



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

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27.02.2025

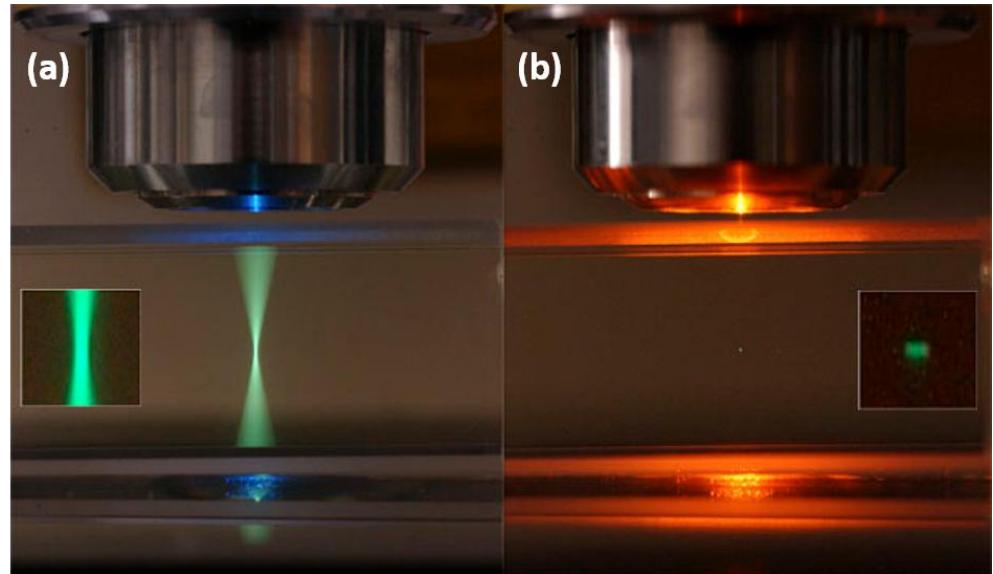


**Maria Göppert Mayer**

1906 – 1972

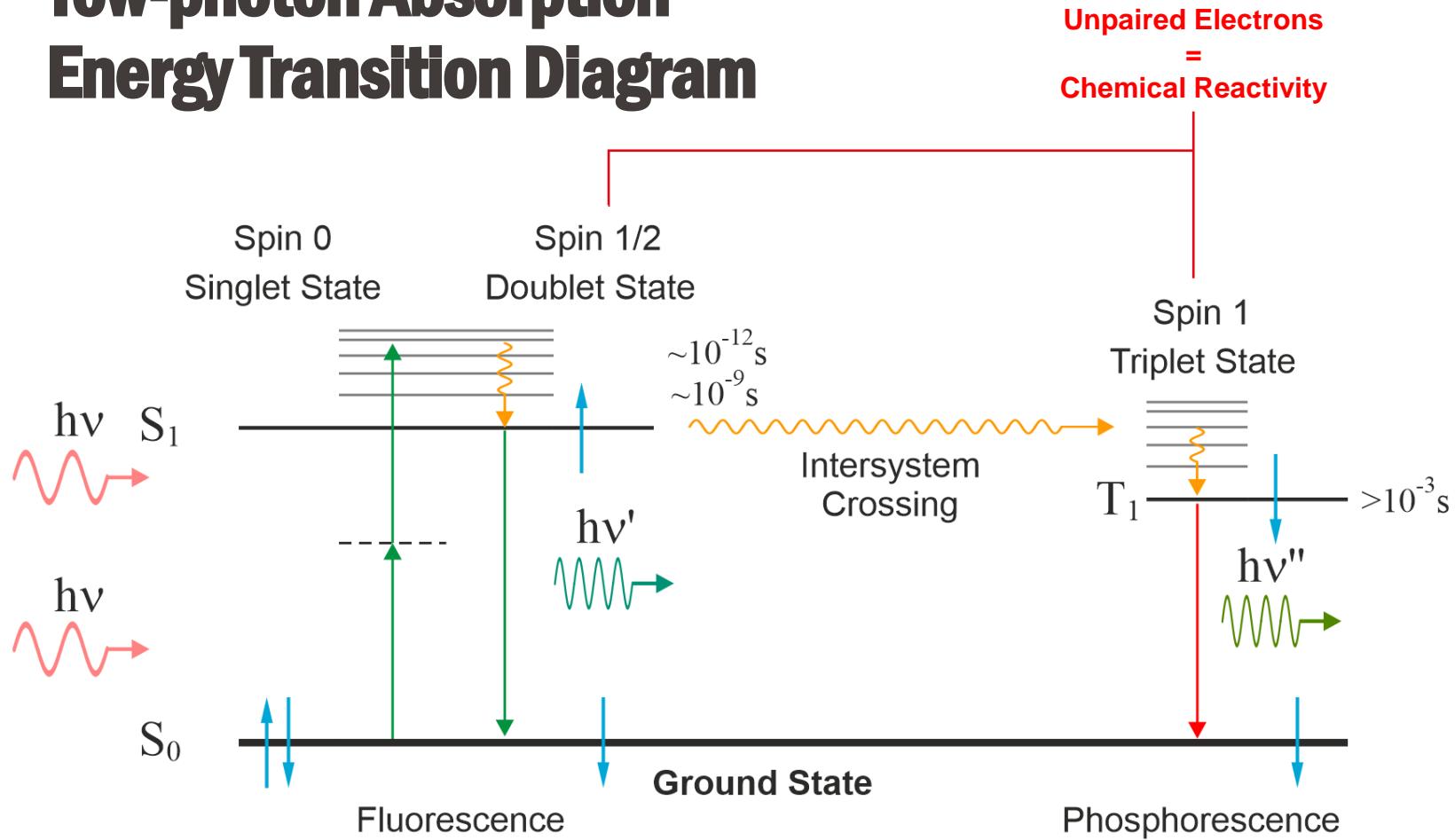
Nobel laureate for Physics 1963  
for shell nuclear model

