

Using Ultrashort Laser Pulses to Study and Manipulate Matter



Wednesday Night Research Seminar
Harvard University
Cambridge, MA 7 February 2007



Outline

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

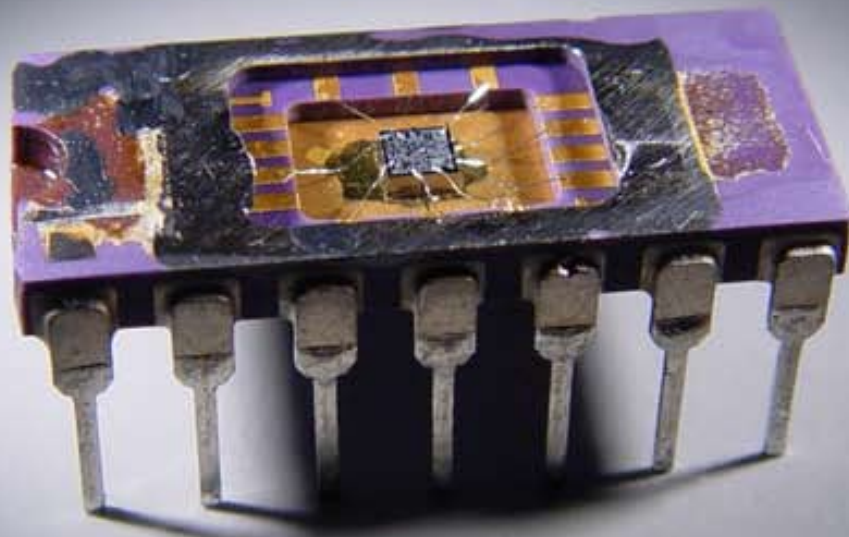
Silica nanowires

1 μm

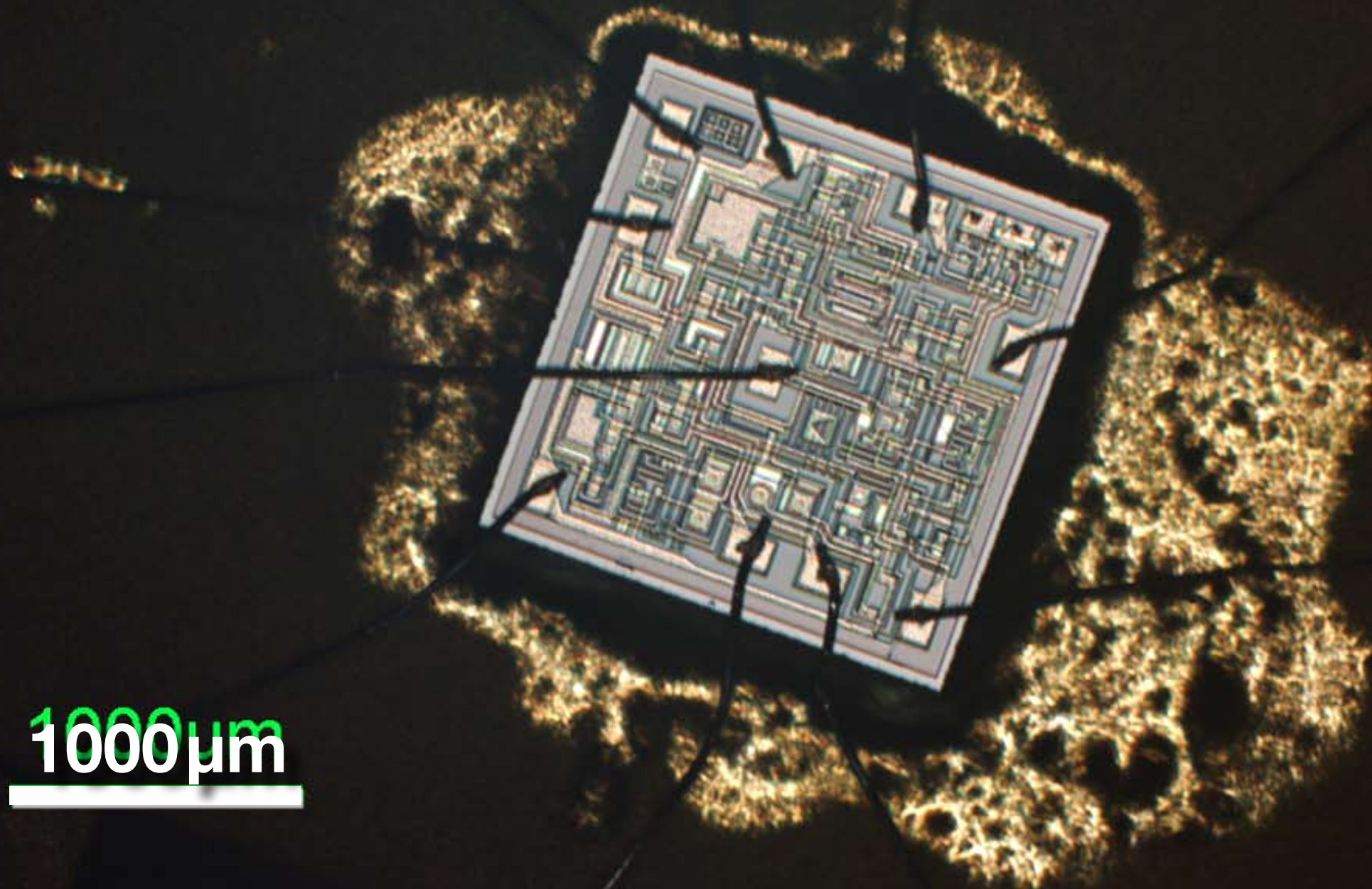


Nature, 426, 816 (2003)

