a) It is possible to observe a good adhesion of the formed BC film around the microstructures, including (b) inside the cylinders.



Bacterial cellulose growth on 3D micro-environments

(a) BC film formed after 6 h of the bacteria incubation and (b) SEM image of the BC network grown in these structures. (c) BC film formed after 24 h of the bacteria incubation and (d) SEM image of the BC network grown in these structures.



The end

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Virtual Lab Tour

https://youtu.be/tDzJ7v0olsA