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

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

One-photon absorption  
cross-section

Unit:  $\text{cm}^2$

## Two-photon Absorption

Number of absorbed  
photons



Light Intensity

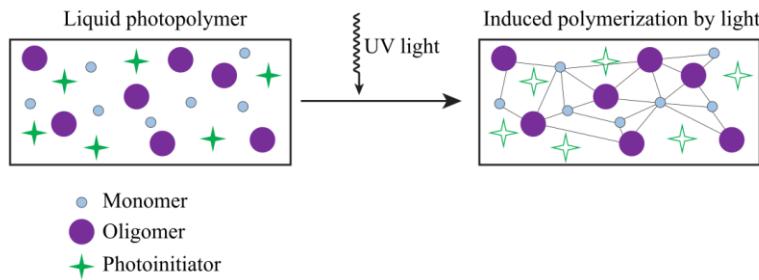
$$= \sigma_2 I^2$$

Two-photon absorption  
cross-section

Unit: GM

$$1 \text{ GM} = 1 \times 10^{-50} \text{ cm}_4 \text{ s photon}^{-1}$$

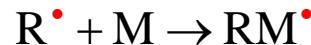
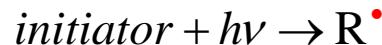
# Photo-induced Radical Polymerization



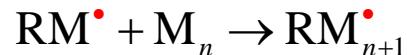
- Polymerization induced by light
- Liquid monomer solidify upon irradiation
- Polymerizable monomer + photoinitiator
- Key: photoinitiator

