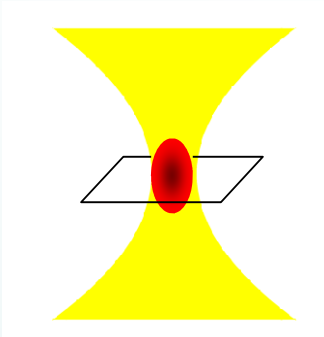
Two Photon Stereolithography (TPS)

Advantage

- sub-100 nm Resolution
  - energy threshold in polymerization (inhibitor: oxygene, amine)



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Advantage

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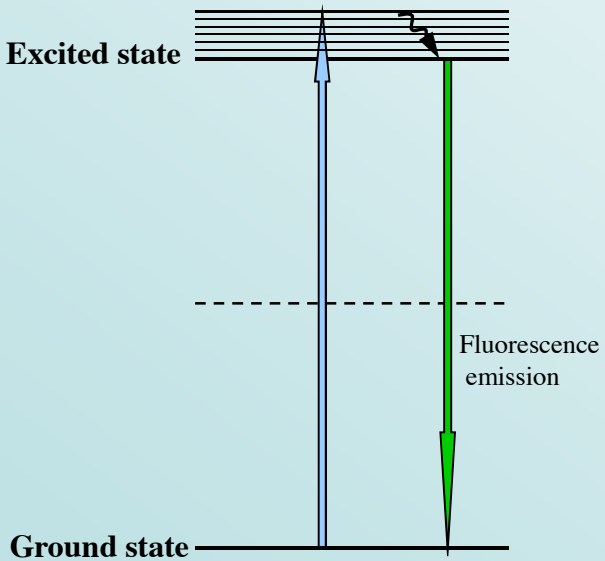
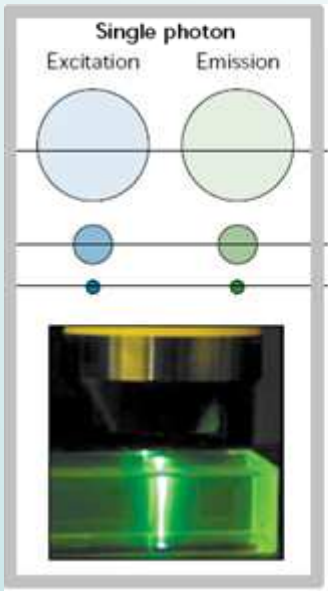
  - non linear effect due to multiphoton absorption

excitation by one photon absorption (OPA)



Type of excitation

OPA

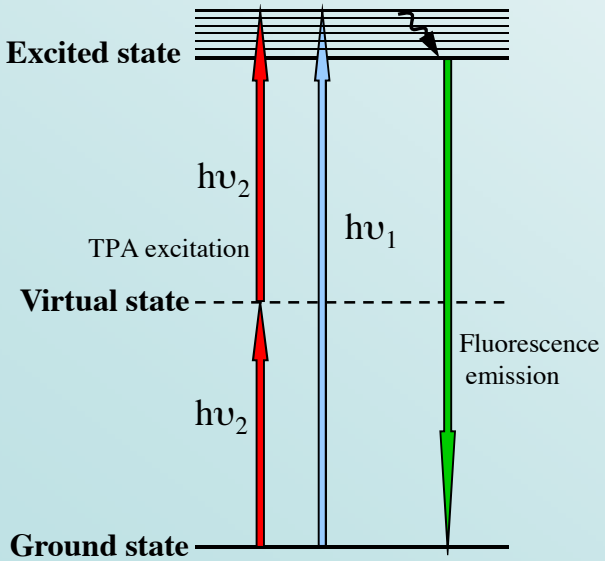


Two Photon Stereolithography (TPS)

