

Two-photon Polymerization and Nanoscribe Two-photon 3D Nanoprinter

MICRO-373
Project Lecture 2

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The background of the slide is a photograph of the EPFL building, a modern structure with a curved glass facade, set against a backdrop of snow-capped mountains. In the foreground, the large red 3D EPFL logo is visible on a grassy area.

EPFL

Tow-photon Absorption

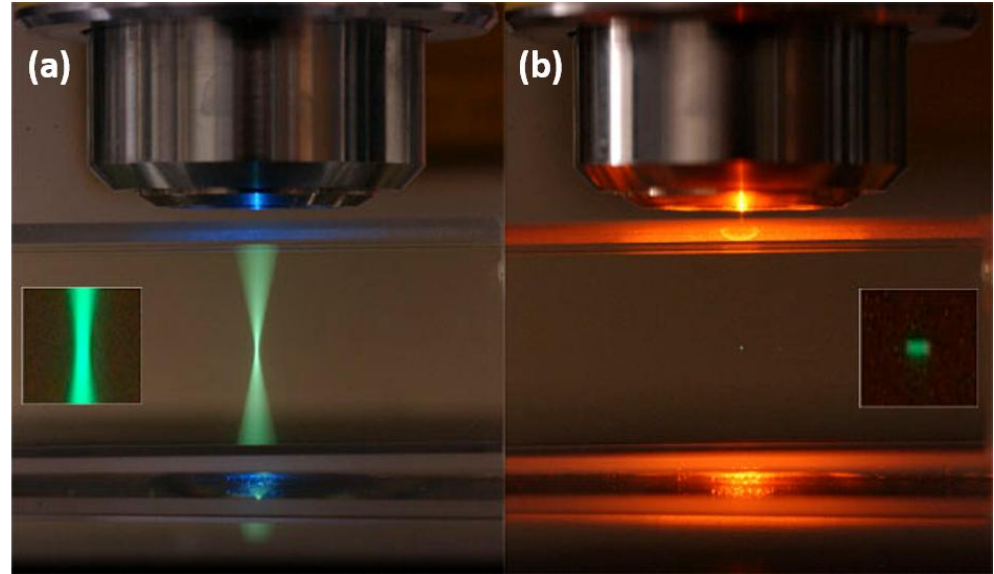


Maria Göppert Mayer

1906 – 1972

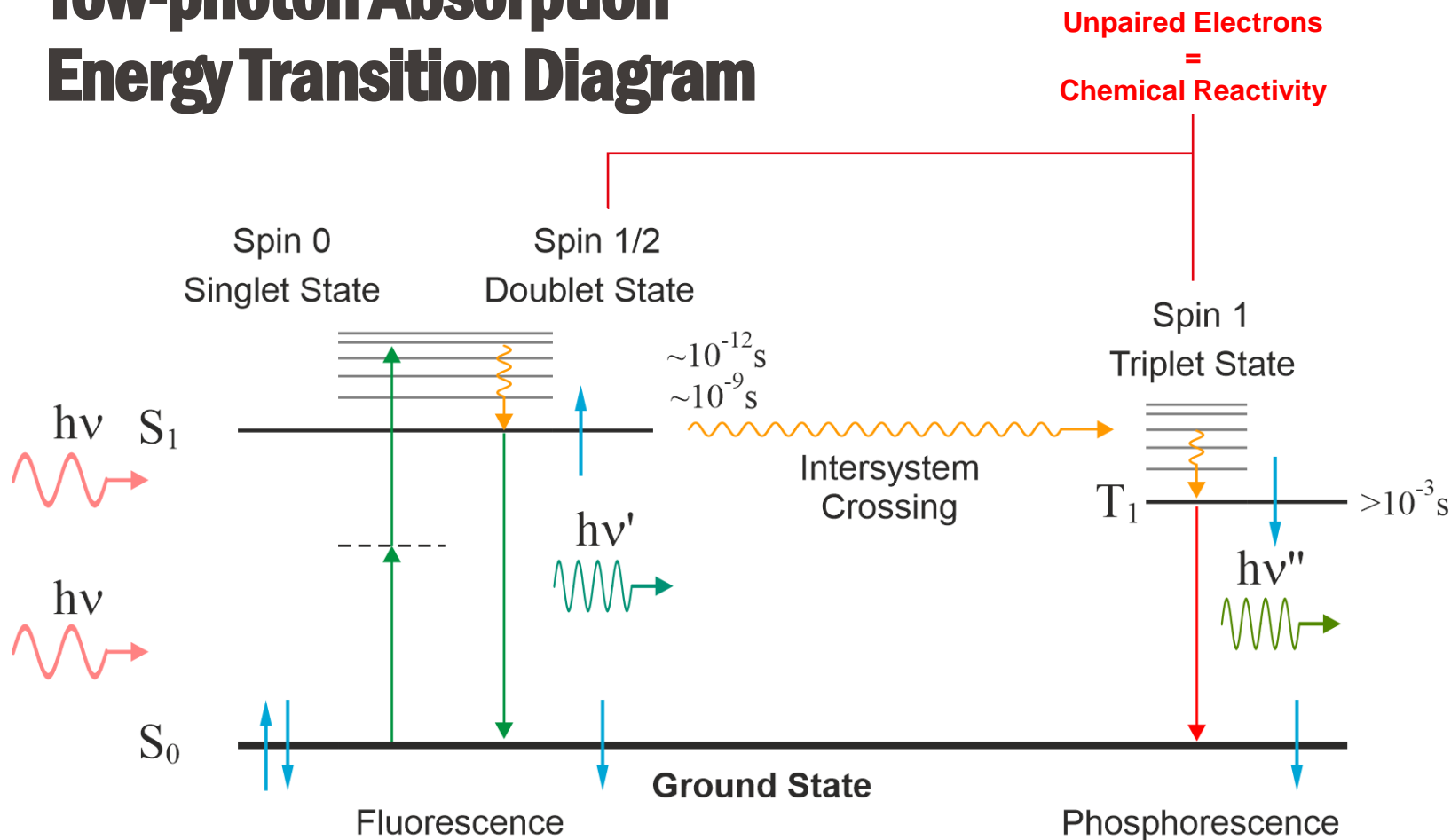
Nobel laureate for Physics 1963
for shell nuclear model

Source: Encyclopædia Britannica.



- Predicted in 1931
- Observed in 1961
- Abbreviated as TPA

Tow-photon Absorption Energy Transition Diagram



Tow-photon Absorption Cross-section

One-photon Absorption

Number of absorbed
photons

N_{abs}