Silica nanowires



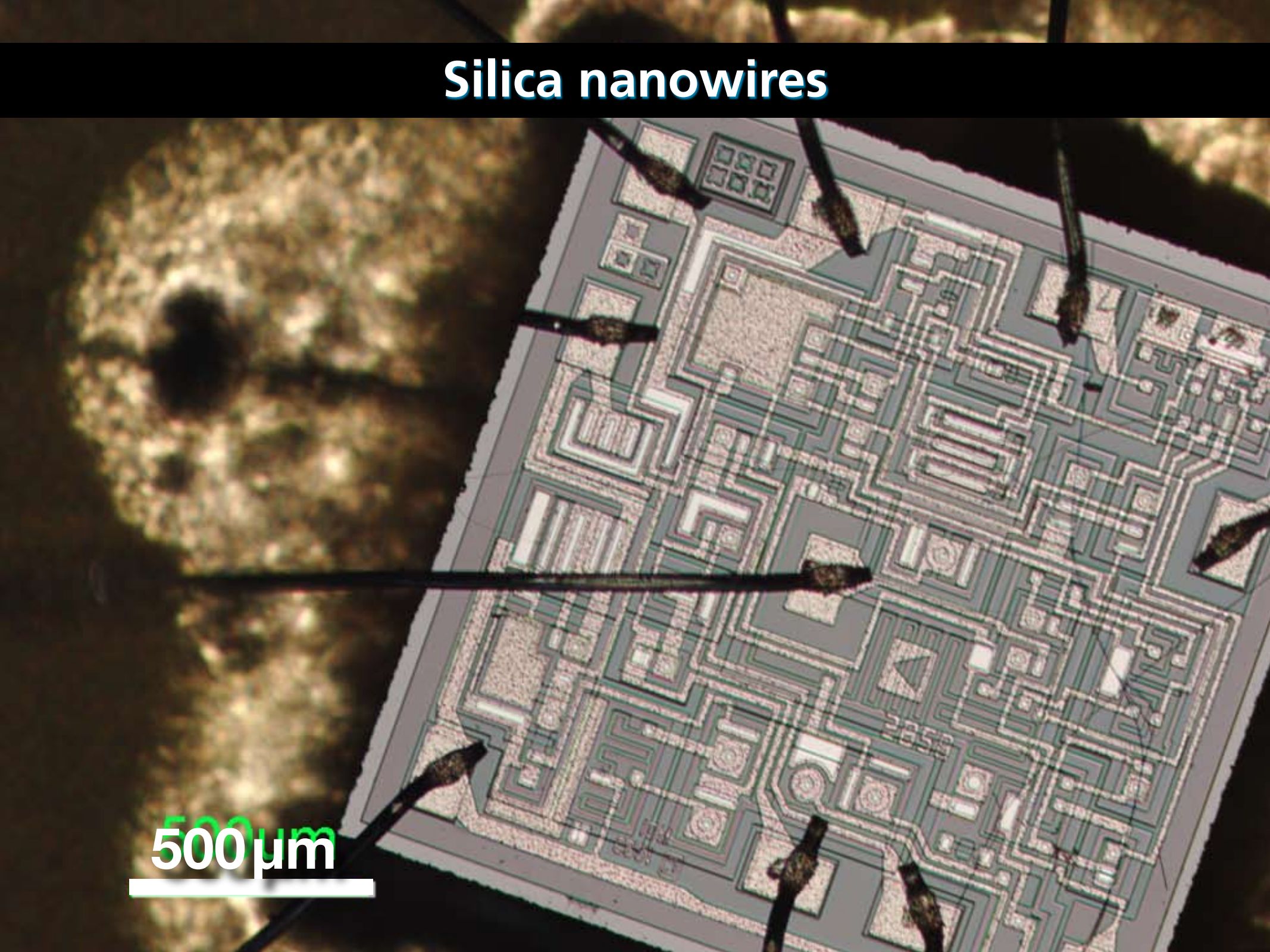
Silica nanowires



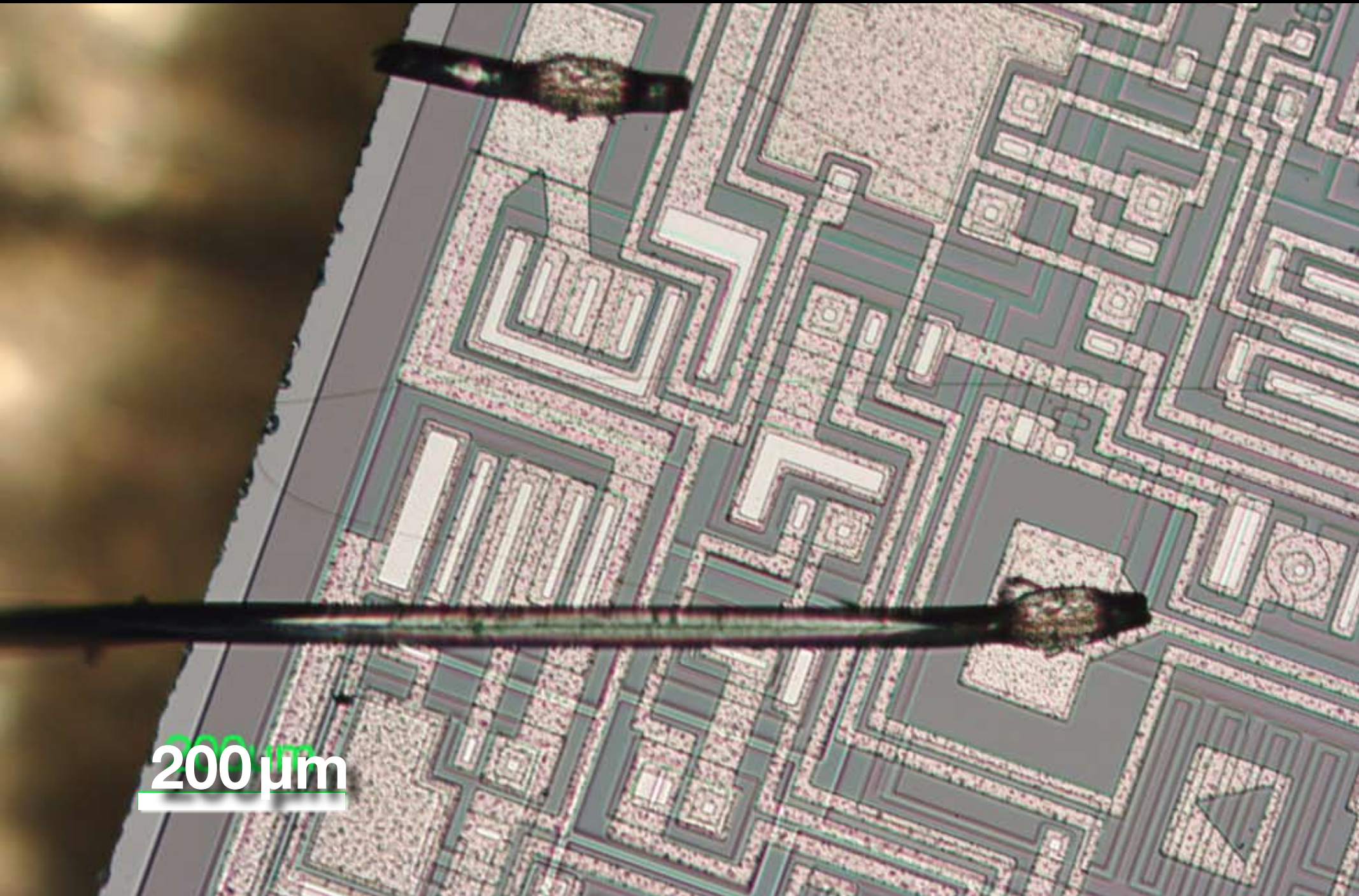
1000 μm

Silica nanowires

500 μm

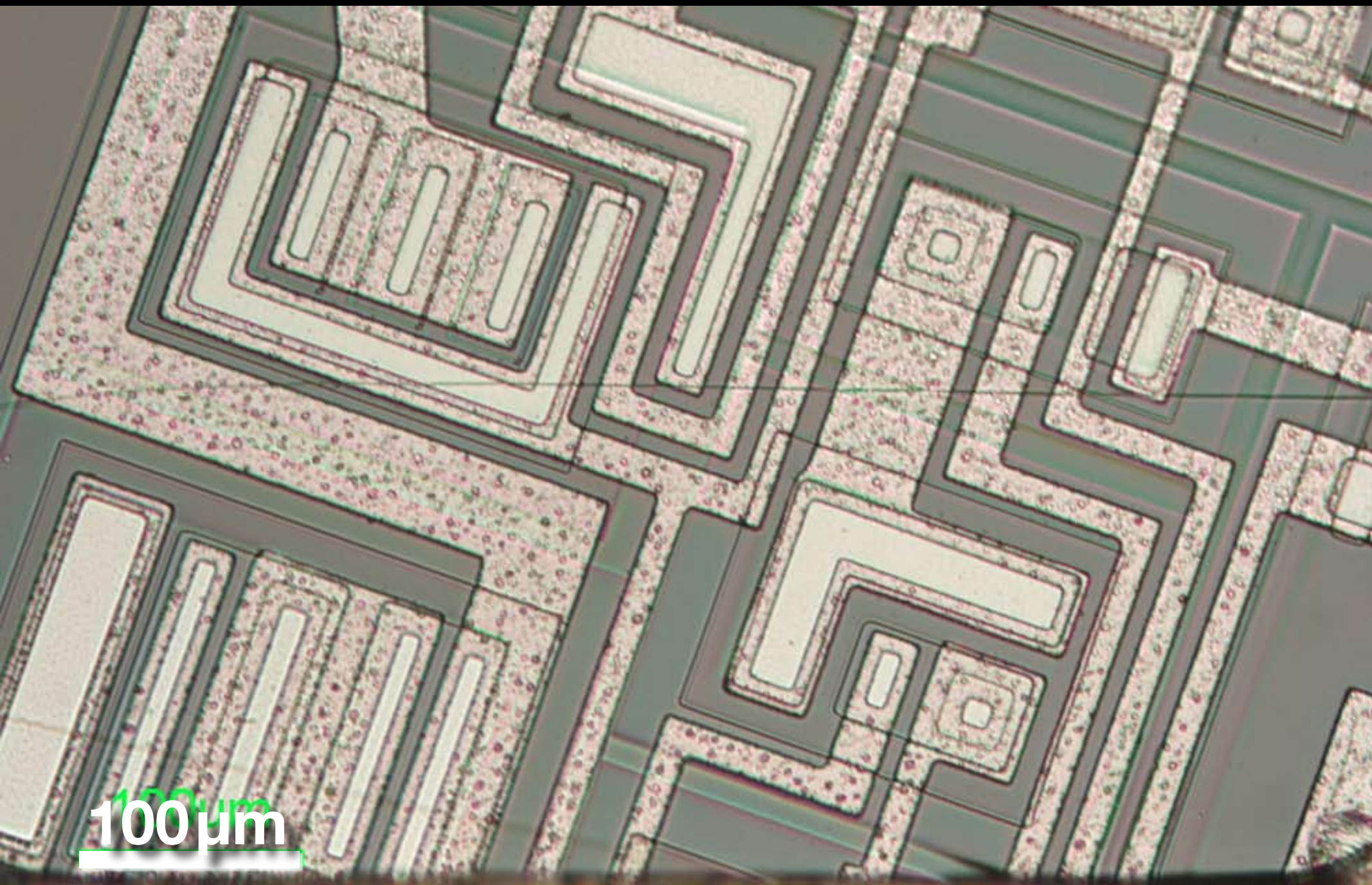


Silica nanowires

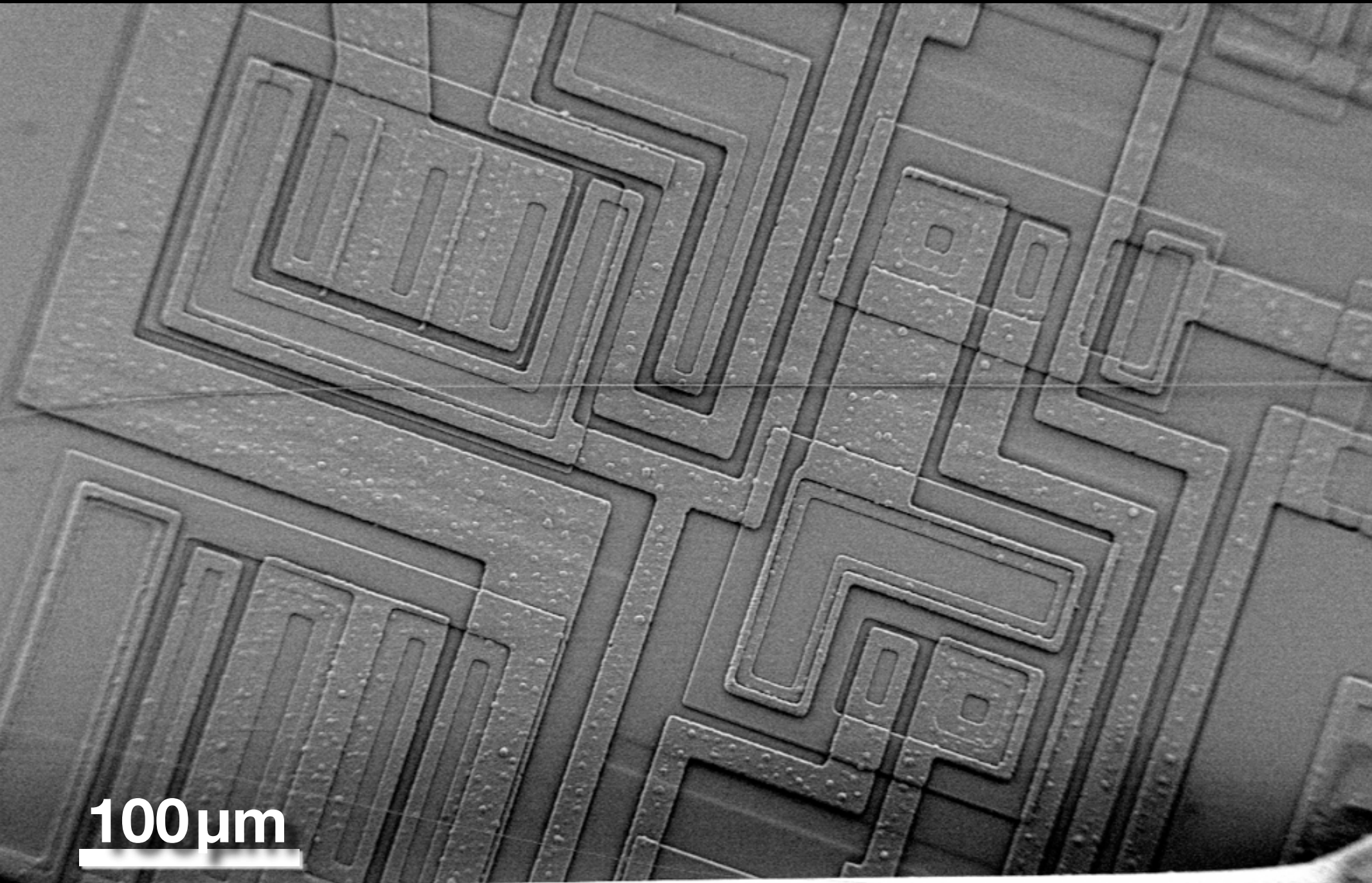


200 μm

Silica nanowires

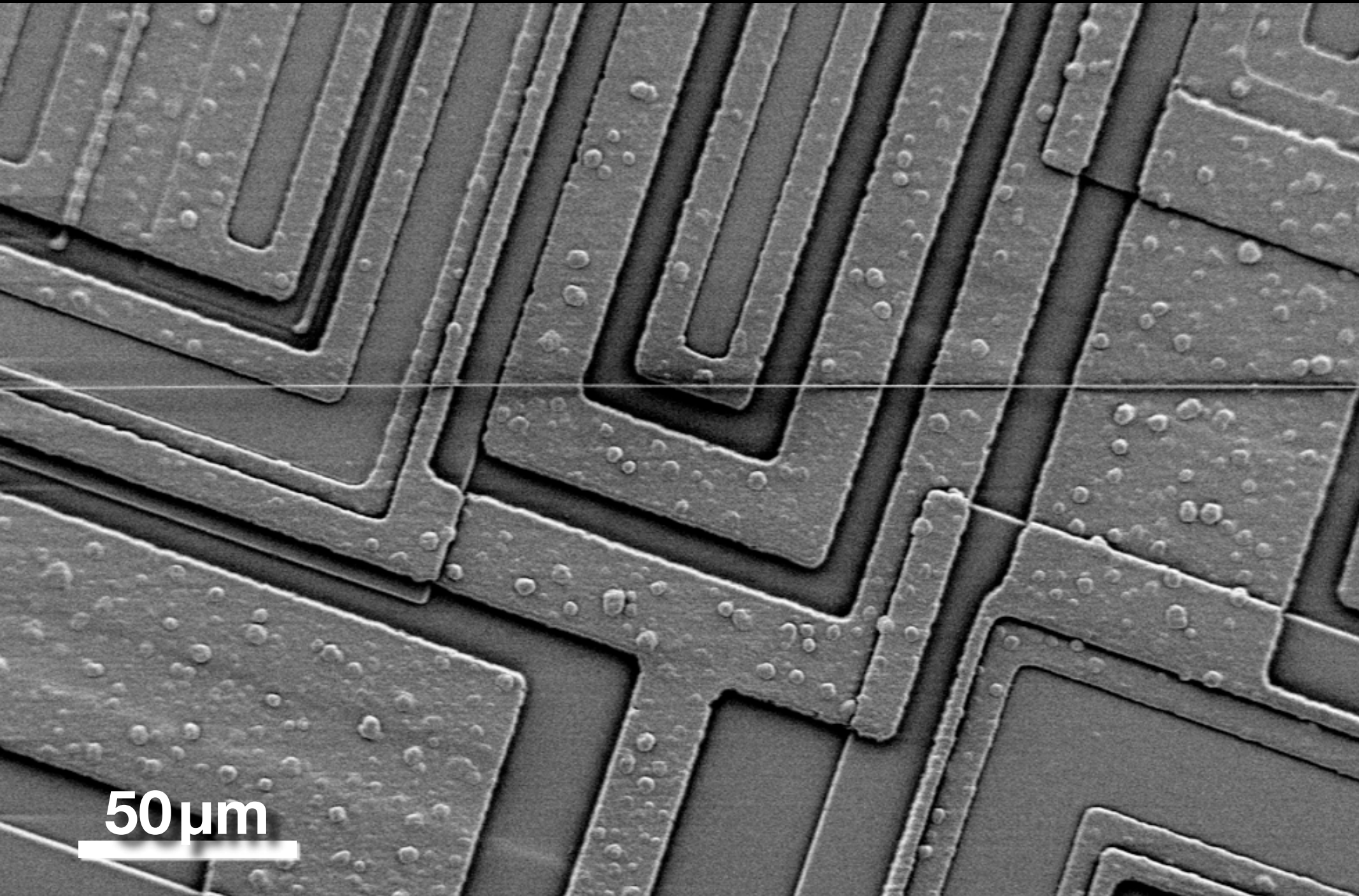


Silica nanowires



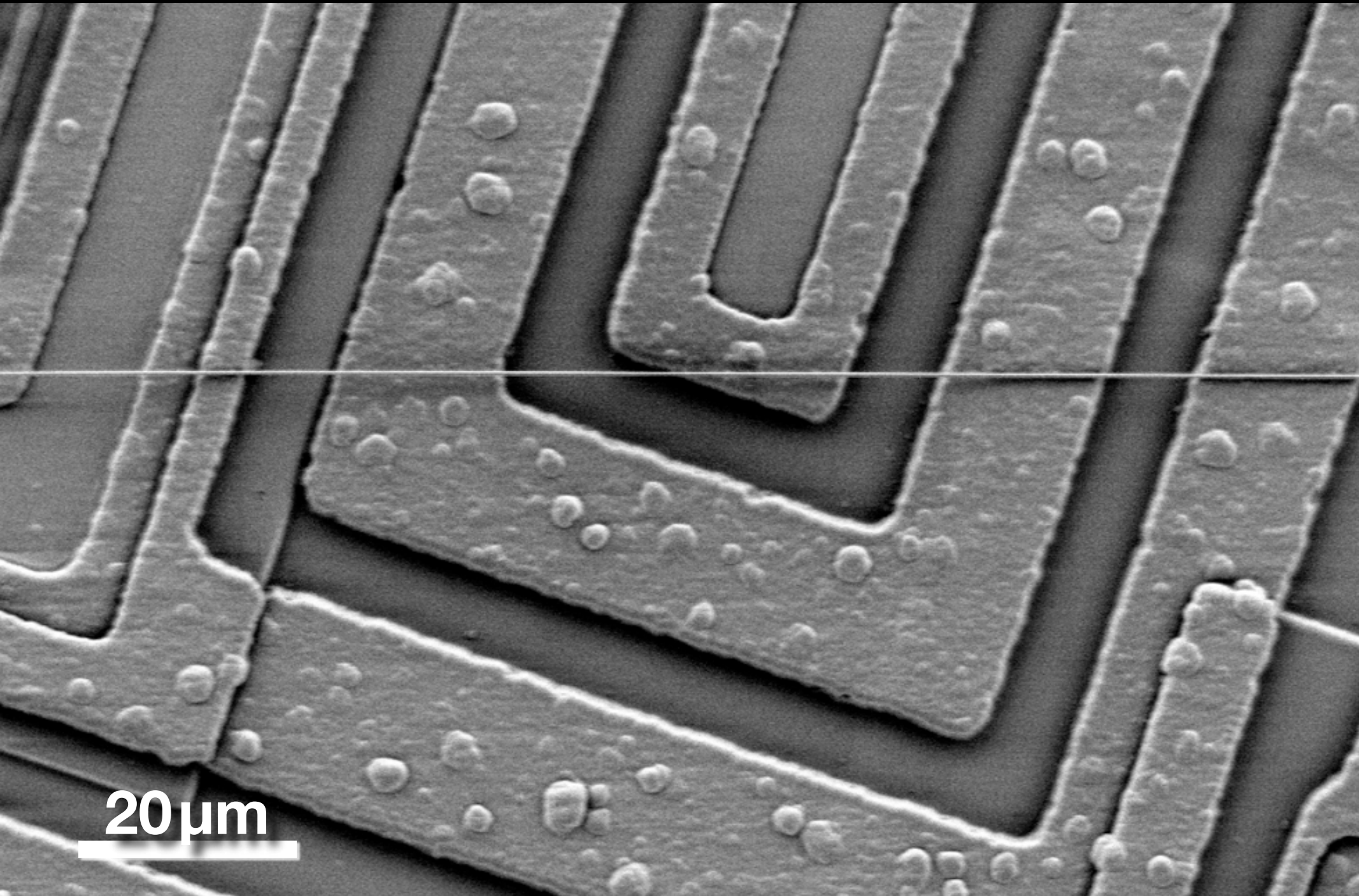
100 μm

Silica nanowires



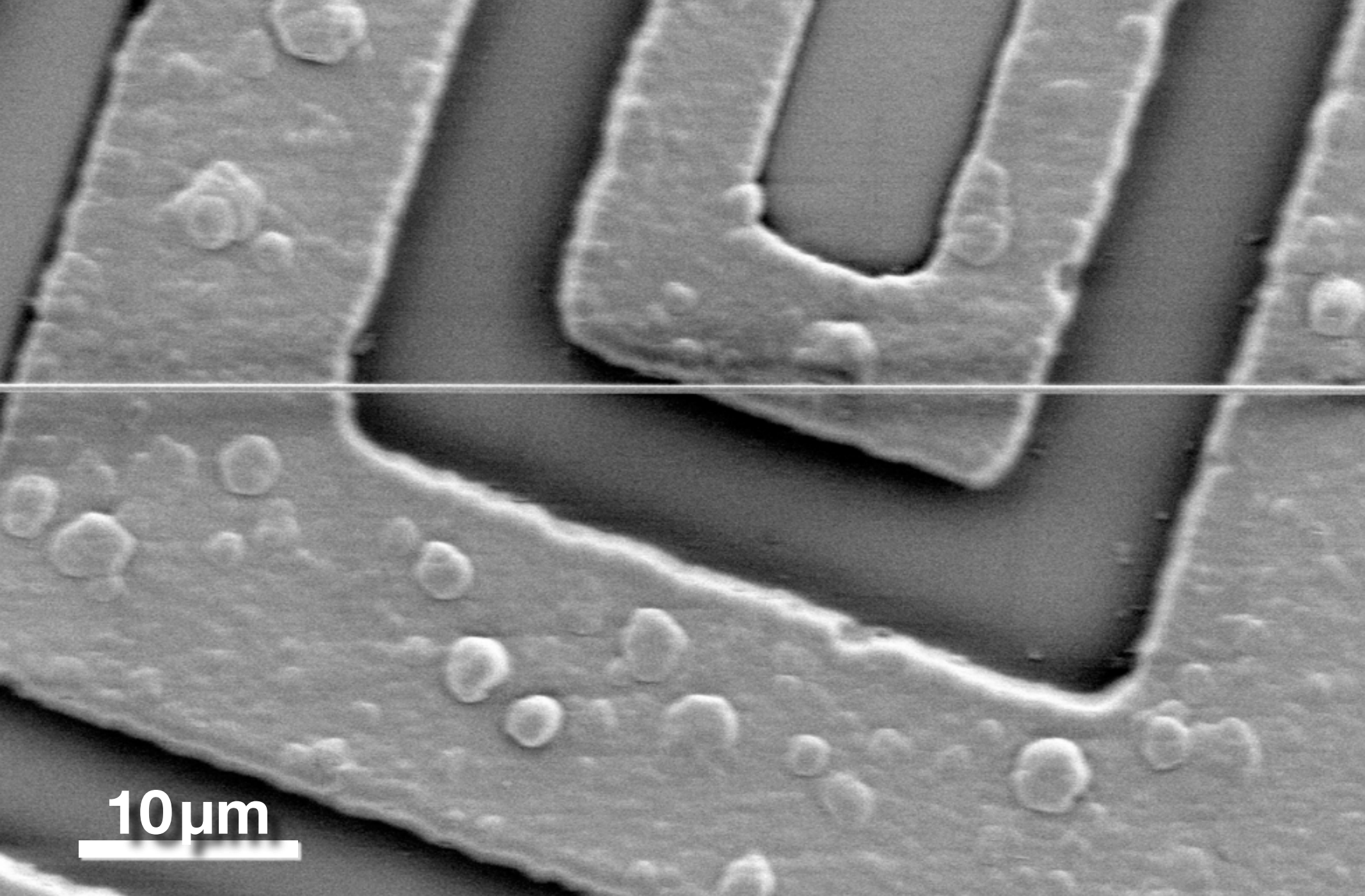
50 μm

Silica nanowires



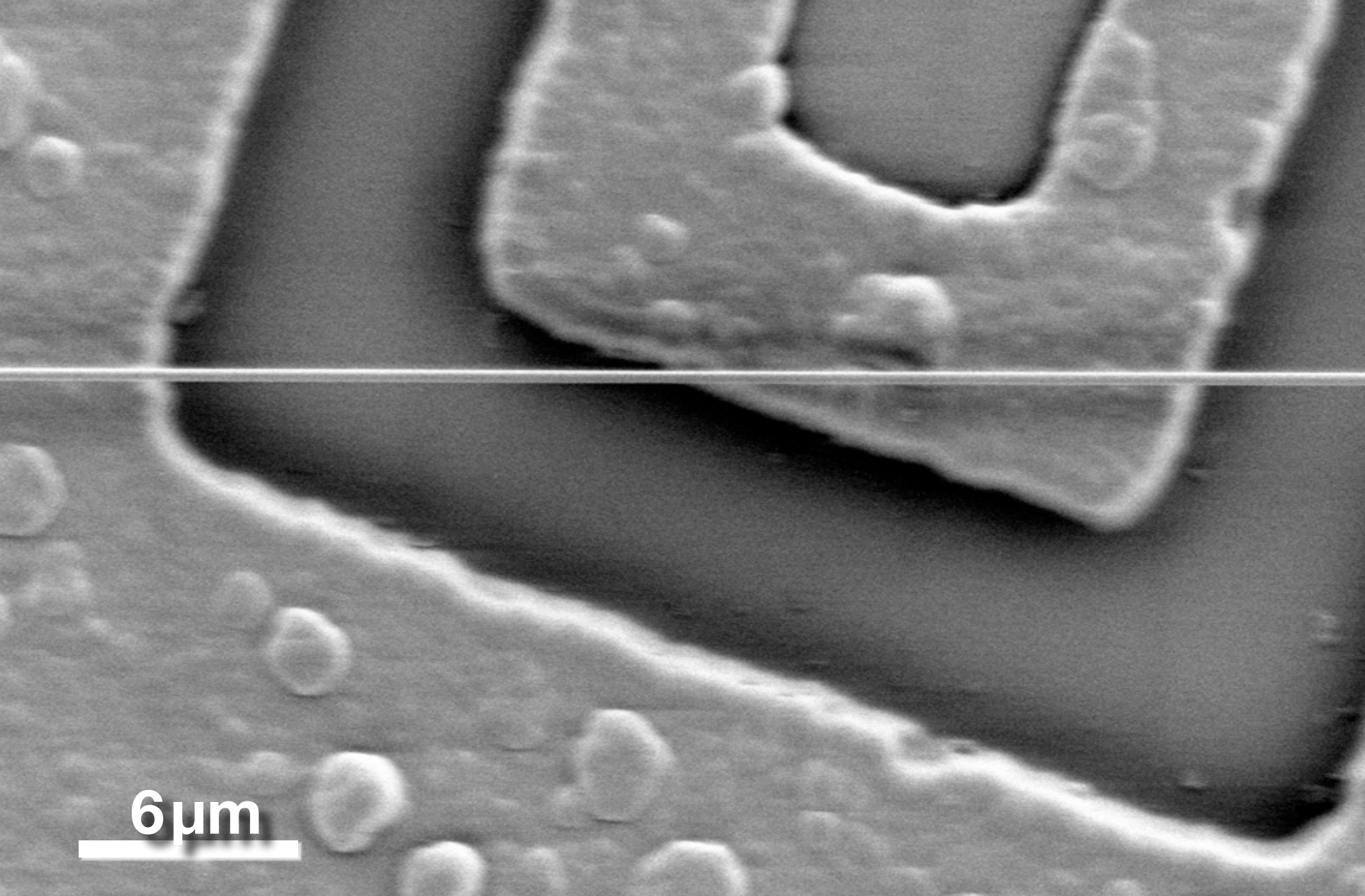
20 μm

Silica nanowires



10 μm

Silica nanowires



6 μm

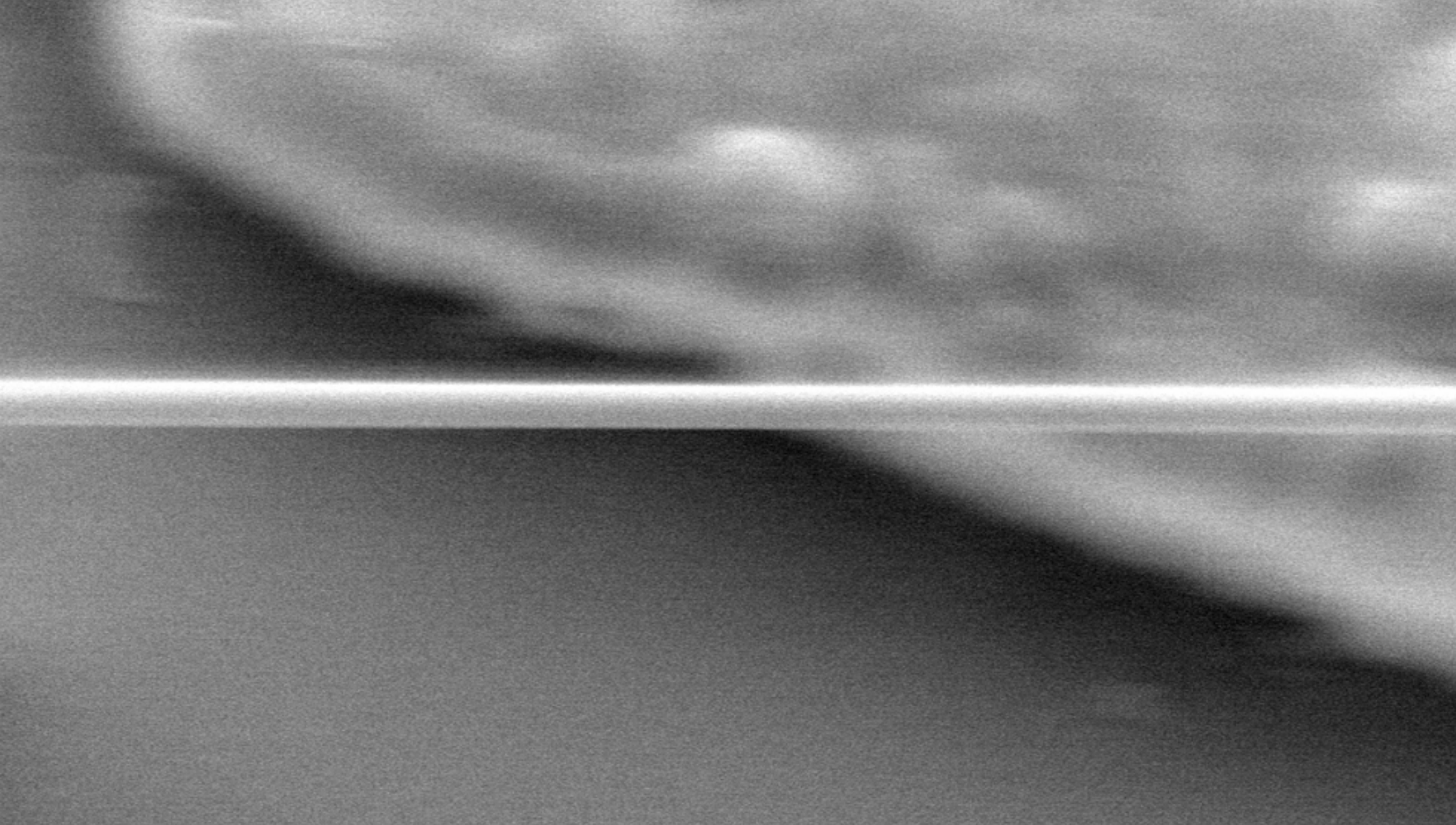


Silica nanowires

4 μm

This scanning electron microscope (SEM) image displays silica nanowires. A single, thin, horizontal nanowire is clearly visible, extending across the middle of the frame. The background shows a textured surface with various irregular shapes and features, likely representing the substrate or other nanowires. A scale bar in the bottom left corner indicates a length of 4 micrometers.

Silica nanowires



2 μm

Silica nanowires

312 nm

A transmission electron micrograph (TEM) showing a single, long, cylindrical silica nanowire. The nanowire is oriented horizontally and appears as a bright, uniform line against a dark background. A vertical white line with a crossbar at the bottom is drawn across the nanowire to indicate its diameter. The text '312 nm' is placed above this vertical line. In the bottom left corner, there is a horizontal white scale bar with the text '1 μm' above it.