Advantage

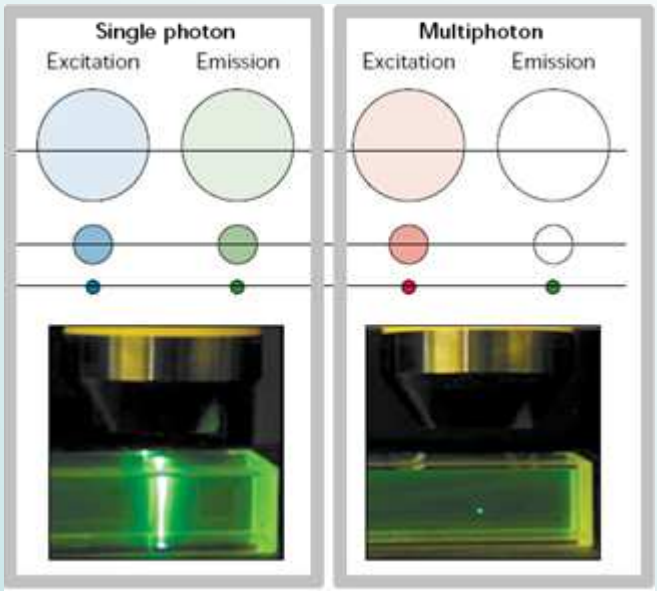
- sub-100 nm Resolution
  - energy threshold in polymerization (inhibitor: oxygene, amine)
  - non linear effect due to multiphoton absorption

Simultaneous excitation by two photon absorption (TPA)



Type of excitation

OPA **TPA**

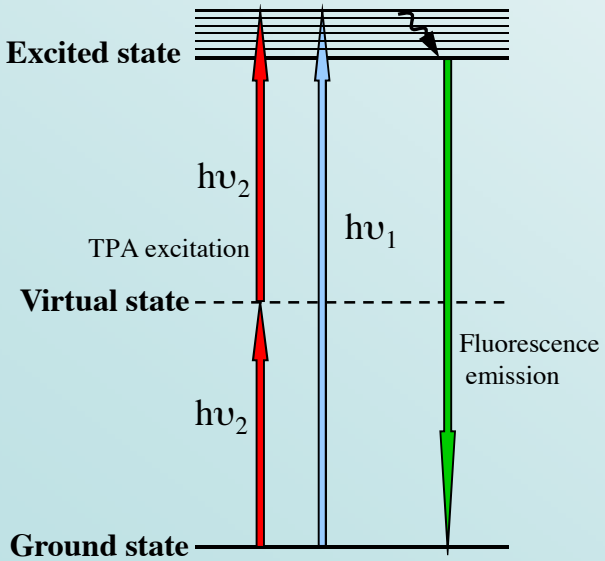


Two Photon Stereolithography (TPS)

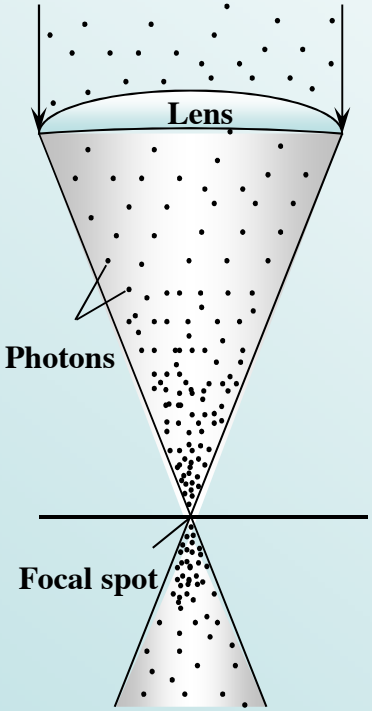
Advantage

- sub-100 nm Resolution
  - energy threshold in polymerization (inhibitor: oxygene, amine)
  - non linear effect due to multiphoton absorption

