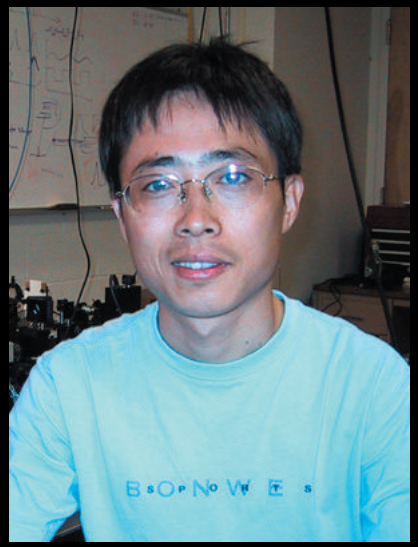
Wrapping light around a hair

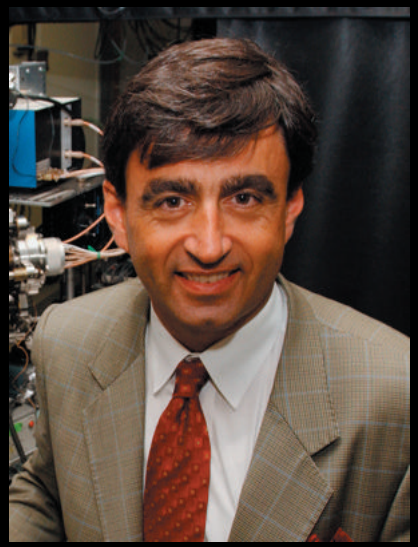
SPS/DSP Lunch Talk
University of Kentucky
Kentucky, KY, 25 October 2007



Limin Tong

Rafael Gattass

Geoff Svacha



Eric Mazur

and also....

at Harvard:

Jonathan Aschom
Mengyan Shen
Iva Maxwell
James Carey
Brian Tull
Dr. Yuan Lu
Dr. Richard Schalek
Prof. Federico Capasso
Prof. Cynthia Friend

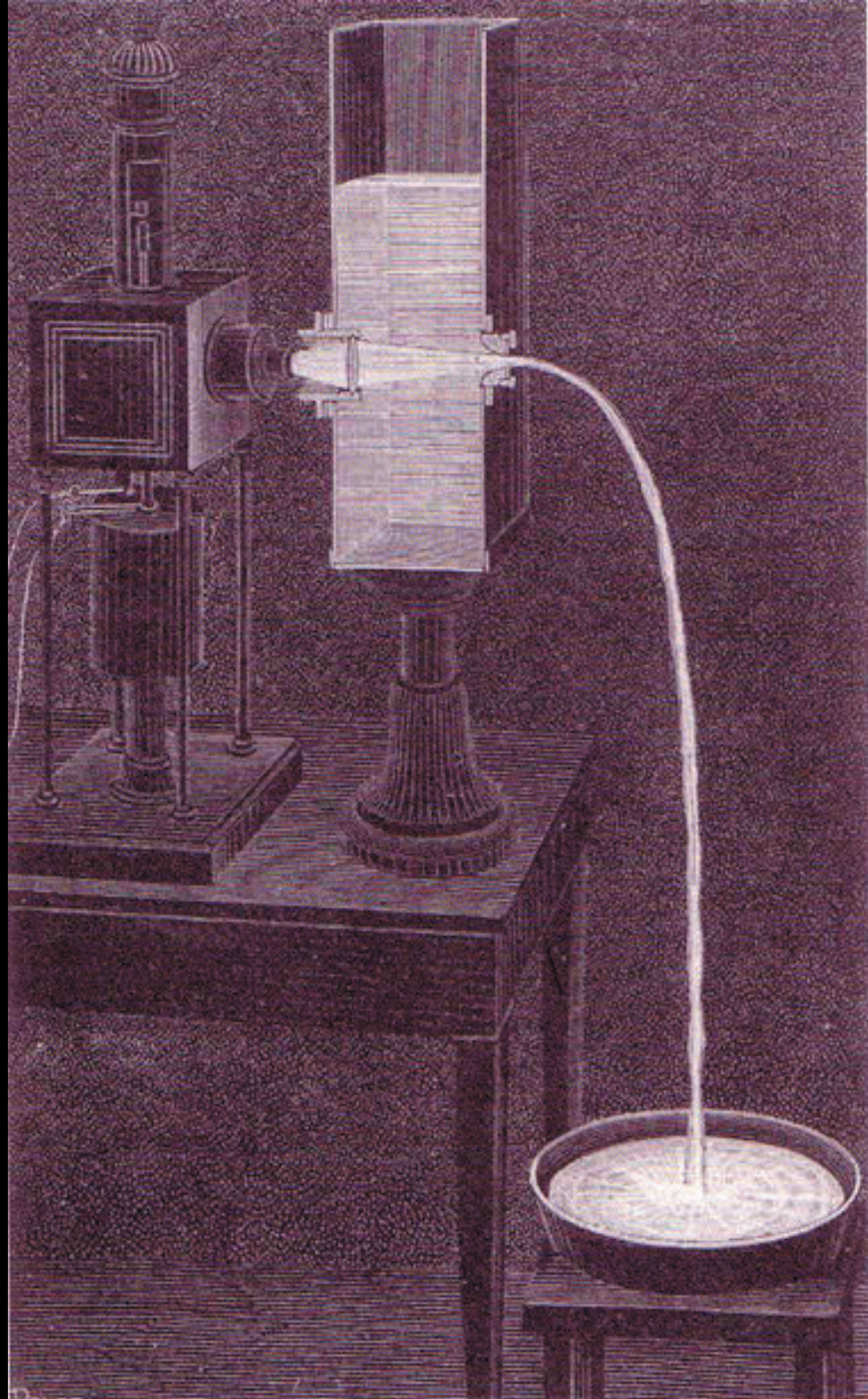
at Zhejiang University:

Dr. Sailing He
Dr. Jingyi Lou
Xuewen Chen
Liu Liu
Zhanghua Han

Dr. Ray Mariella (LLNL)

"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)

(No model.) 4 Sheets—Sheet

W. WHEELER.

APPARATUS FOR LIGHTING DWELLINGS OR OTHER STRUCTURES.

No. 247,229. Patented Sept. 20, 1881.

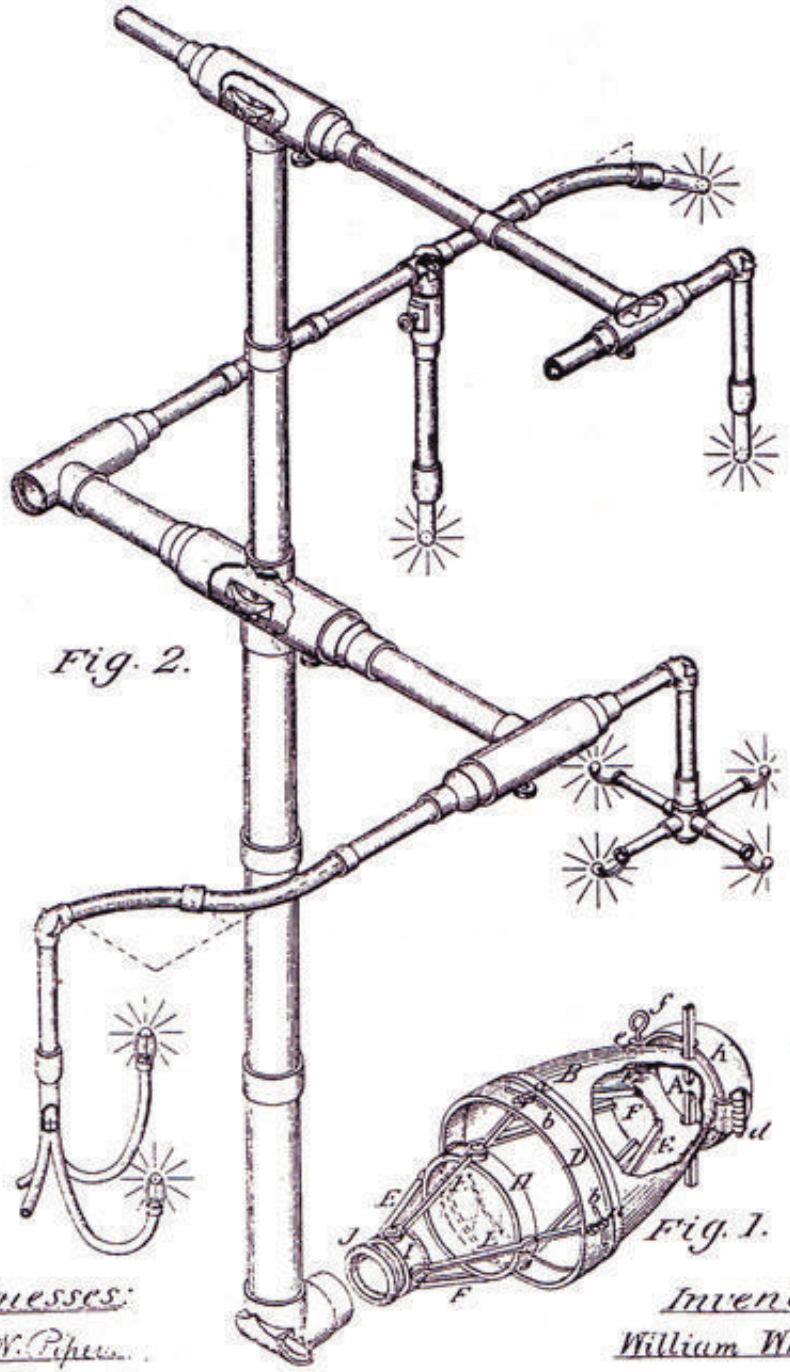


Fig. 2.

Fig. 1.

Witnesses:
A. W. Pipes.