## Steps

### Initiation:



### Propagation:

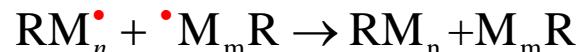


### Termination:

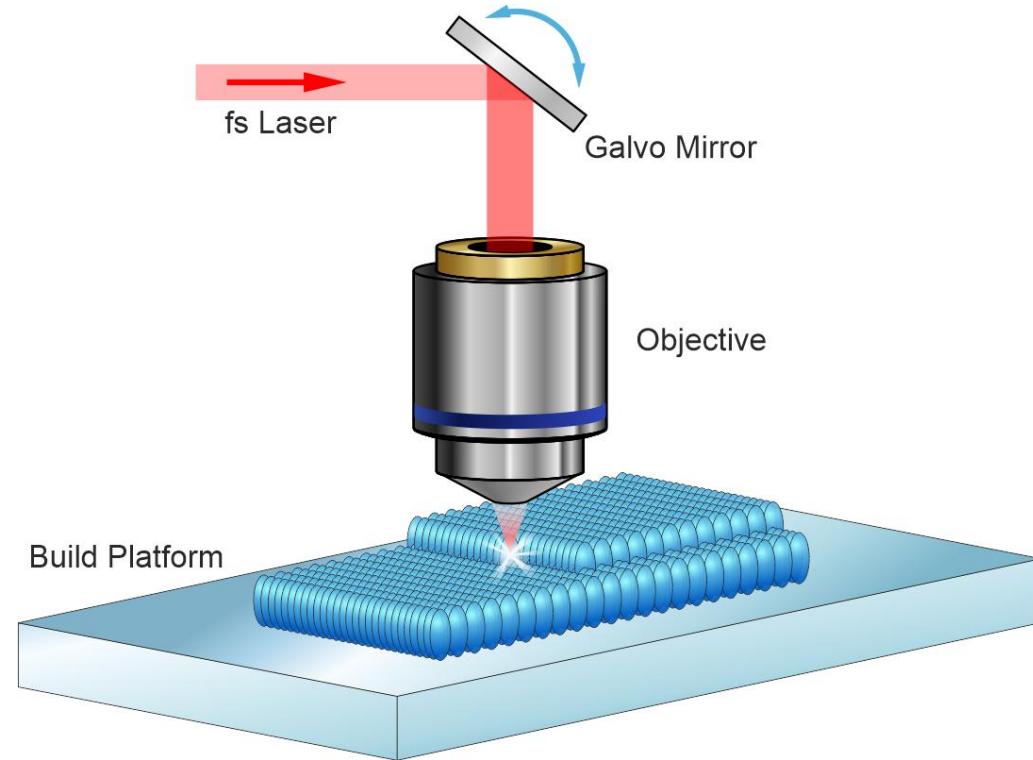
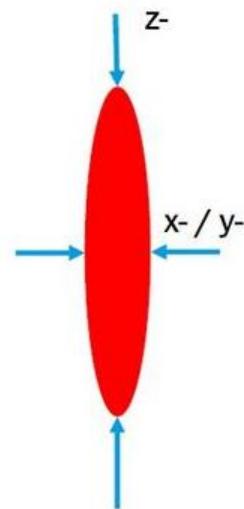
Combination