1 μm

Silica nanowires

Specifications

diameter D : down to 20 nm

length L : up to 90 mm

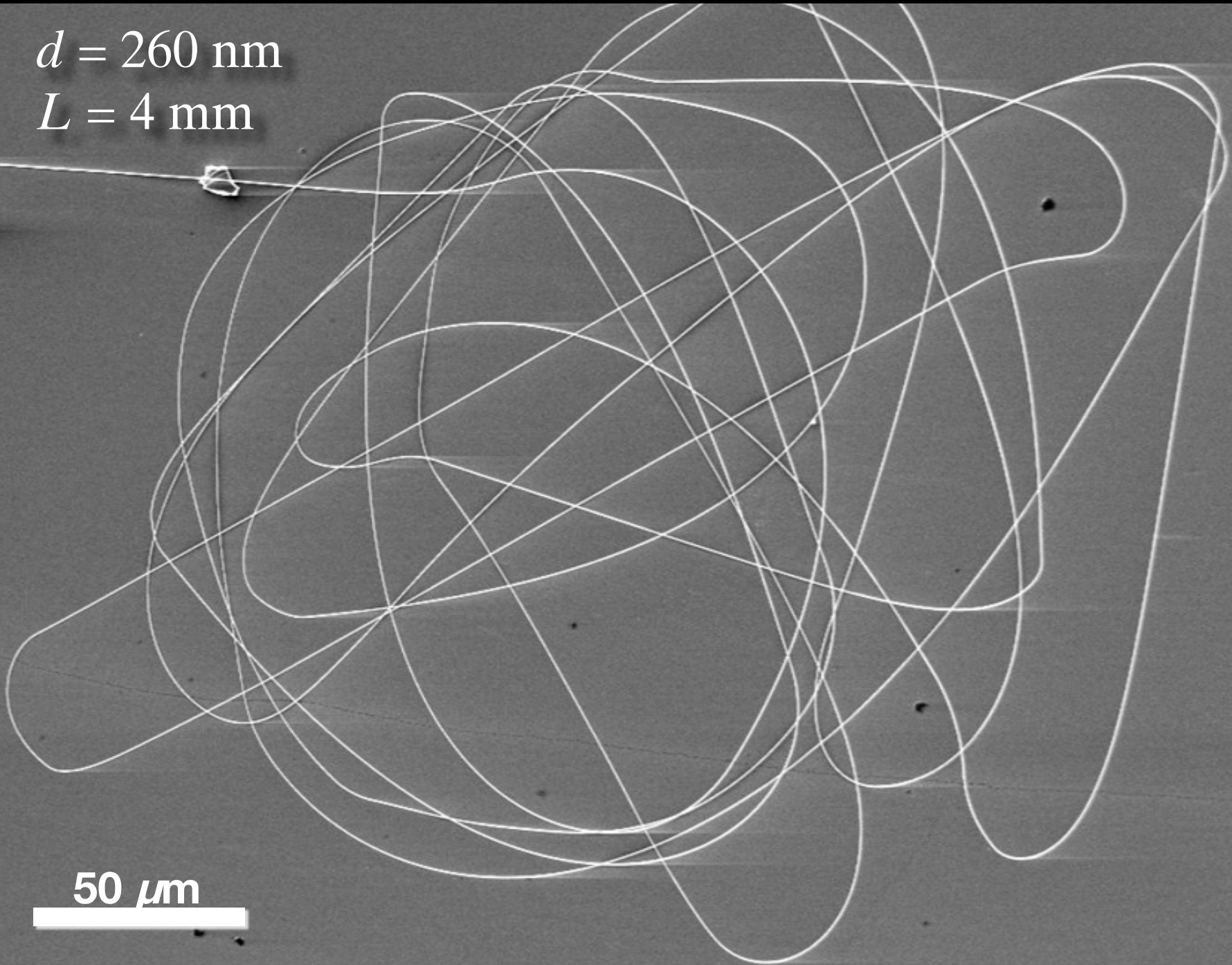
aspect ratio D/L : up to 10^6

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

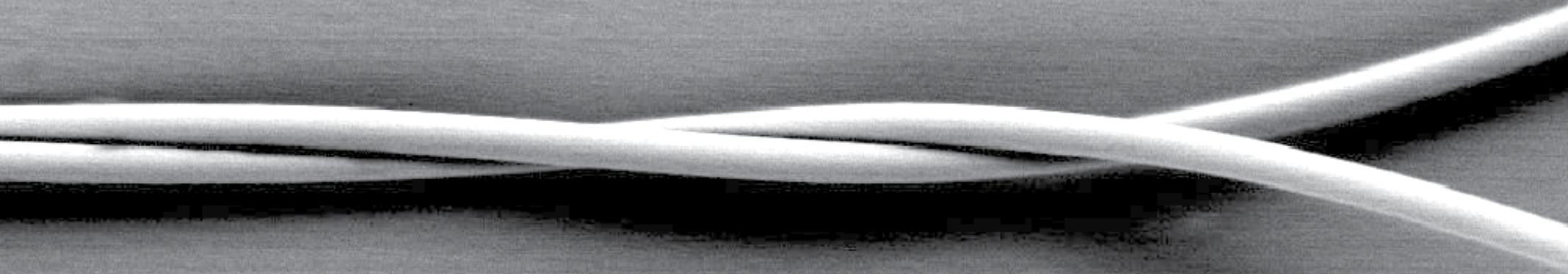
Silica nanowires

$d = 260 \text{ nm}$

$L = 4 \text{ mm}$



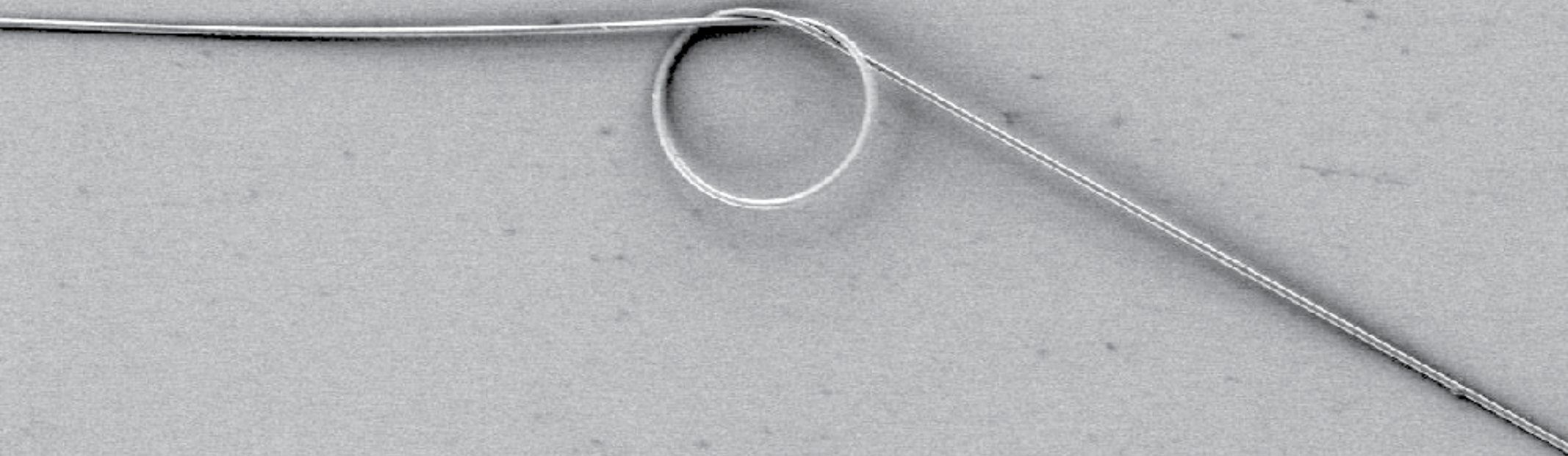
Silica nanowires



2 μm



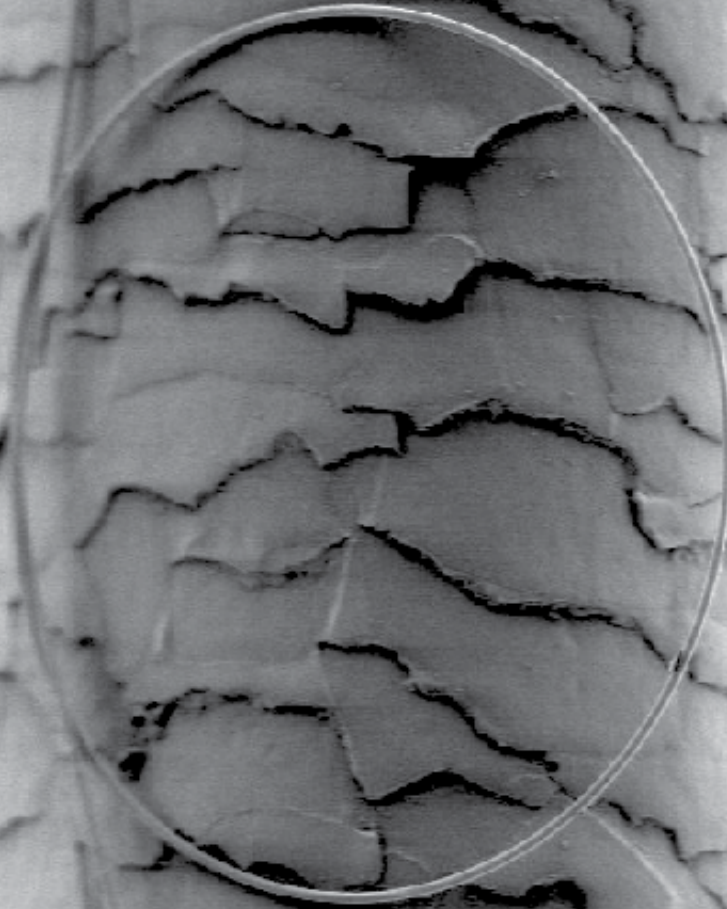
Silica nanowires



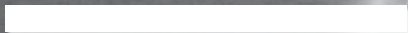
20 μm



Silica nanowires



20 μm



Optical properties



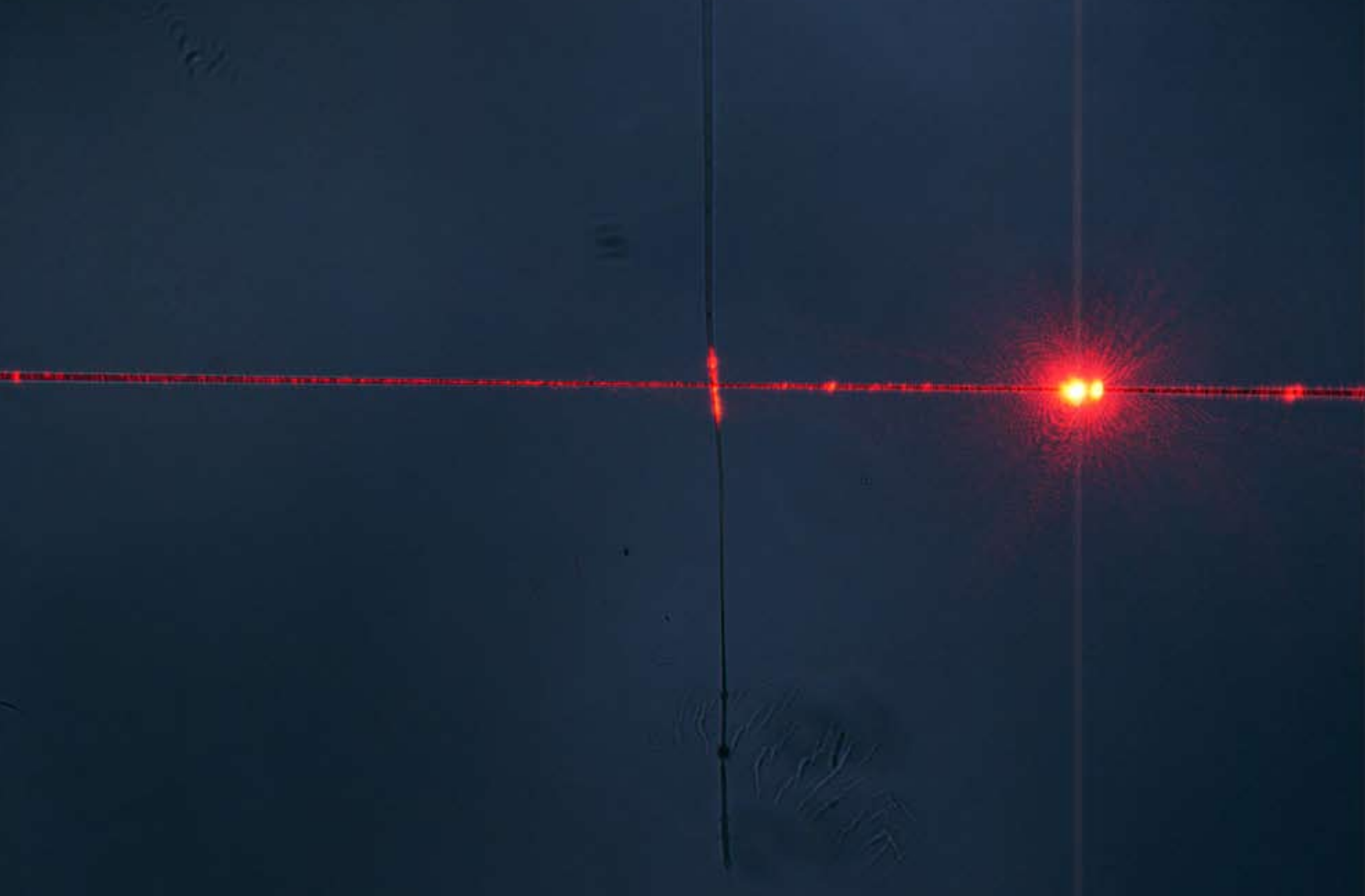
50 μm

Optical properties



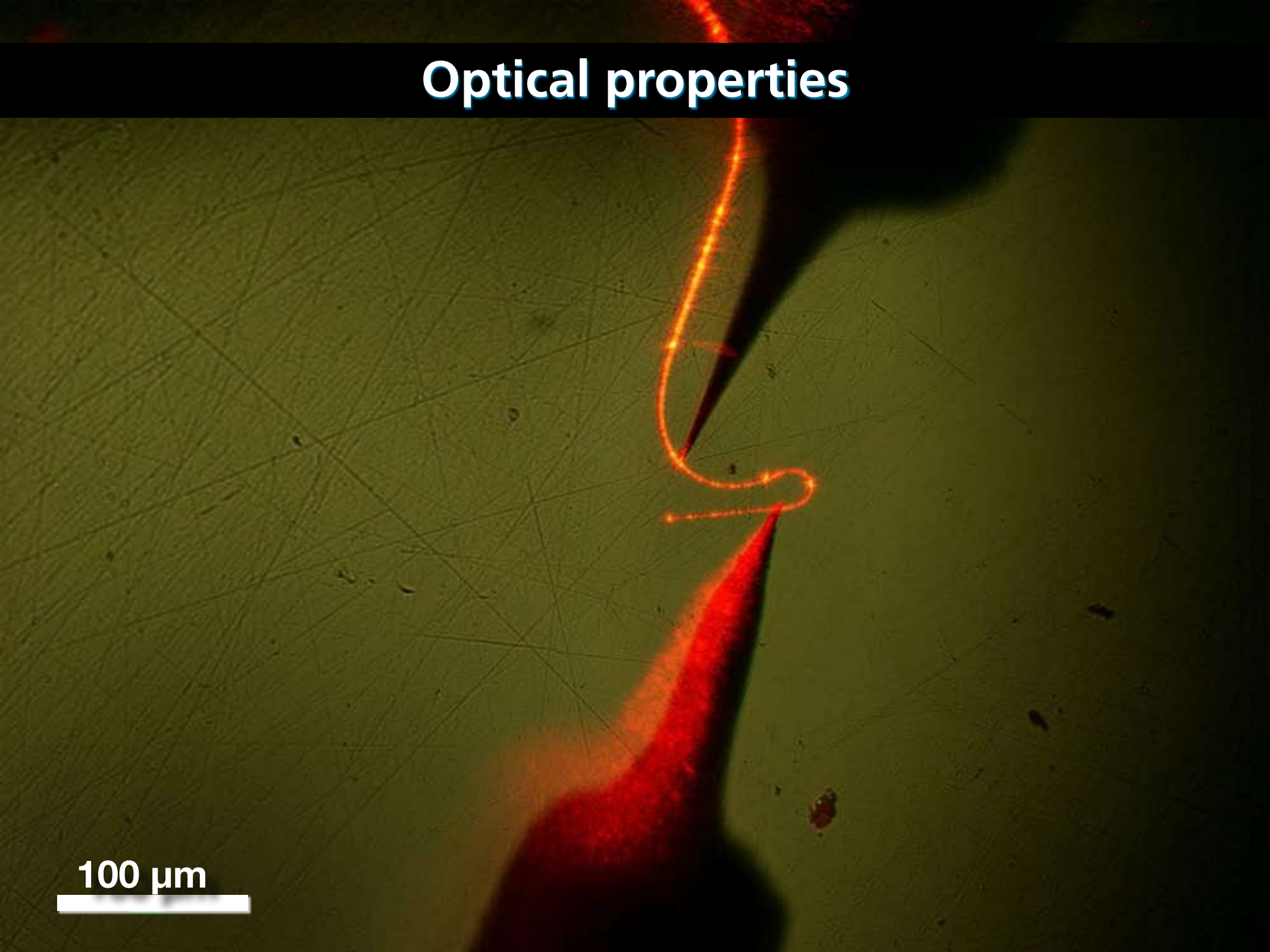
50 μm

Optical properties

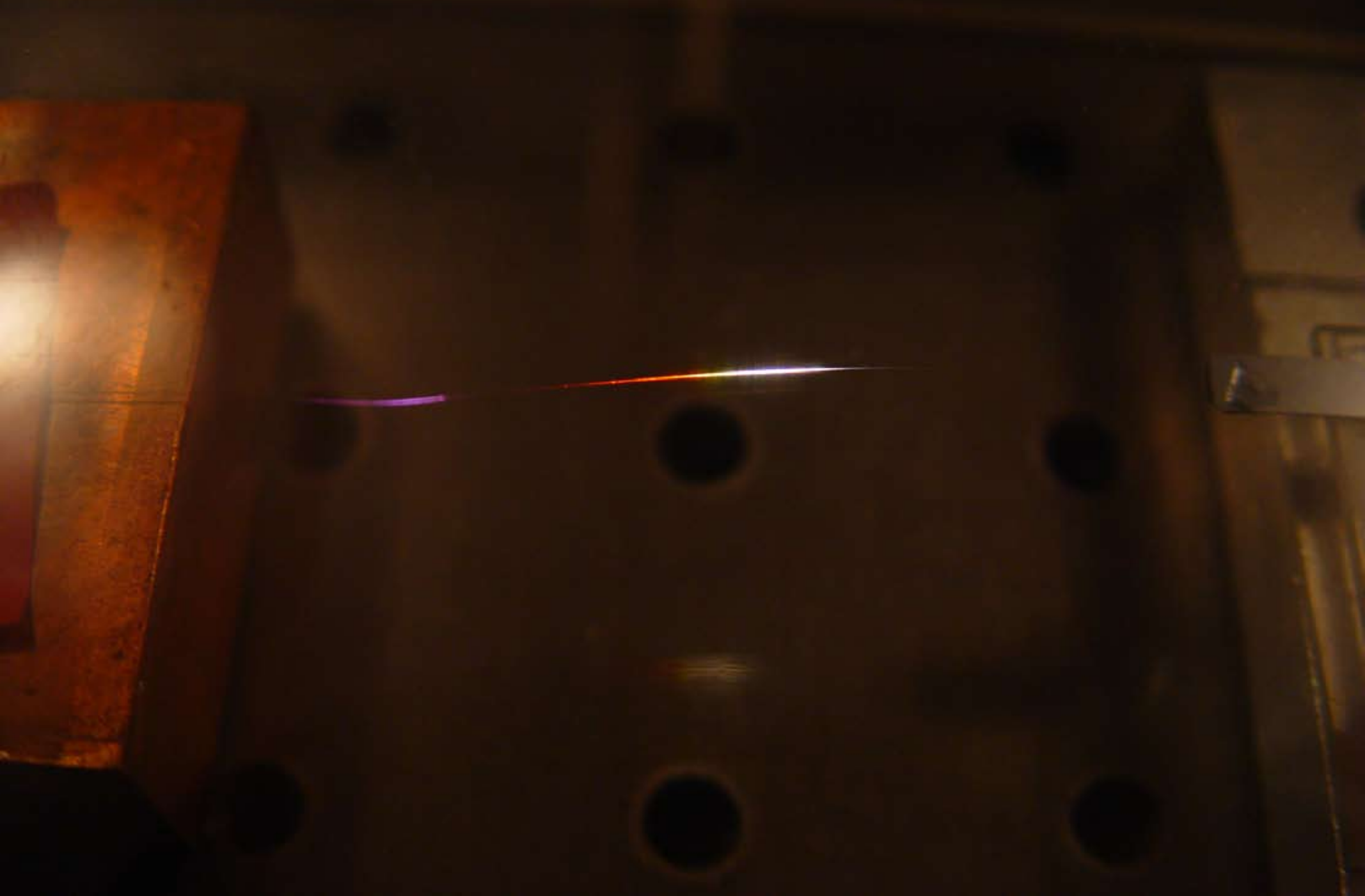


Optical properties

100 μm

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 a grid-like pattern. A white scale bar is located in the bottom left corner, labeled "100 μm".