Inventor:
William Wheeler
by attorney

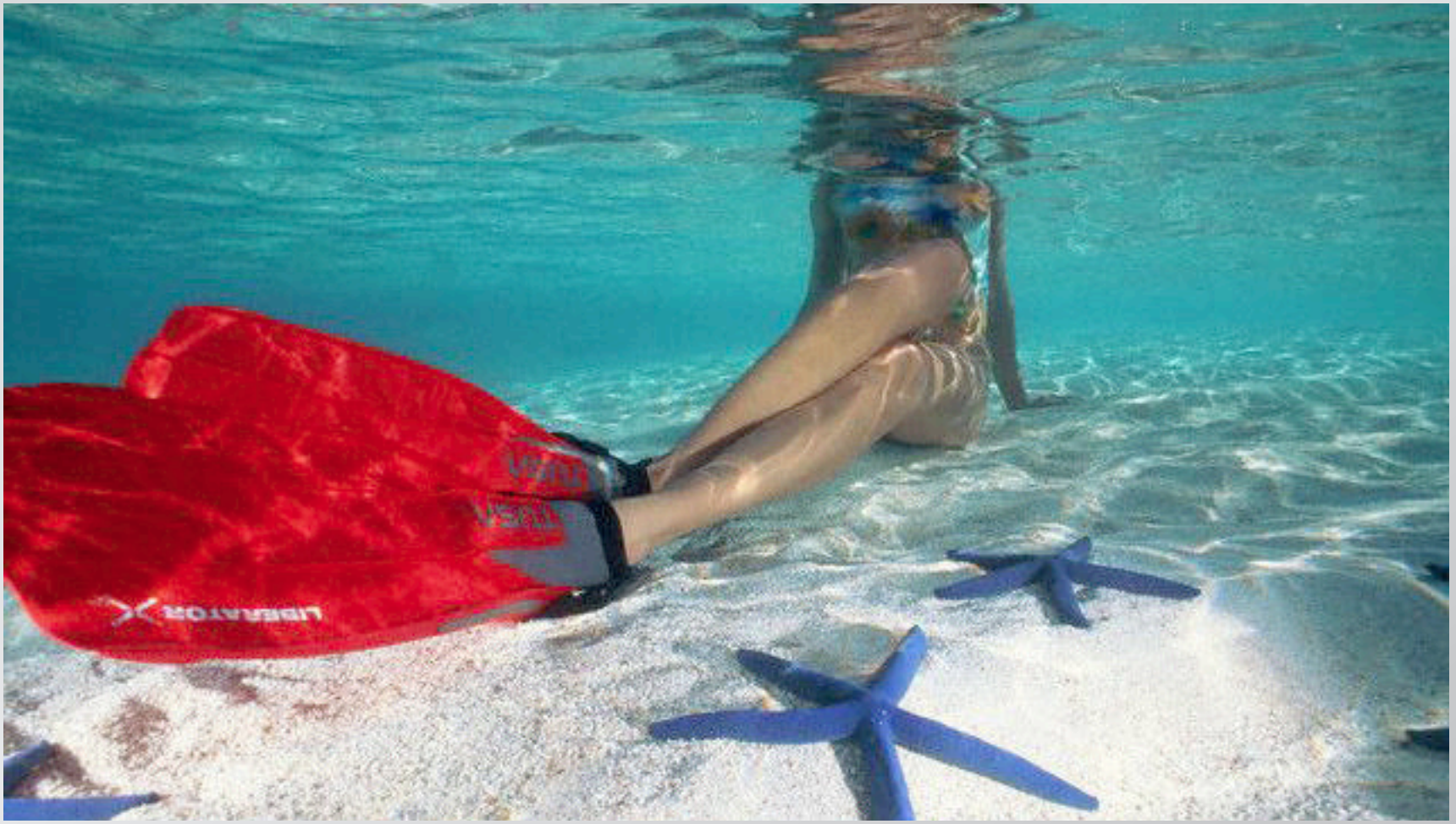
US Patent 247, 229 (1881)

Outline

- waveguiding
- nanowire fabrication
- optical properties

Waveguiding

how does water surface look from bottom?



Waveguiding

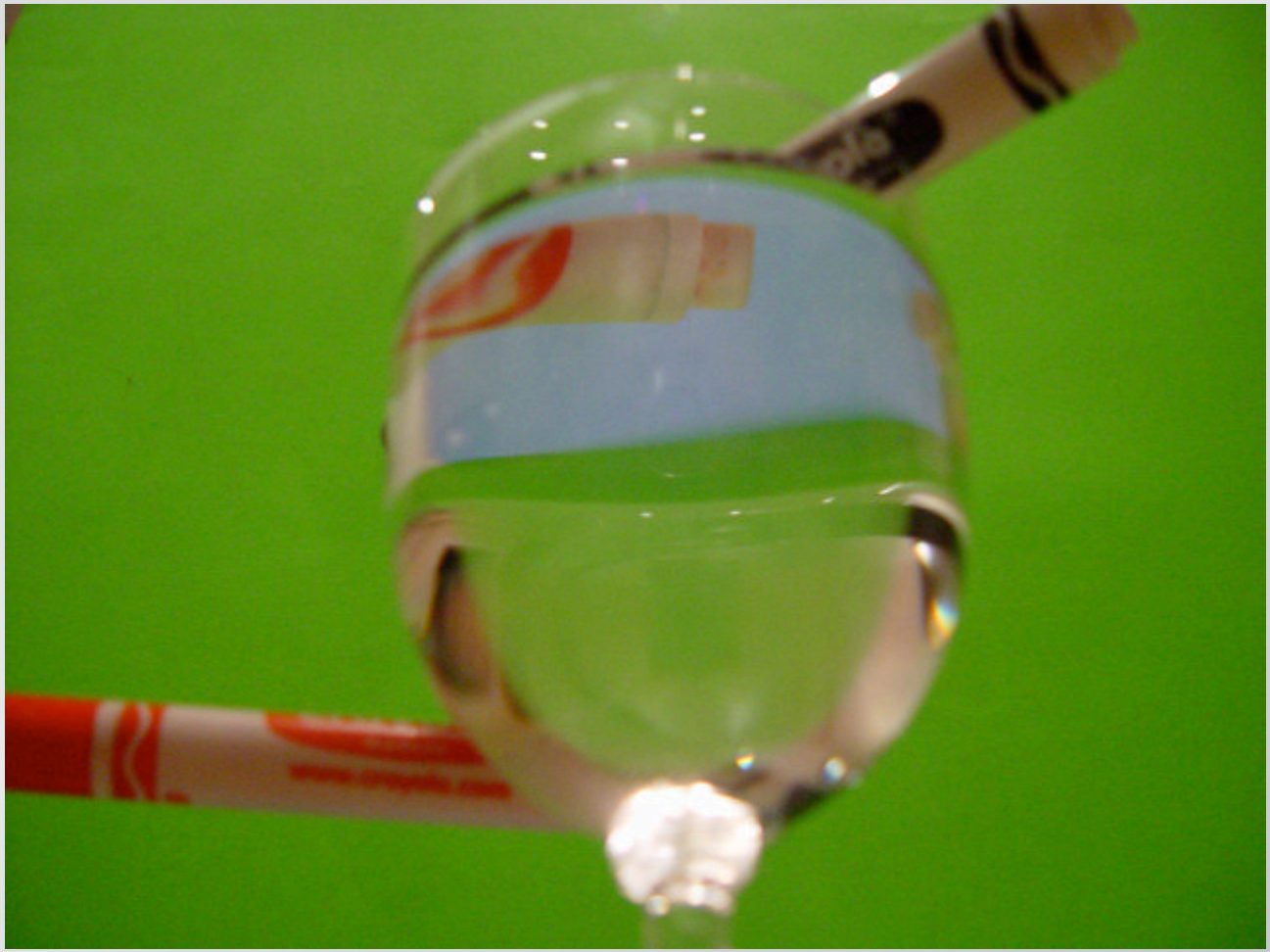
from top partially transmitting!

Waveguiding

Waveguiding

Waveguiding

water surface is perfect one-way mirror!

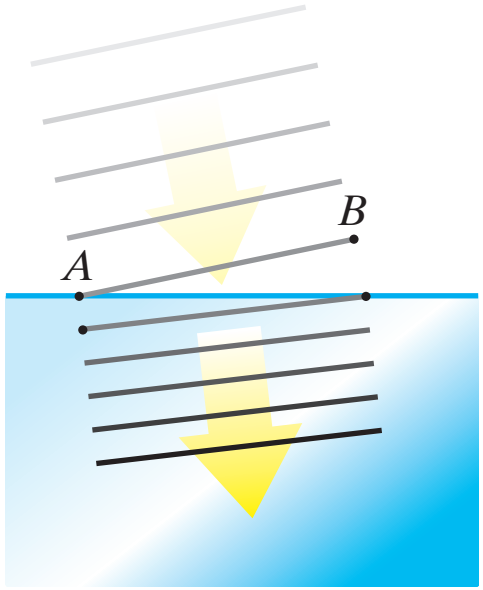


Waveguiding

Why? Because light travels more slowly in water…

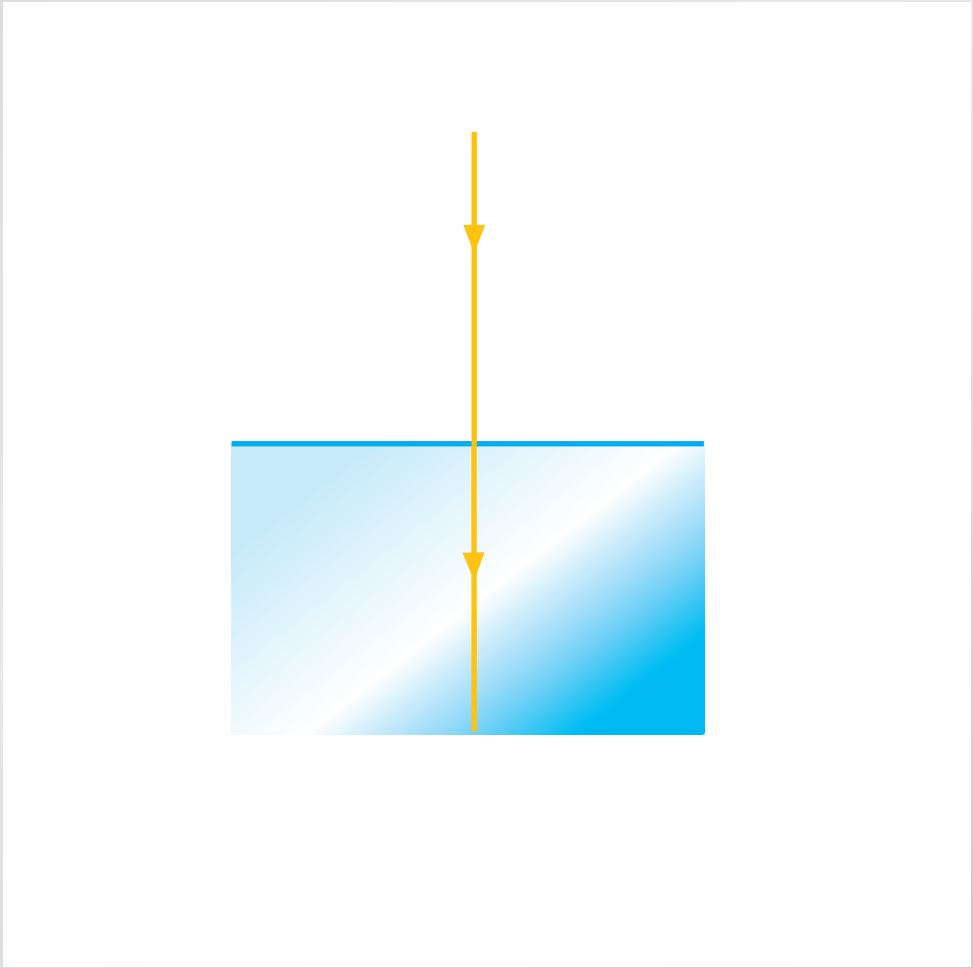
Waveguiding

…making it bend as it crosses surface



Waveguiding

The more angled the incident ray, the stronger the bending



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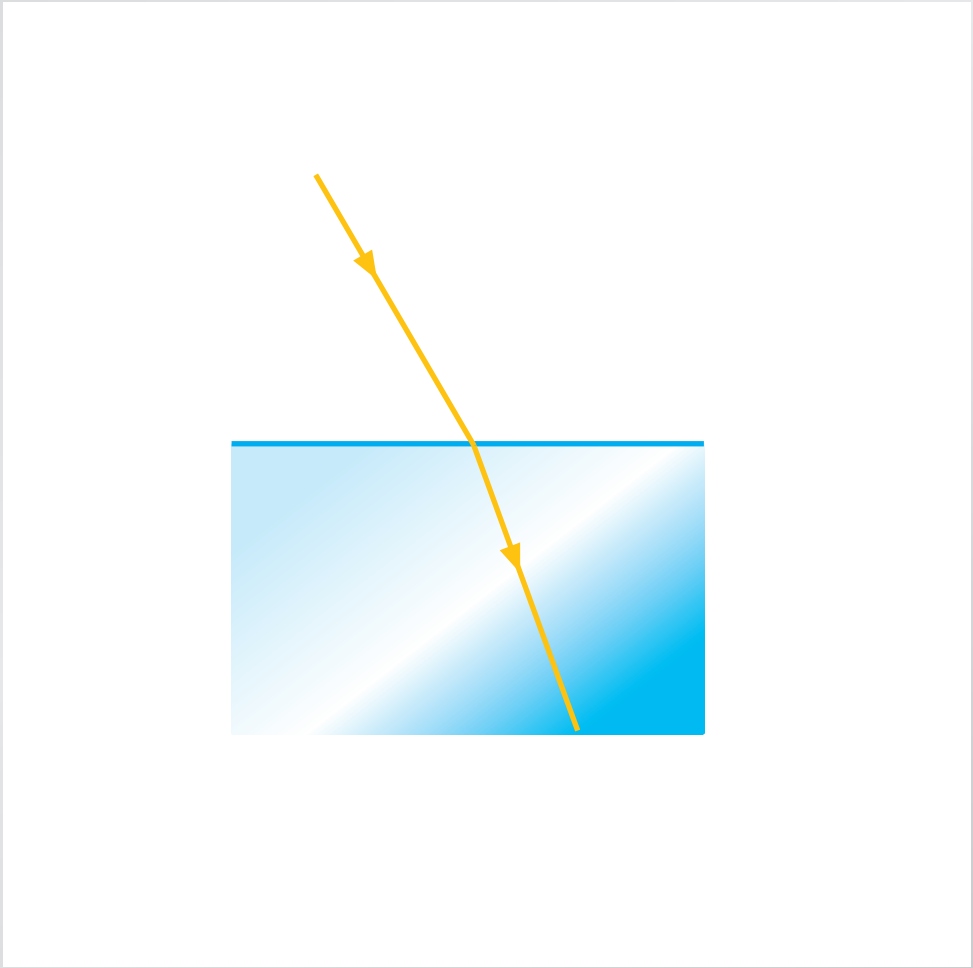