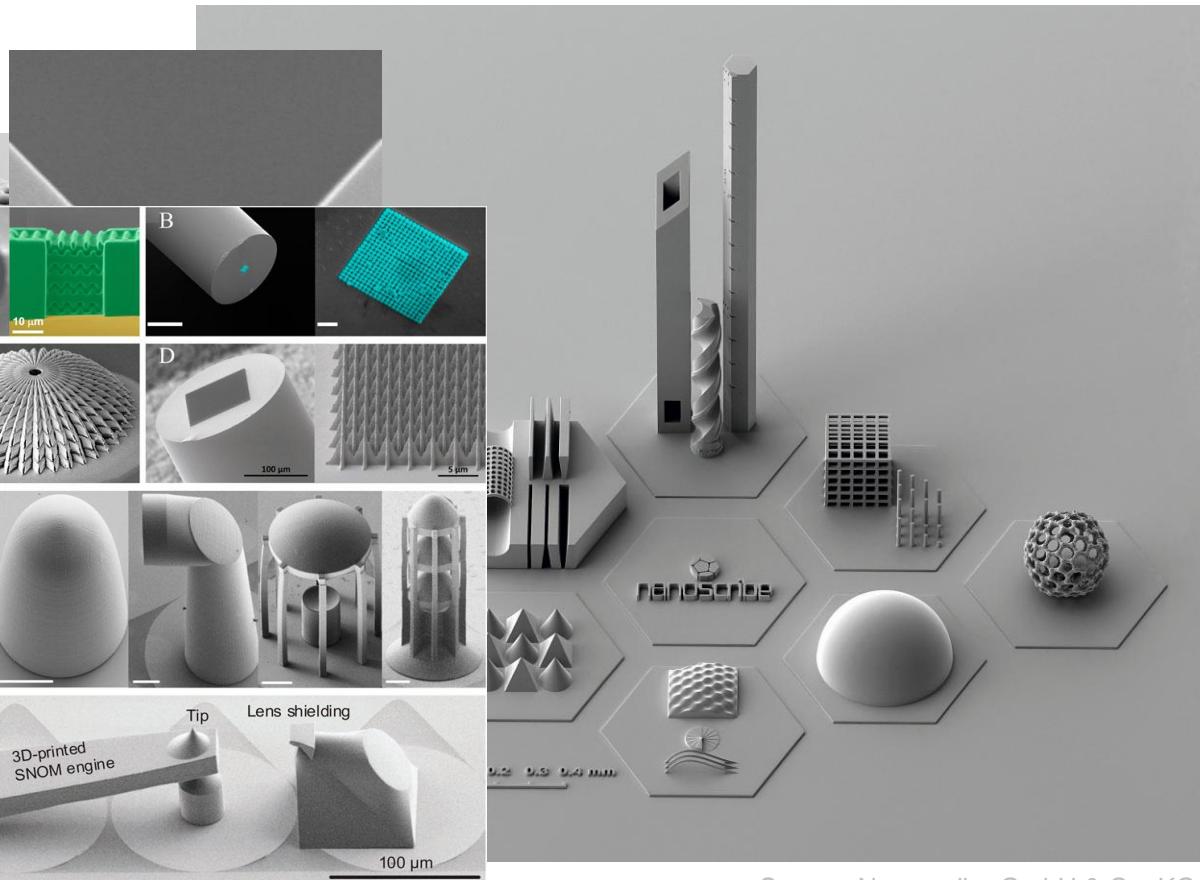
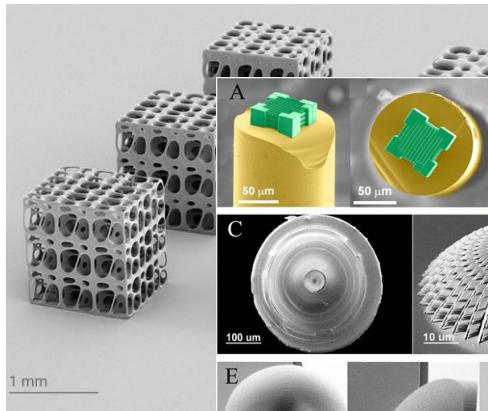
Disproportionation



# Two-photon SLA



# Two-photon 3D Printing Examples



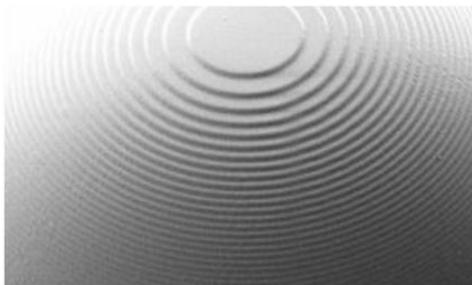
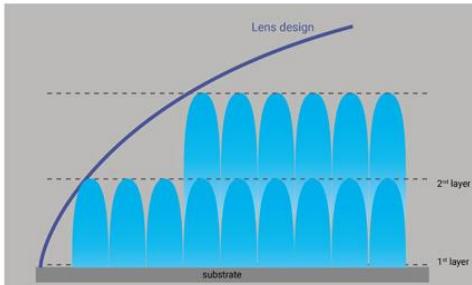
Source: Xiong C. et al, Front. Mater. , 28 October 2020