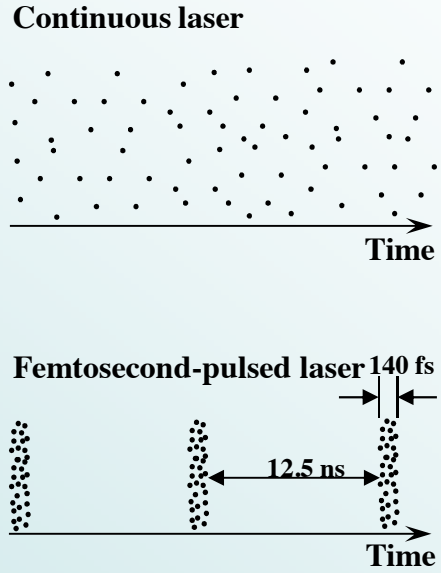
Simultaneous excitation by TPA



Spatial compression of photons by objective lens



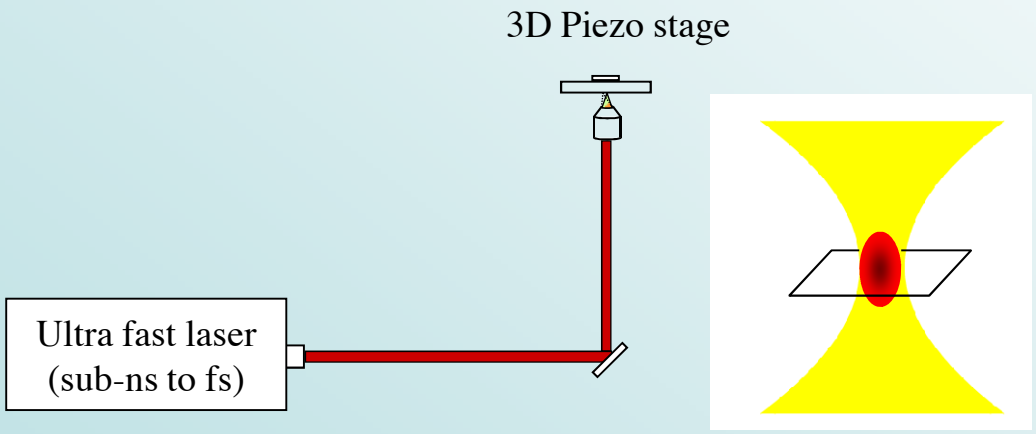
Temporal compression of photons



Two Photon Stereolithography (TPS)

Advantage

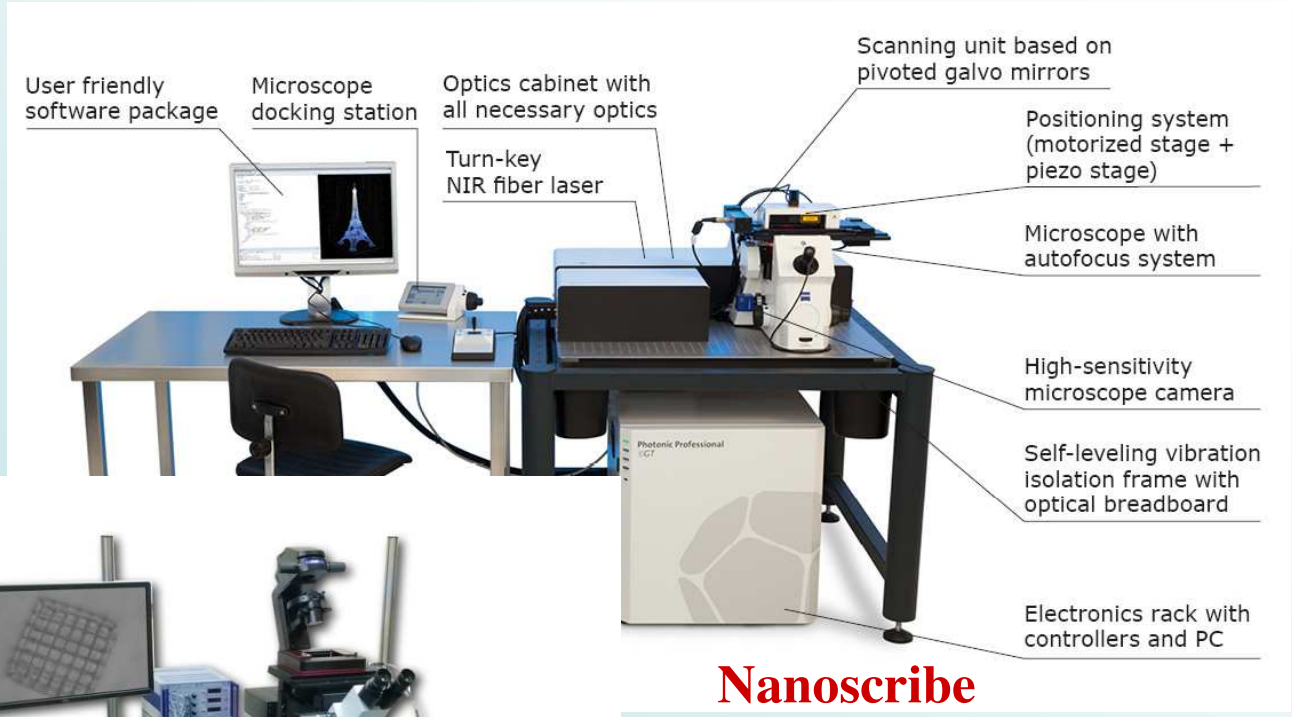
- sub-100 nm Resolution
  - energy threshold in polymerization (inhibitor: oxygene, amine)
  - non linear effect due to multiphoton absorption



