

# Nano and biophotonics

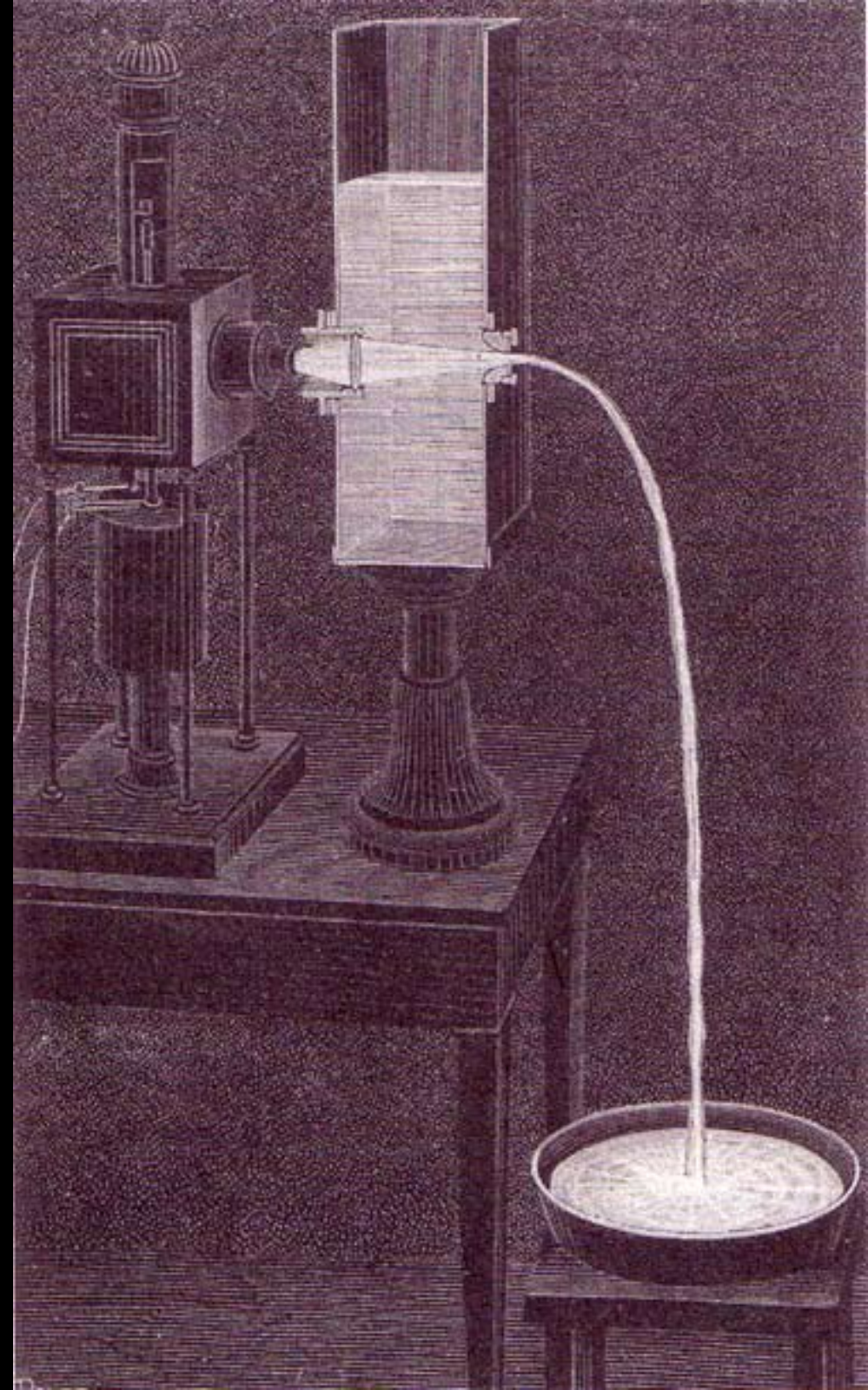


DEAS Dean's Leadership Council Meeting  
Cambridge, MA, 26 October 2005



***“I managed to illuminate the interior of a stream in a dark space. I have discovered that this strange arrangement offers one of the most beautiful, and most curious experiments that one can perform in a course on Optics.”***