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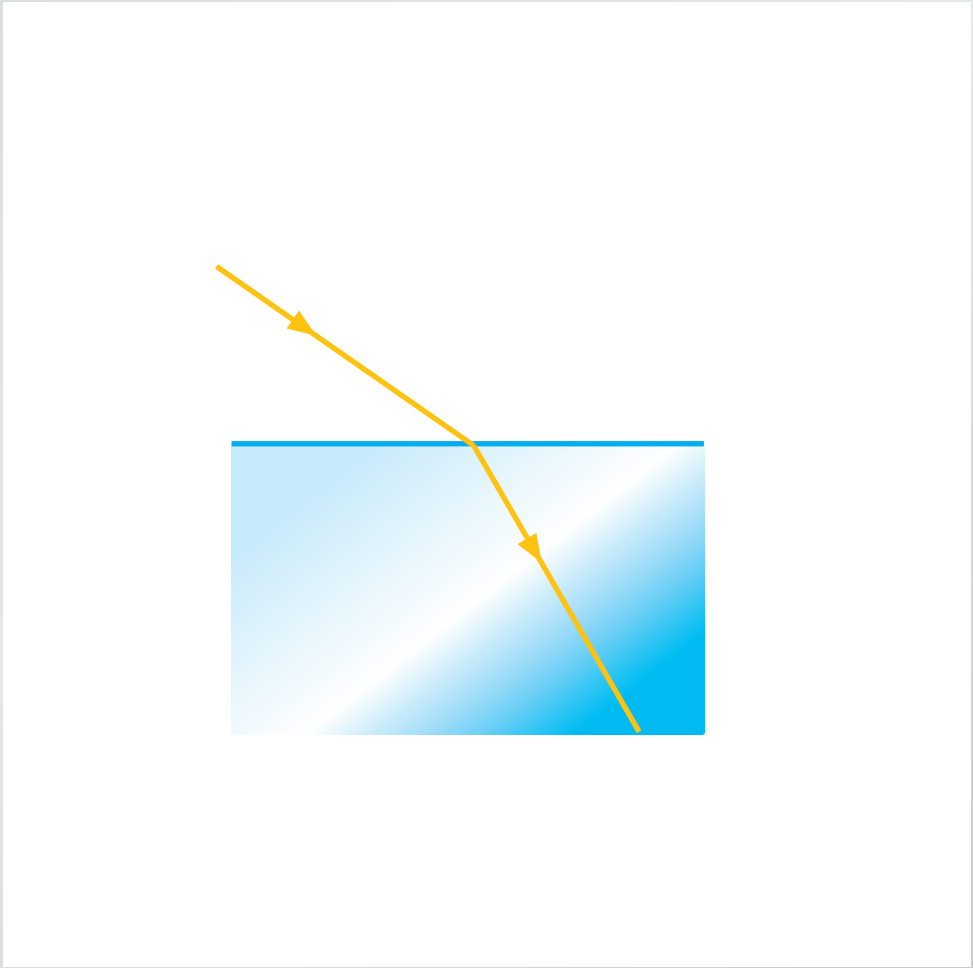

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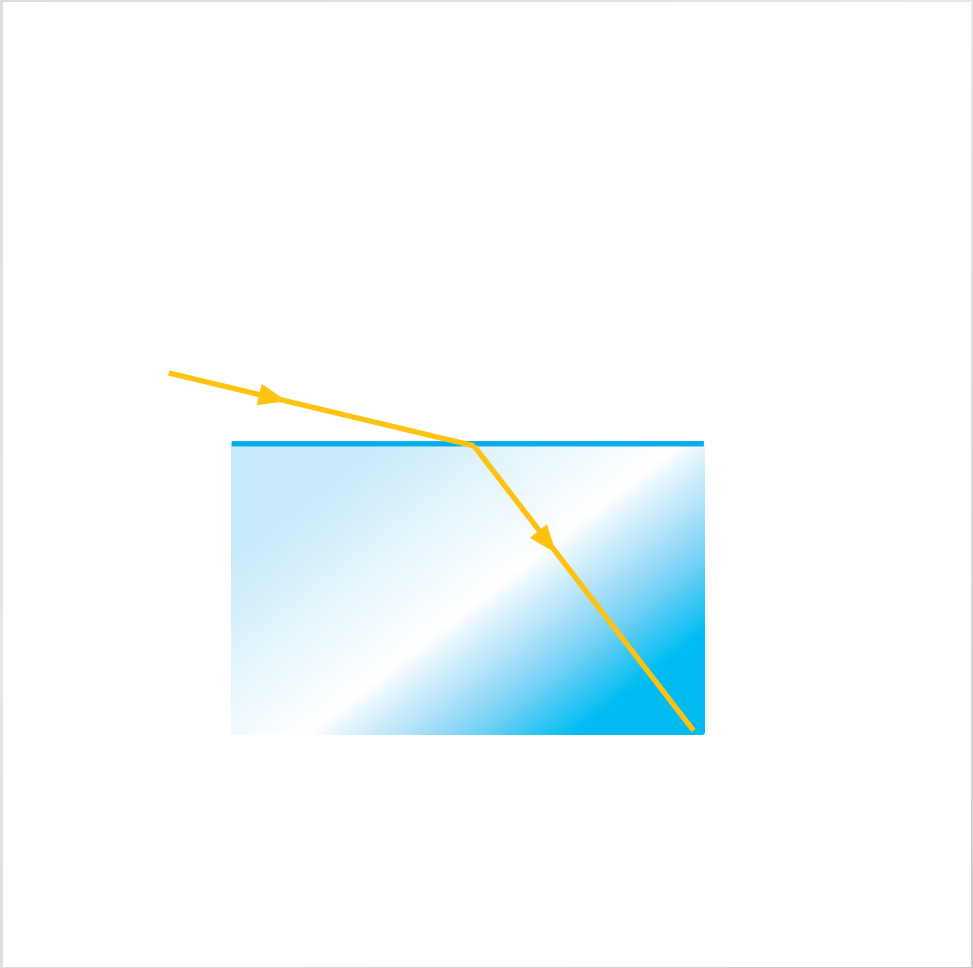
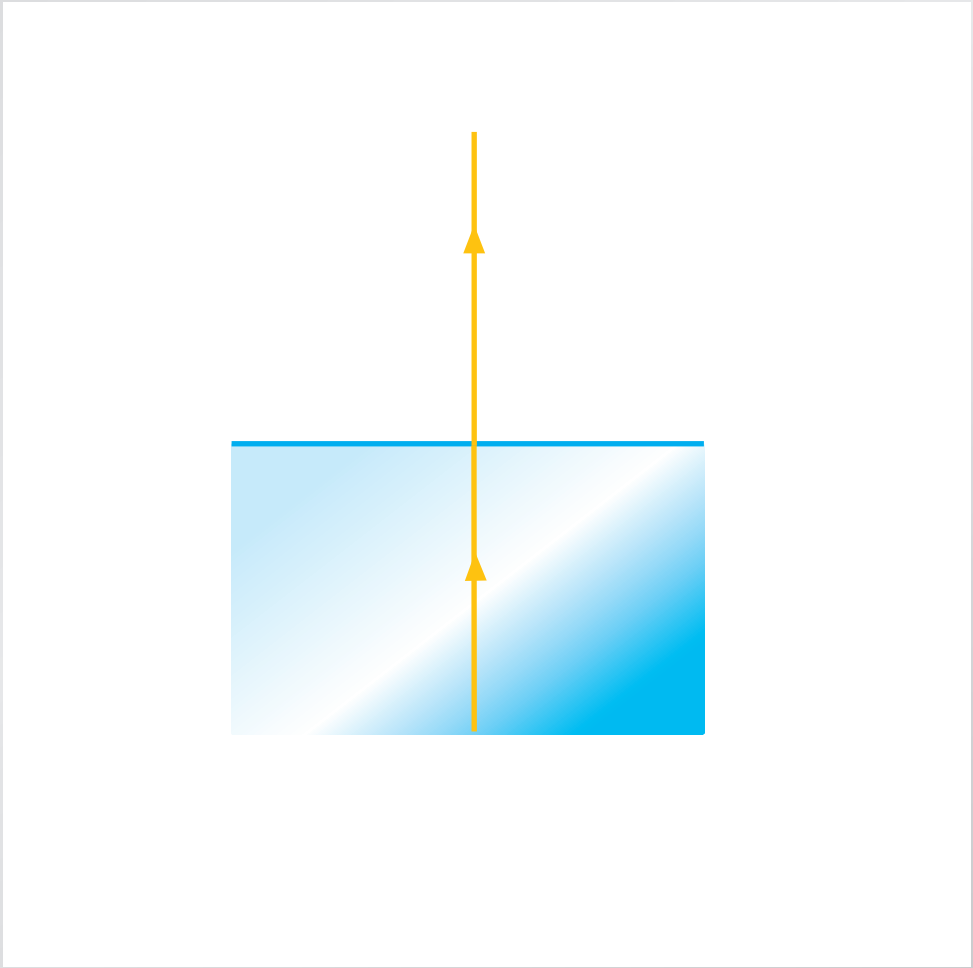