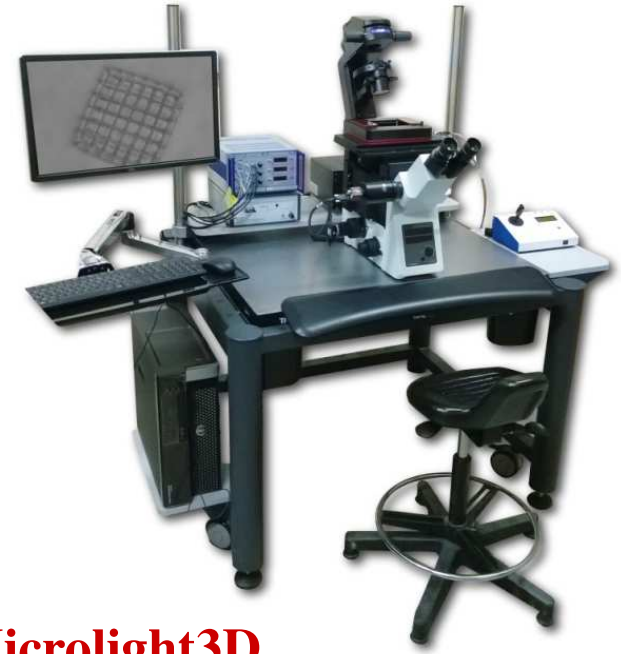
➔ confinement of the polymerization to the focal point / voxel (resolution λ/10)

Two Photon Stereolithography (TPS)

Commercial set-ups



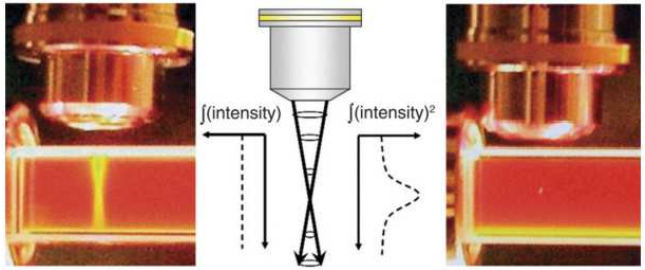
Nanoscribe



Microlight3D

Outline

1



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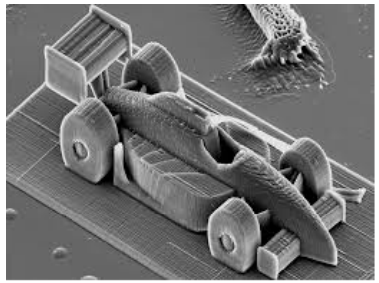
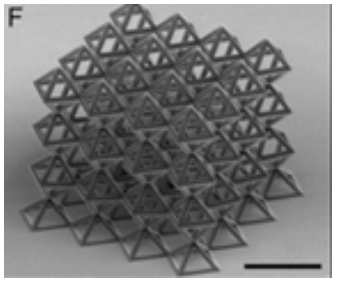
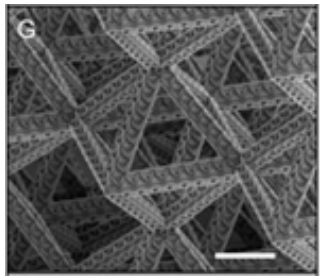