**Daniel Colladon, *Comptes Rendus*, 15, 800–802 (1842)**



D. Colladon, *La Nature*, 325 (1884)

# Outline

- **silica nanowires**
- **fs laser micromachining**
- **biophotonics**

# Silica nanowires

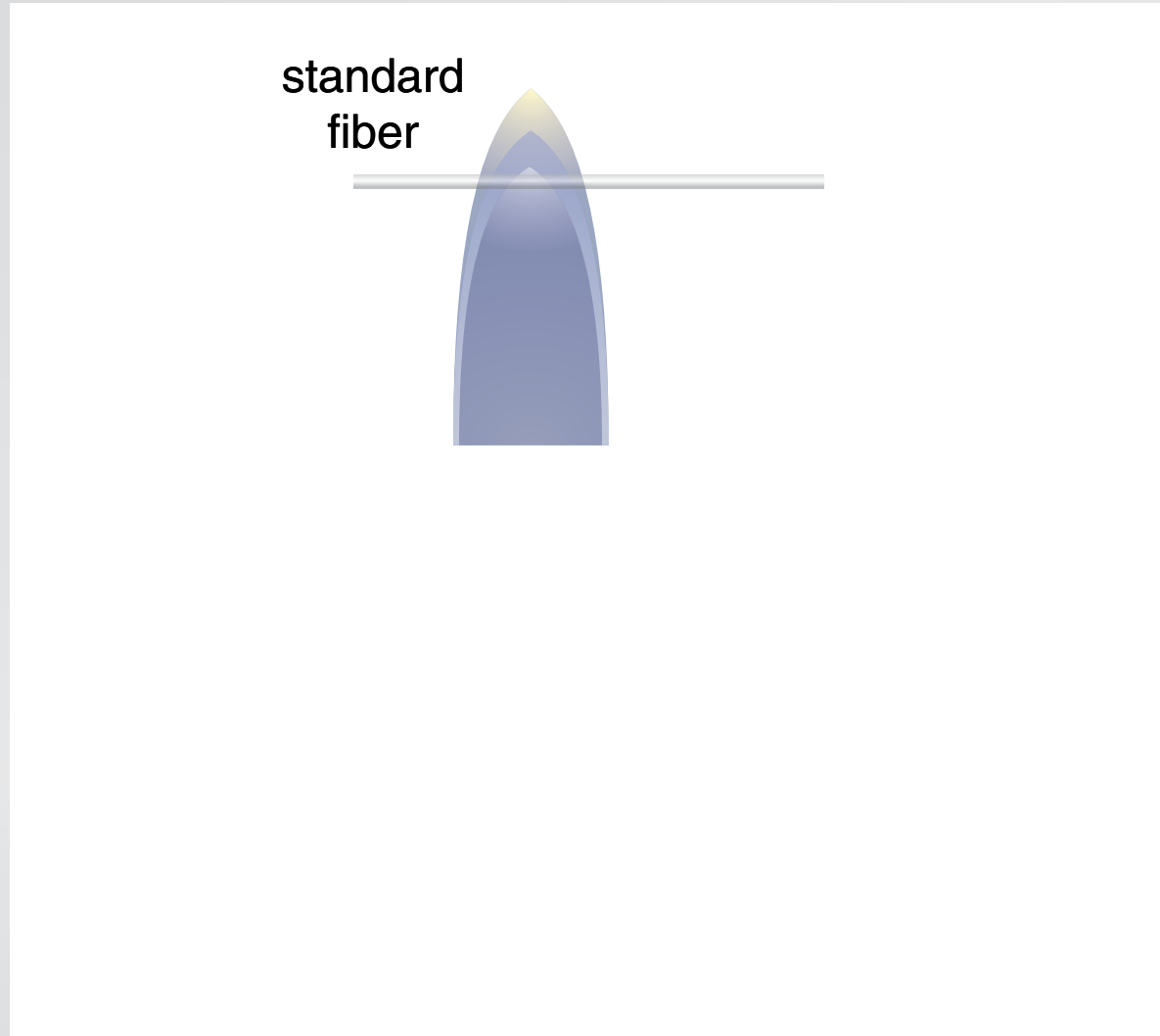
two-step drawing process

standard  
fiber



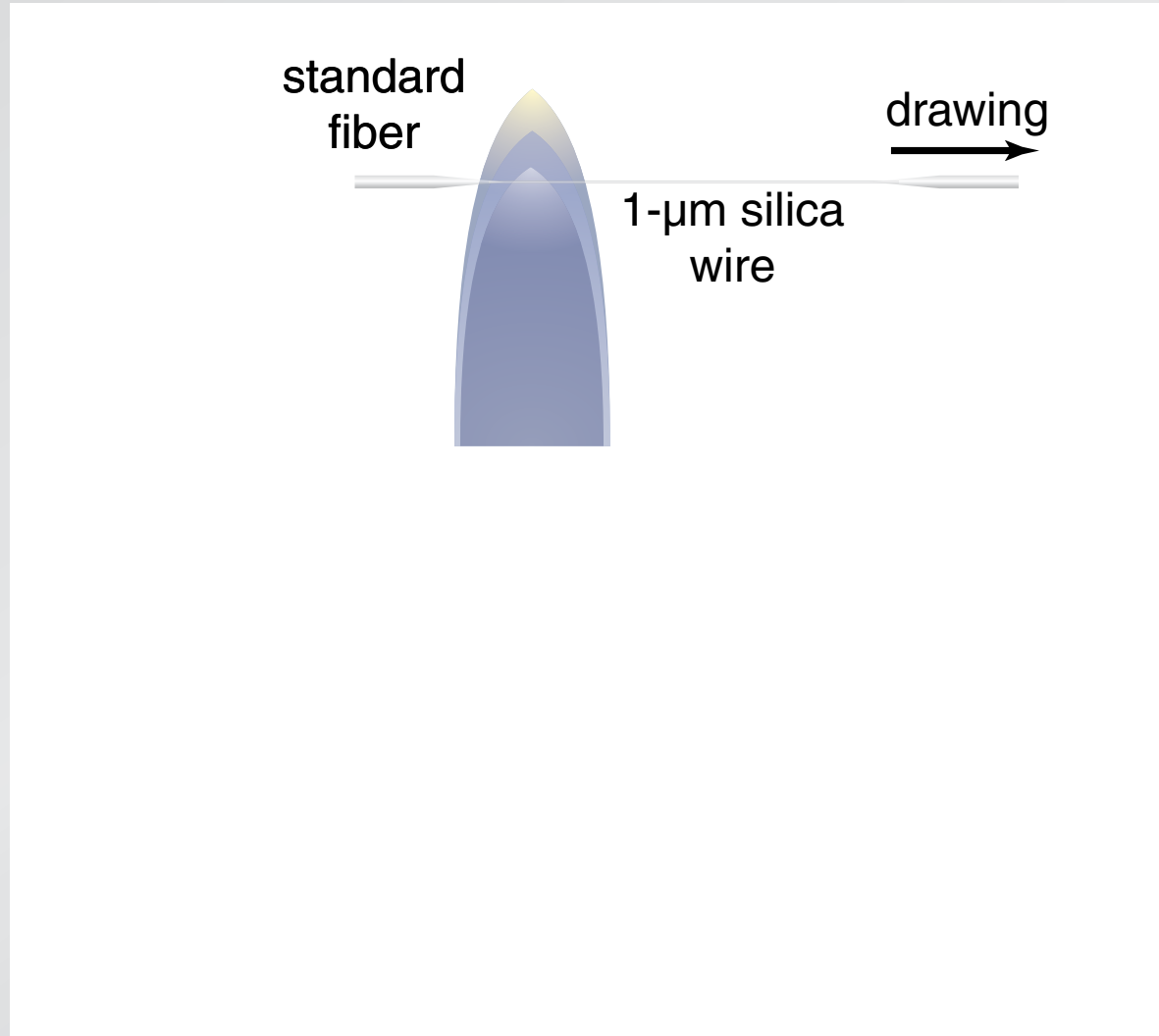
# Silica nanowires

two-step drawing process



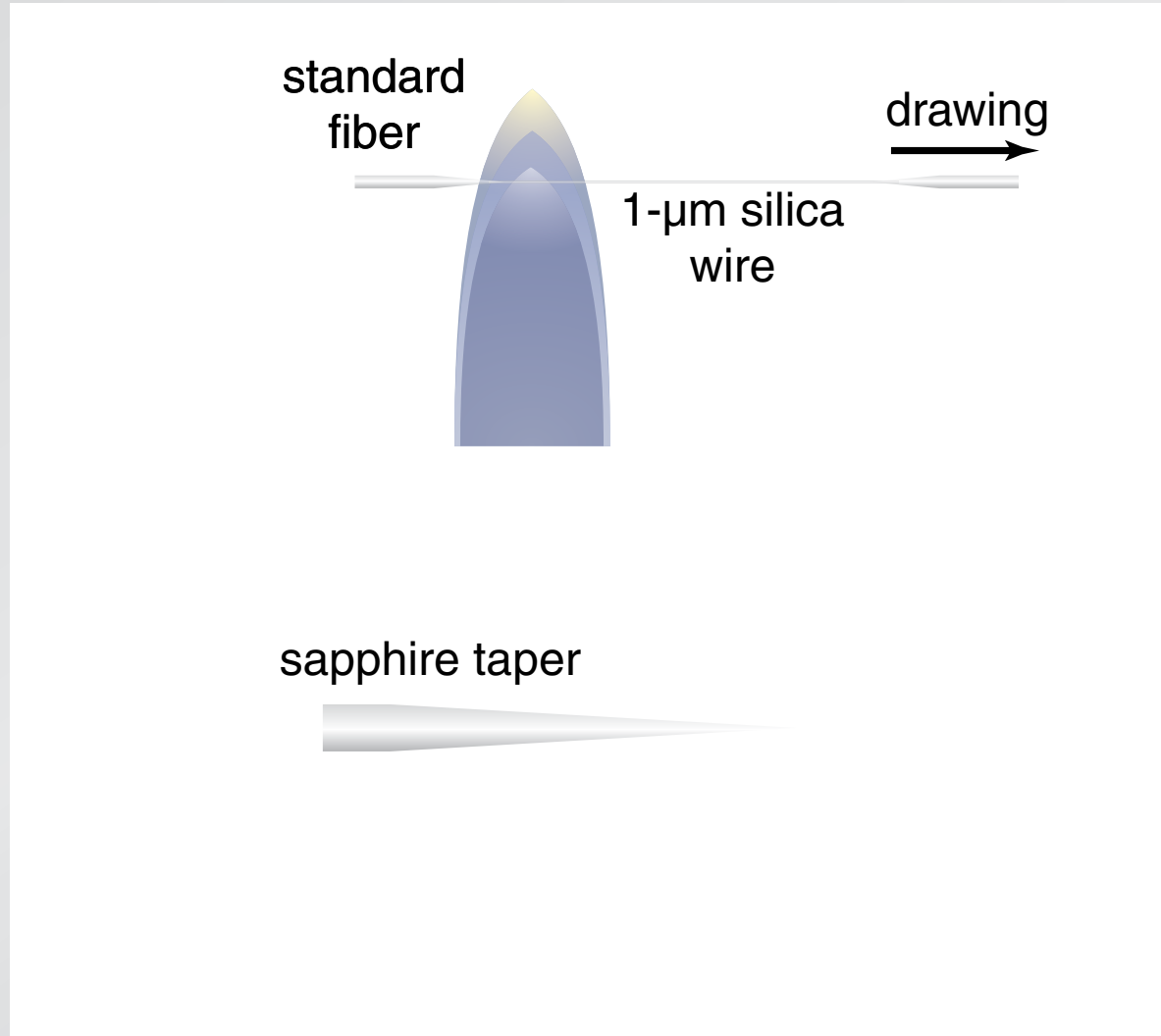
# Silica nanowires

two-step drawing process



# Silica nanowires

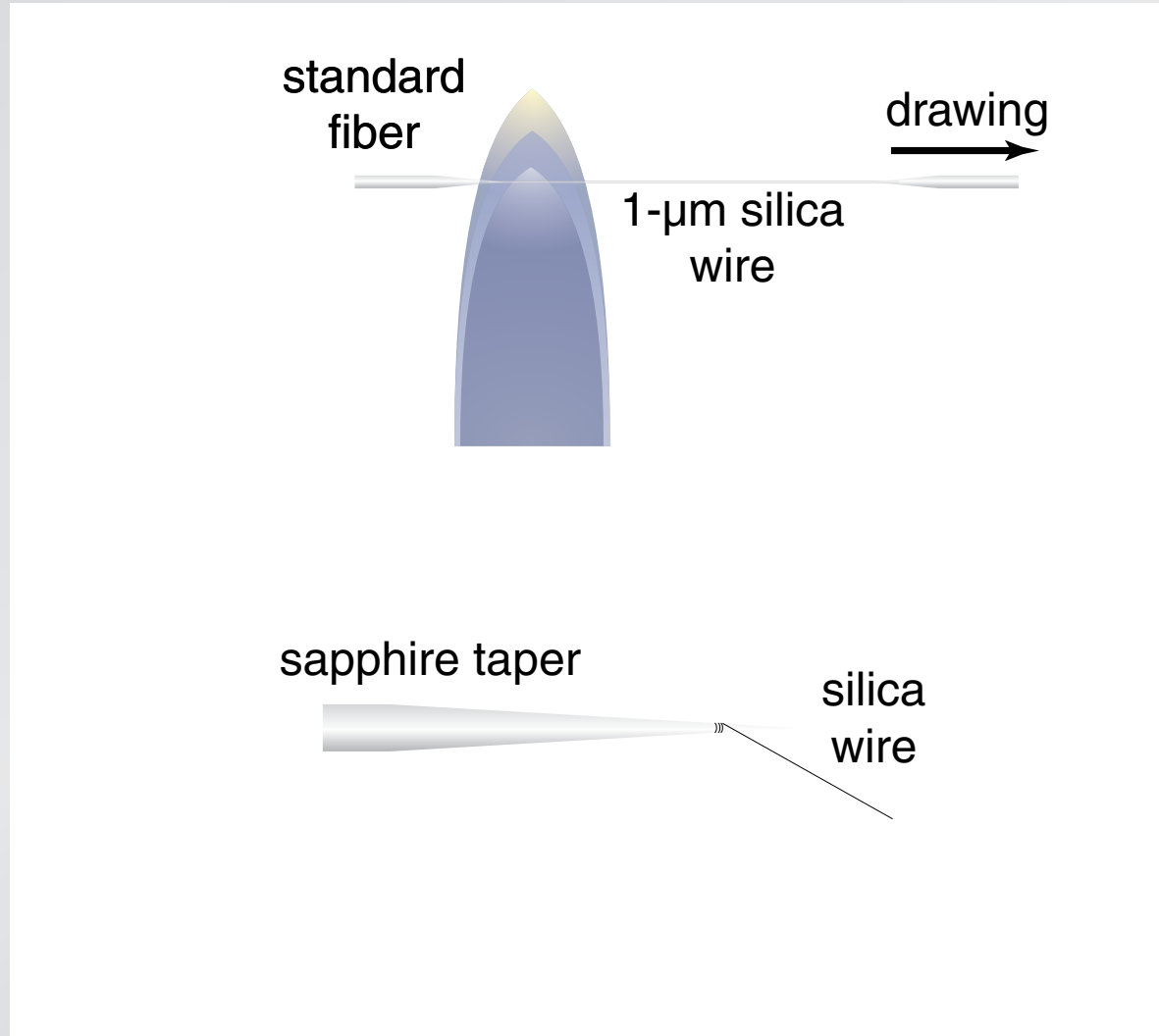
two-step drawing process





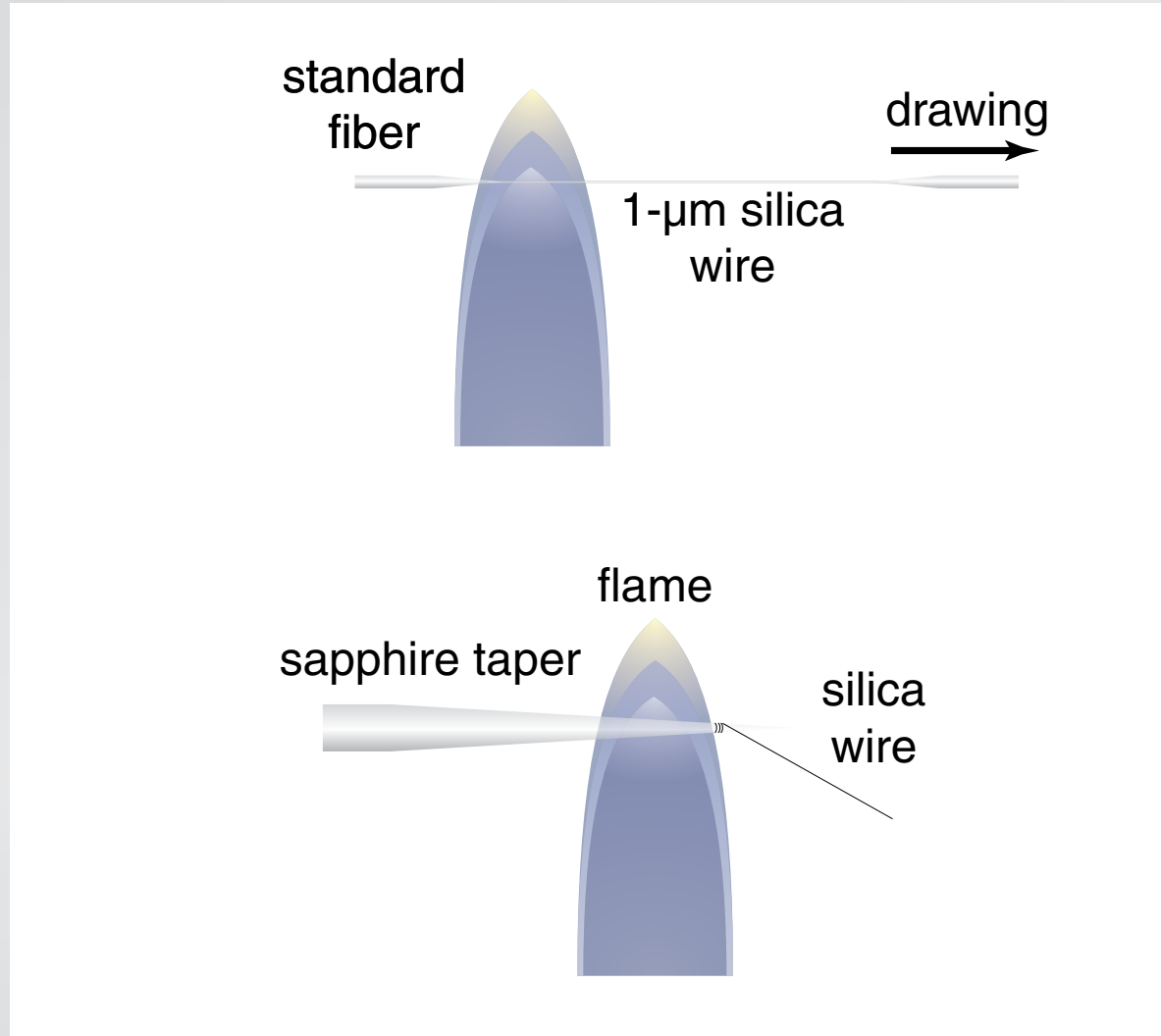
# Silica nanowires

## two-step drawing process



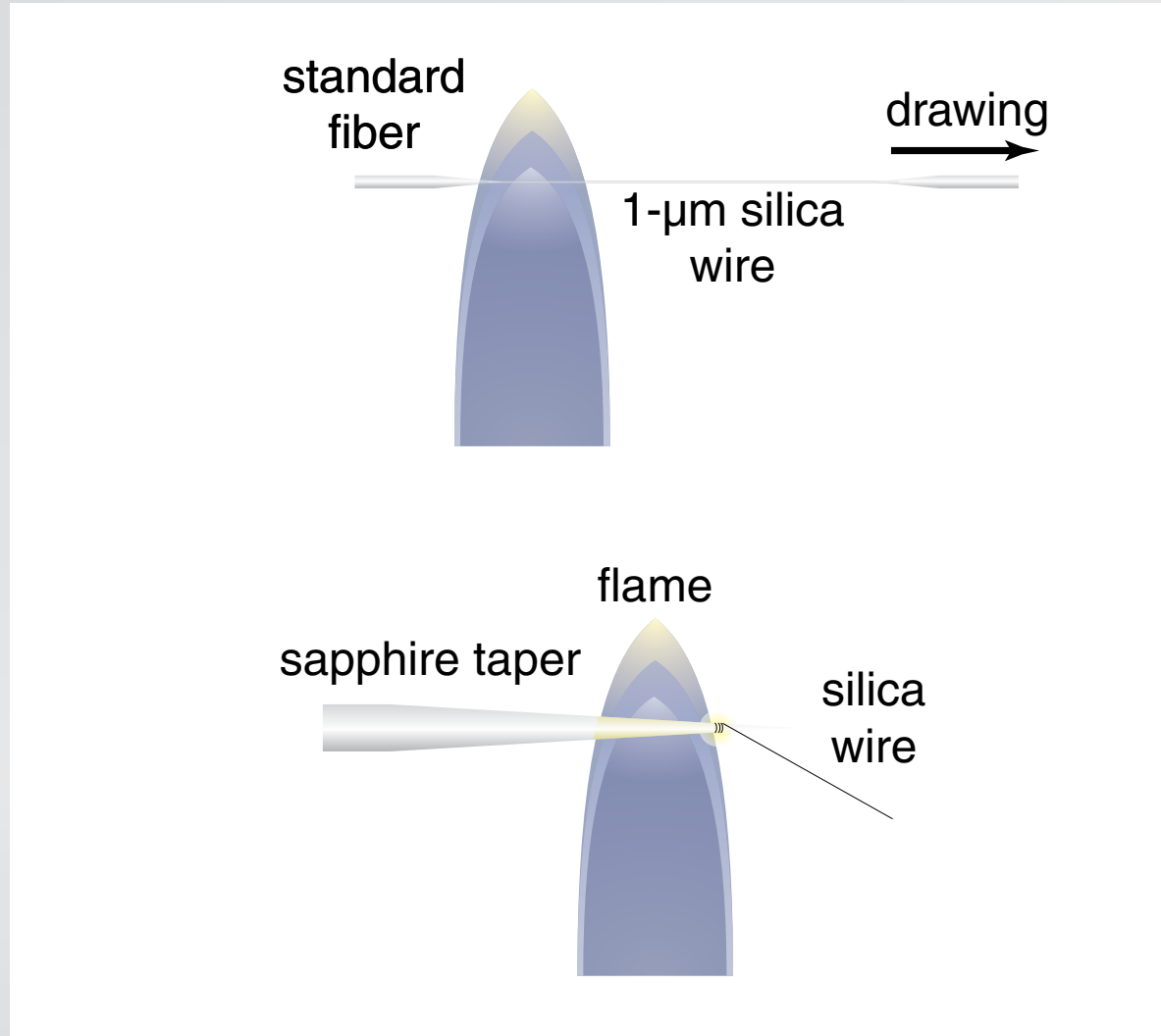
# Silica nanowires

## two-step drawing process



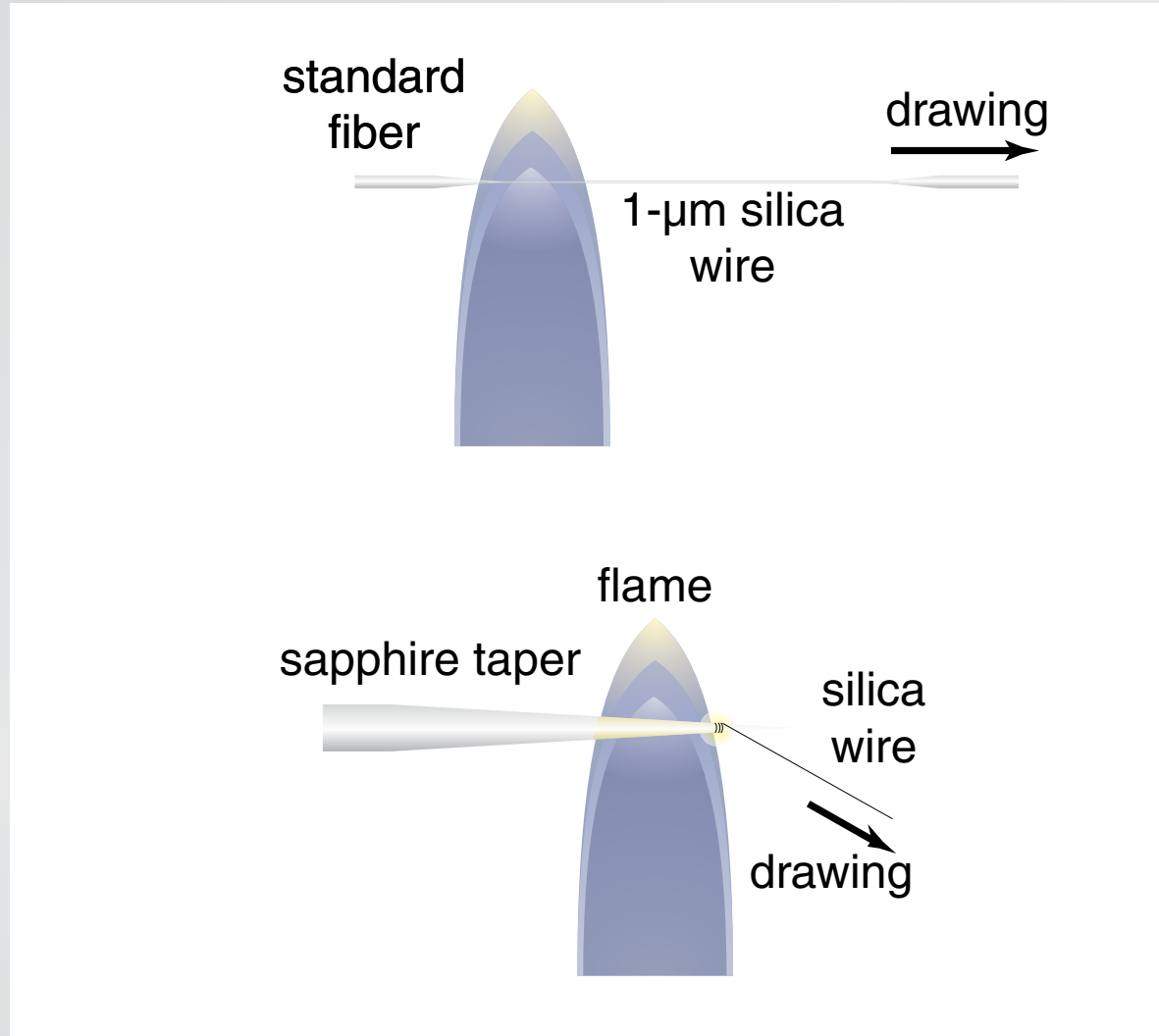
# Silica nanowires

## two-step drawing process



# Silica nanowires

## two-step drawing process



# Silica nanowires



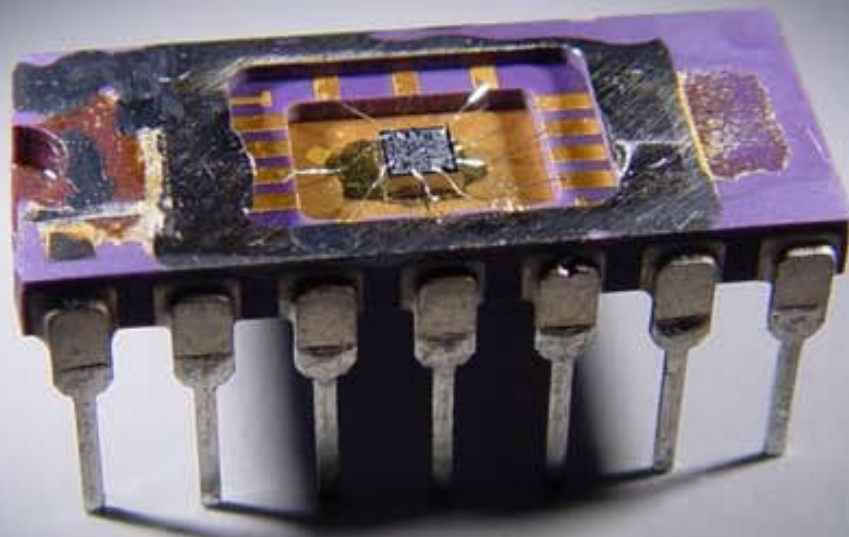
# Silica nanowires

1  $\mu\text{m}$

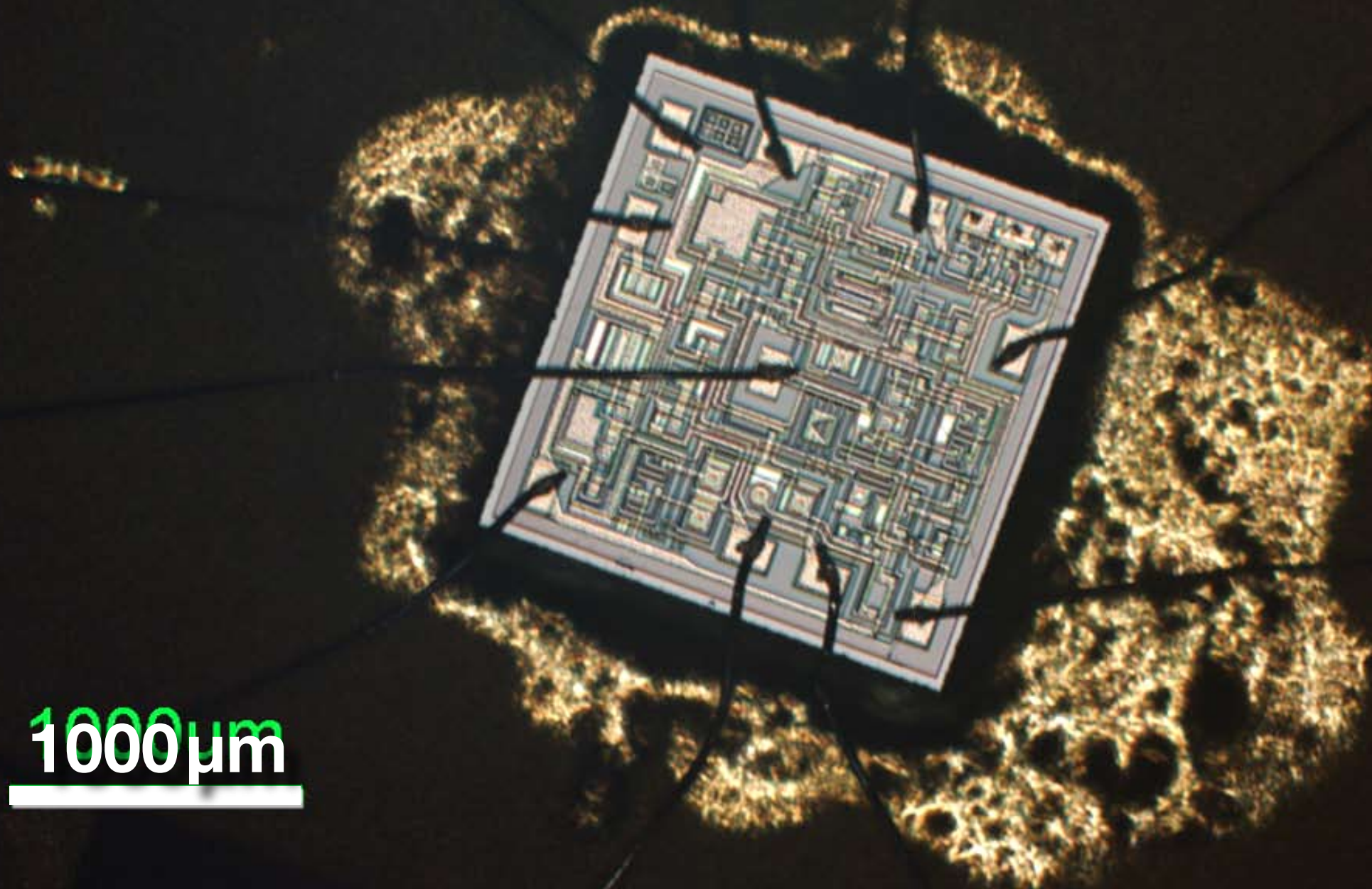


*Nature*, 426, 816 (2003)