Waveguiding

The amount of bending is the same in reverse



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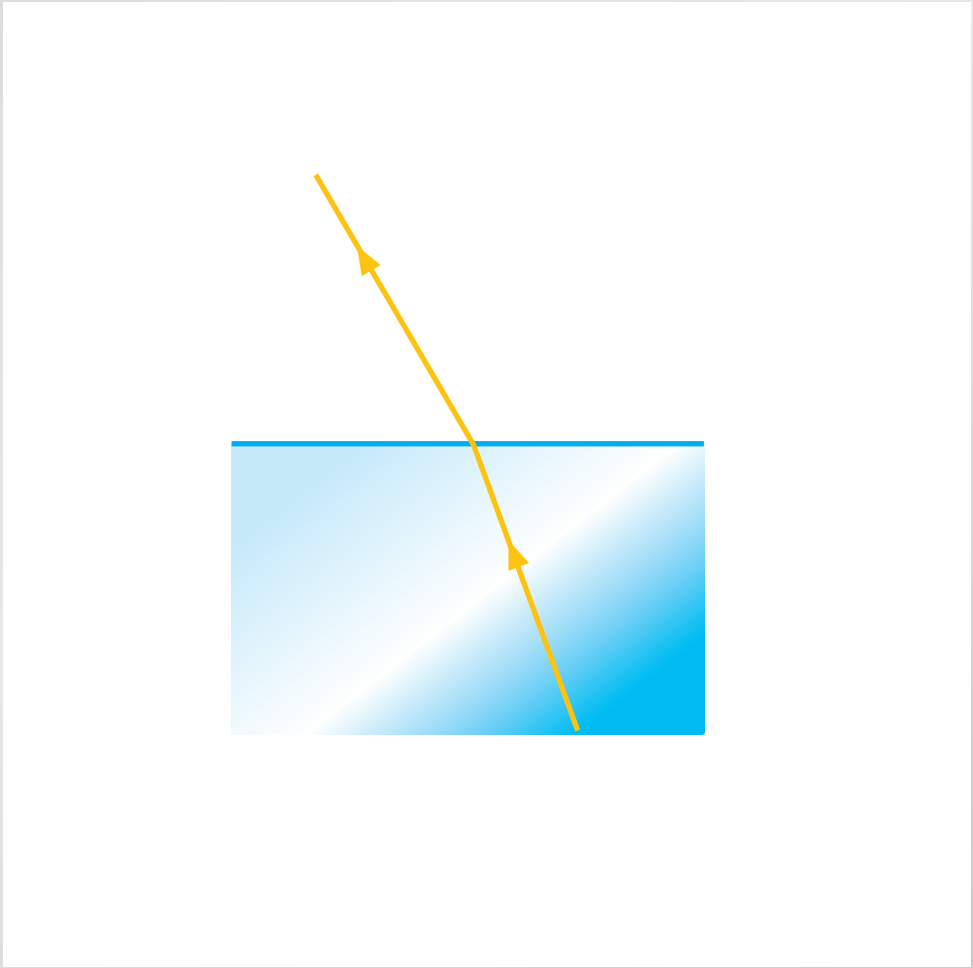

Waveguiding

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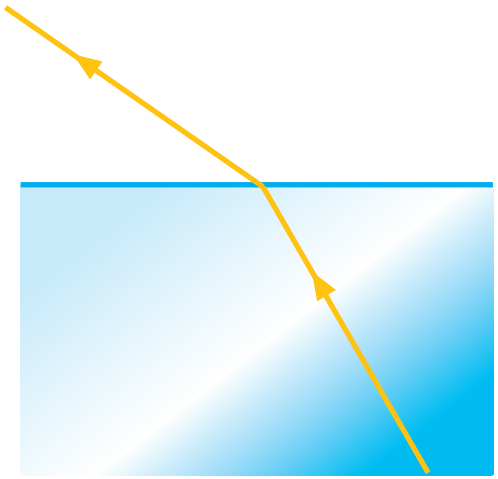
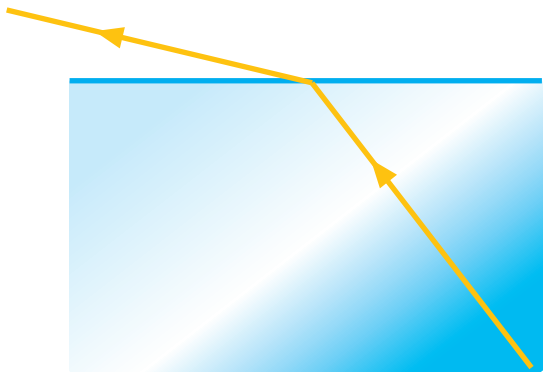