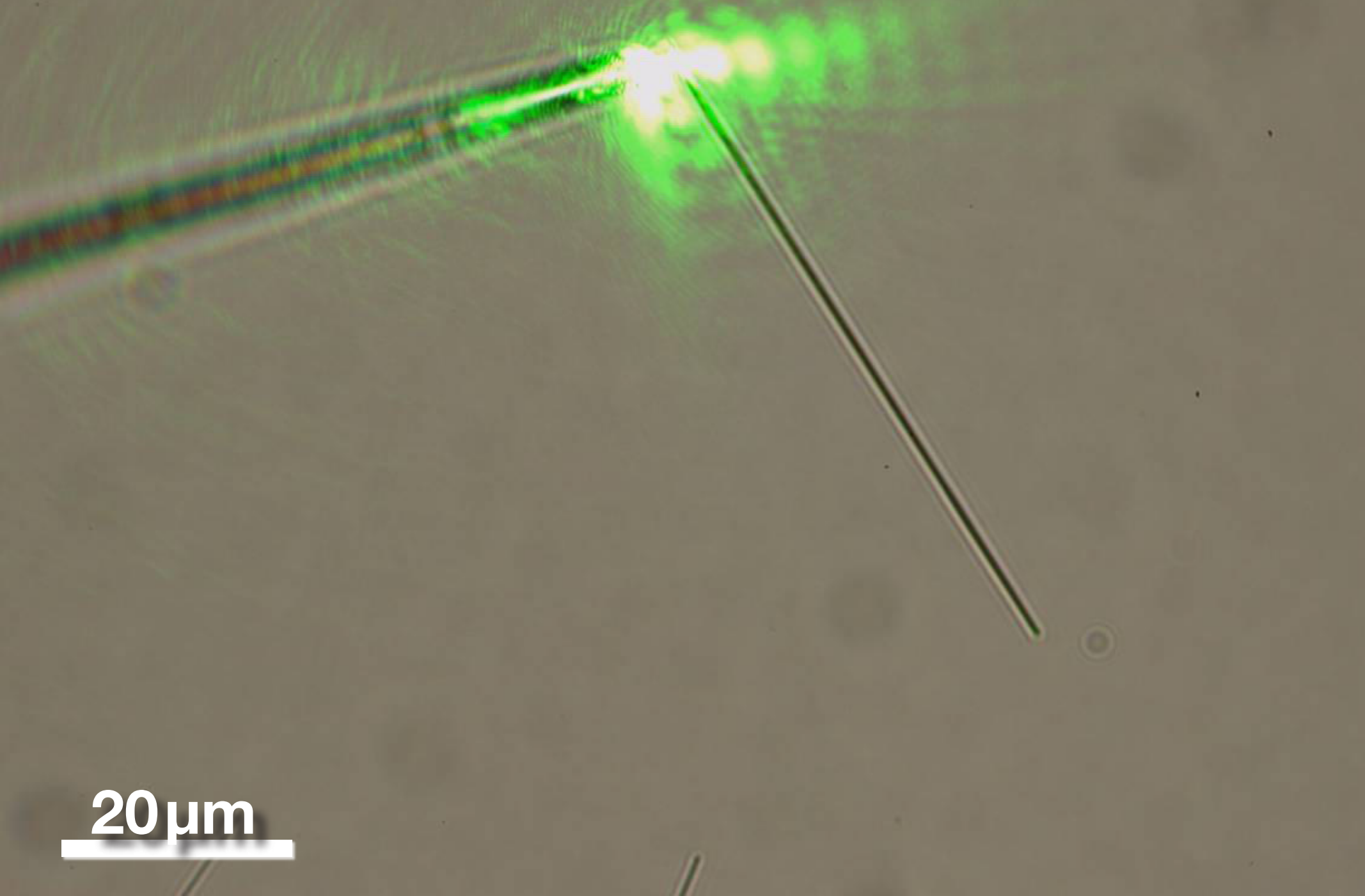
Nonlinear properties



Nonlinear properties

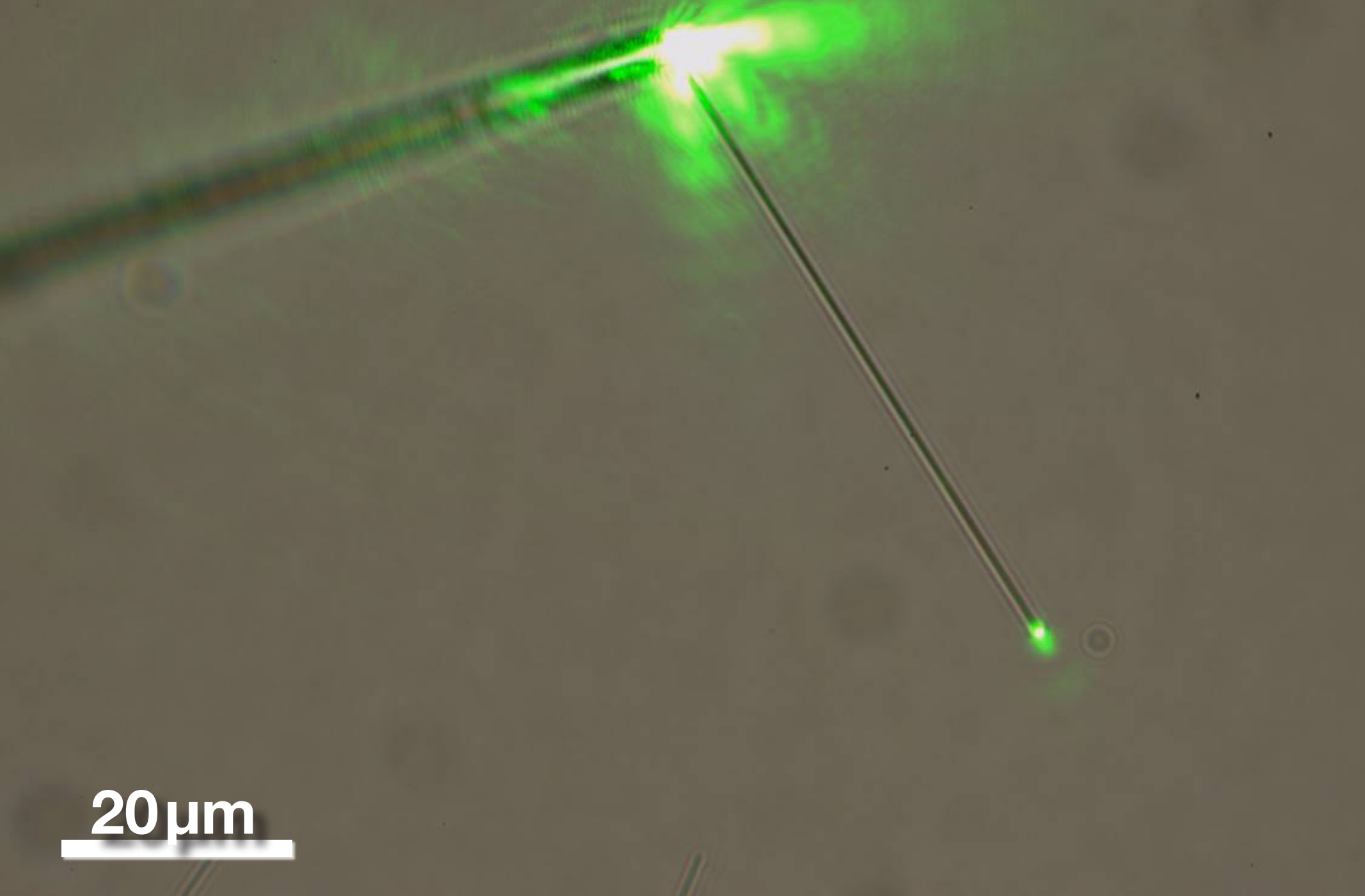


Coupling with semiconductor nanowires



20 μm

Coupling with semiconductor nanowires



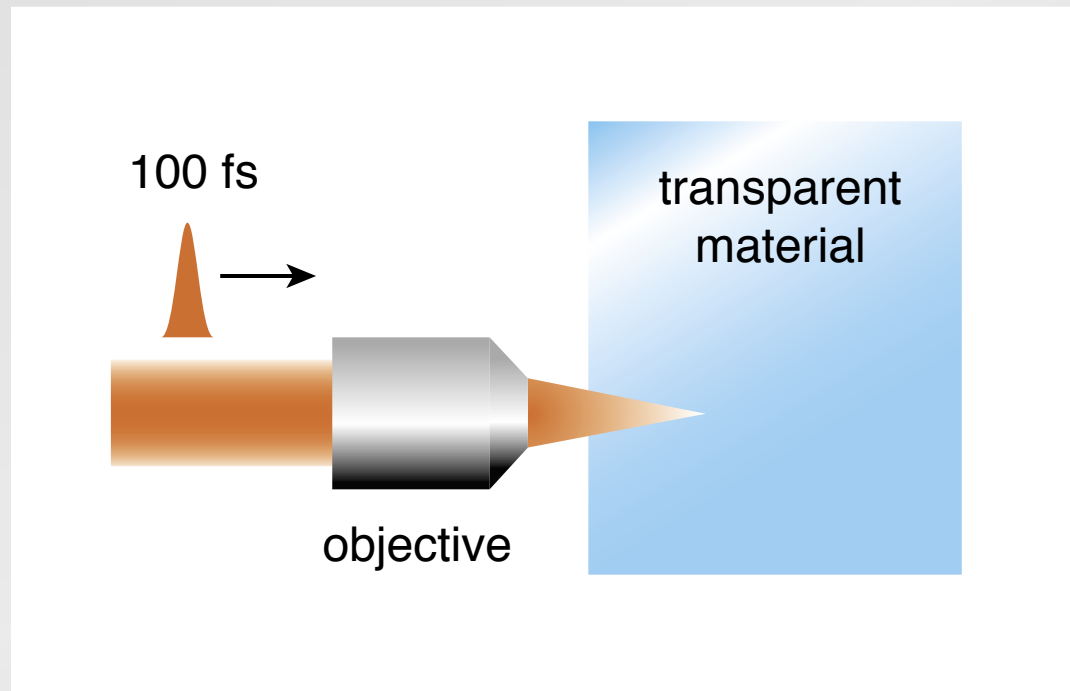
20 μm

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- fs laser micromachining
- biophotonics

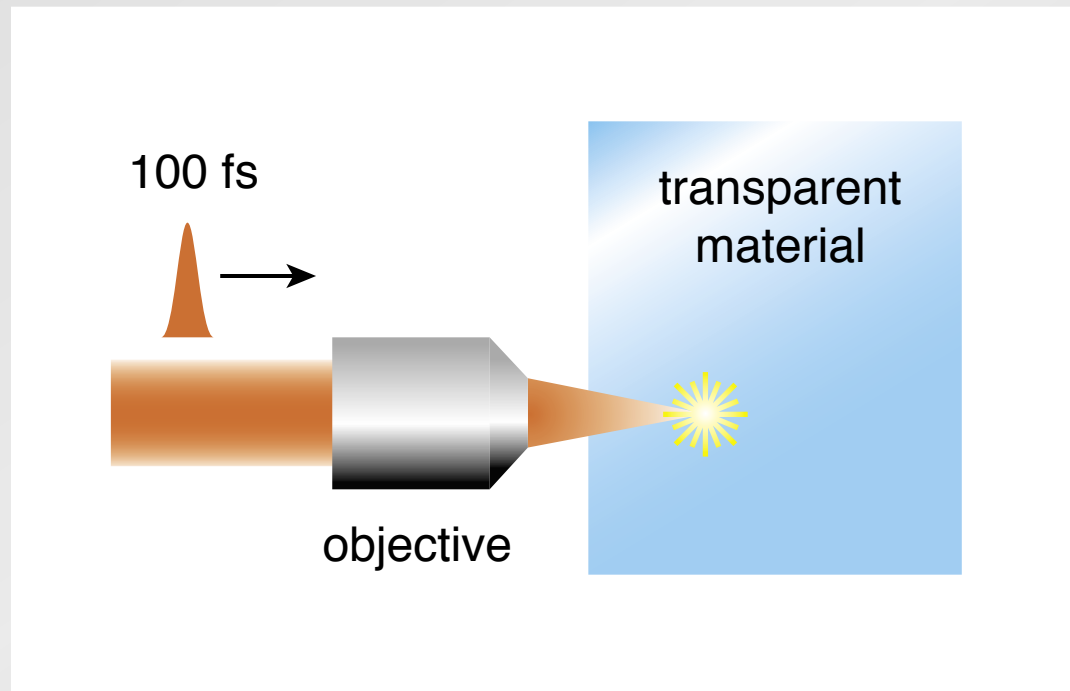
Femtosecond micromachining

high intensity at focus...



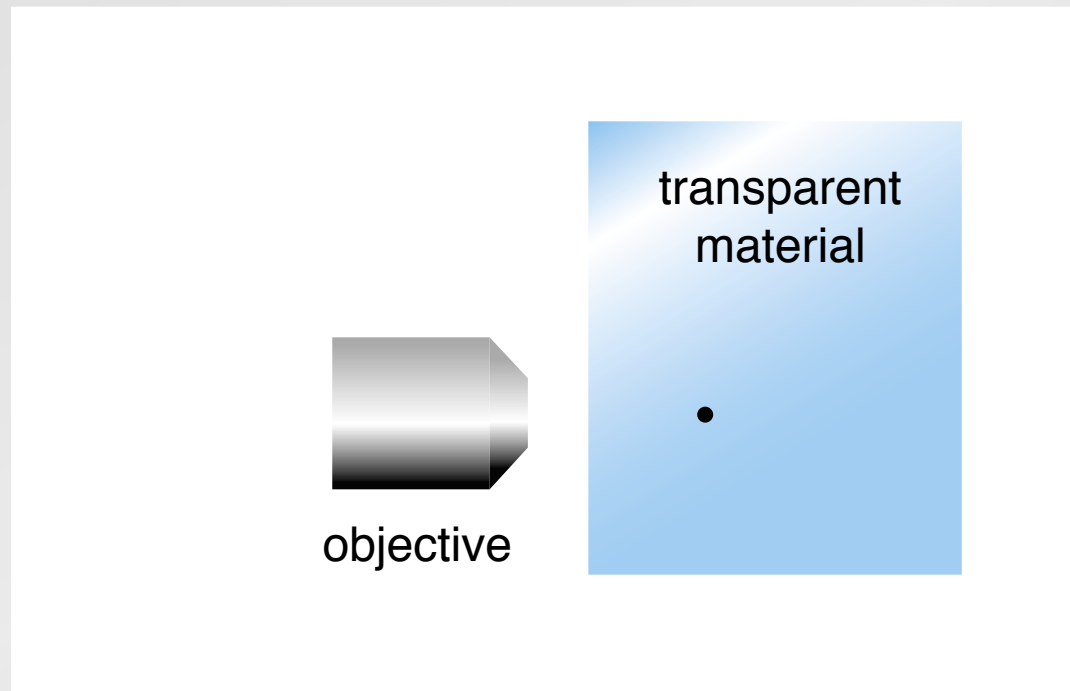
Femtosecond micromachining

...causes nonlinear ionization...