Writing speed & resolution

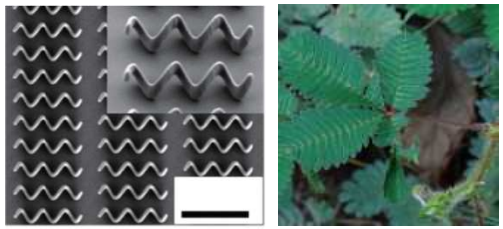
3





Applications
Medecine & Robotics

4

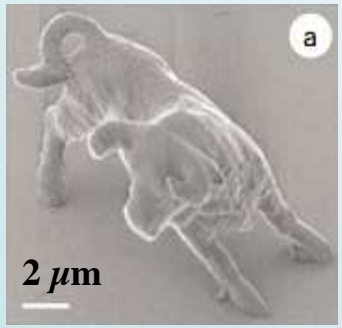


Advanced Functional
Materials

TPS Resolution

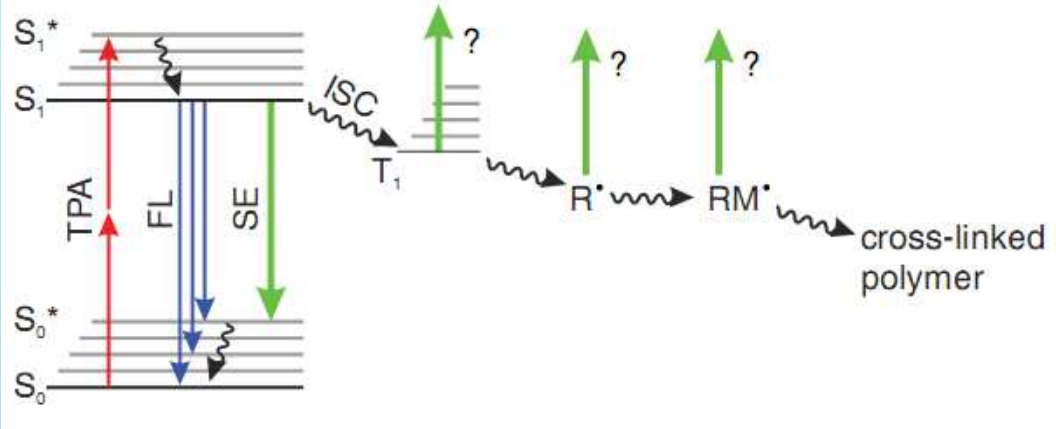
State of the art:

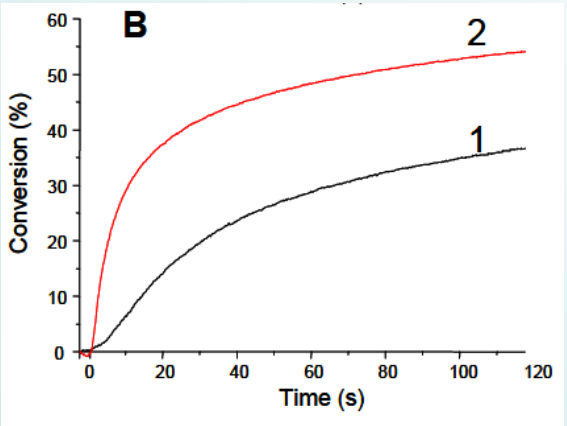
- **Resolution**



S. Kawata, **Nature 2001**, *412*, 697-698.
Rés: abs. biphoton. Rx,y = 120 nm
λ = 780 nm, λ / 6.5

➔Resolution due to optical and chemical confinement of the photoreaction
Key role of chemistry ➔ Nanophotochemistry (inhibition of radical polymerization by oxygene, diffusion controlled reaction)

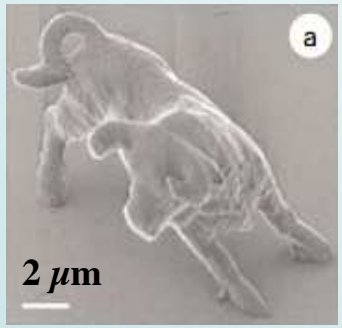




TPS Resolution

State of the art:

- **Resolution**



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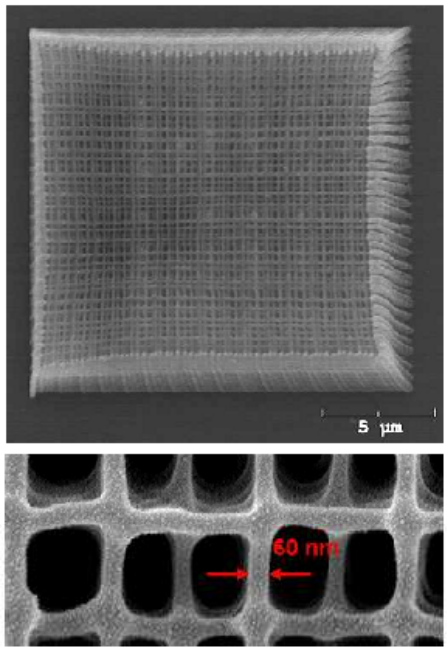


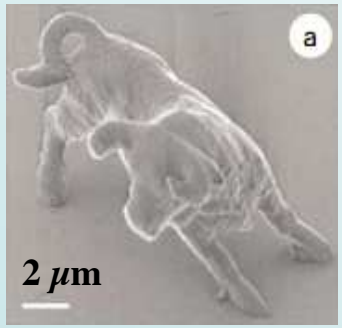
Perry, Marder, **Opt. Exp. 2007**, *15*, 3426-3436.
Rés: abs. biphoton. Rx,y = 65 nm
λ = 520 nm, λ / 8