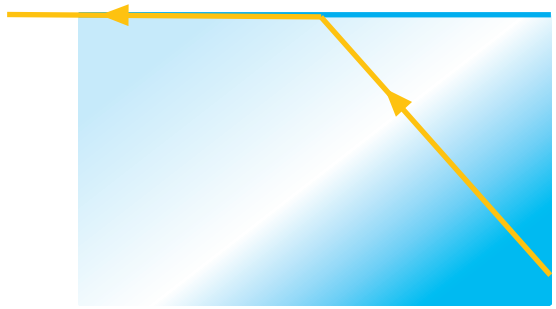
Waveguiding

The amount of bending is the same in reverse



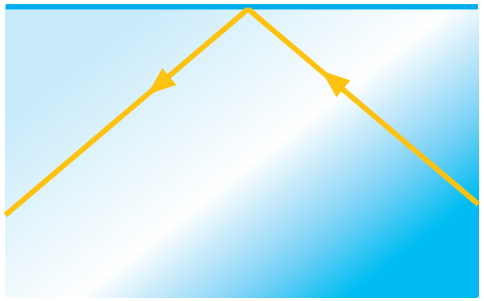
Waveguiding

At ‘critical angle’ bent ray travels along surface



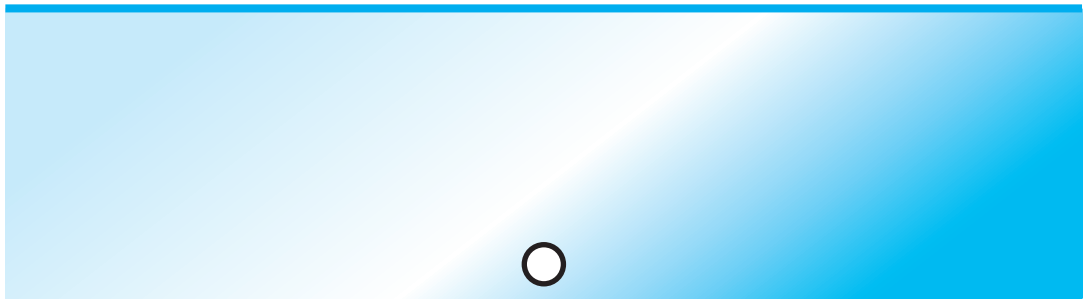
Waveguiding

Beyond ‘critical angle’: total internal reflection



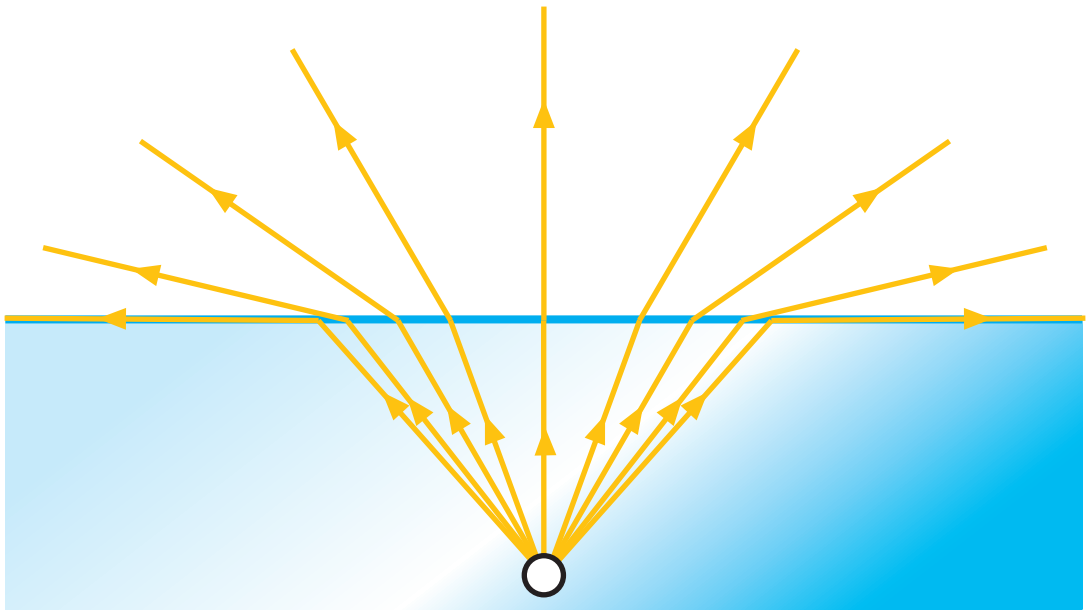
Waveguiding

seeing underwater



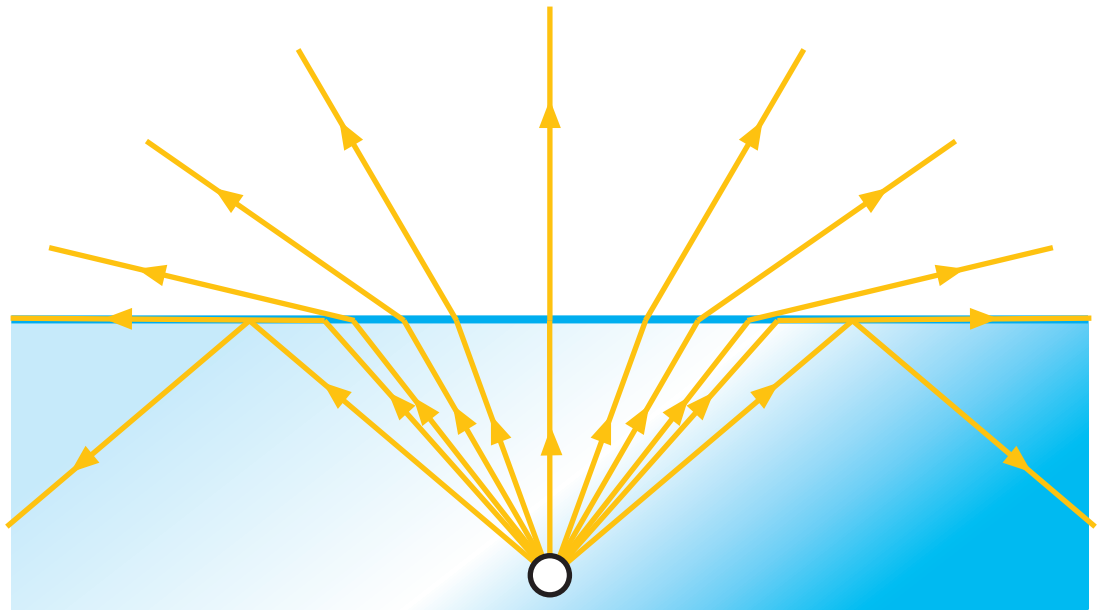
Waveguiding

seeing underwater



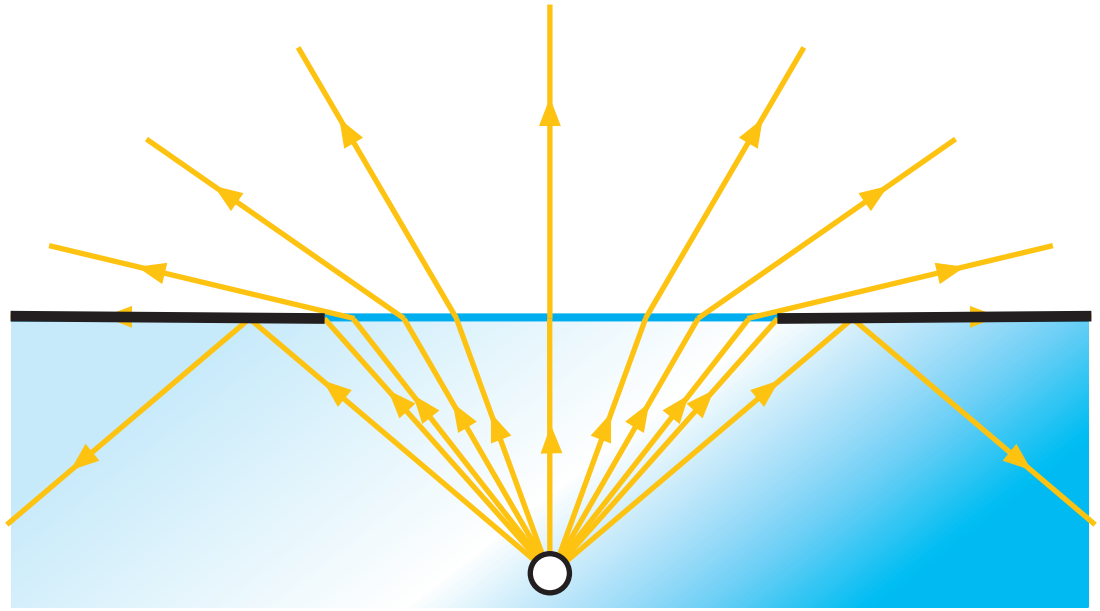
Waveguiding

seeing underwater



Waveguiding

surface looks like mirror with a circular hole



Waveguiding

Waveguiding

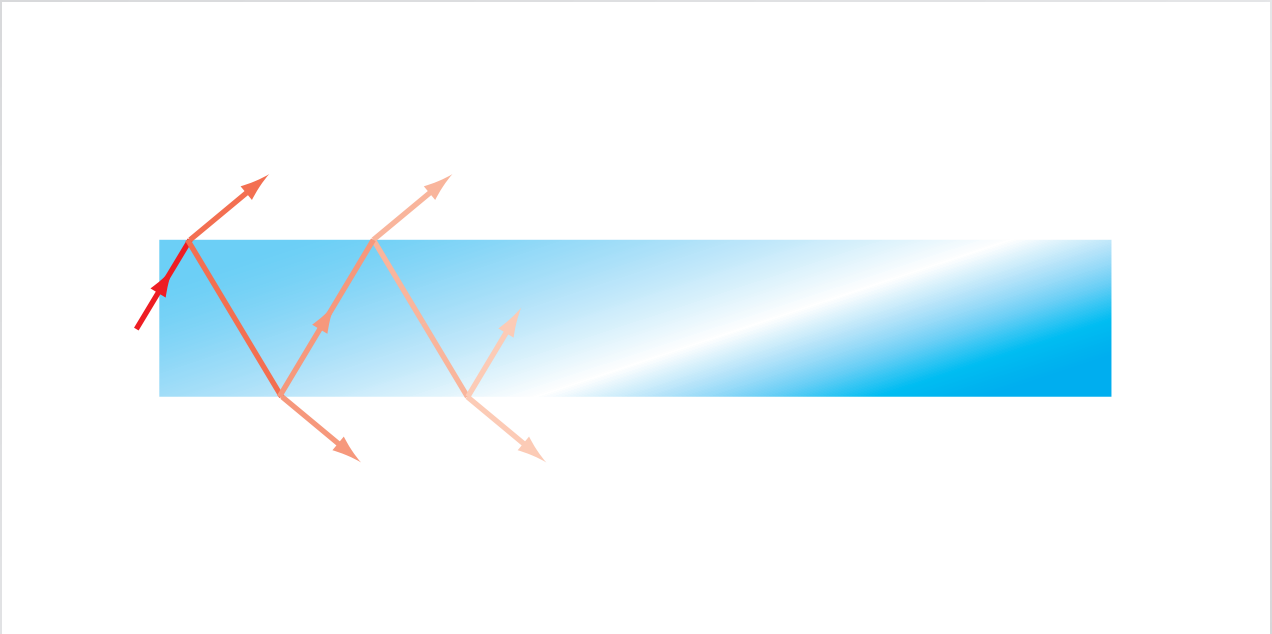
Waveguiding

Waveguiding

Waveguiding

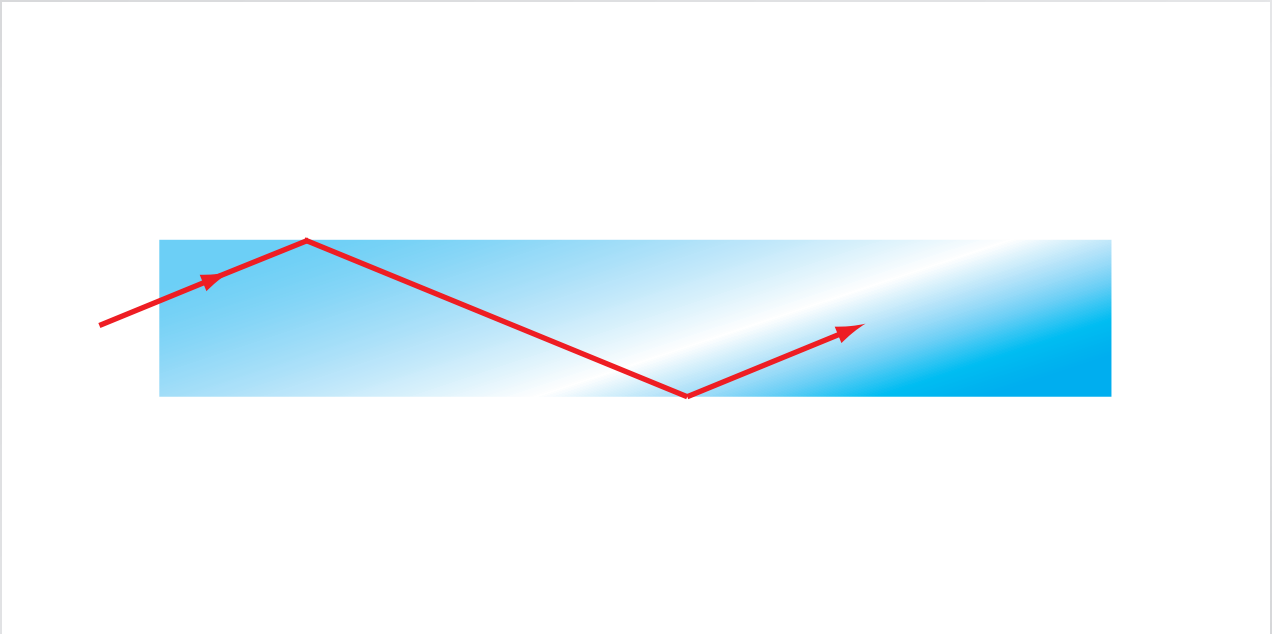
now consider a planar dielectric waveguide