Femtosecond micromachining

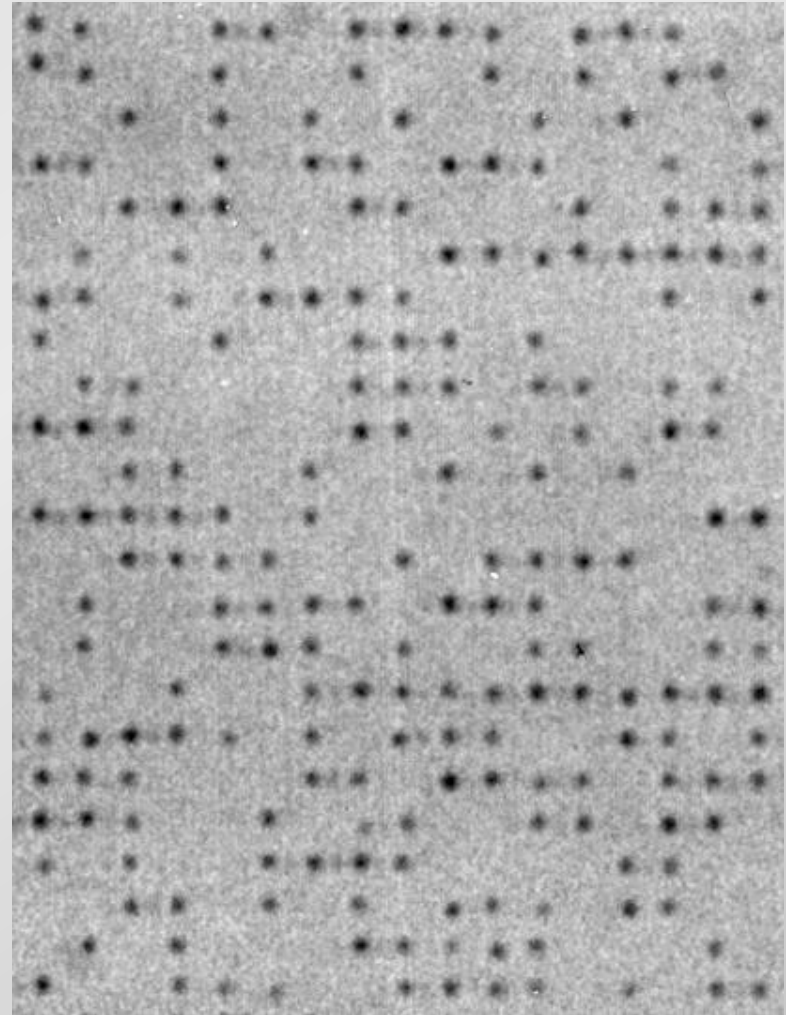
and 'microexplosion' causes microscopic damage...



Femtosecond micromachining

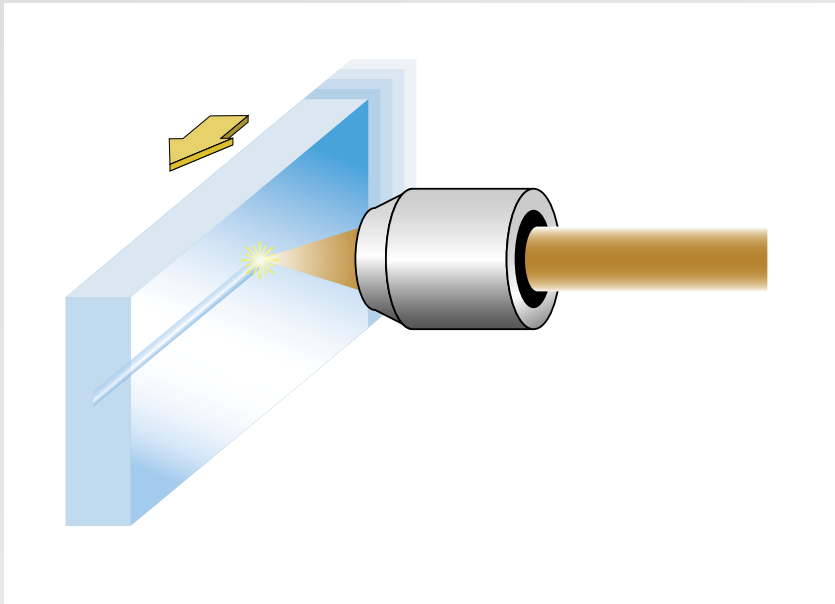
Some applications:

- data storage
- waveguides
- microfluidics



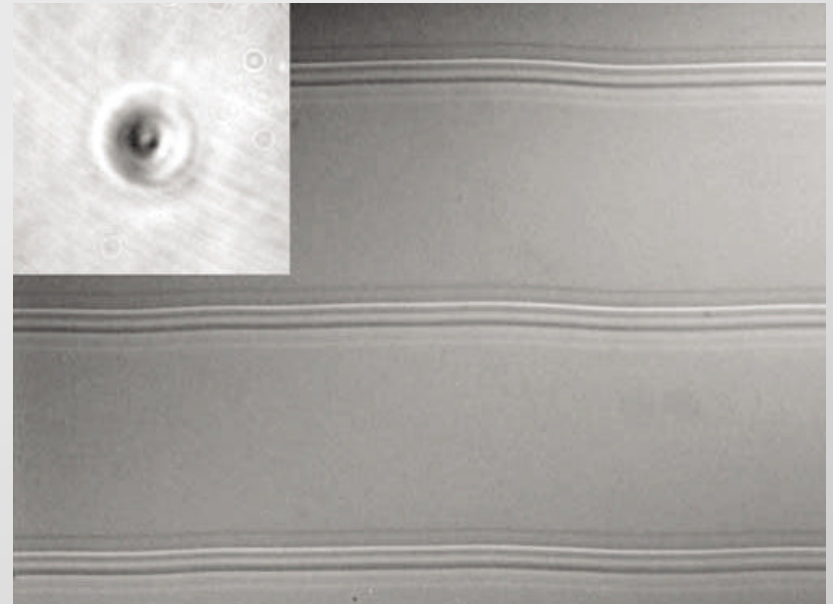
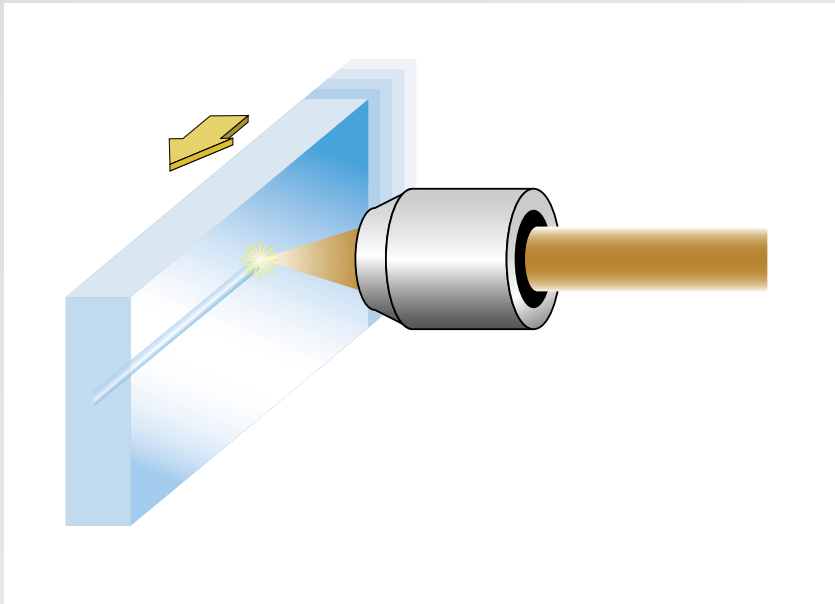
Low-energy machining

waveguide micromachining



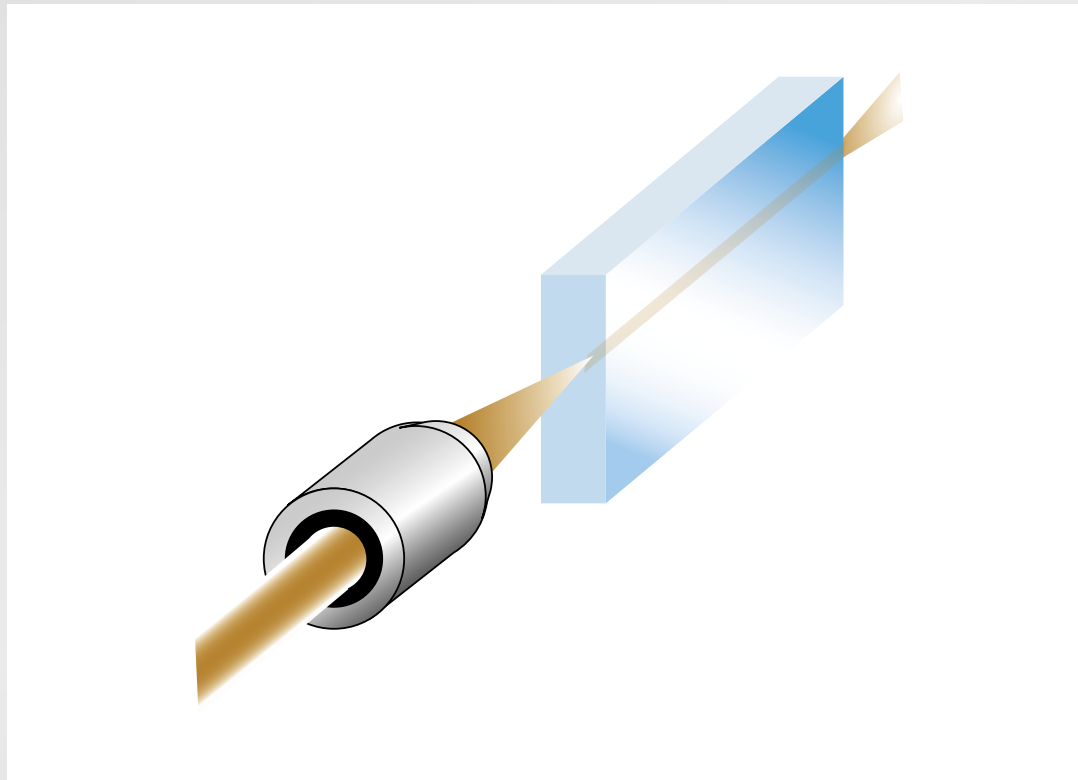
Low-energy machining

waveguide micromachining

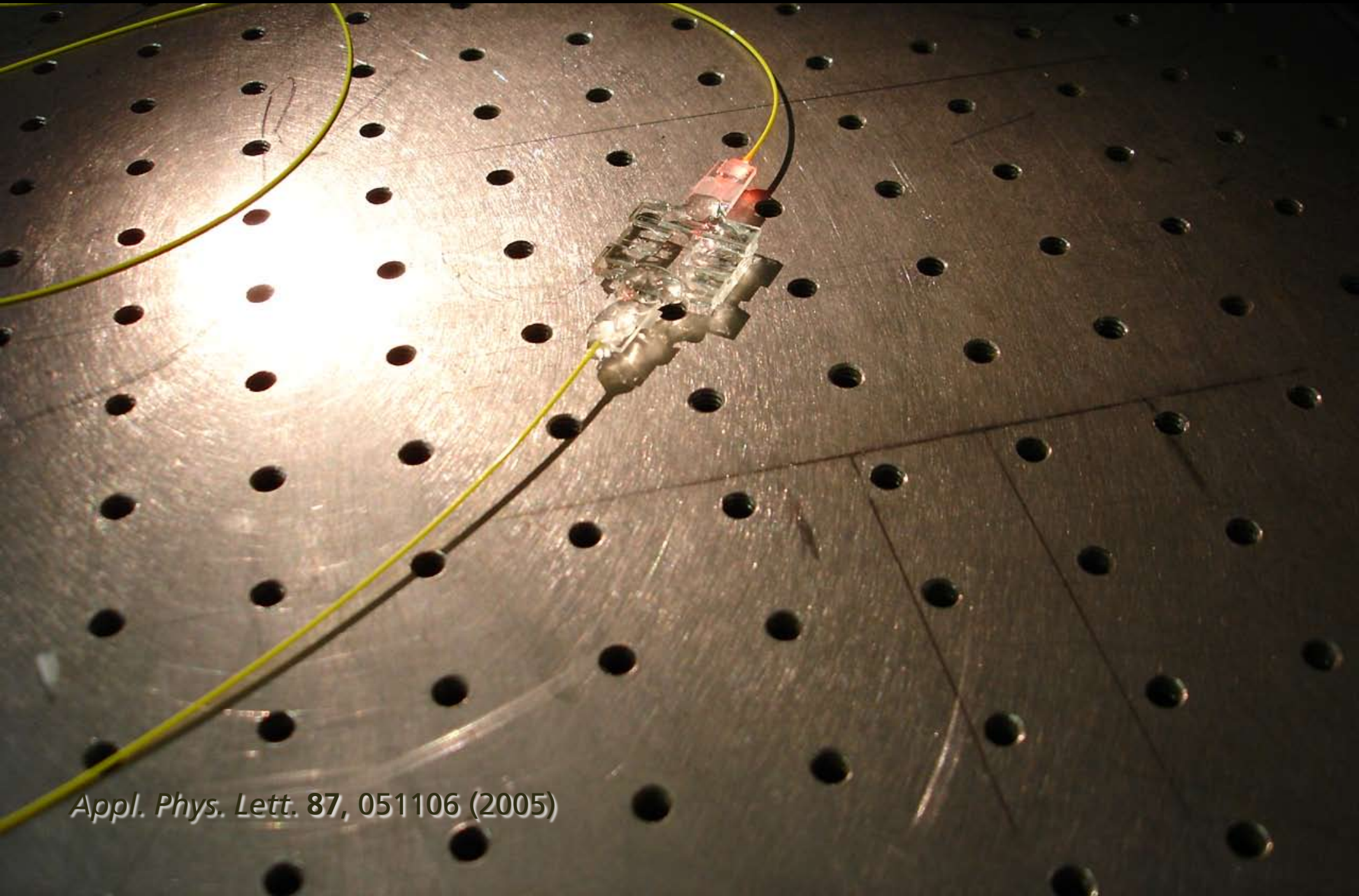


Low-energy machining

structures guide light



Applications



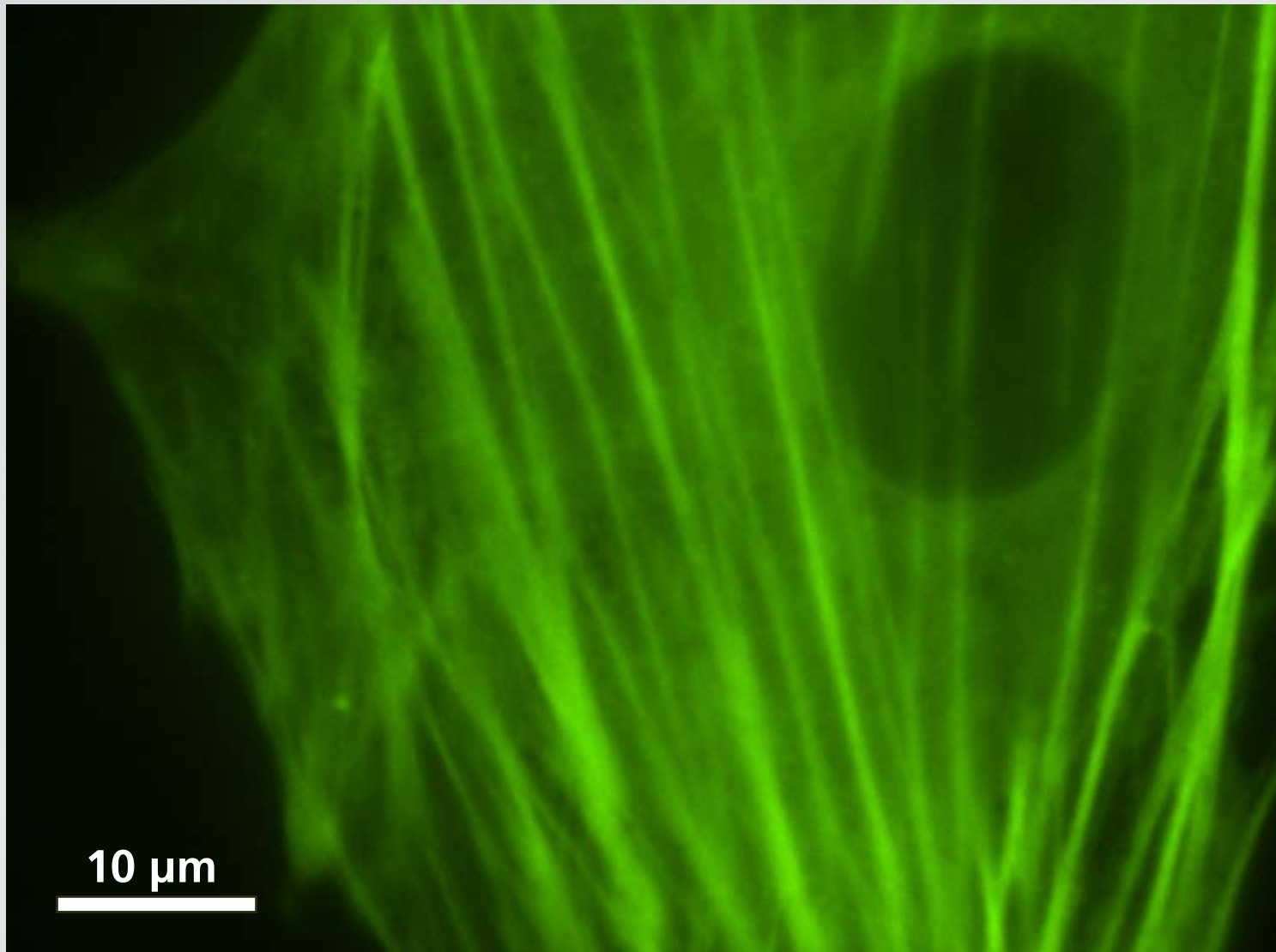
Appl. Phys. Lett. 87, 051106 (2005)