➔Lower resolution due to optical (irradiation wavelength) and chemical strategies
Key role of chemistry ➔ *Molecular engineering (design & photophysical characterization of photoinitiator)*

Two-photon Polymerization

State of the art:

- **Resolution**



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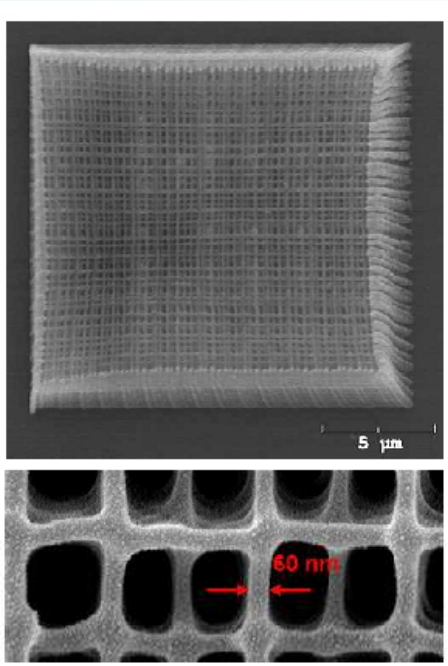

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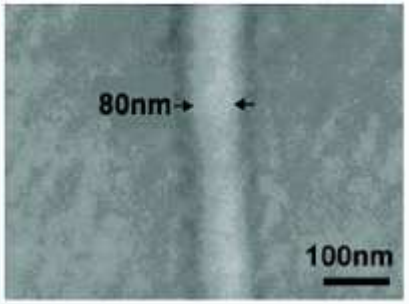


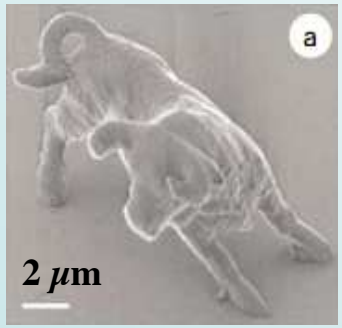
S. Kawata, **Appl. Phys. Lett. 2007**, *90*,
Rés: abs. biphoton. Rx,y = 80 nm
λ = 800 nm, λ / 10

➔Resolution due to optical and chemical confinement of the photoreaction
Key role of chemistry ➔ *Nanophotochemistry (inhibition of radical polymerization by additive, diffusion controlled reaction)*

Two-photon Polymerization

State of the art:

- **Resolution**



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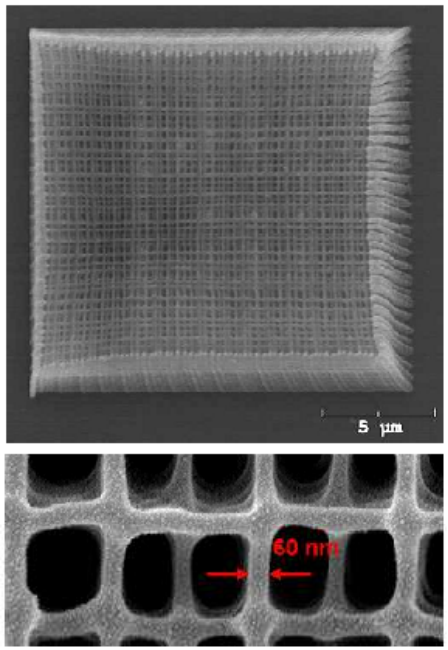

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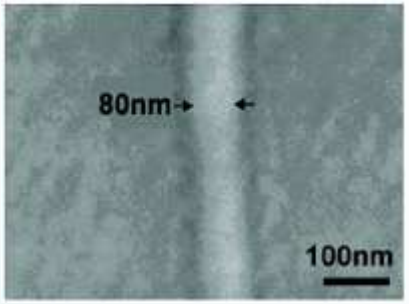