Waveguiding



rays incident at angle $\theta > \pi/2 - \theta_c$ are unguided

Waveguiding



rays incident at angle $\theta < \pi/2 - \theta_c$ are guided

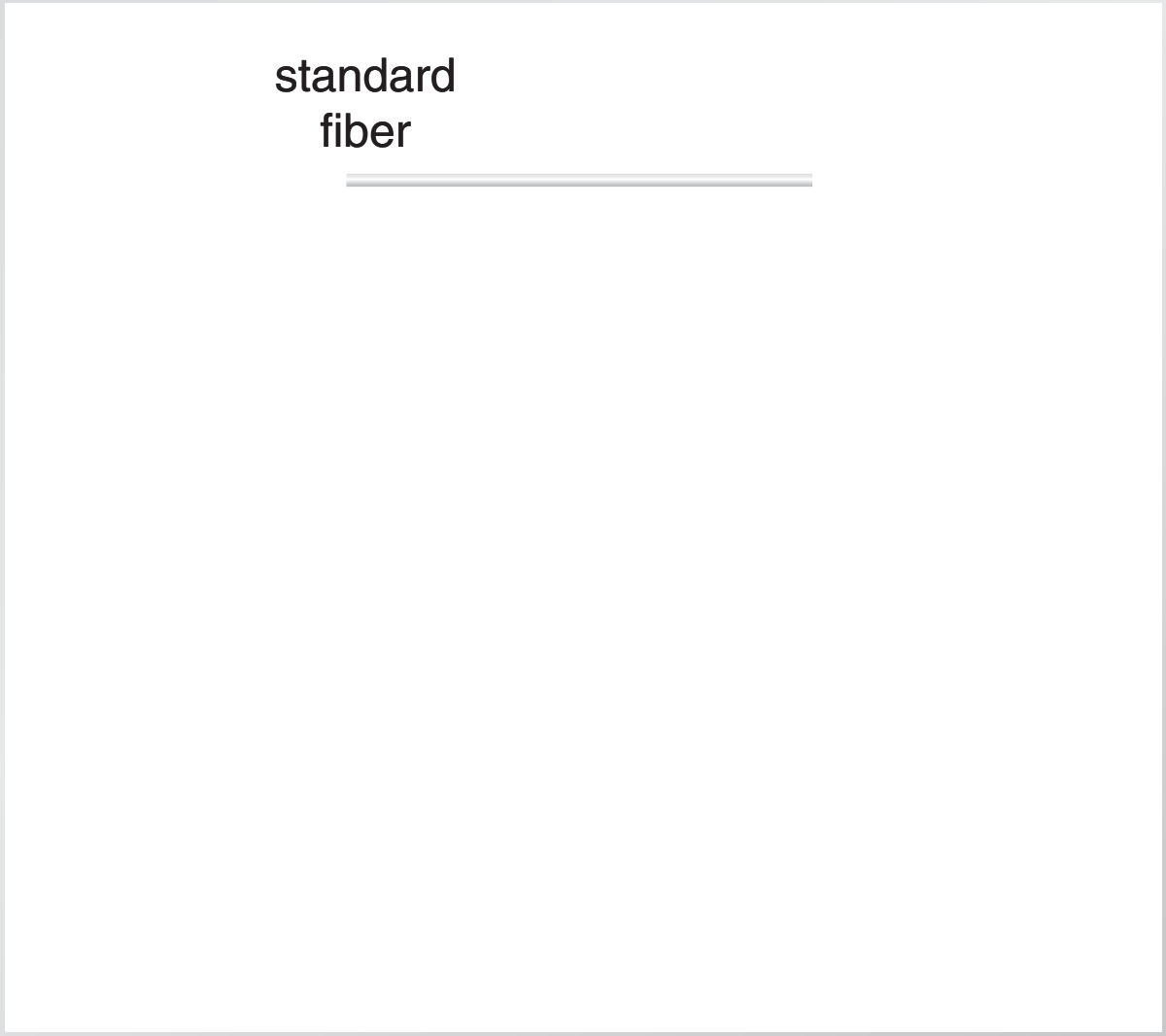
Waveguiding

Outline

- waveguiding
- **nanowire fabrication**
- optical properties

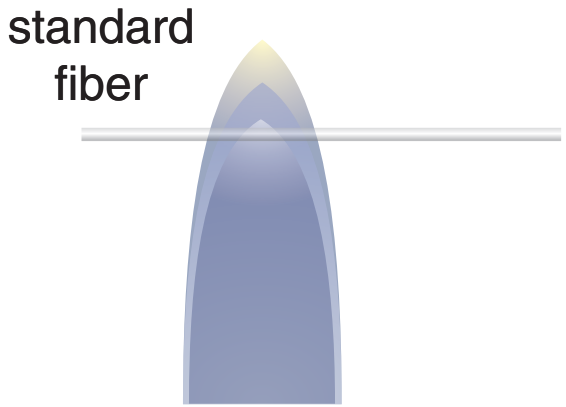
Nanowire fabrication

two-step drawing process



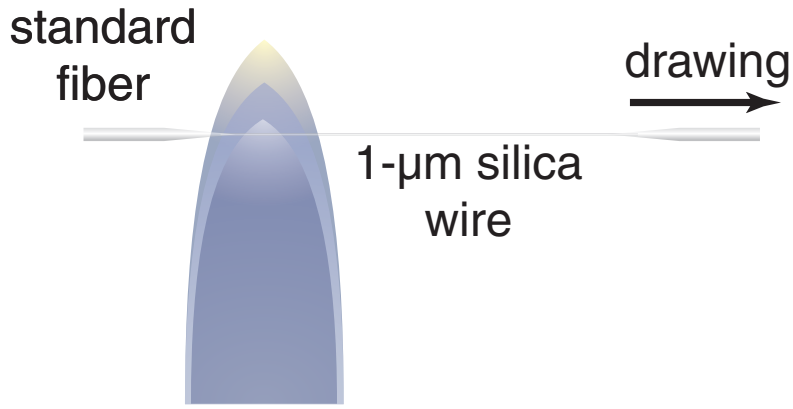
Nanowire fabrication

two-step drawing process



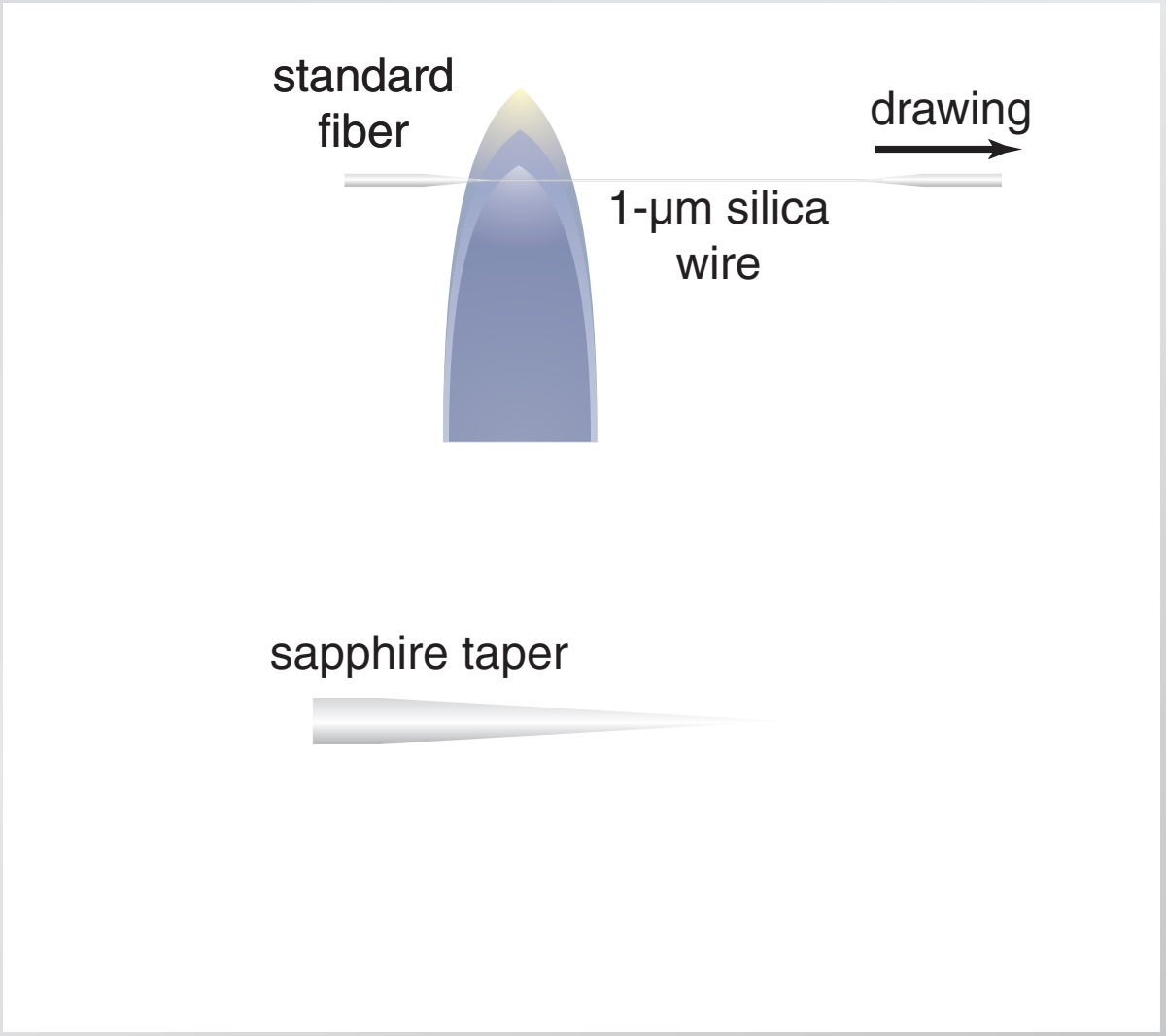