# Silica nanowires



# Silica nanowires

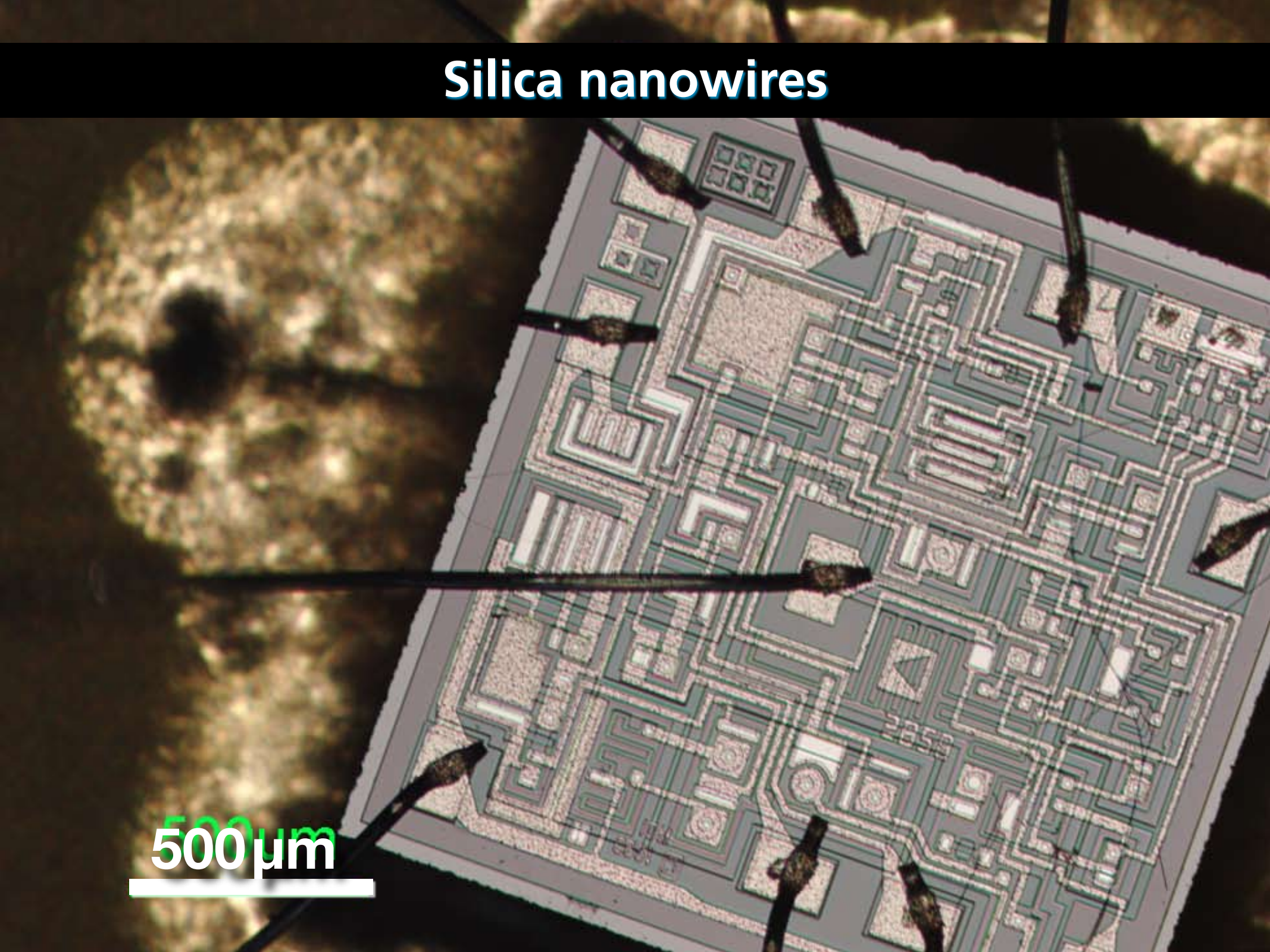


1000  $\mu\text{m}$

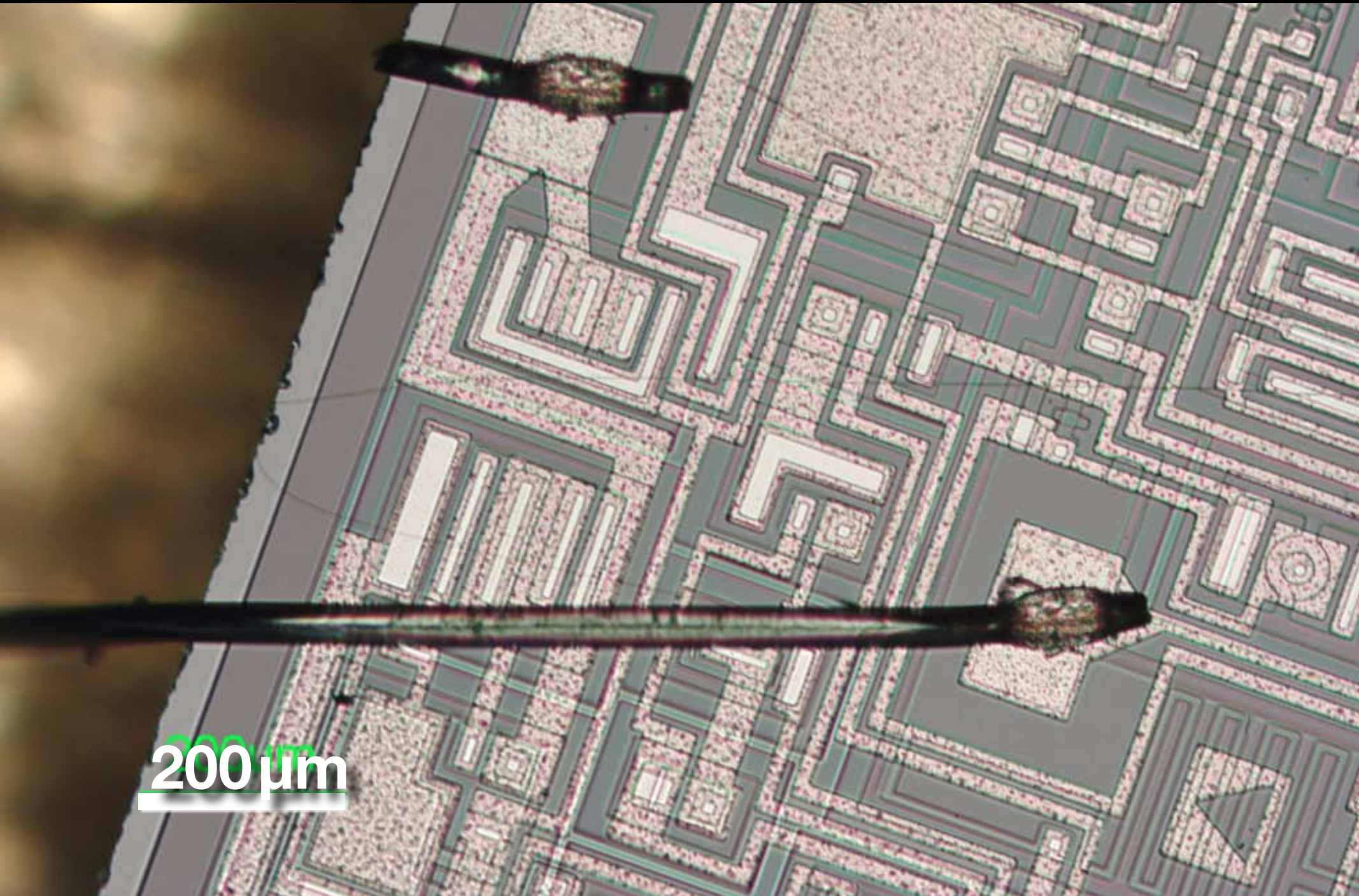


# Silica nanowires

500  $\mu\text{m}$

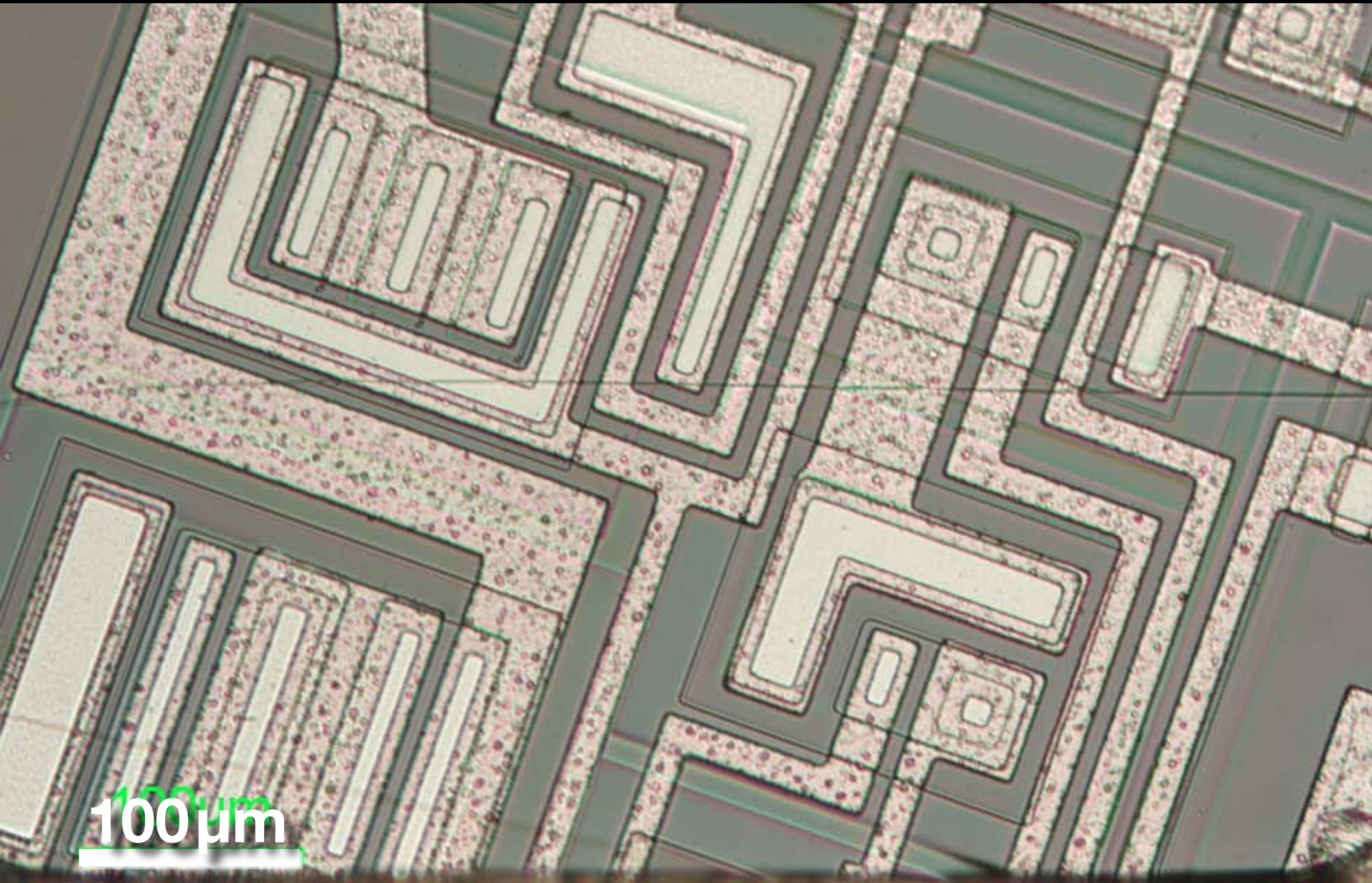


# Silica nanowires

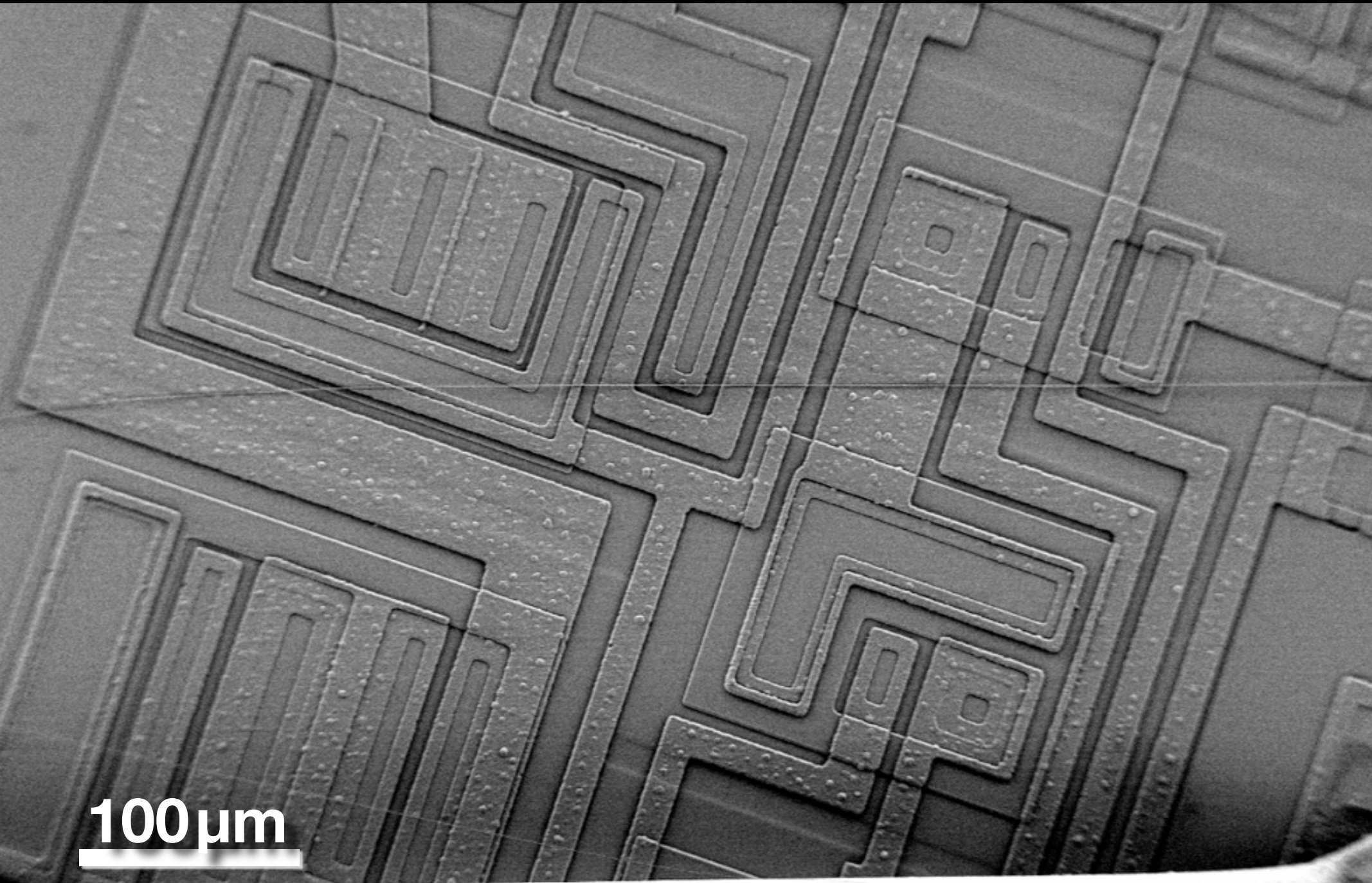


200  $\mu\text{m}$

# Silica nanowires

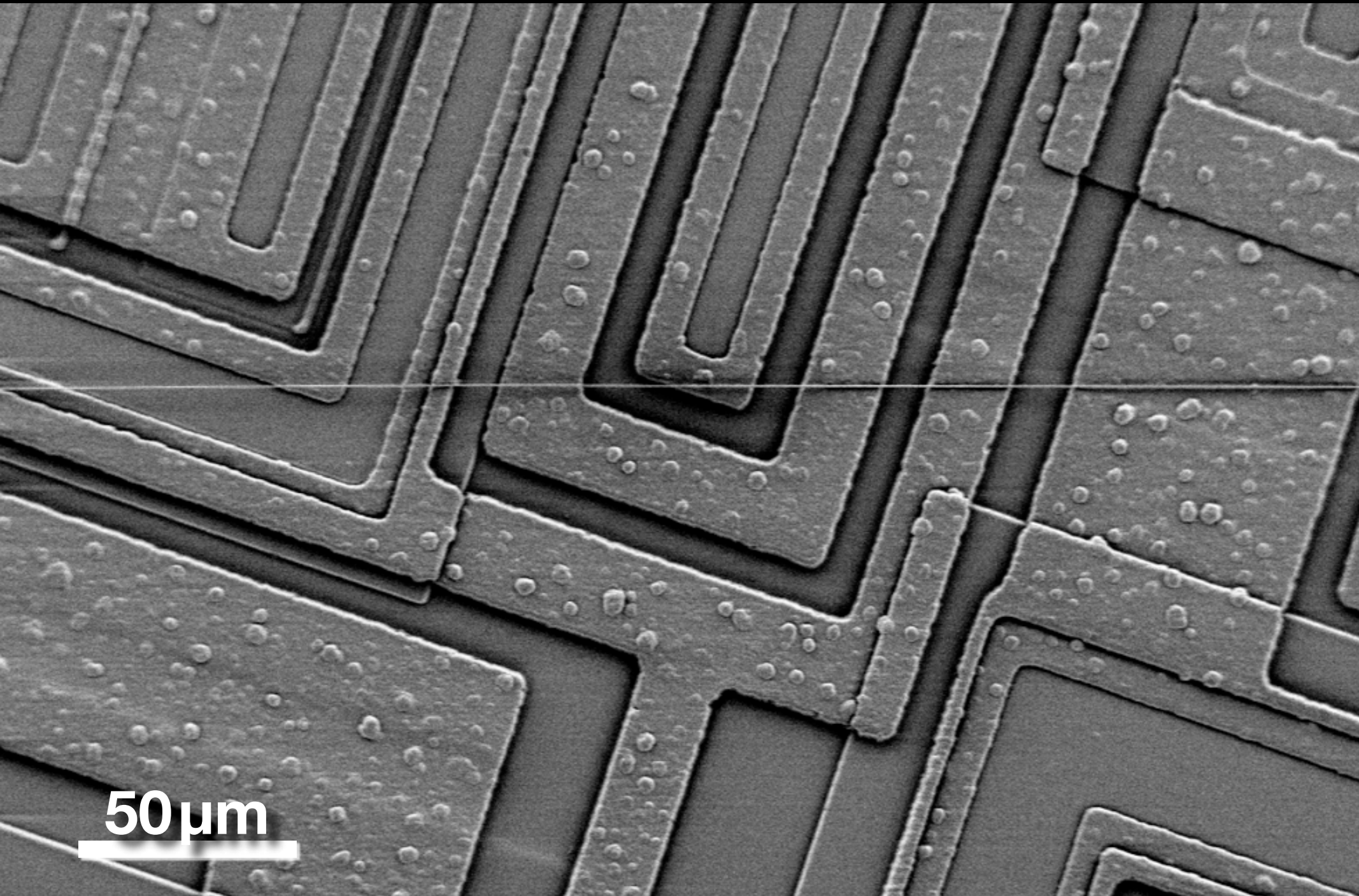


# Silica nanowires



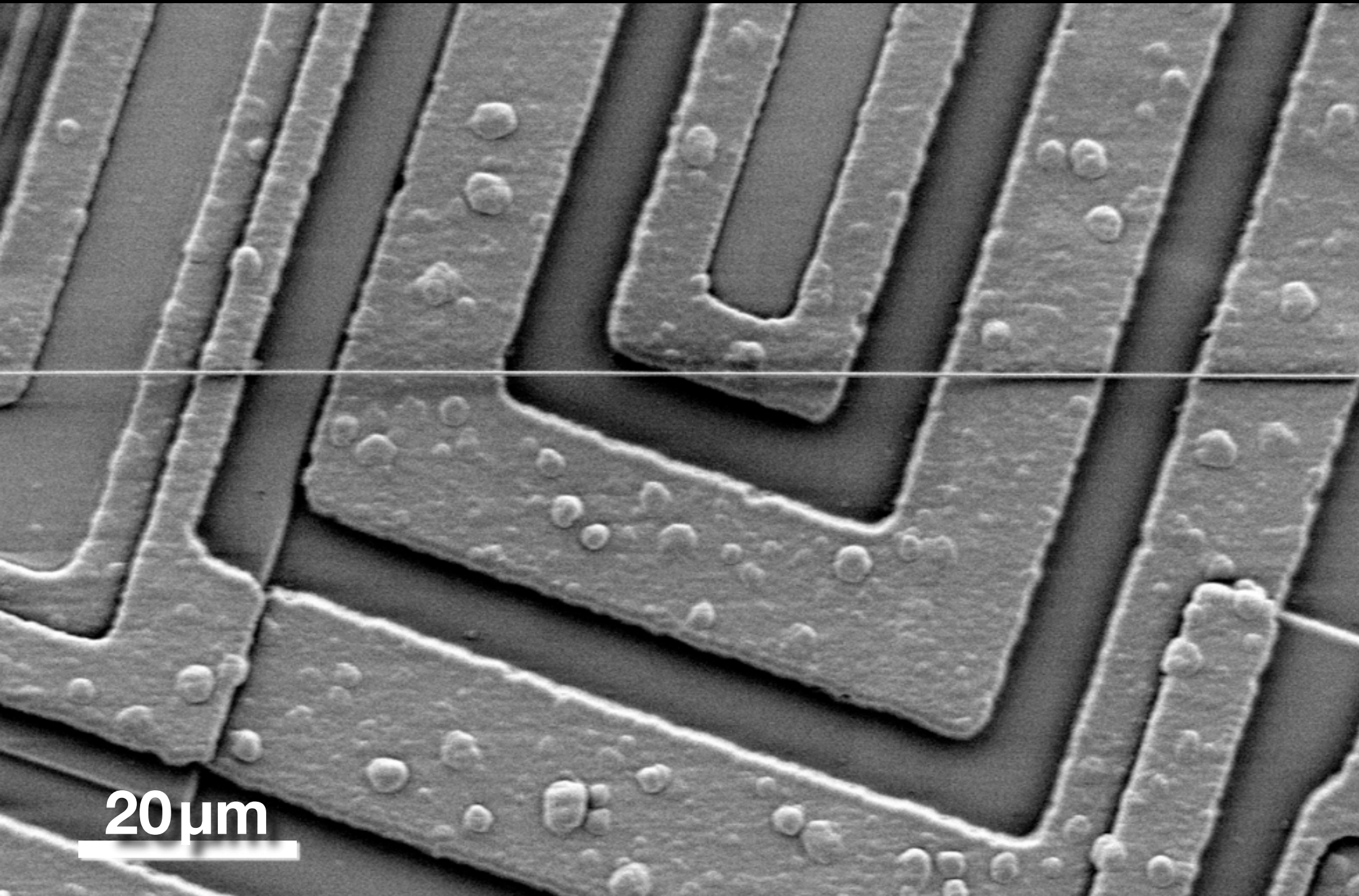
100 μm

# Silica nanowires



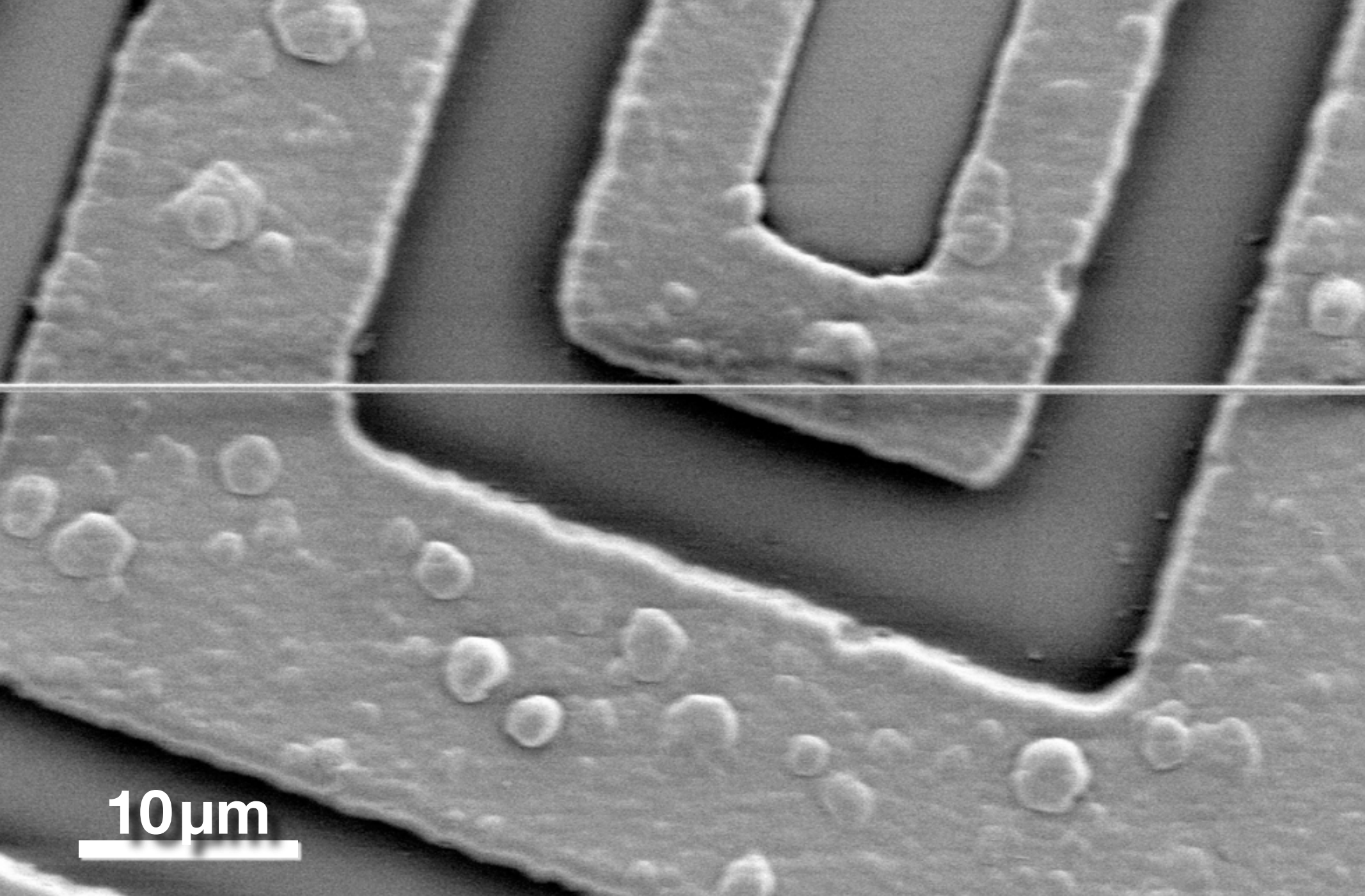
50  $\mu\text{m}$

# Silica nanowires



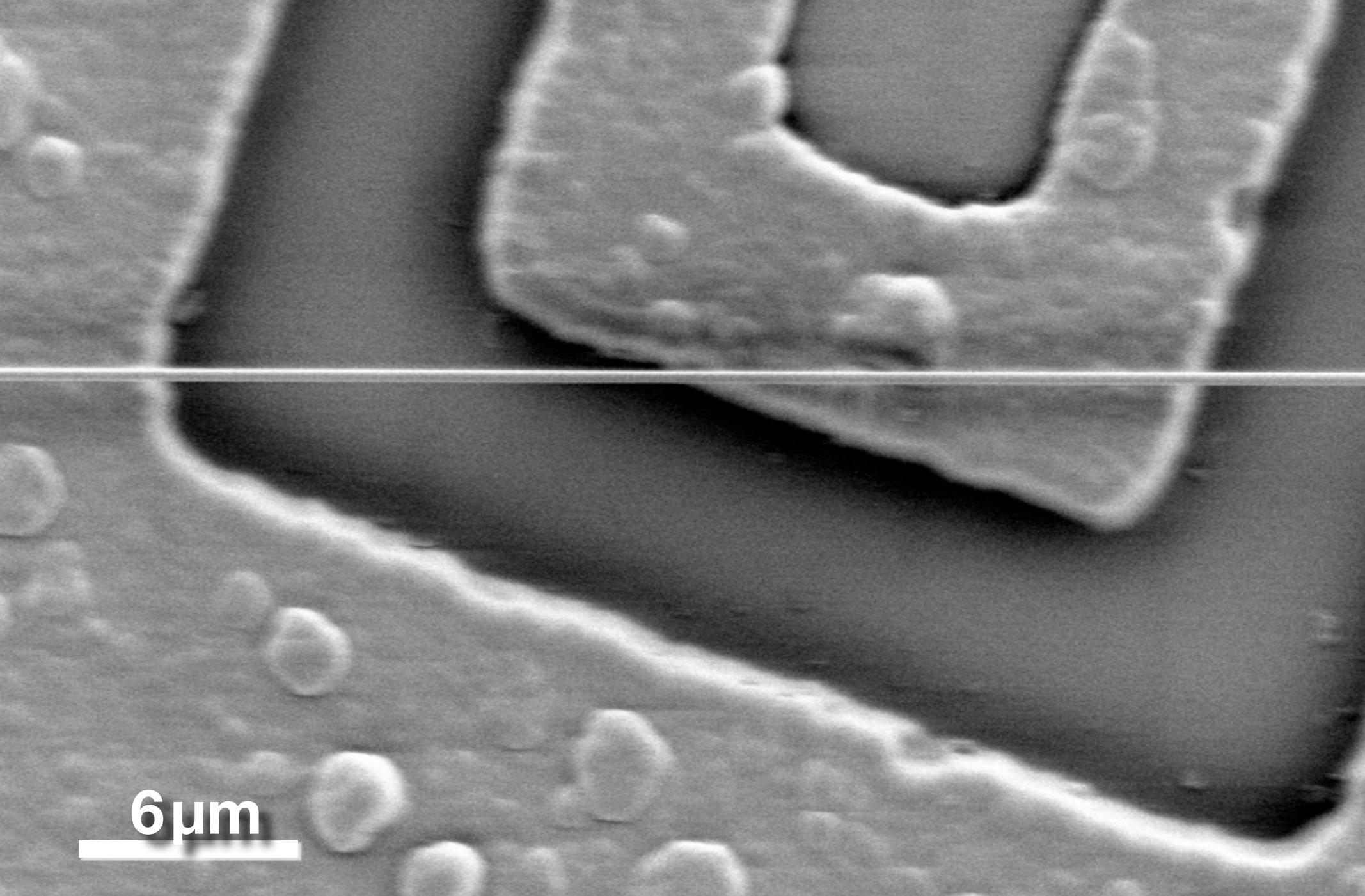
20  $\mu\text{m}$

# Silica nanowires



10  $\mu\text{m}$

# Silica nanowires



6  $\mu\text{m}$





# Silica nanowires

4  $\mu\text{m}$