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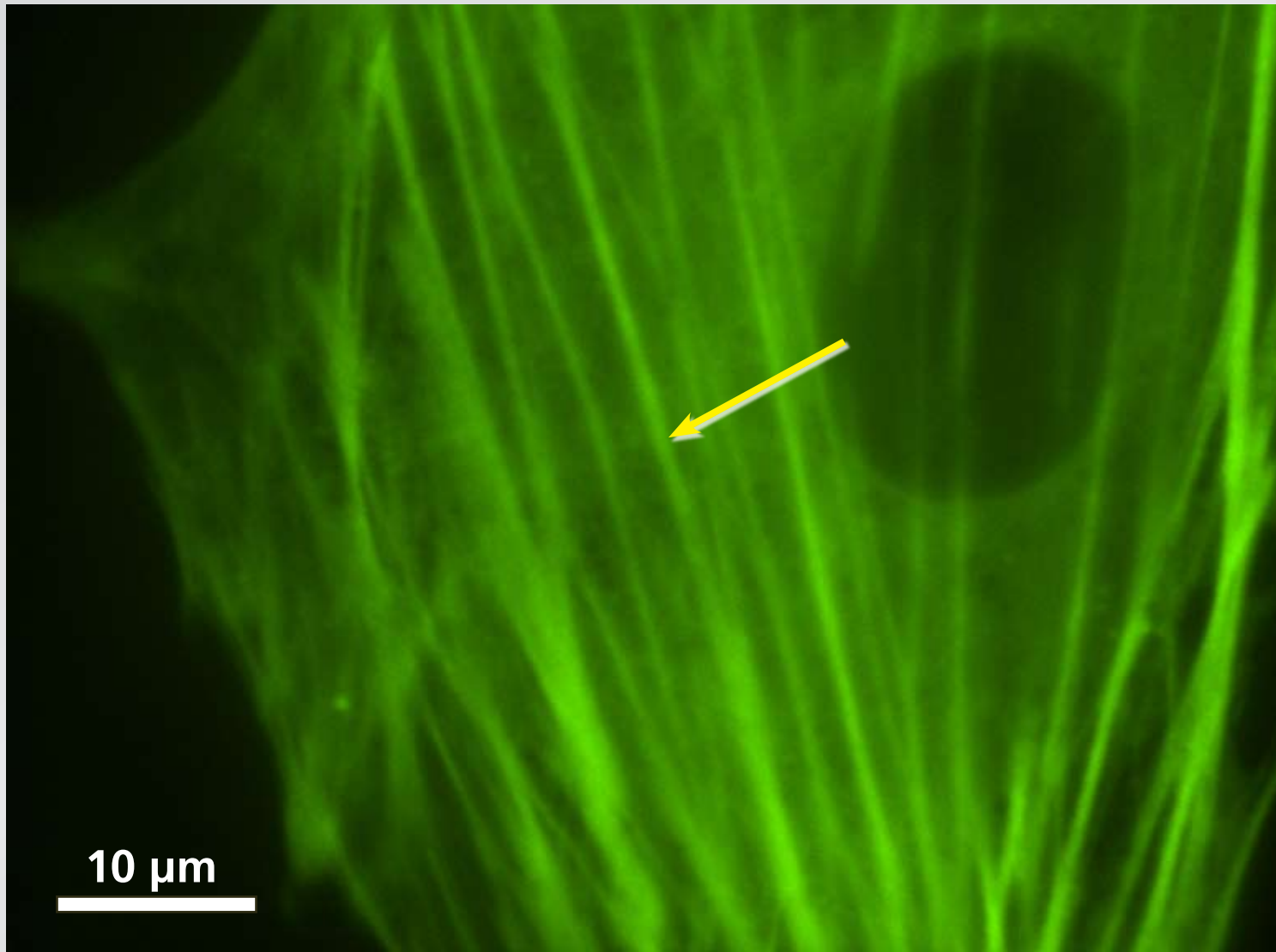
Applications