Nanowire fabrication

two-step drawing process



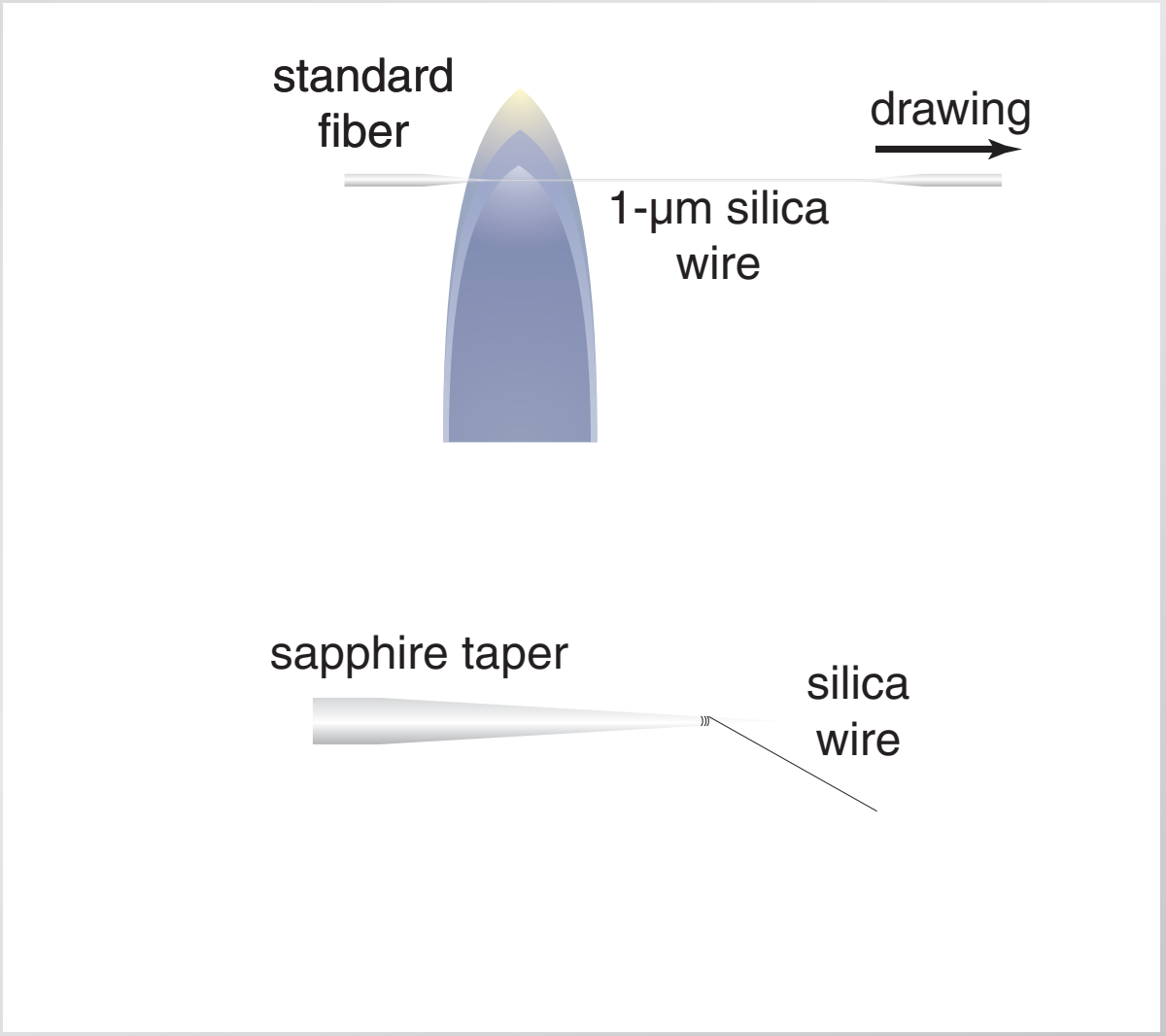
Nanowire fabrication

two-step drawing process



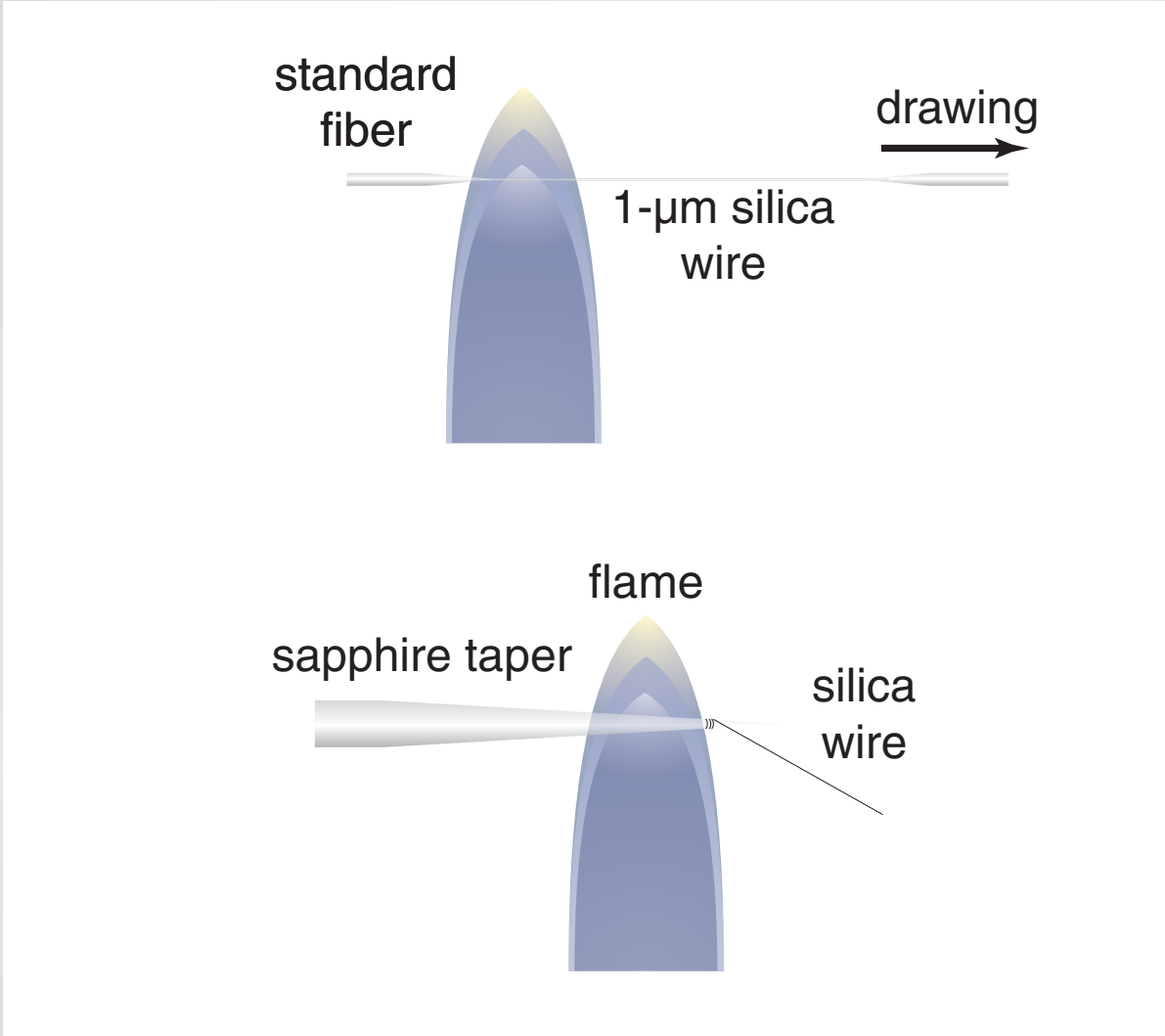
Nanowire fabrication

two-step drawing process



Nanowire fabrication

two-step drawing process



Nanowire fabrication

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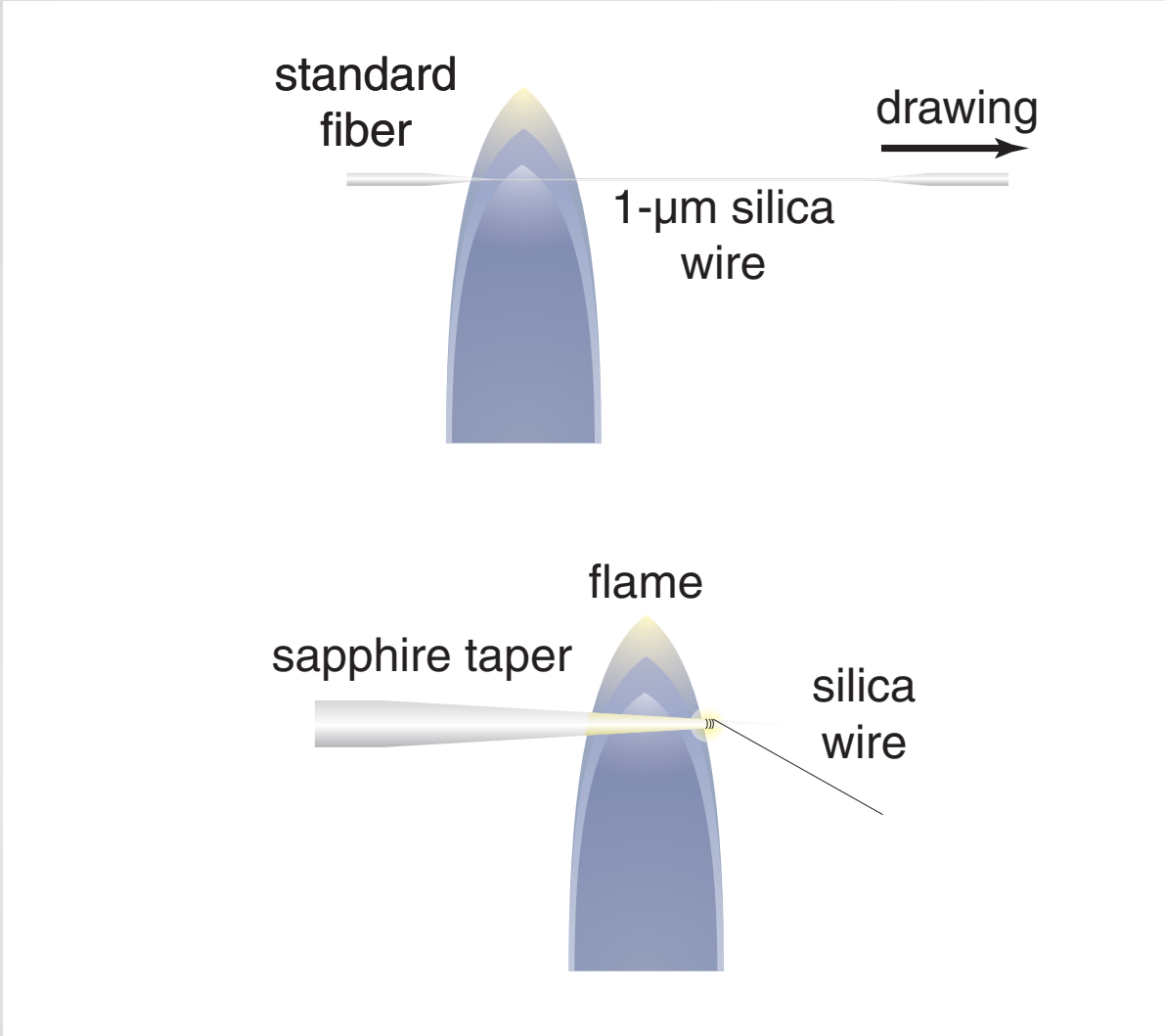

Nanowire fabrication

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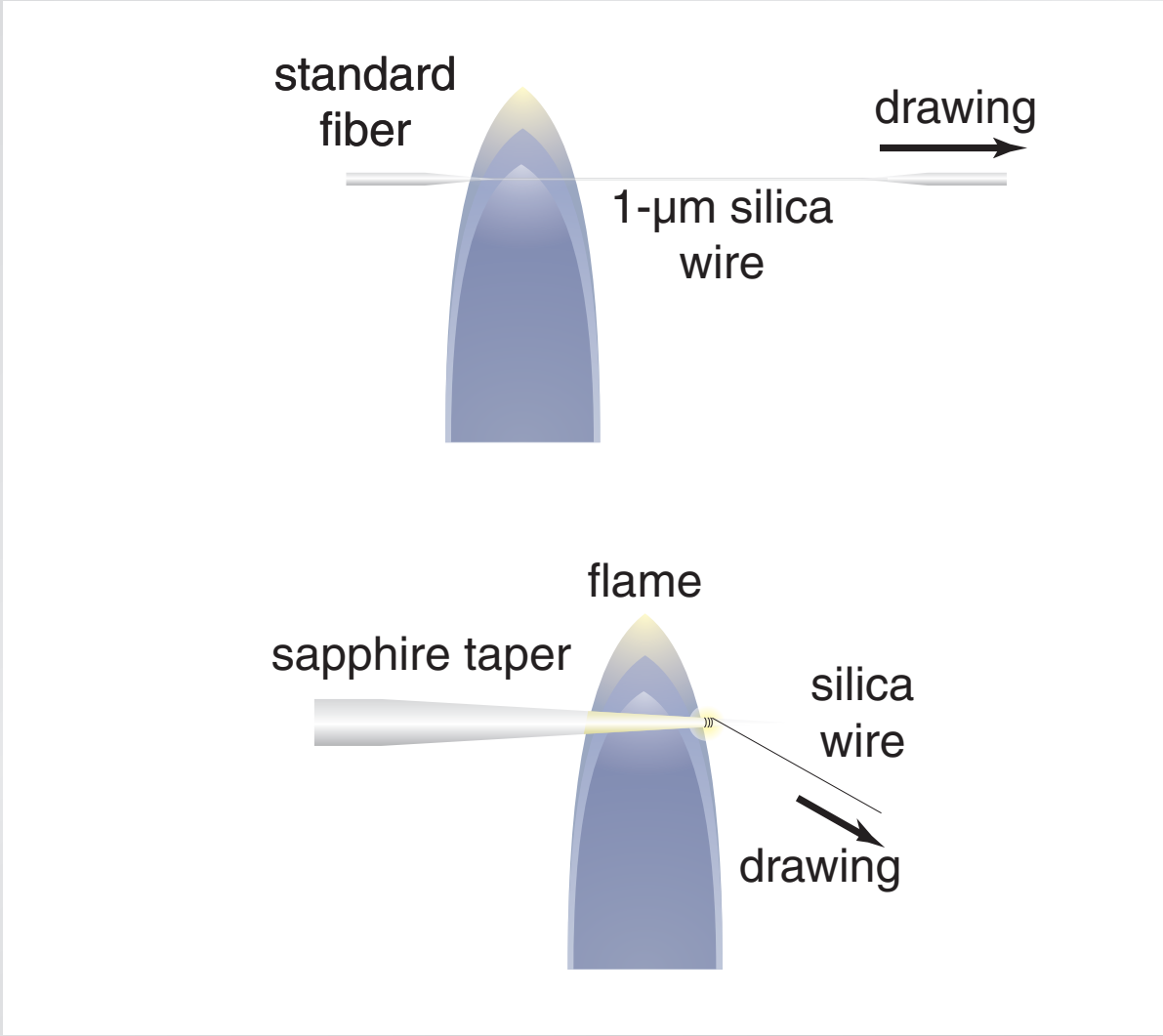