Light Intensity

One-photon absorption
cross-section

Unit: cm^2

Two-photon Absorption

Number of absorbed
photons

Light Intensity

$= \sigma_2 I^2$

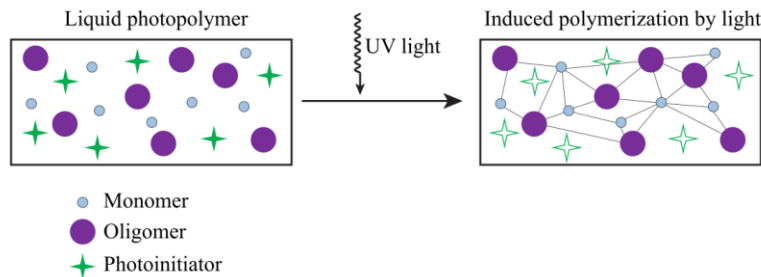
Two-photon absorption
cross-section

Unit: GM

1 GM = $1 \times 10^{-50} \text{ cm}^4 \text{ s photon}^{-1}$

- Appreciable two-photon absorption requires very high photon flux (light intensity $> 10^6 \text{ W/cm}^2$)
- Usually need an ultrafast pulsed laser

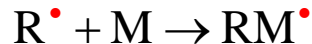
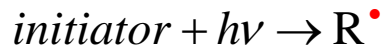
Photo-induced Radical Polymerization



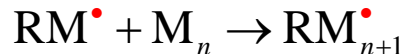
- Polymerization induced by light
- Liquid monomer solidify upon irradiation
- Polymerizable monomer + photoinitiator
- Key: photoinitiator

Steps

Initiation:

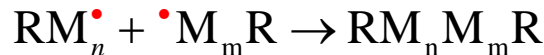


Propagation:

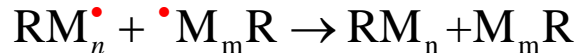


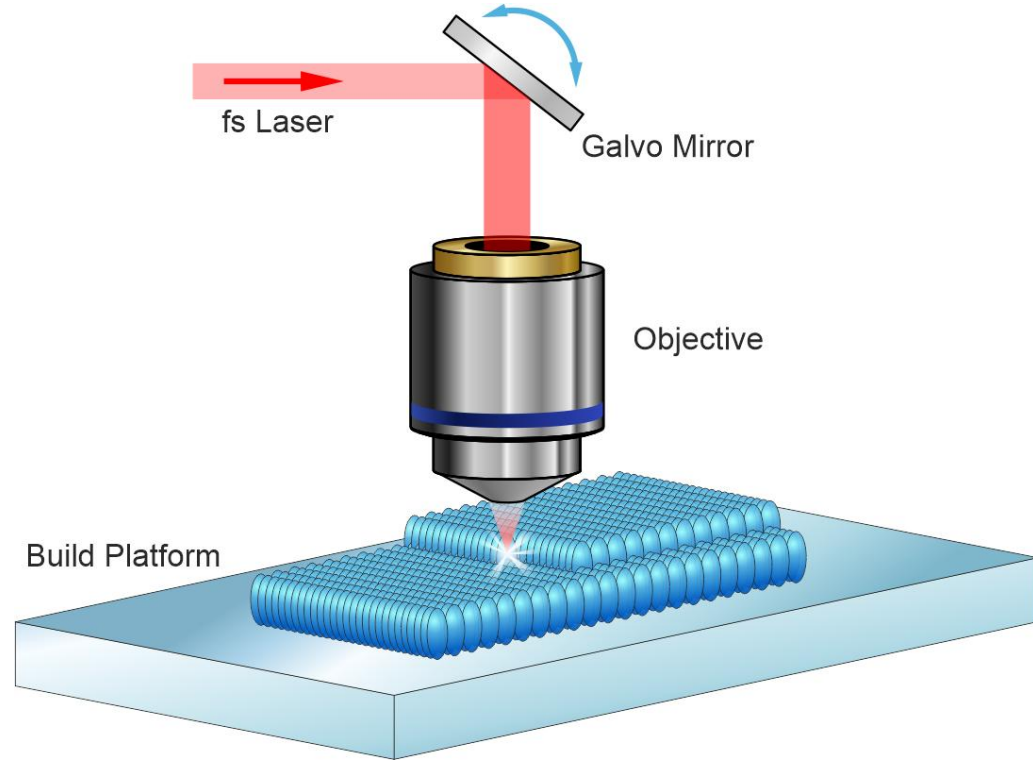
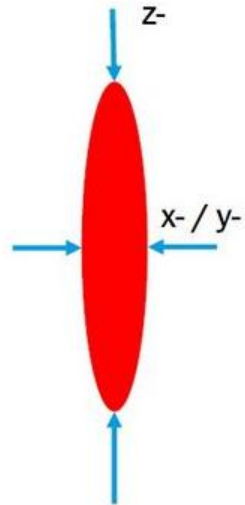
Termination:

Combination

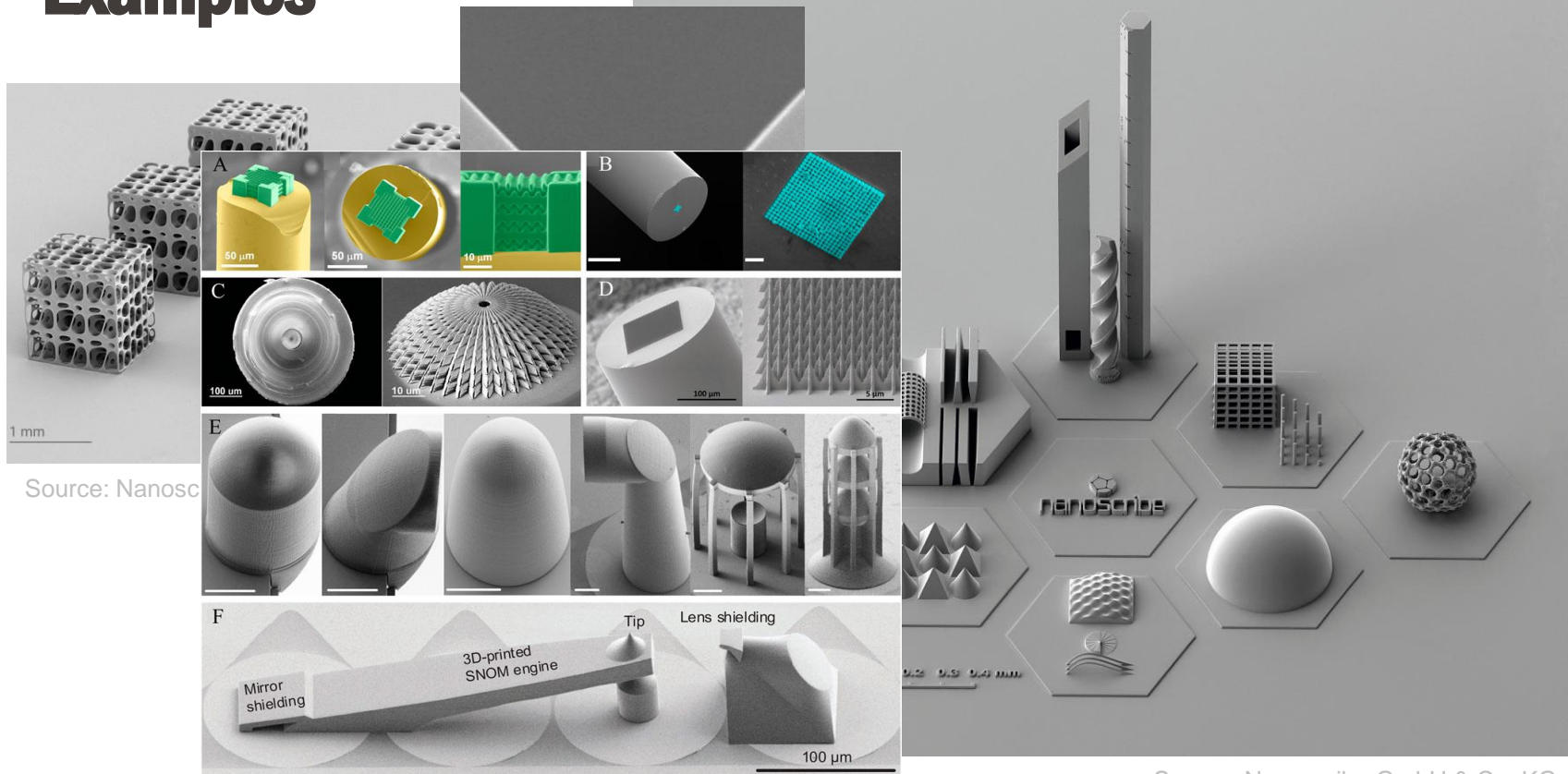


Disproportionation





Two-photon 3D Printing Examples



Source: Nanoscribe GmbH & Co. KG

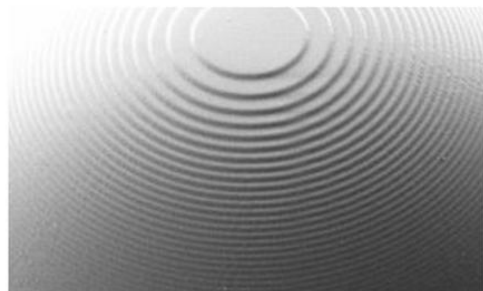
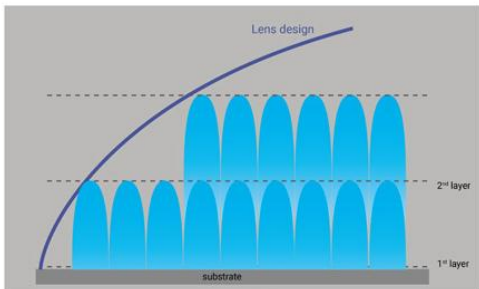
Source: Xiong C. et al, Front. Mater. , 28 October 2020

Source: Nanoscribe GmbH & Co. KG

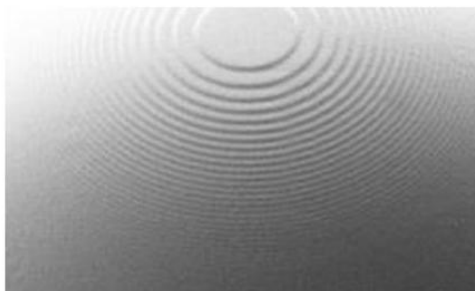
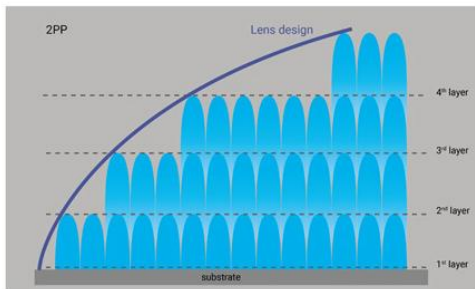
Two-photon Grayscale Lithography: The Next Level