Scanning electron micrograph (SEM) showing silica nanowires. The image displays a network of thin, interconnected nanowires against a dark background. A prominent horizontal nanowire runs across the center of the frame. Other nanowires are visible in the upper and lower regions, some appearing as curved or branched structures. The nanowires have a uniform, cylindrical appearance. A scale bar in the bottom left corner indicates a length of 4 micrometers.

# Silica nanowires

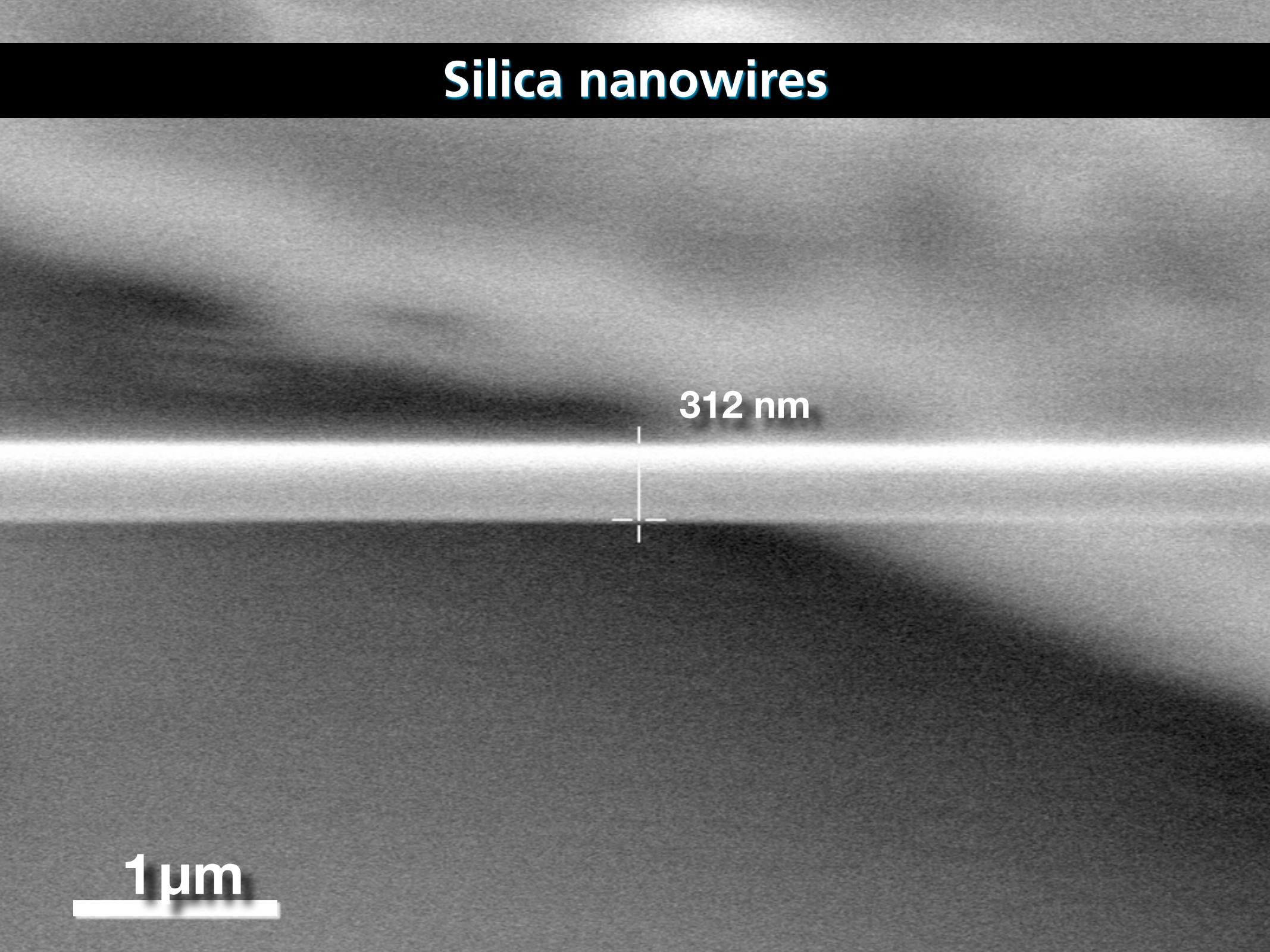
2  $\mu\text{m}$

A grayscale micrograph showing a single, long, thin silica nanowire oriented horizontally across the center of the frame. The nanowire is very uniform in thickness and extends across most of the width of the image. In the bottom-left corner, there is a white horizontal scale bar with the text "2 μm" positioned above it.