Source: Nanoscribe GmbH & Co. KG

# Two-photon Grayscale Lithography: The Next Level

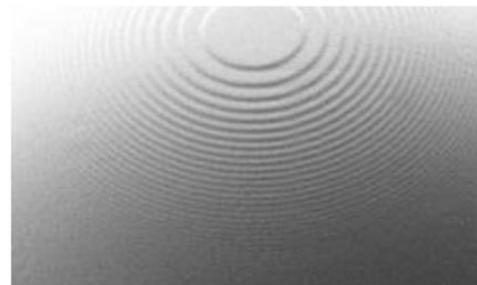
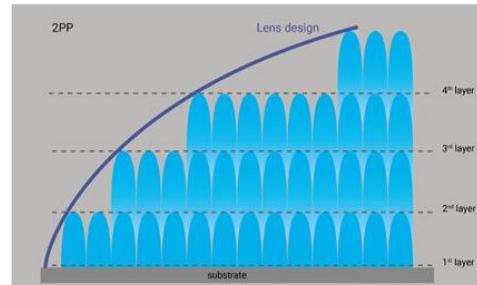
## Conventional Two-photon Lithography: Resolution-Speed Conflict

Coarse/Fast

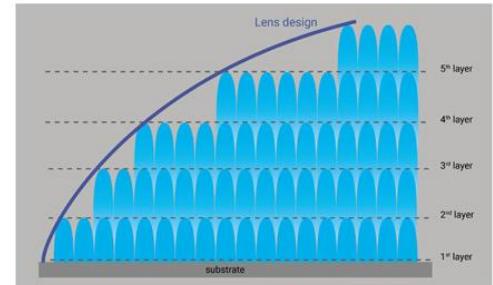


Slicing distance 2  $\mu\text{m}$

Fine/Slow



Slicing distance 1  $\mu\text{m}$

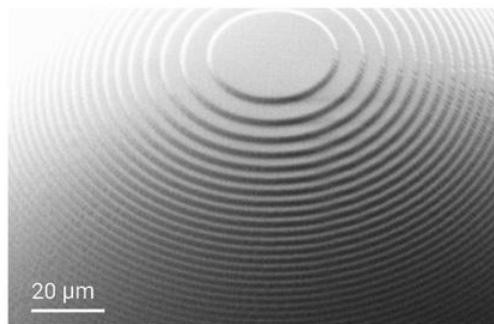
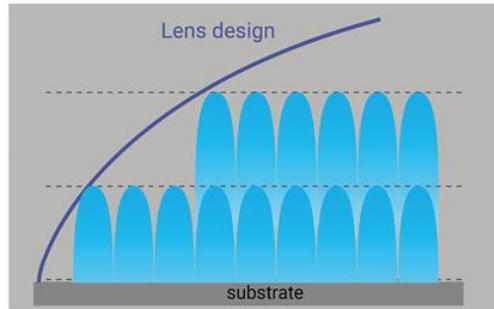


Slicing distance 0.6  $\mu\text{m}$

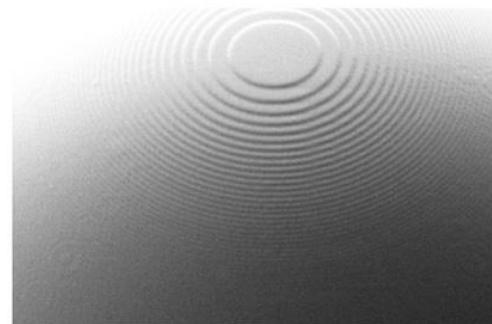
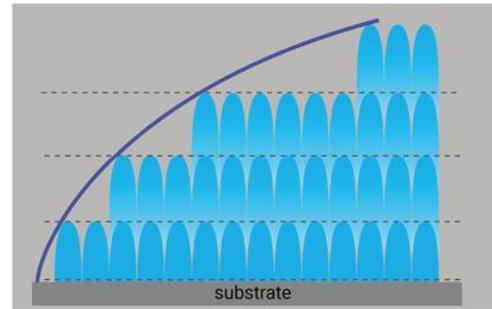
# Two-photon Grayscale Lithography: The Next Level

Fine & Fast!