Conventional Two-photon Lithography: Resolution-Speed Conflict

Coarse/Fast ←

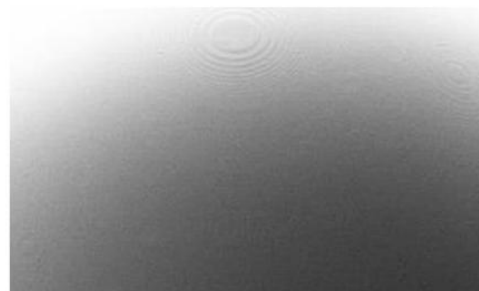
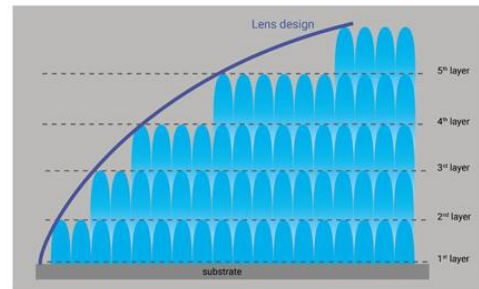


Slicing distance 2 μm



Slicing distance 1 μm

→ Fine/Slow

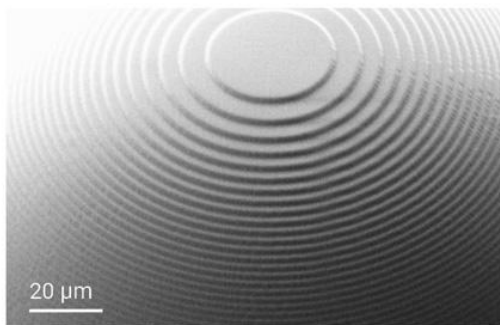
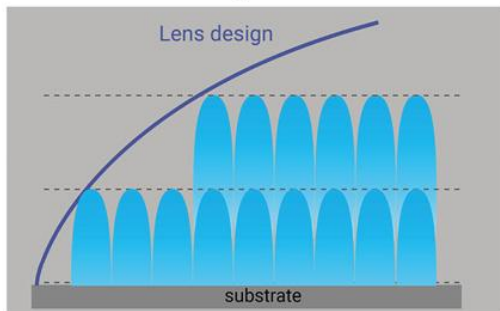


Slicing distance 0.6 μm

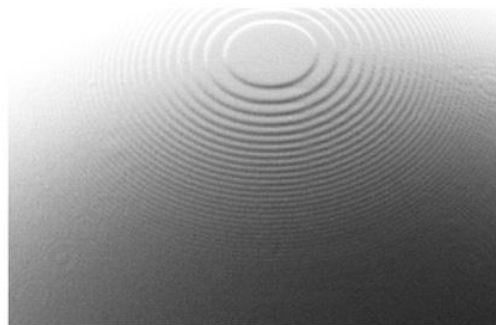
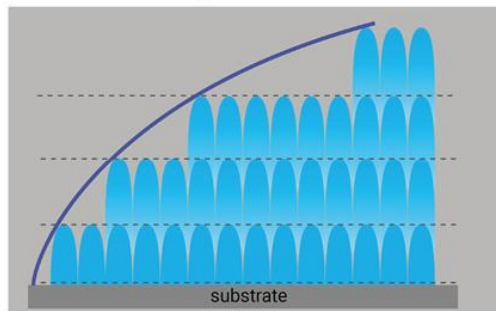
Two-photon Grayscale Lithography: The Next Level

Fine & Fast!