# Silica nanowires

312 nm

1  $\mu\text{m}$



# Silica nanowires

## Specifications

diameter  $D$ : down to 20 nm

length  $L$ : up to 90 mm

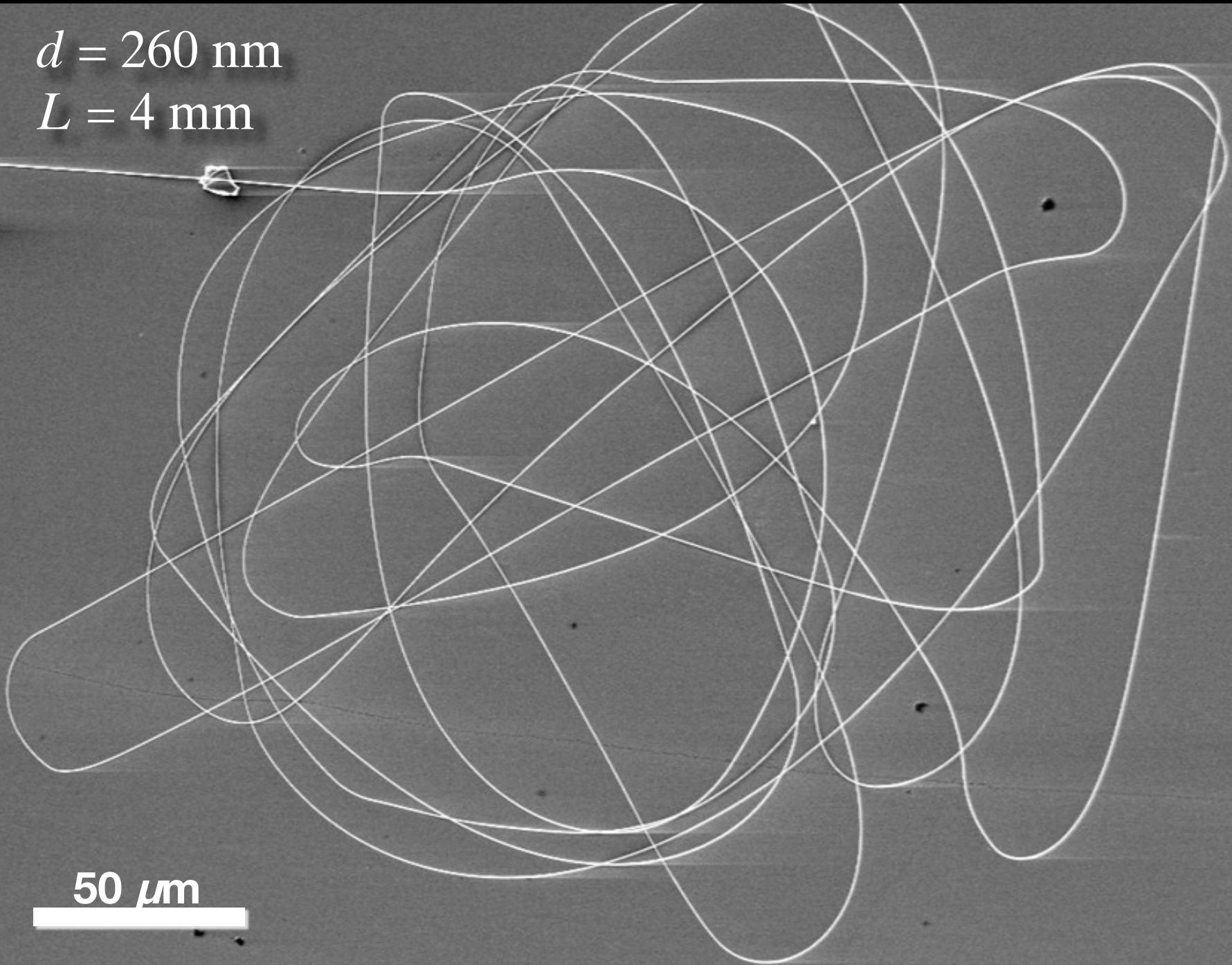
aspect ratio  $D/L$ : up to  $10^6$

diameter uniformity  $\Delta D/L$ :  $2 \times 10^{-6}$

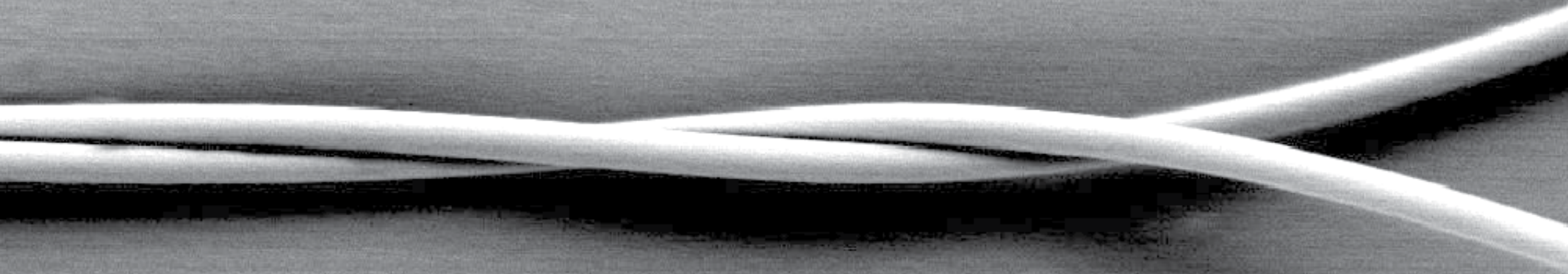
# Silica nanowires

$d = 260 \text{ nm}$

$L = 4 \text{ mm}$



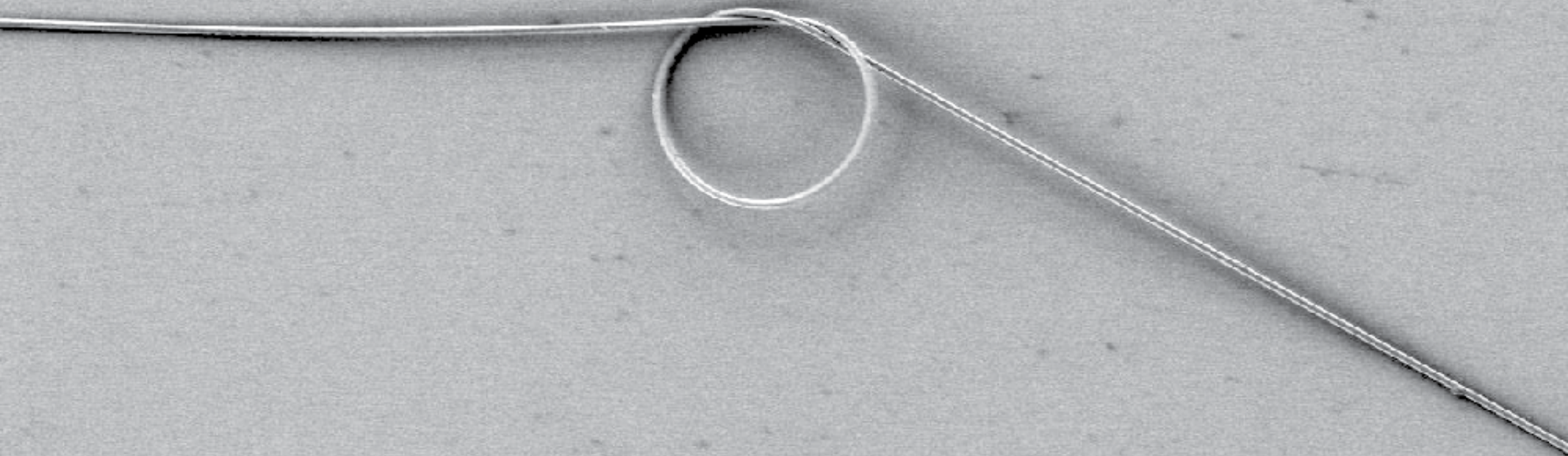
# Silica nanowires



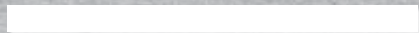
2  $\mu\text{m}$



# Silica nanowires

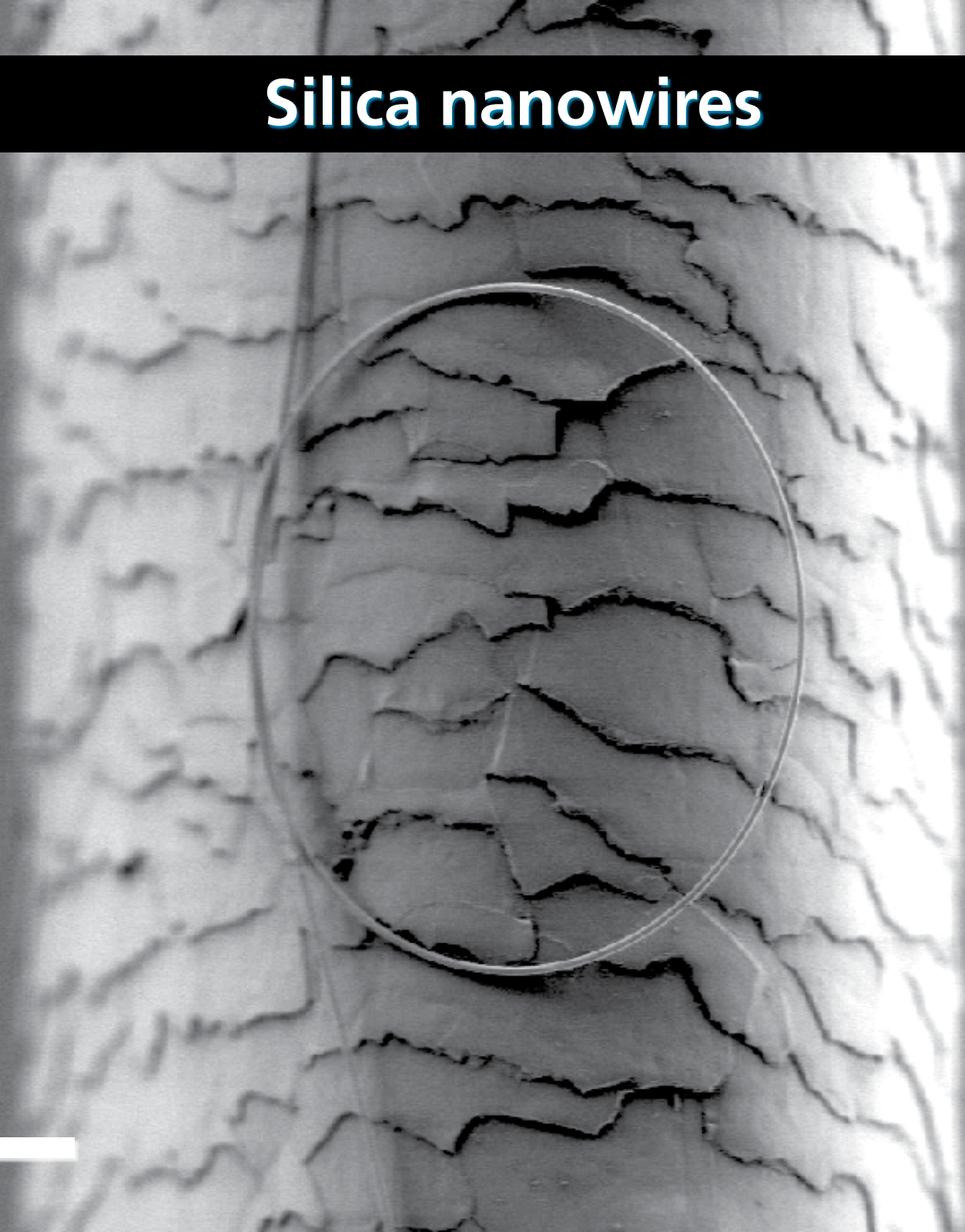


20  $\mu\text{m}$



# Silica nanowires

20  $\mu\text{m}$





# Optical properties



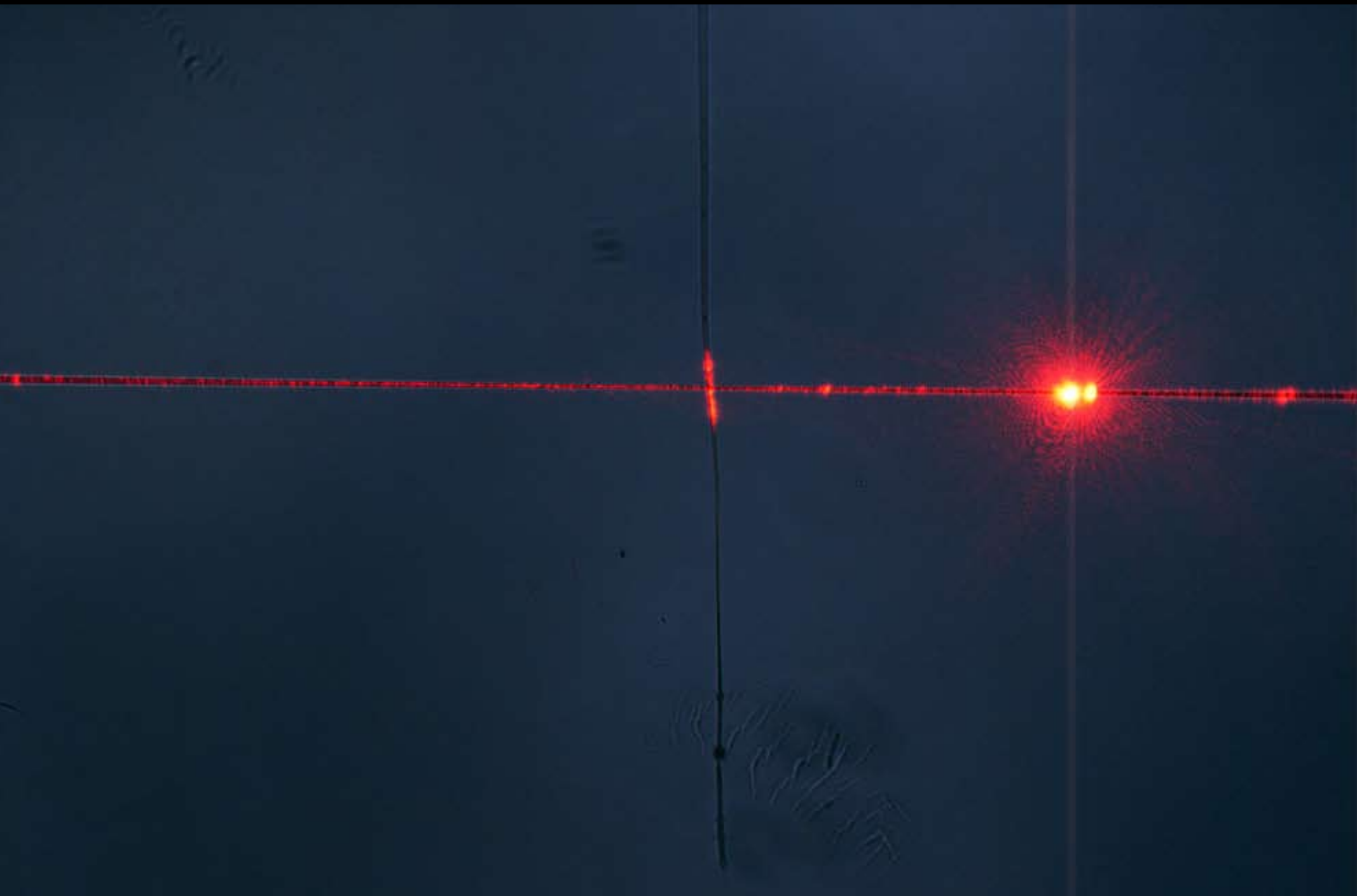
**50  $\mu\text{m}$**

# Optical properties



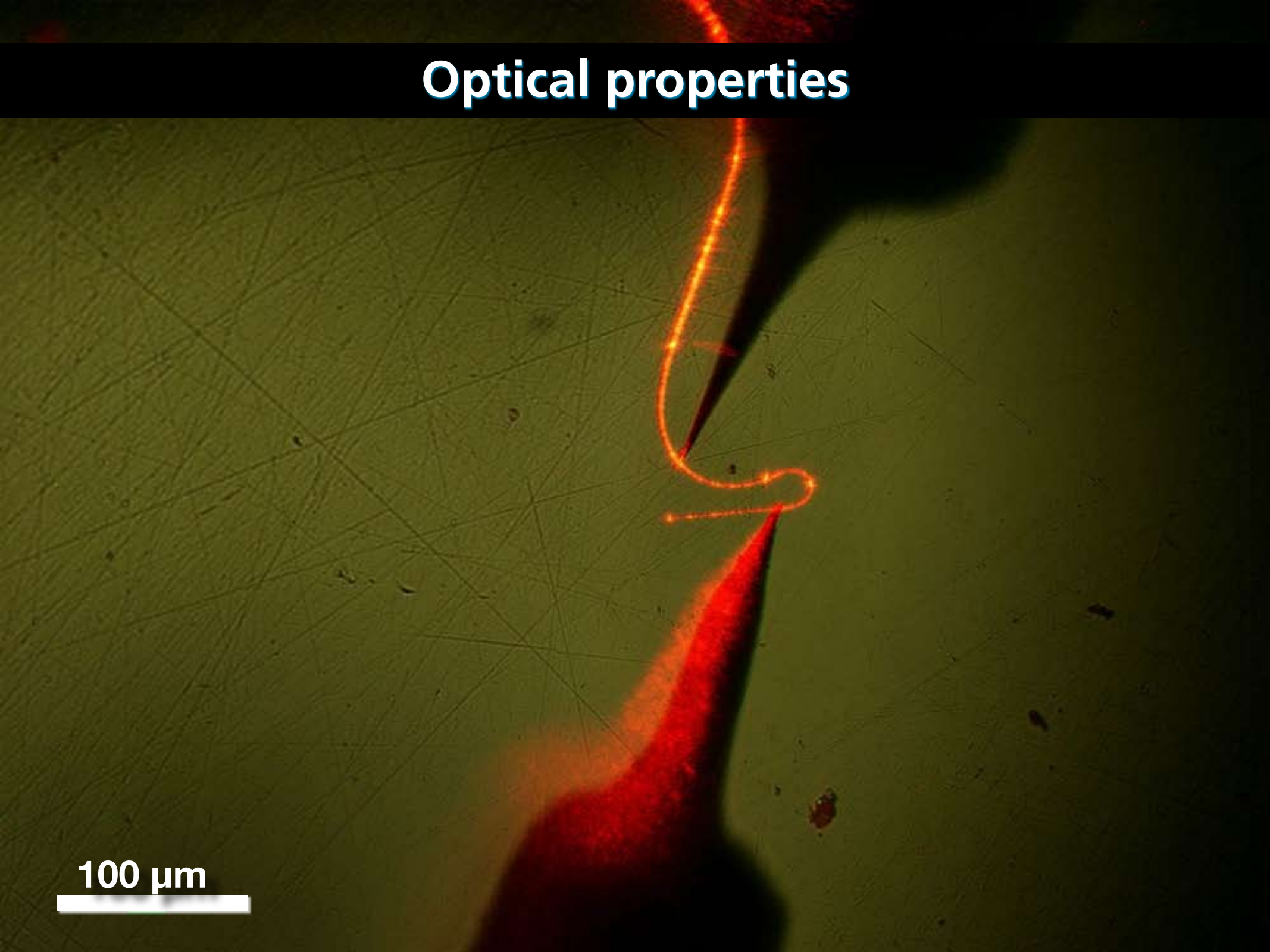
**50  $\mu\text{m}$**

# Optical properties



# Optical properties

100  $\mu\text{m}$

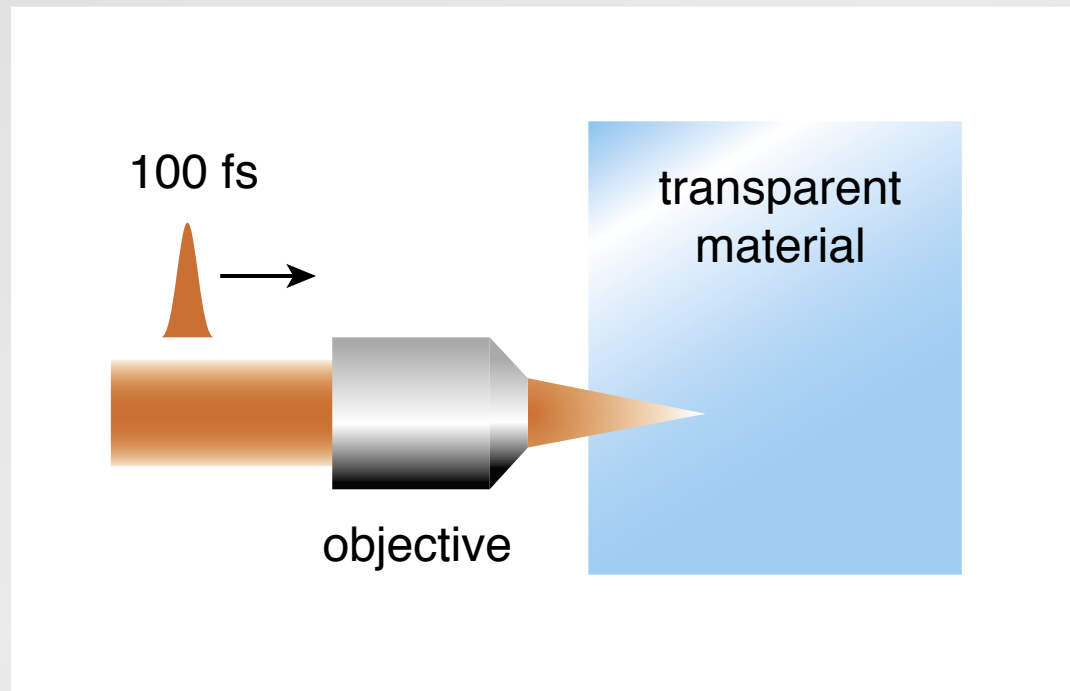
An optical micrograph showing a fiber optic tip on the right side. A bright red laser beam is directed at the tip, creating a visible red glow. A thin, curved red line of light extends from the tip towards the top of the frame. The background is a dark, textured surface with fine scratches. A white scale bar in the bottom left corner indicates a length of 100 micrometers.