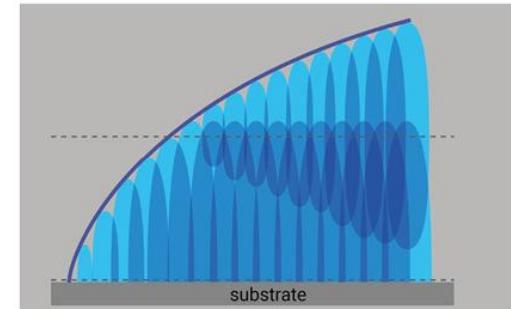
2PP coarse slicing



2PP fine slicing



2GL voxel tuning



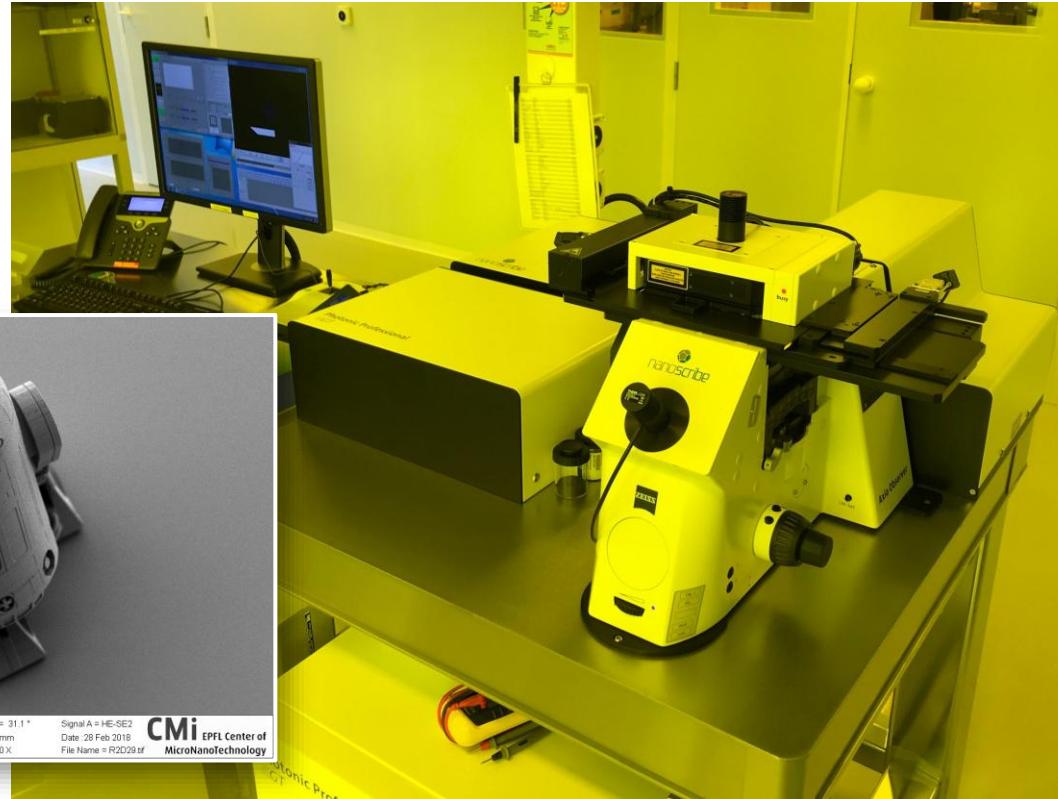
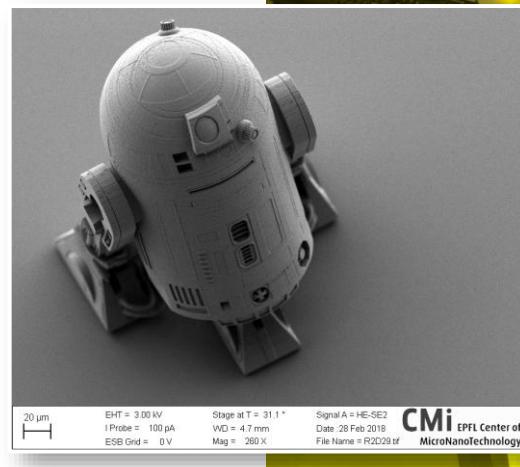
# Two-photon Grayscale Lithography: The Next Level

- 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!