actin fiber network of a live cell



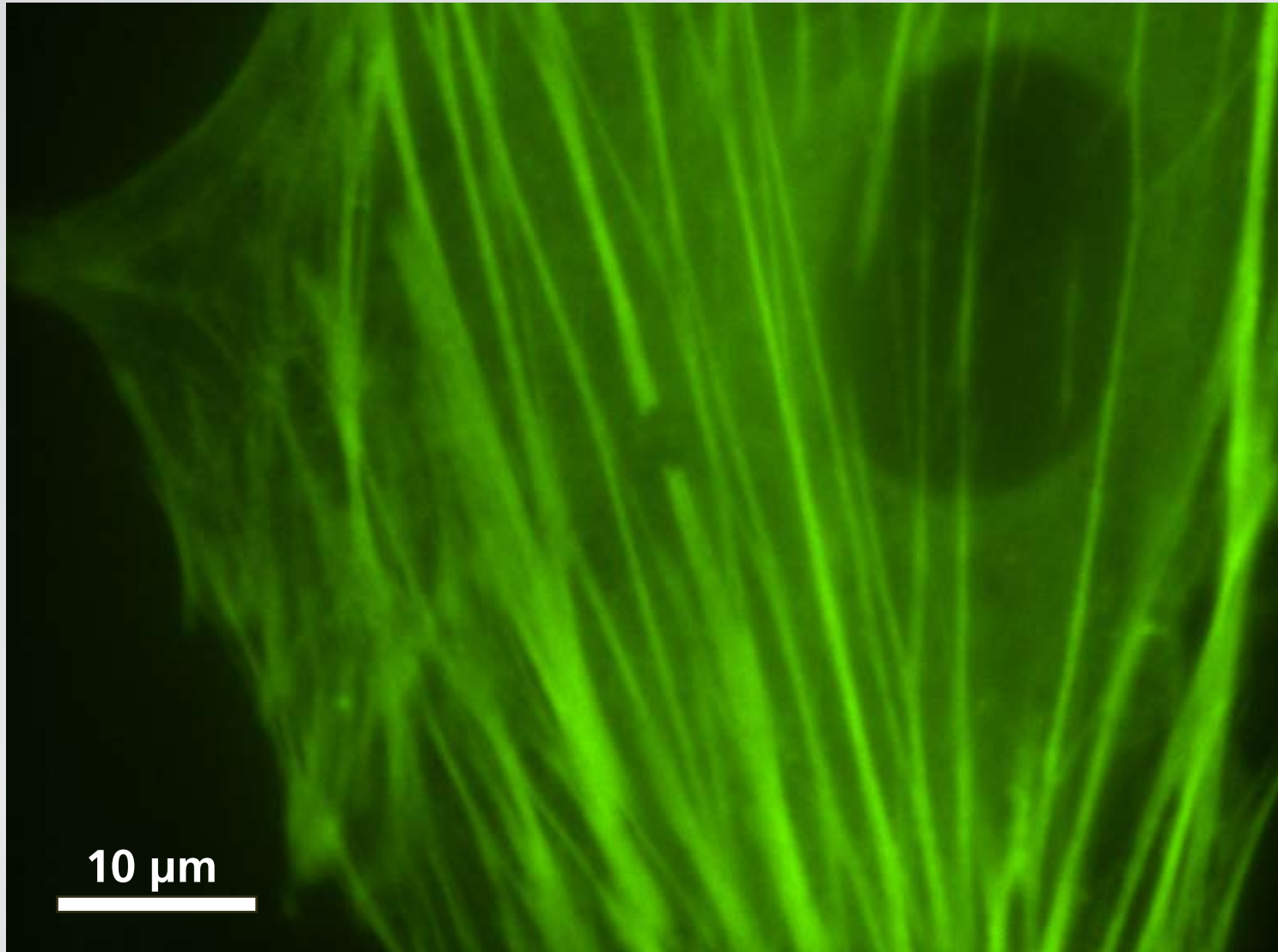
Applications

cut a single fiber bundle



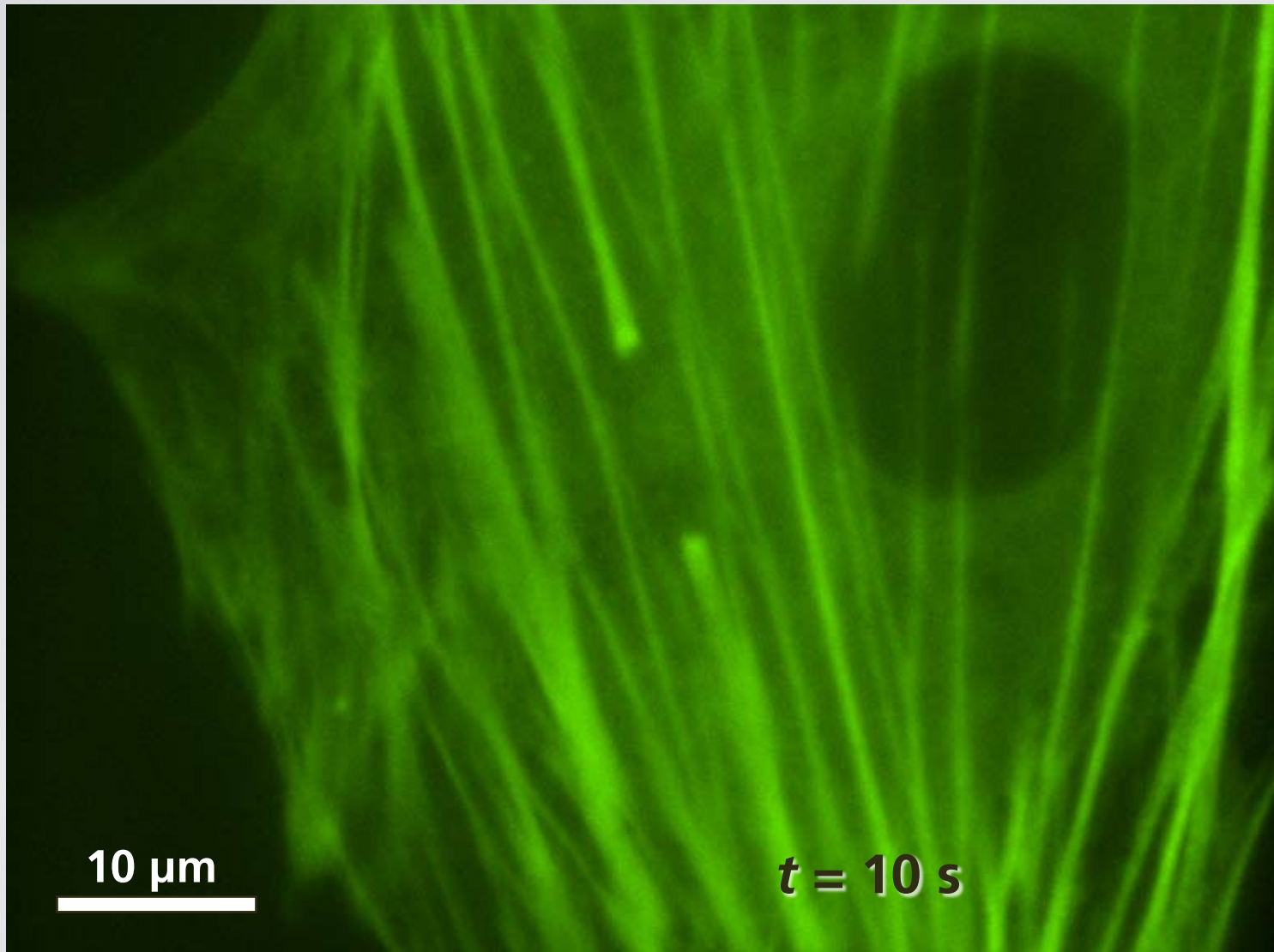
Applications

cut a single fiber bundle



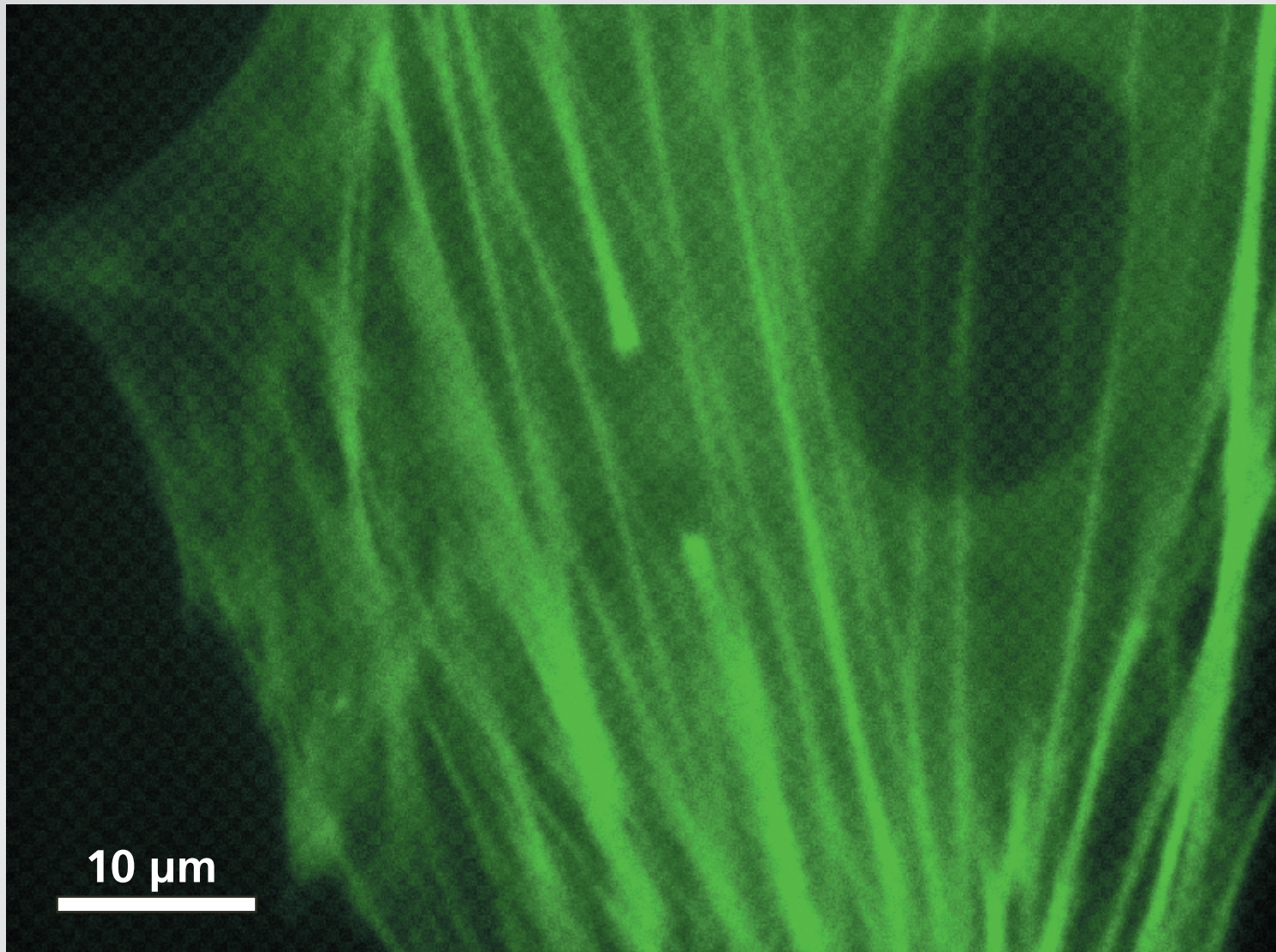
Applications

gap widens with time

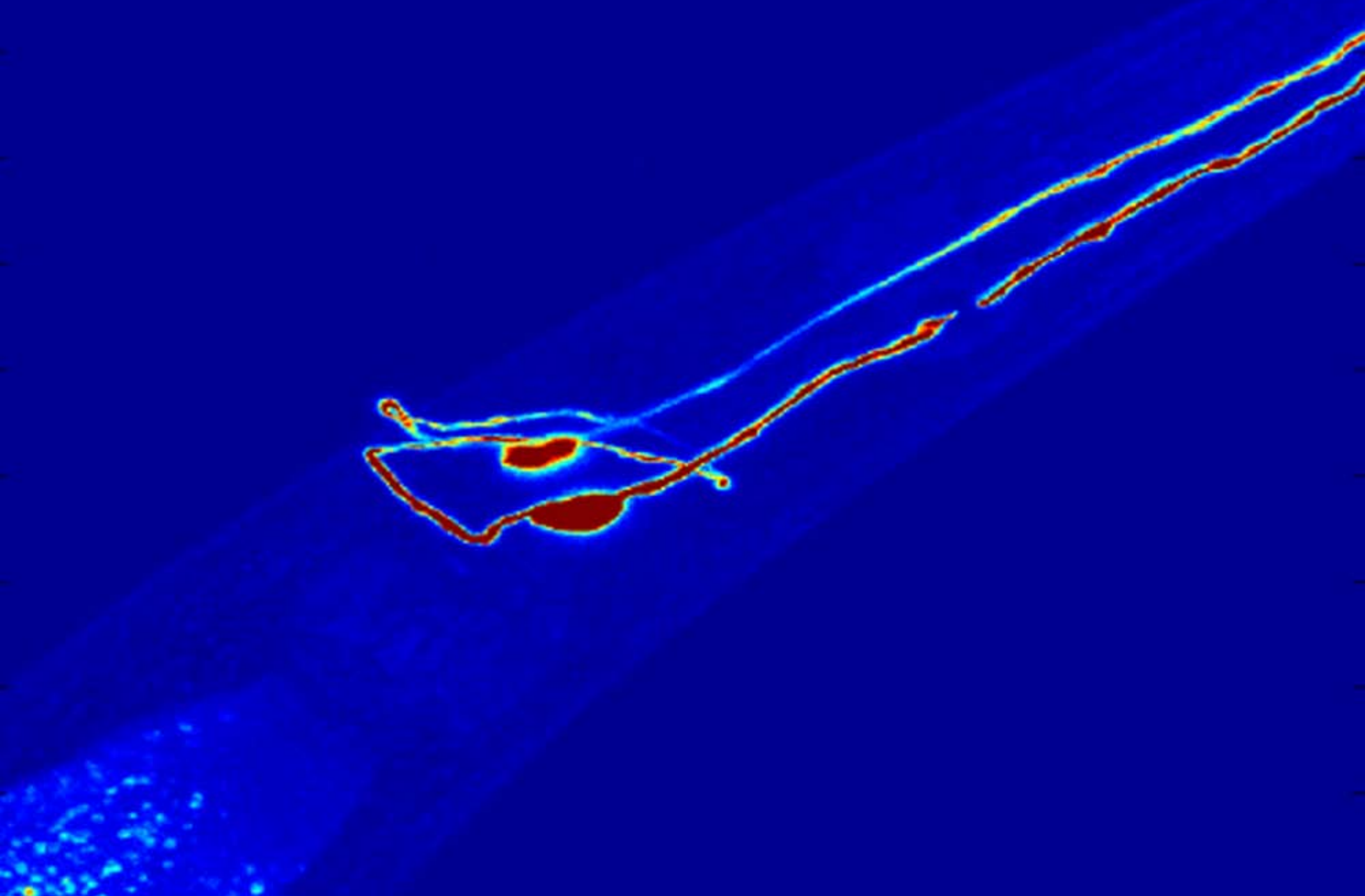


Applications

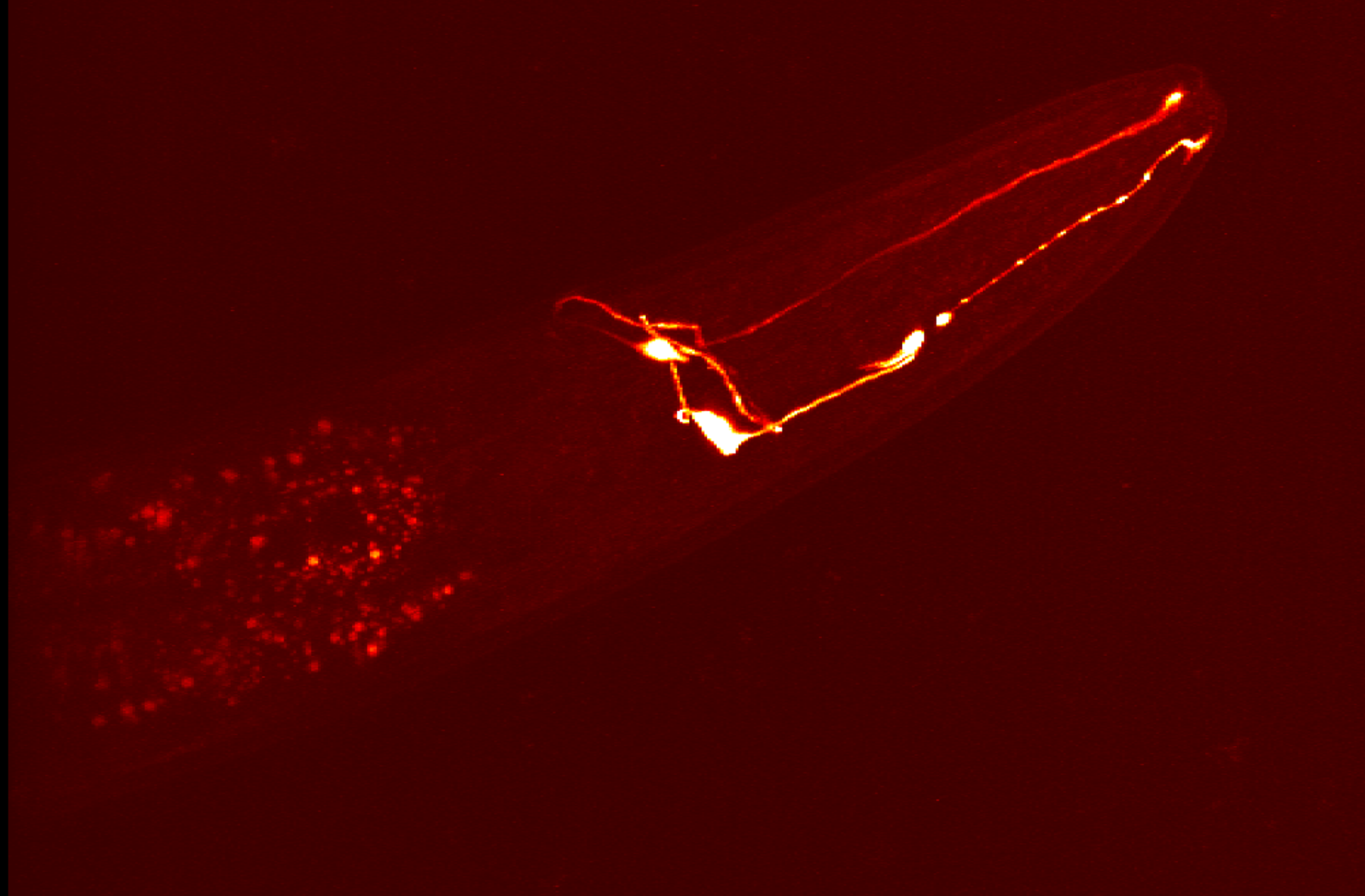
dynamics provides information on *in vivo* mechanics



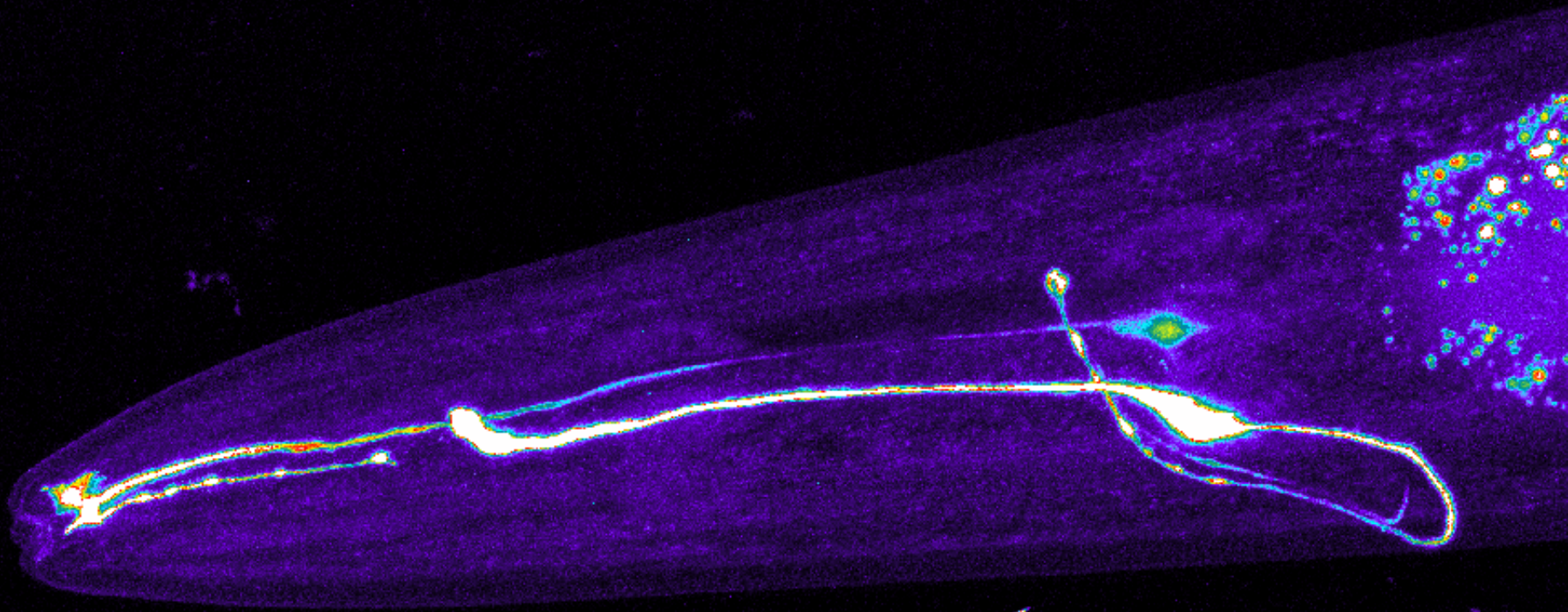
Applications



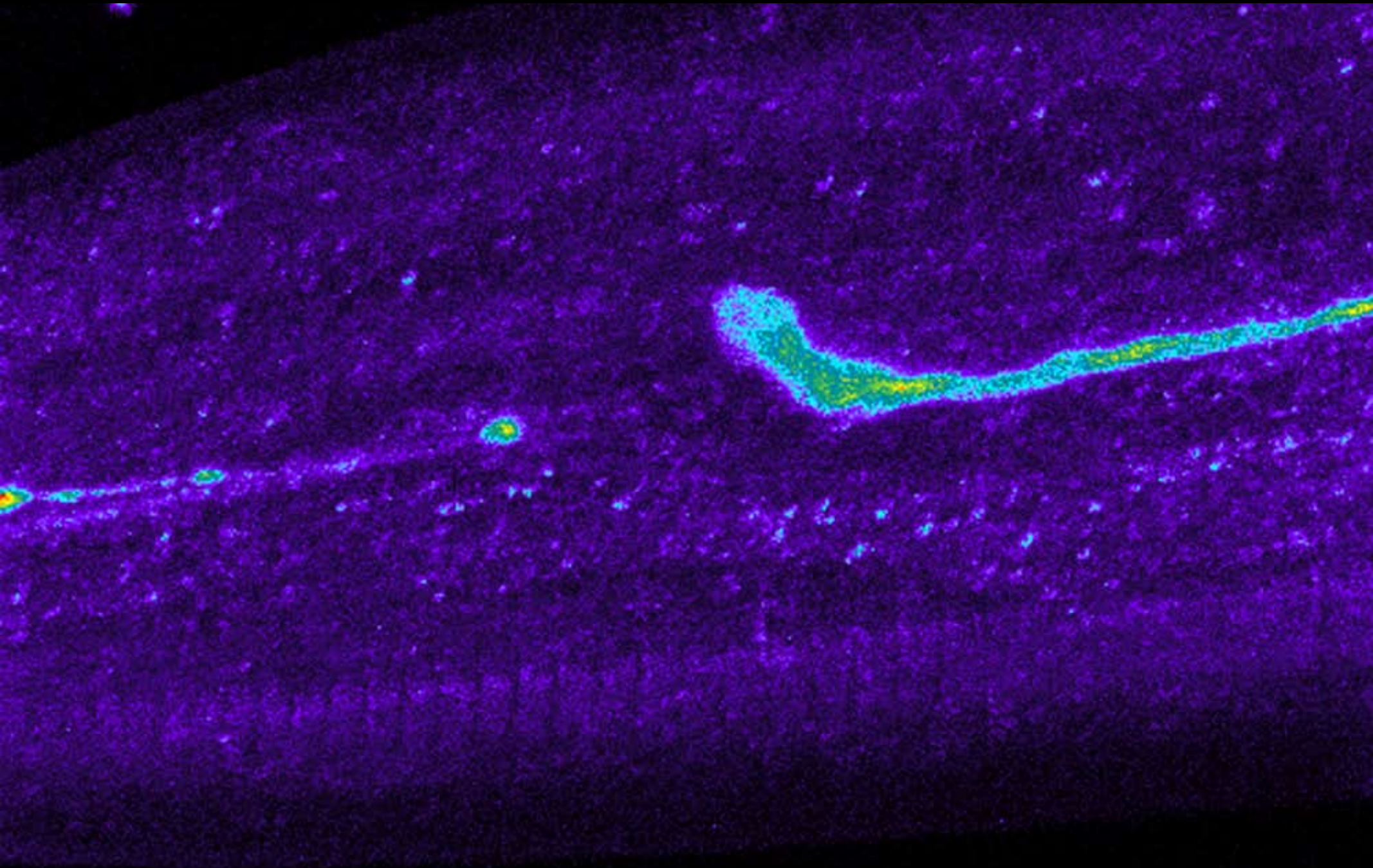
Applications



Applications



Applications



Summary

great tool for

- "wiring light"
- micromanipulating the machinery of life

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Funding:

National Science Foundation



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