# Outline

- silica nanowires
- fs laser micromachining
- biophotonics

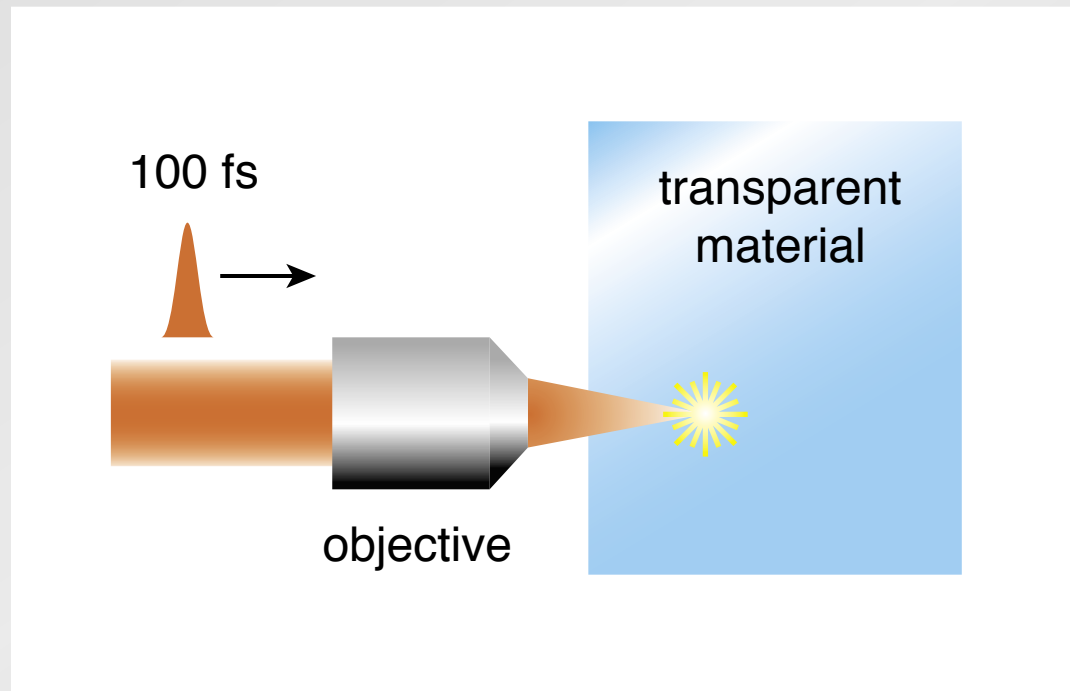
# Femtosecond micromachining

high intensity at focus...



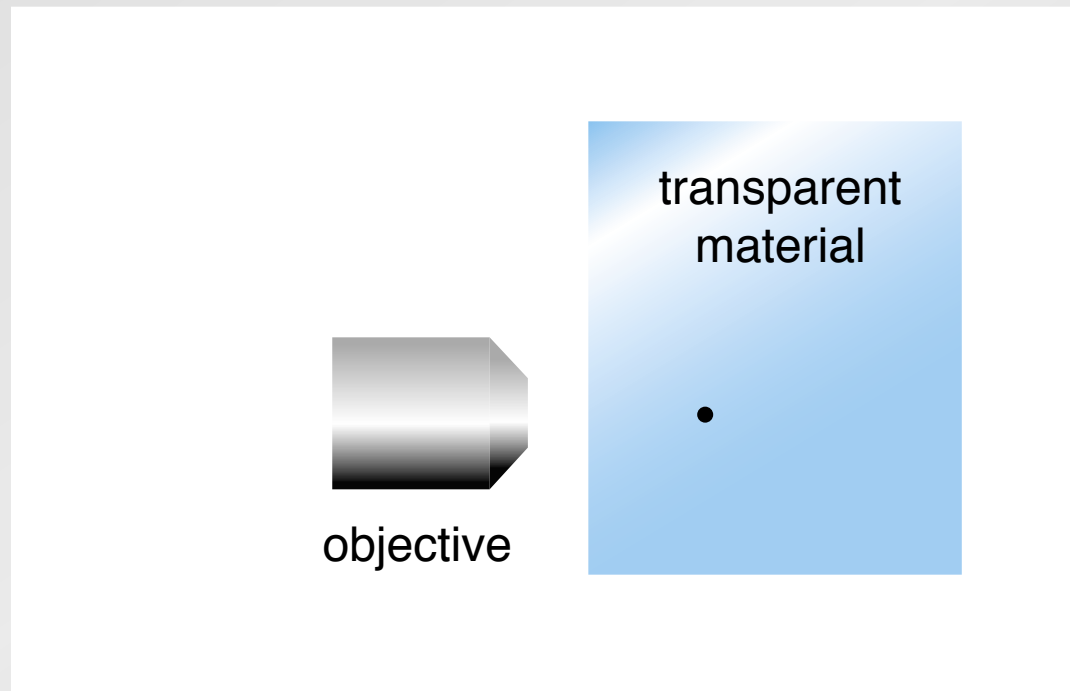
# Femtosecond micromachining

...causes nonlinear ionization...



# Femtosecond micromachining

and 'microexplosion' causes microscopic damage...

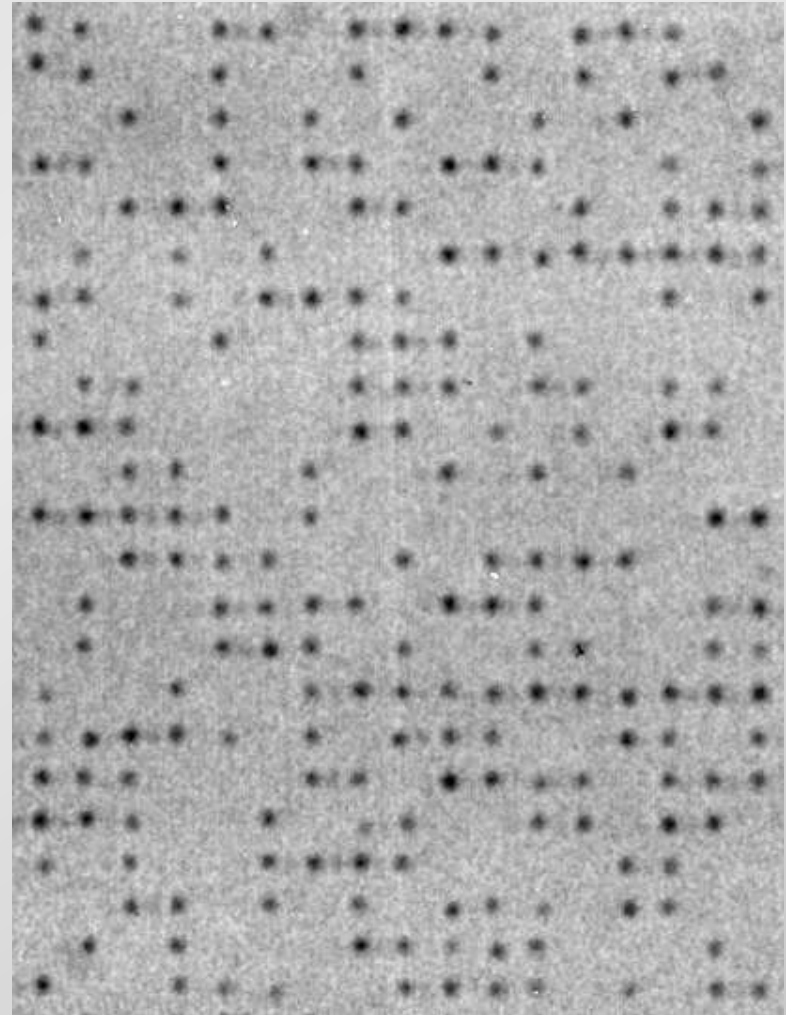




# Femtosecond micromachining

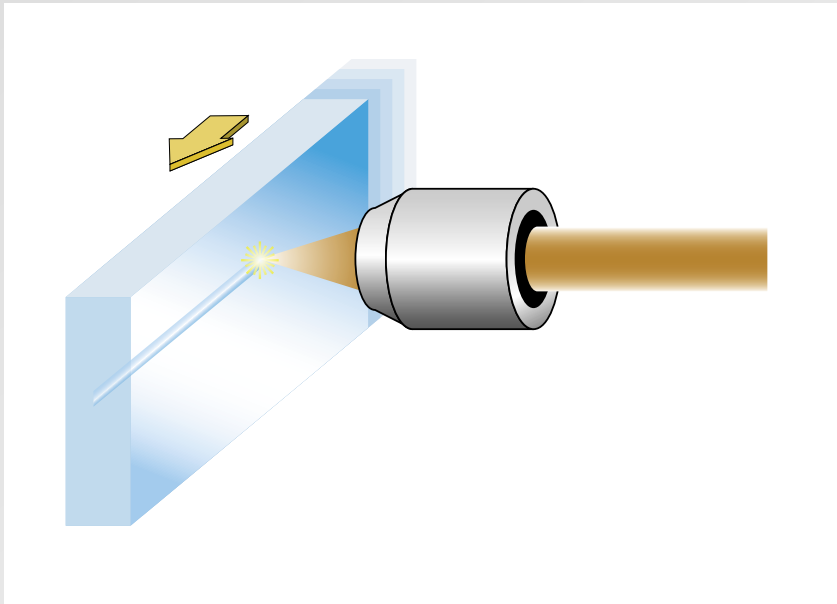
**Some applications:**

- **data storage**
- **waveguides**
- **microfluidics**



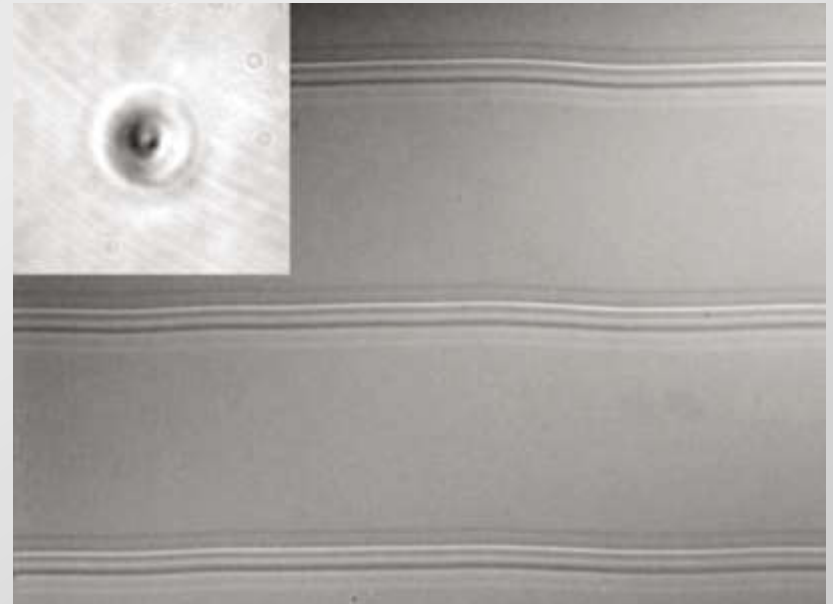
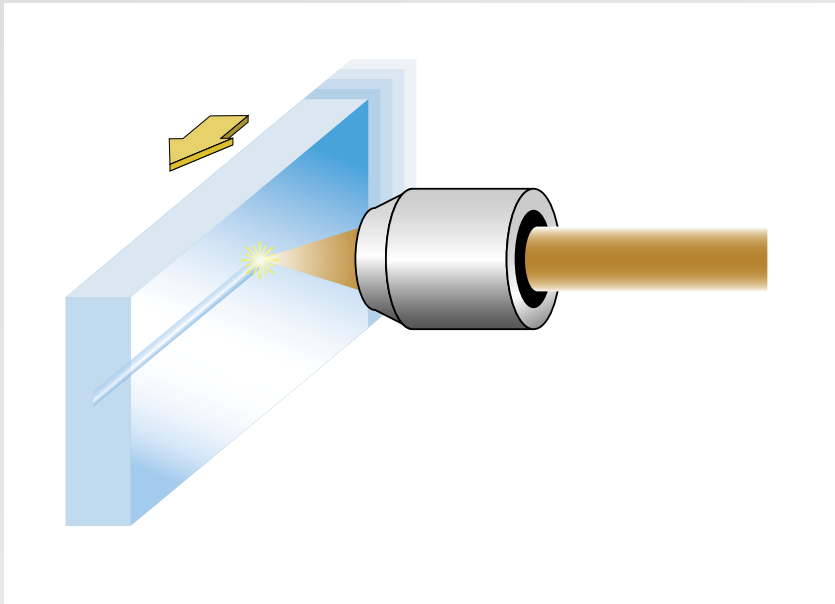
# Low-energy machining