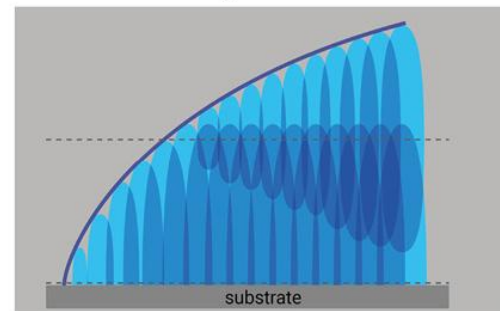
2PP coarse slicing



2PP fine slicing



2GL voxel tuning



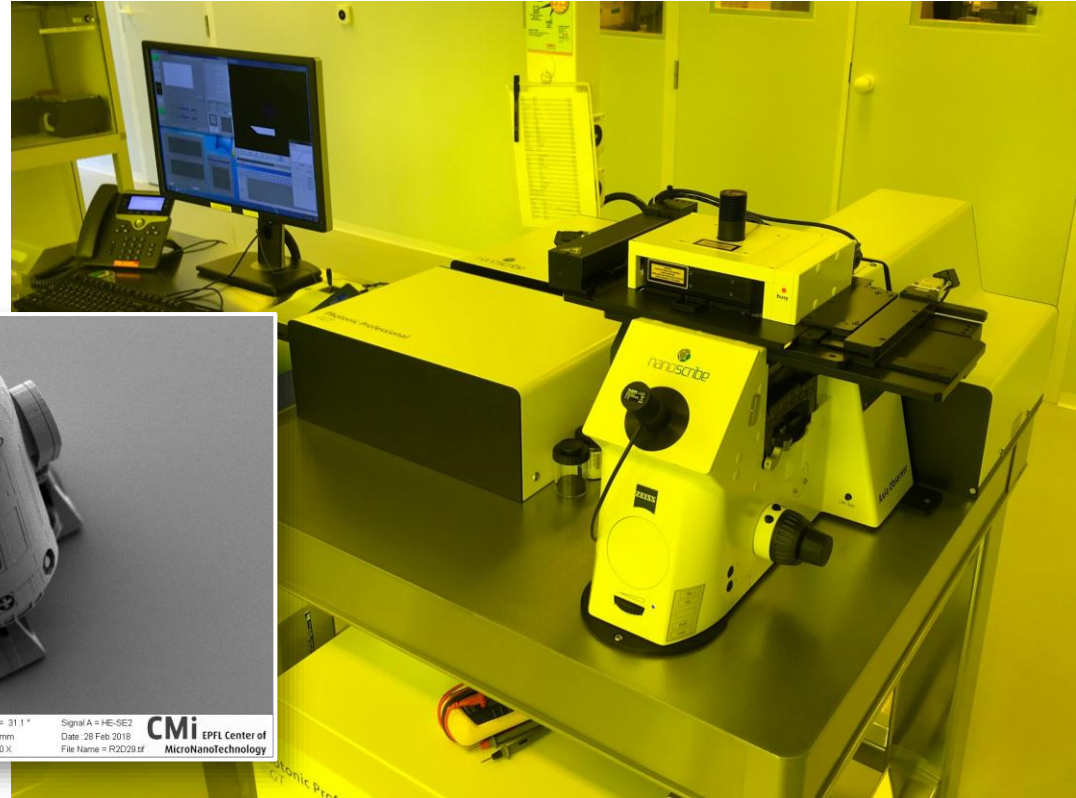
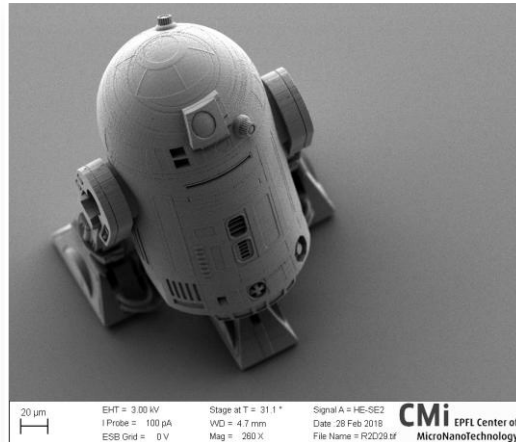
Two-photon Grayscale Lithography: The Next Level

- Quantum X
- Adaptive print beam intensity
- Precise sizing of voxel
- Perfect match to the contours of any 3D shape
- 60 times faster



Source: Nanoscribe GmbH & Co. KG.

- Nanoscribe Photonic Professional GT+
- Two-photon polymerization
- Max. resolutions:
 - X-Y: 200 nm
 - Z: 700 nm



Thank You!