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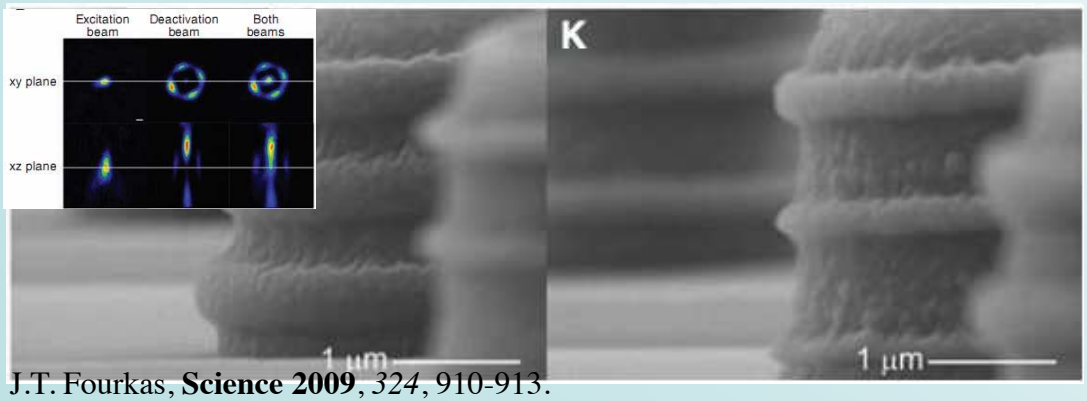


J.T. Fourkas, **Science 2009**, *324*, 910-913.
Rés: abs. biphoton. Rx,y = 40 nm
Rz = 40 nm ➔ λ = 800 nm, λ / 20

➔ < 10 nm ?

Two-photon Polymerization

- Resolution sub-100 nm

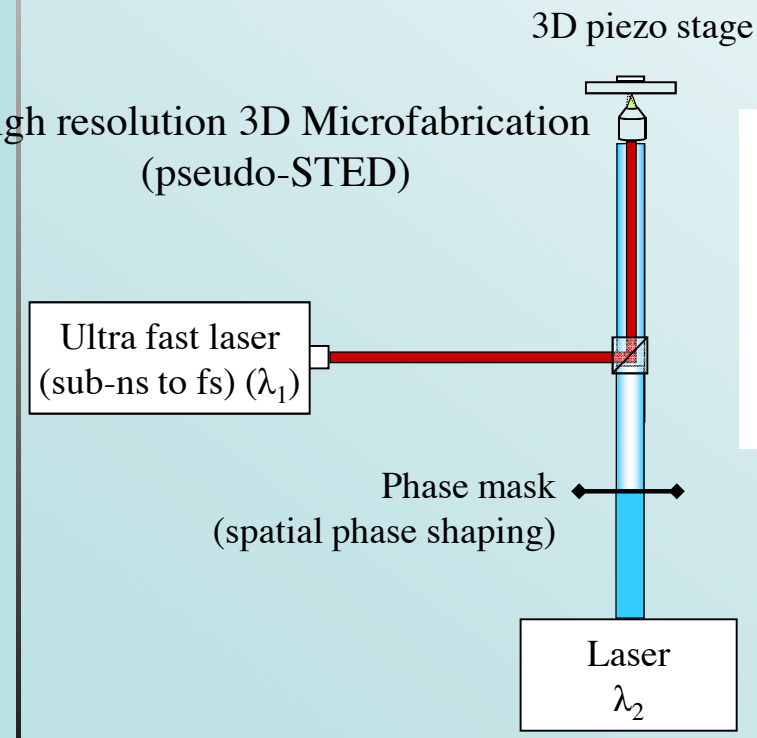
3D Microfabrication by two-photon absorption = two-photon stereolithography (TPS)

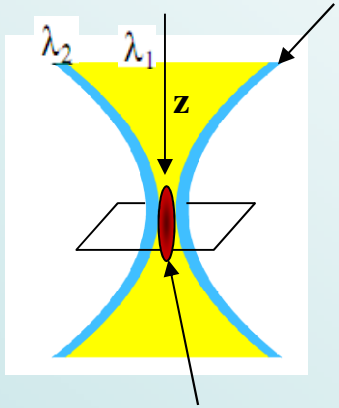
- non linear effect due to multiphoton absorption
- energy threshold in polymerization

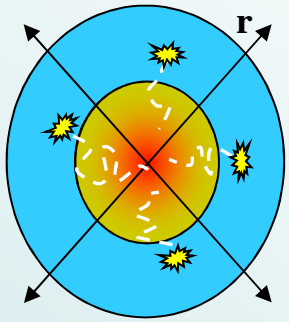
(inhibitor: oxygene, amine)

➔ confinement of the polymerization to the focal point / voxel (resolution λ/10)

High resolution 3D Microfabrication (pseudo-STED)