## waveguide micromachining



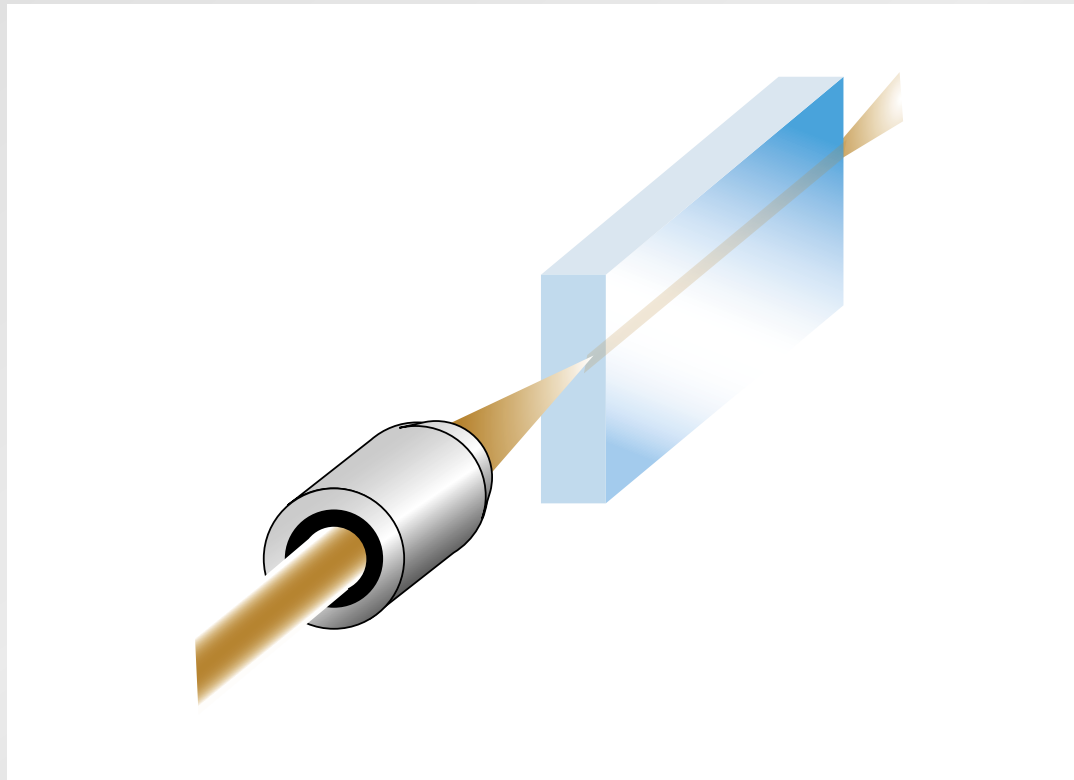
# Low-energy machining

## waveguide micromachining

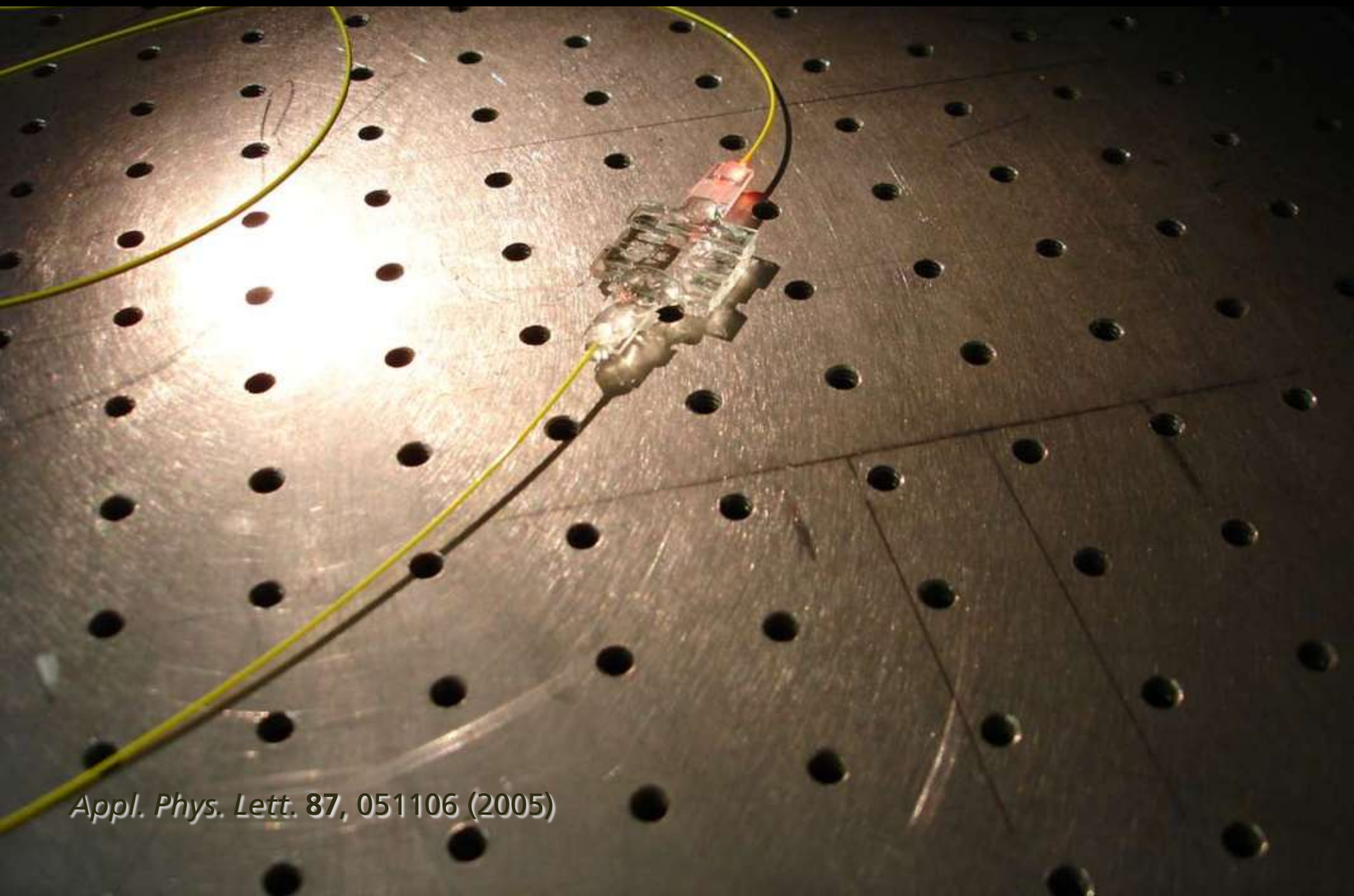


# Low-energy machining

structures guide light



# Applications



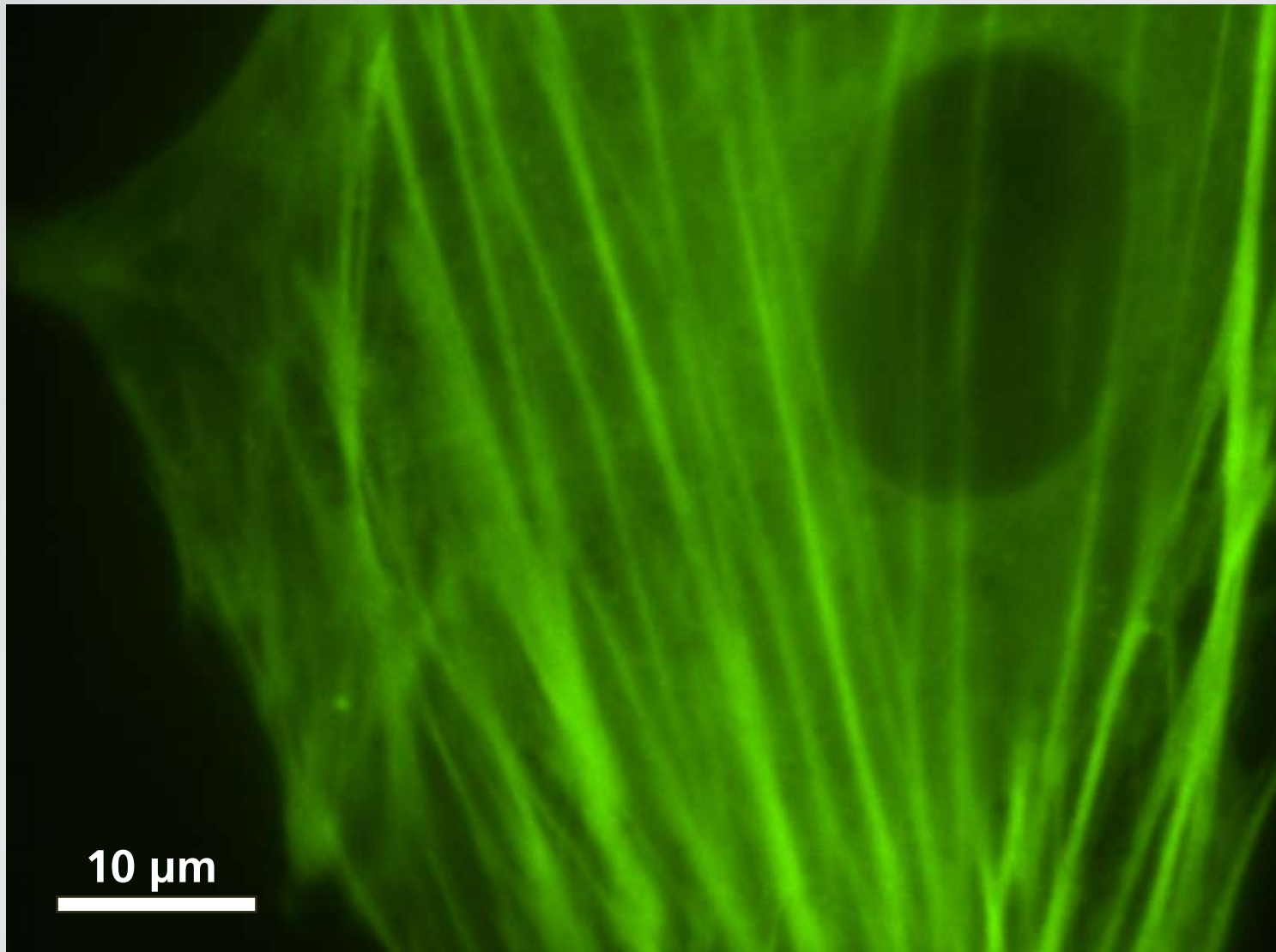
*Appl. Phys. Lett.* 87, 051106 (2005)

# Outline

- silica nanowires
- fs laser micromachining
- biophotonics

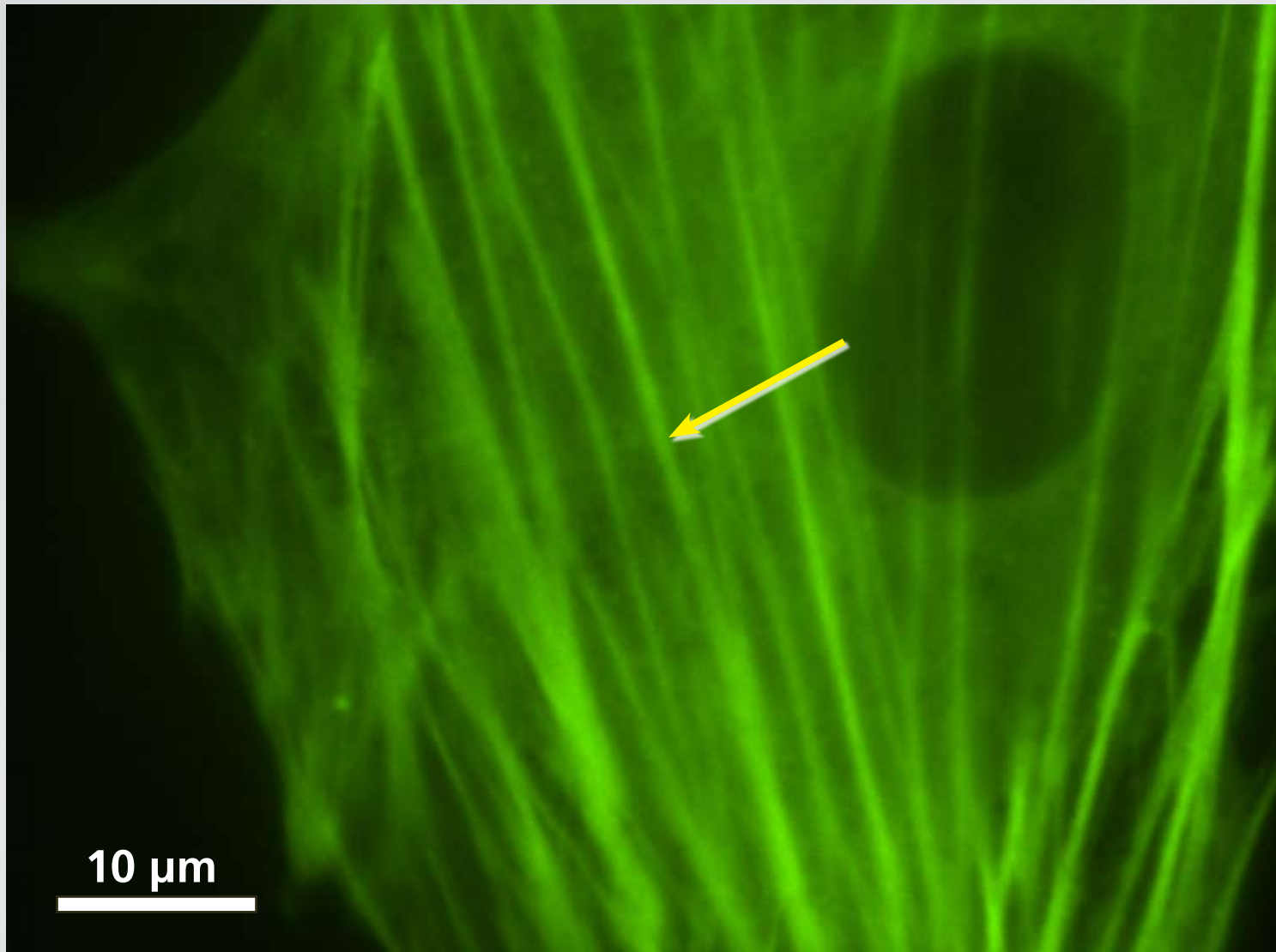
# Applications

actin fiber network of a live cell



# Applications

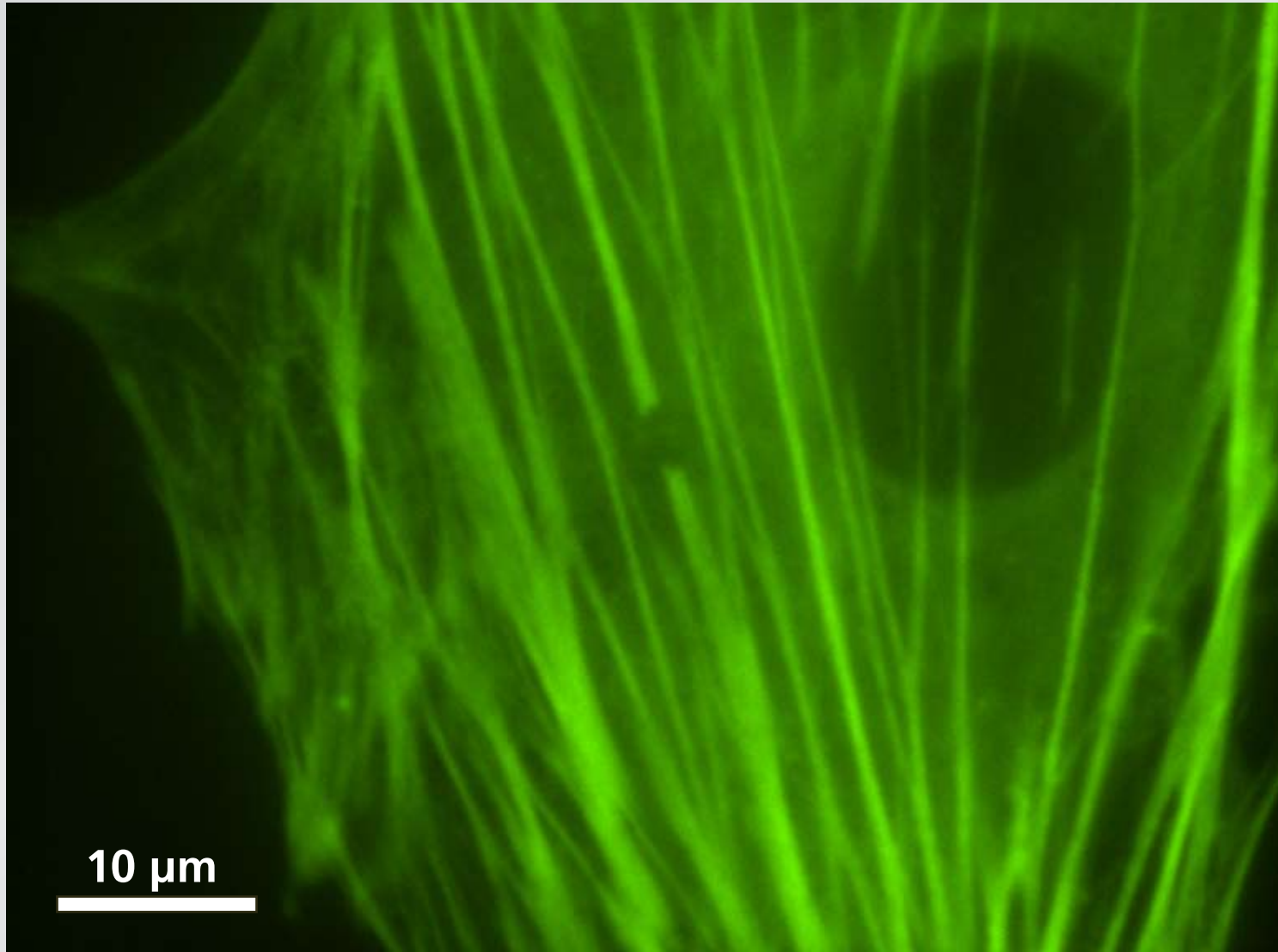
cut a single fiber bundle





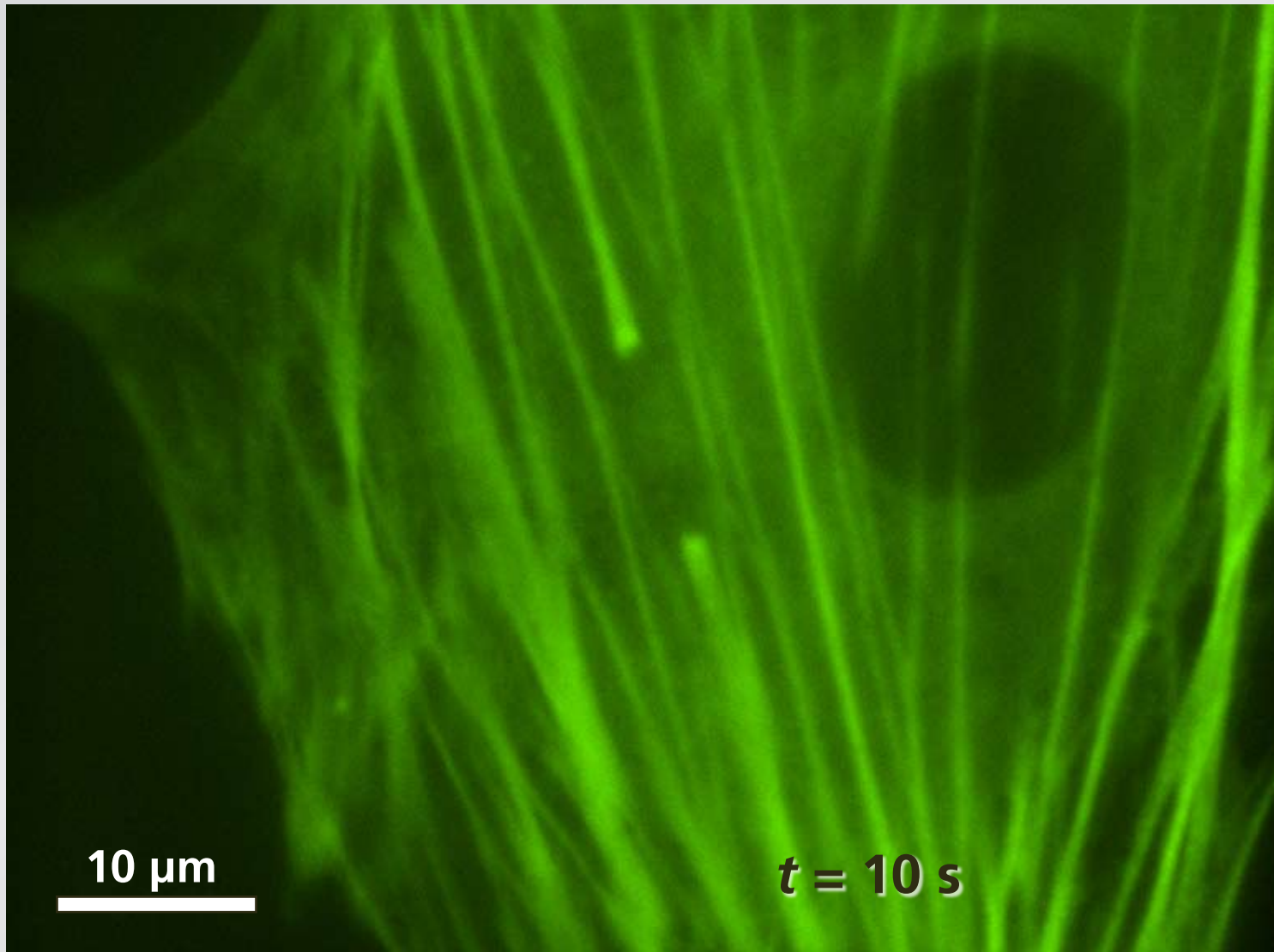
# Applications

cut a single fiber bundle



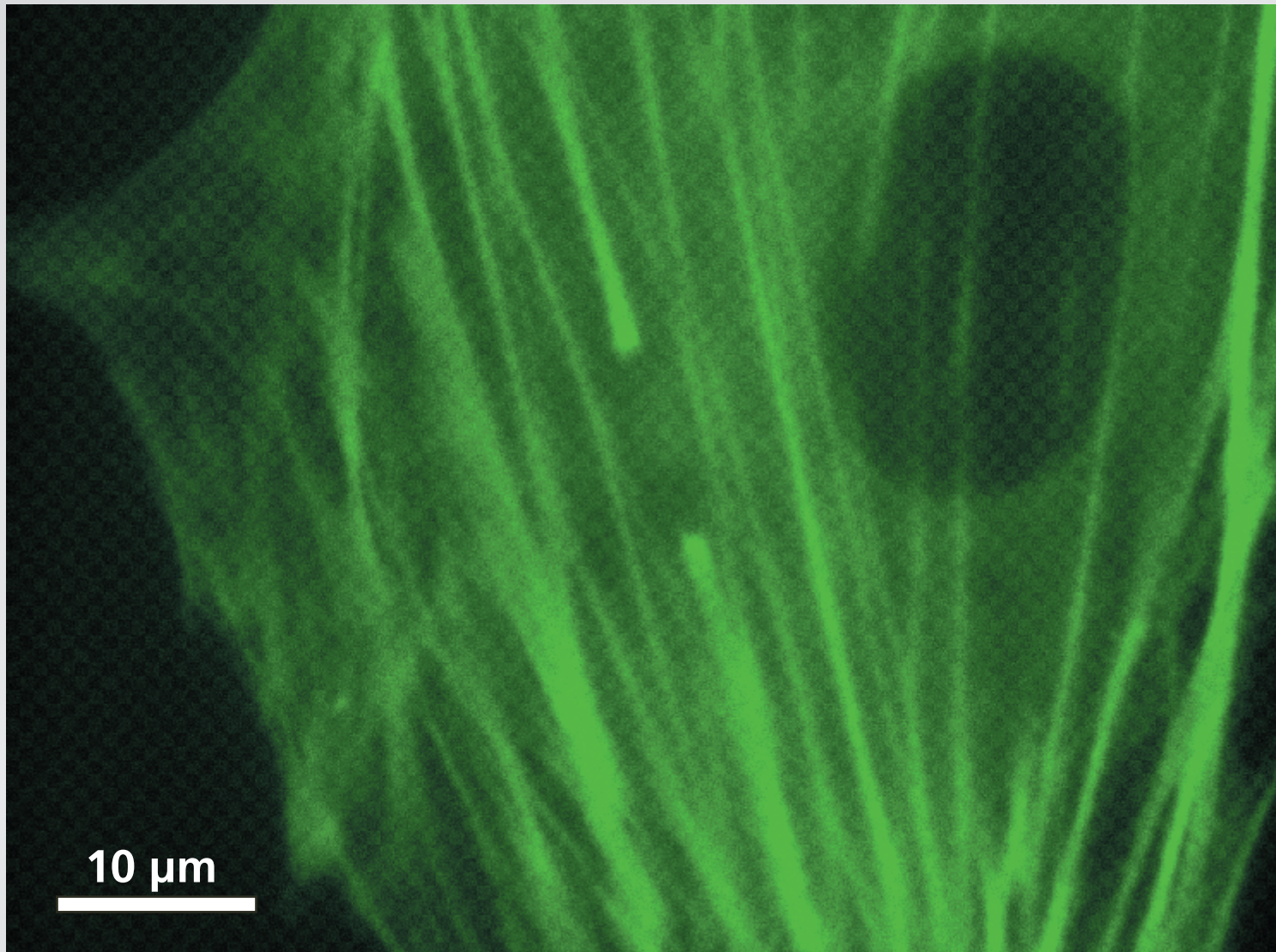
# Applications

gap widens with time

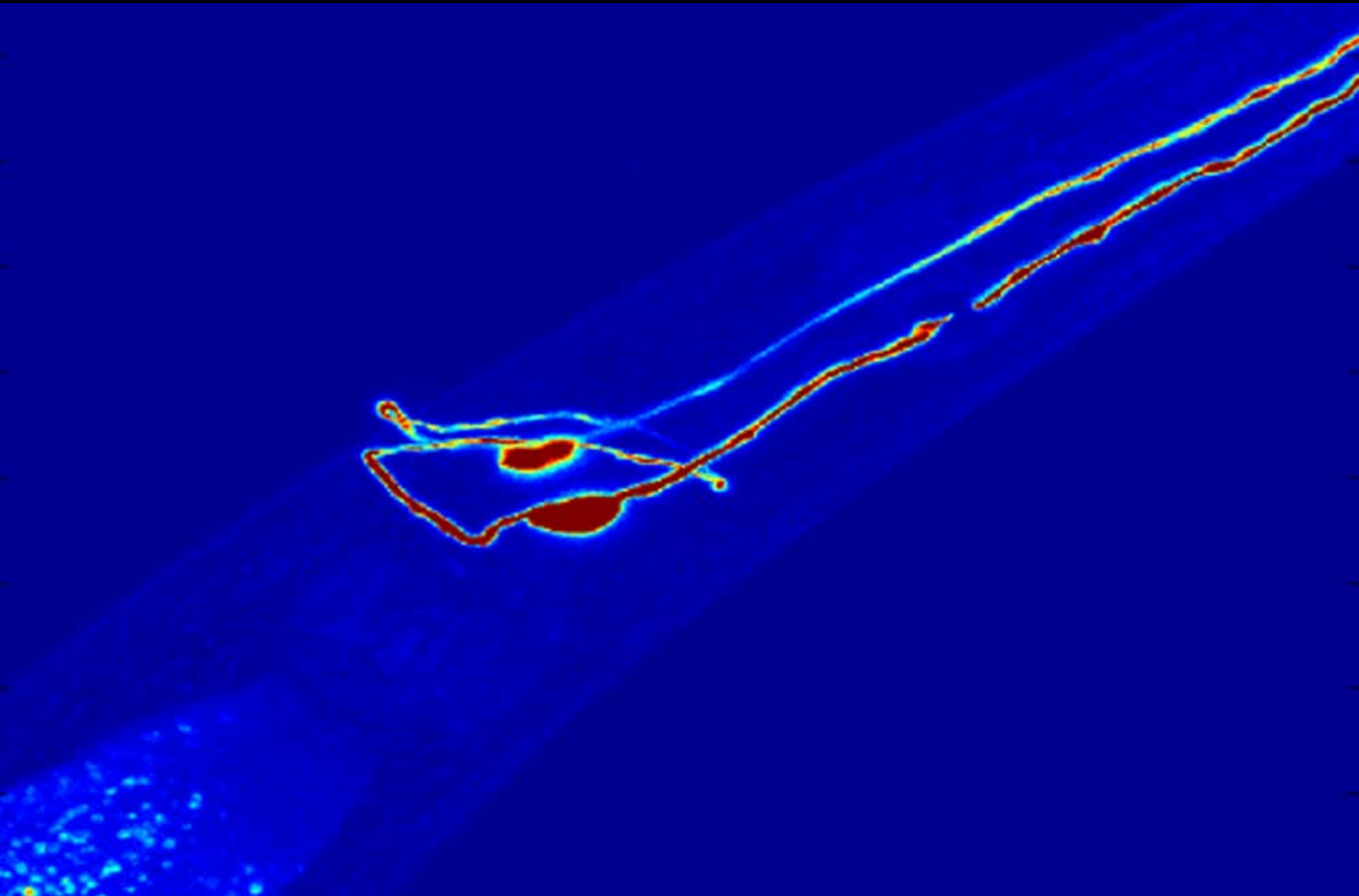


# Applications

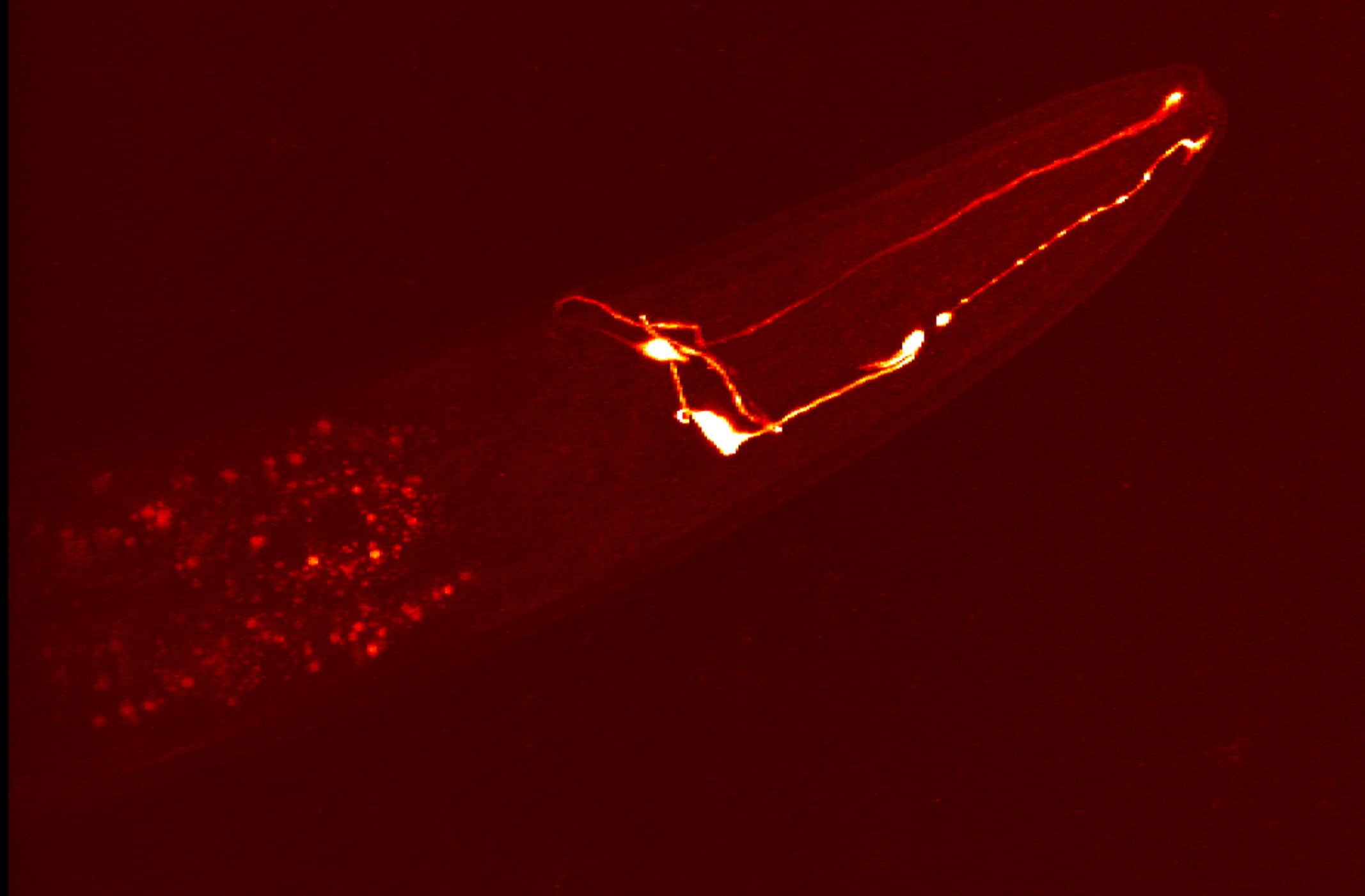
dynamics provides information on *in vivo* mechanics



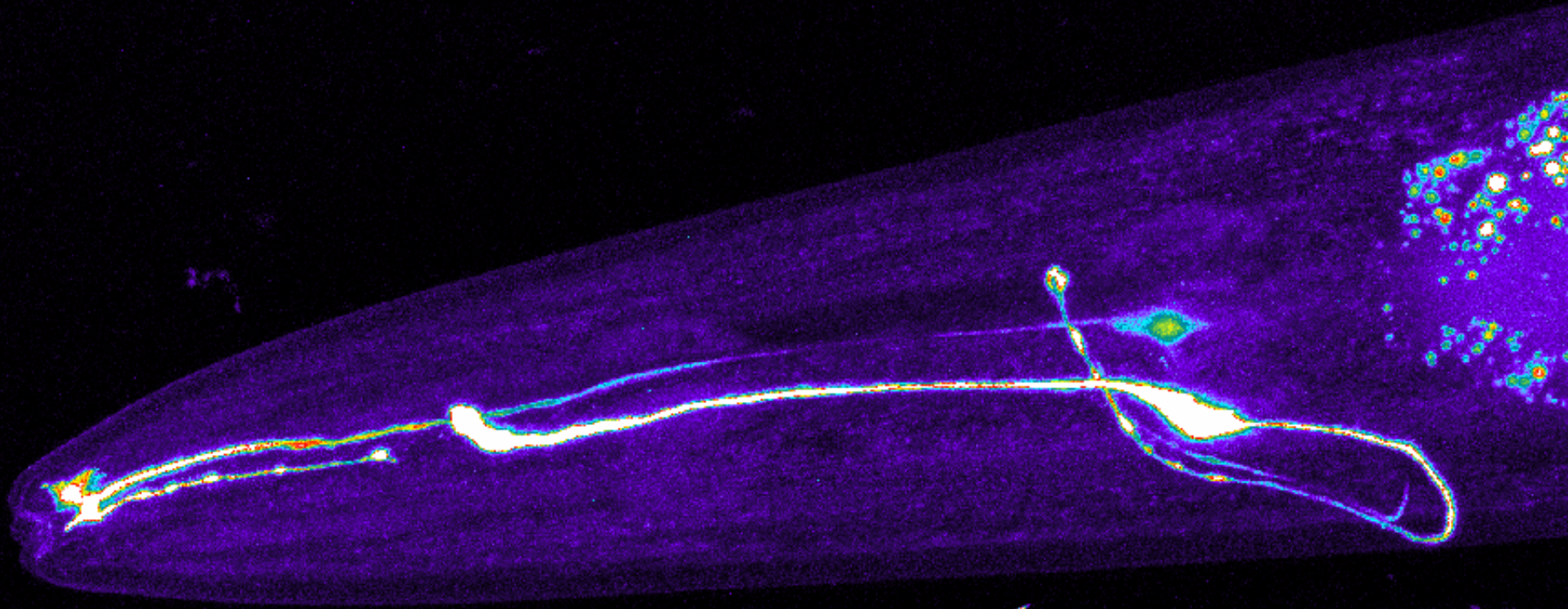
# Applications



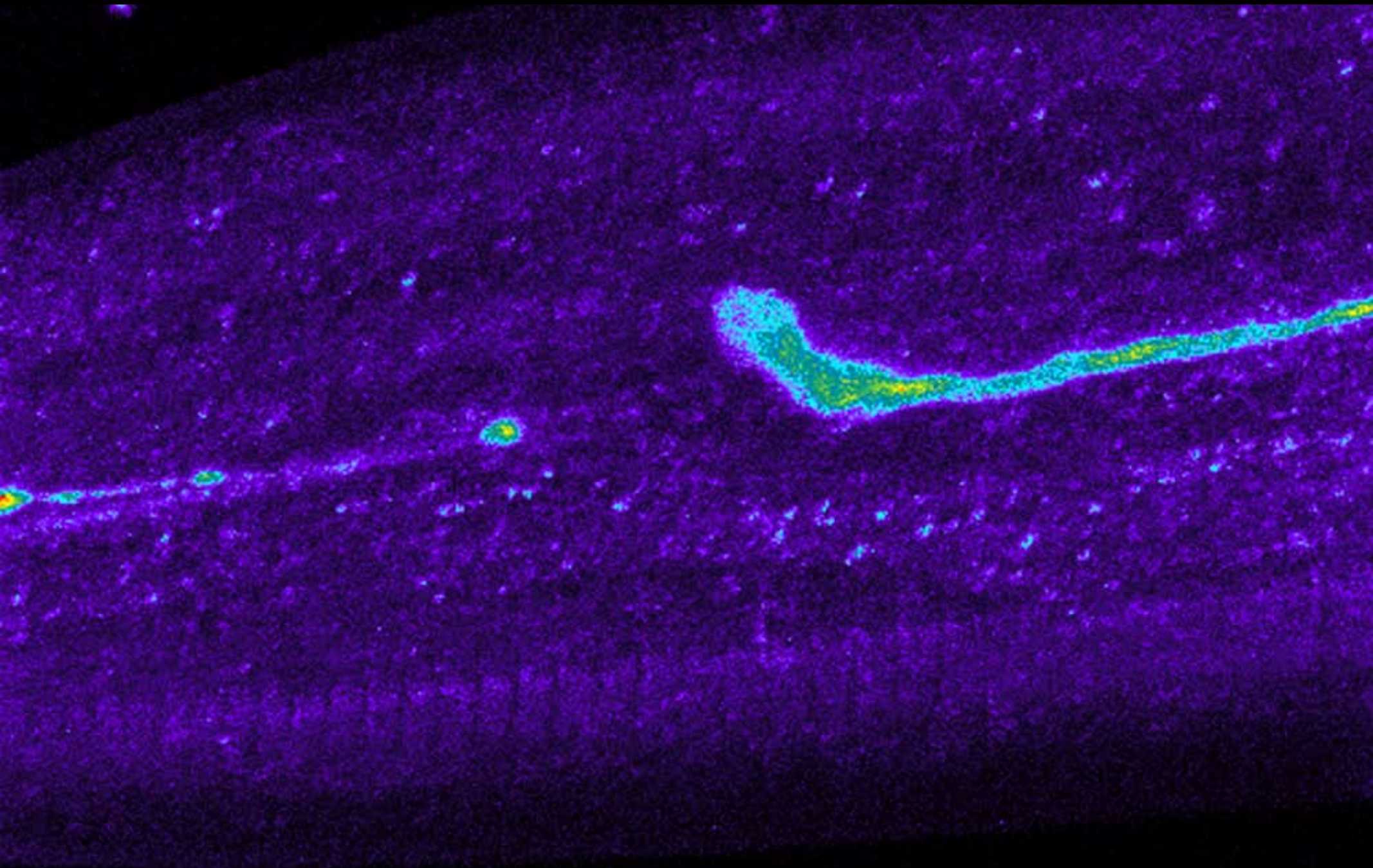
# Applications



# Applications



# Applications



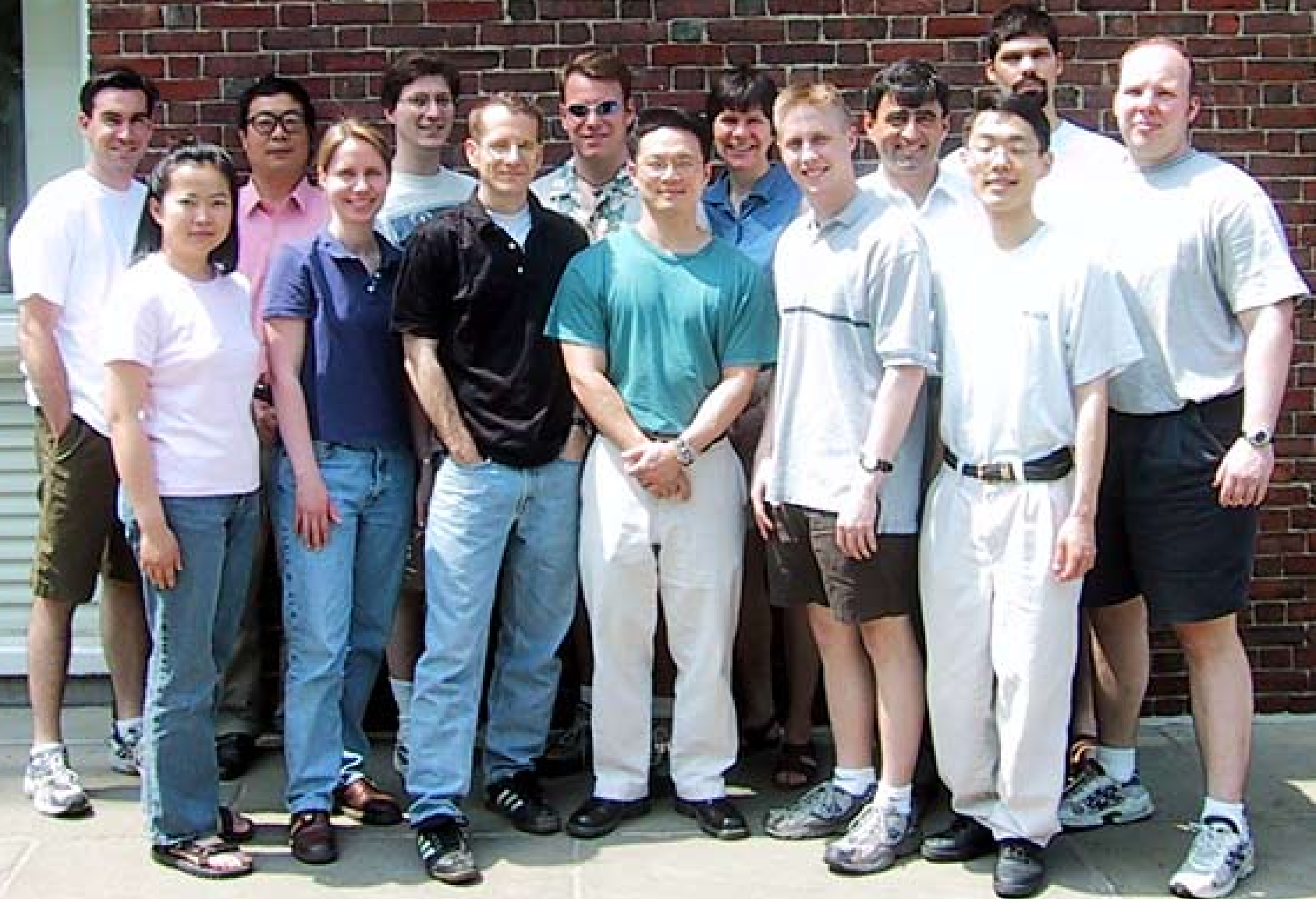
# Summary

great tool for

- "wiring light"
- micromanipulating the machinery of life



GORDON MCKAY  
LABORATORY OF  
APPLIED SCIENCE



GORDON WICKAY  
LABORATORY OF  
APPLIED SCIENCE

**Funding:**

**National Science Foundation**



**for a copy of this presentation:**

**<http://mazur-www.harvard.edu>**

Google™

Google Search

I'm Feeling Lucky

Google™

mazur

Google Search

I'm Feeling Lucky

# Google™

Google Search

I'm Feeling Lucky

# Google™

Google Search

I'm Feeling Lucky

GORDON VICKAY  
LABORATORY OF  
APPLIED SCIENCE

**Funding:**

**National Science Foundation**



**for a copy of this presentation:**

**<http://mazur-www.harvard.edu>**