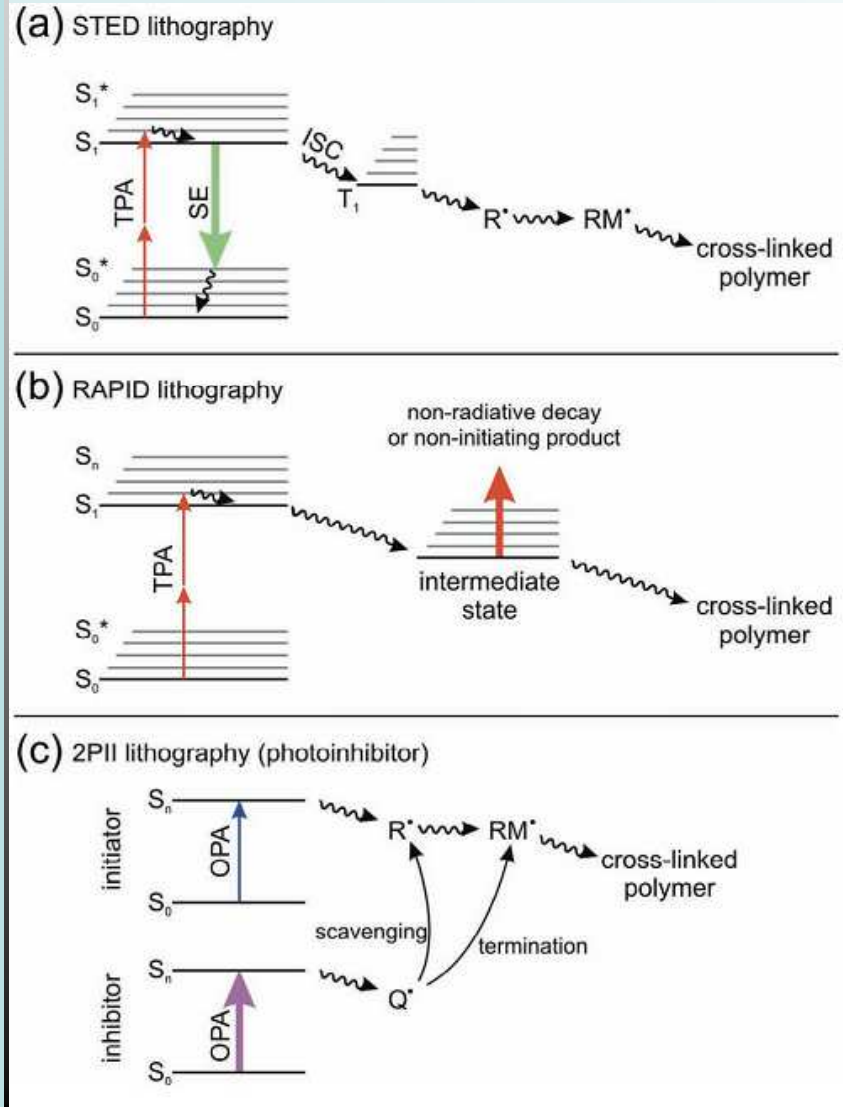
Fourkas et al. Science 2009:
Achieving λ/20 Resolution

➔ Axial resolution of voxel : 600 nm à 40 nm

STED Lithography and derivatives

Recent Achievements:

- **Resolution** → New concepts (STED, RAPID, 2PII…)

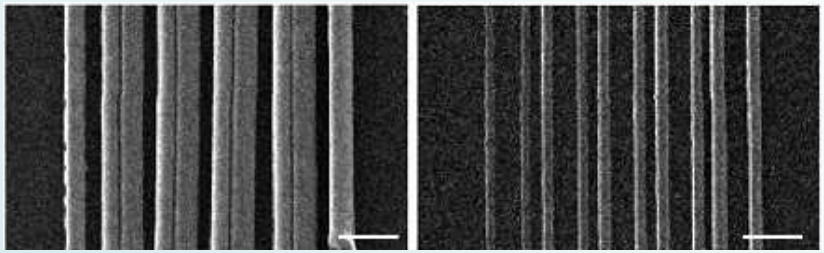


➔ **Polymerization involves T_1**

➔ **Control of the population of intermediate state**

Current challenges:

- Instrumentation issues



- Memory Photoresist ➔ consumption of species beteween 2 adjacent lines

- Unravelling the photophysic & photochemistry behind TPS & STED-like lithography