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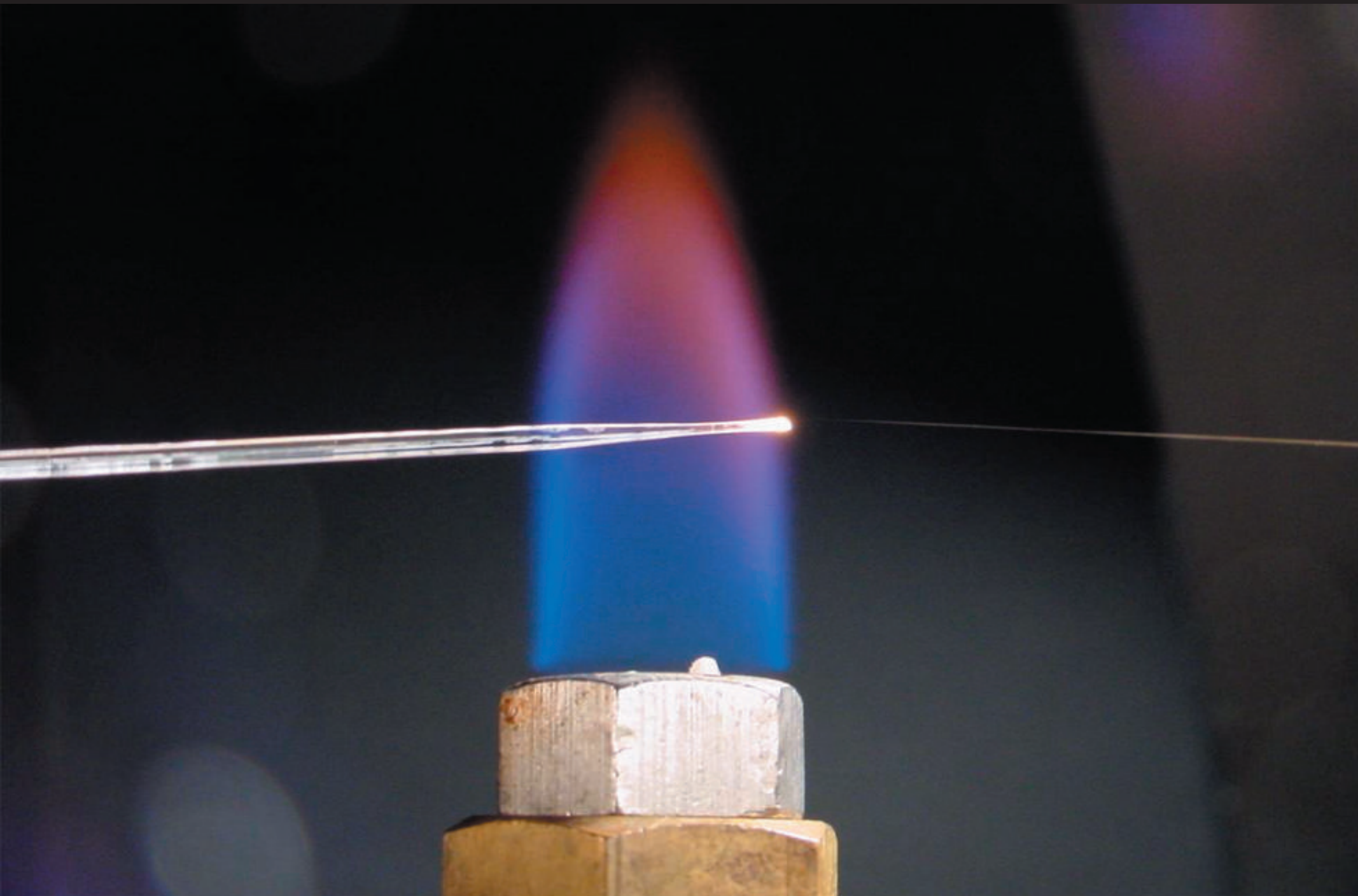
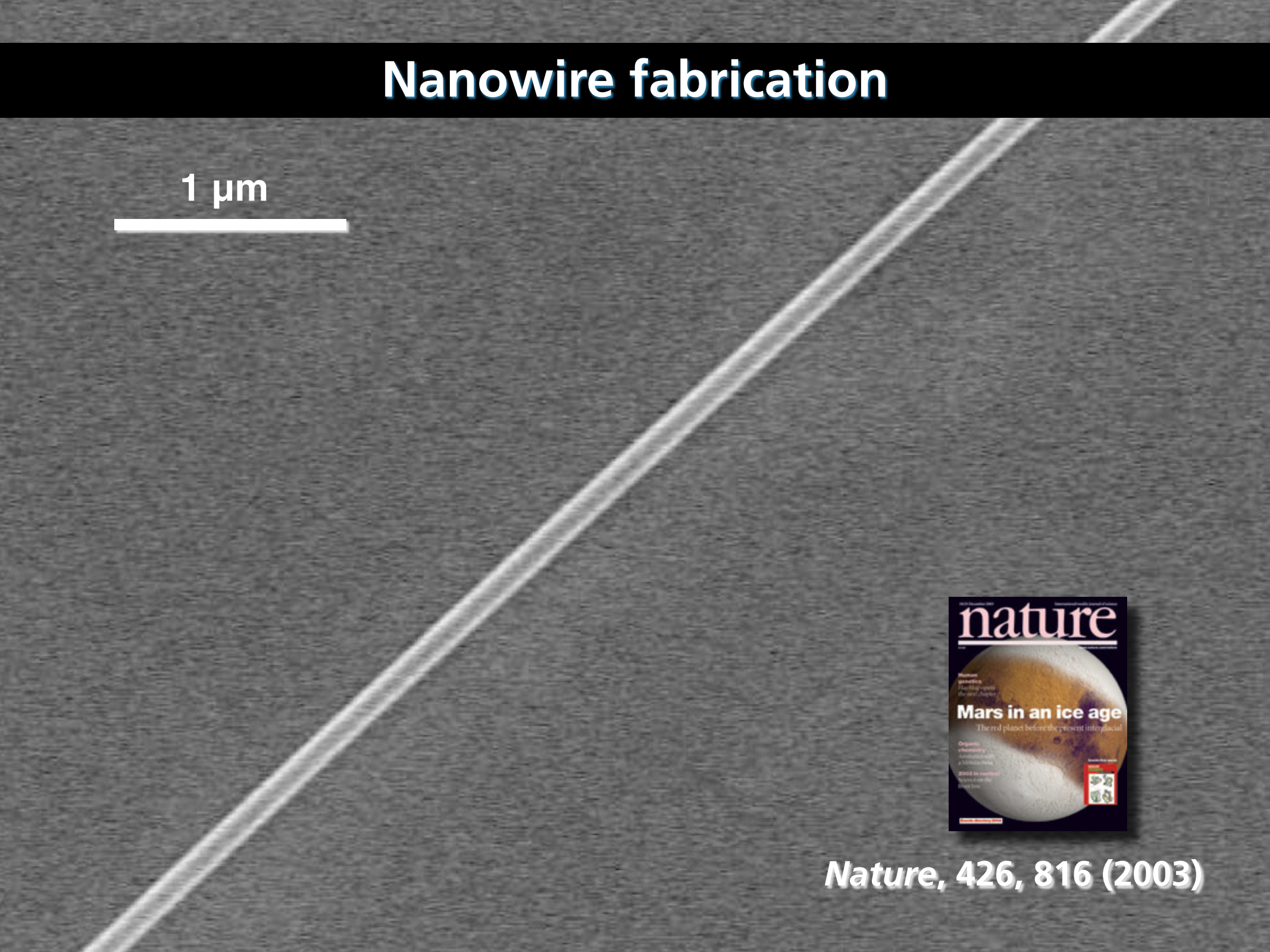
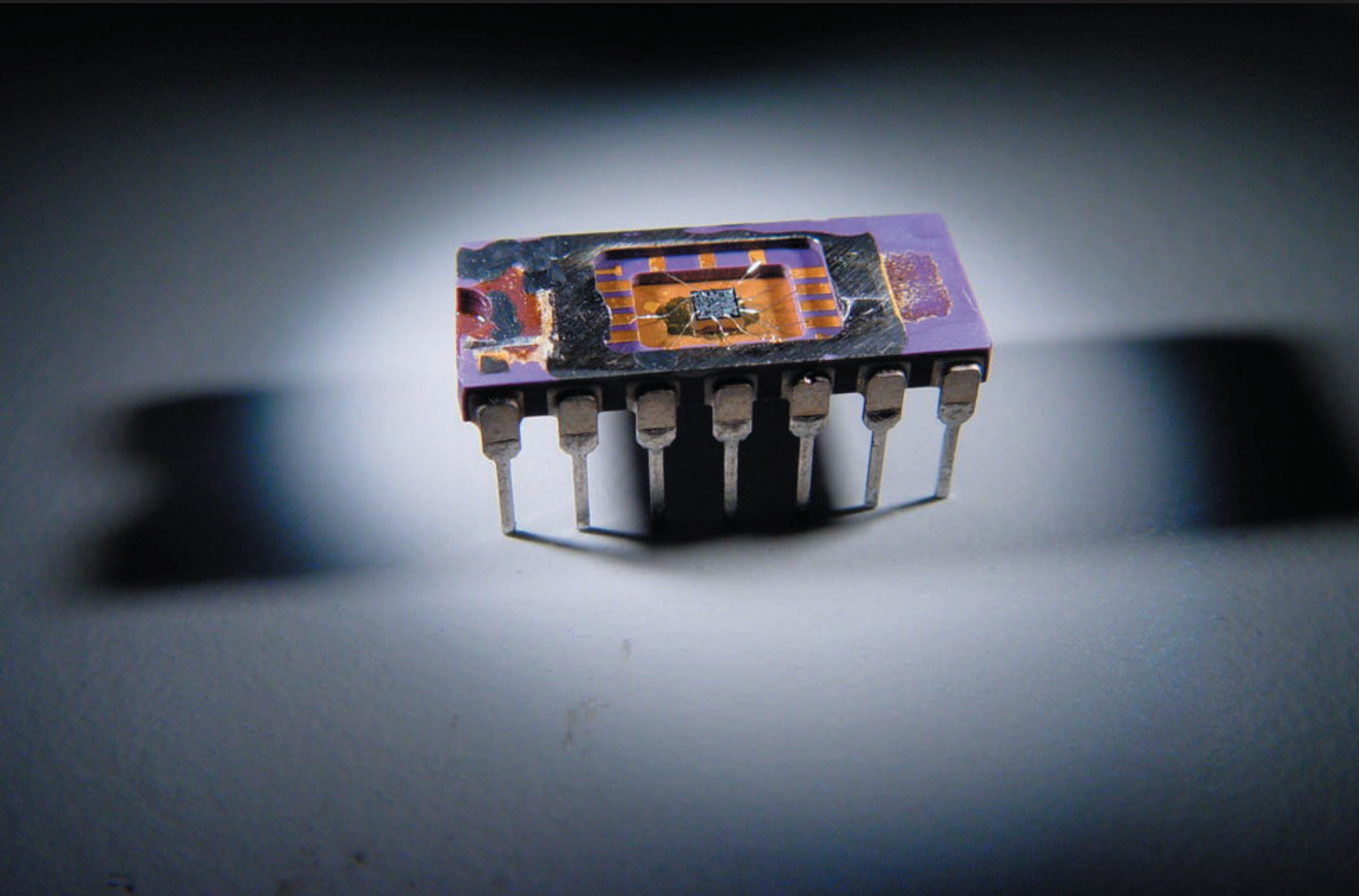


Nanowire fabrication

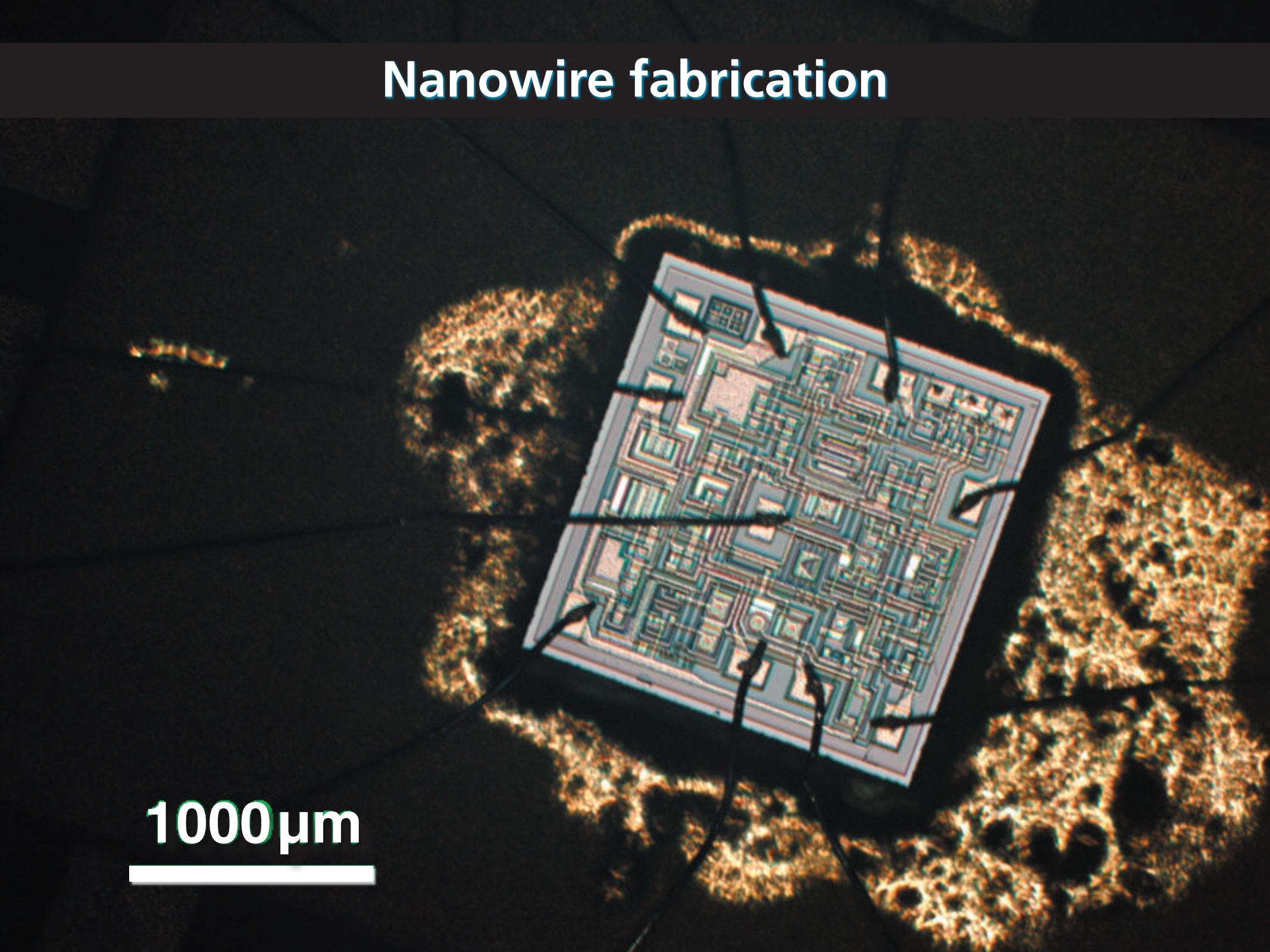


Nature, 426, 816 (2003)

Nanowire fabrication



Nanowire fabrication



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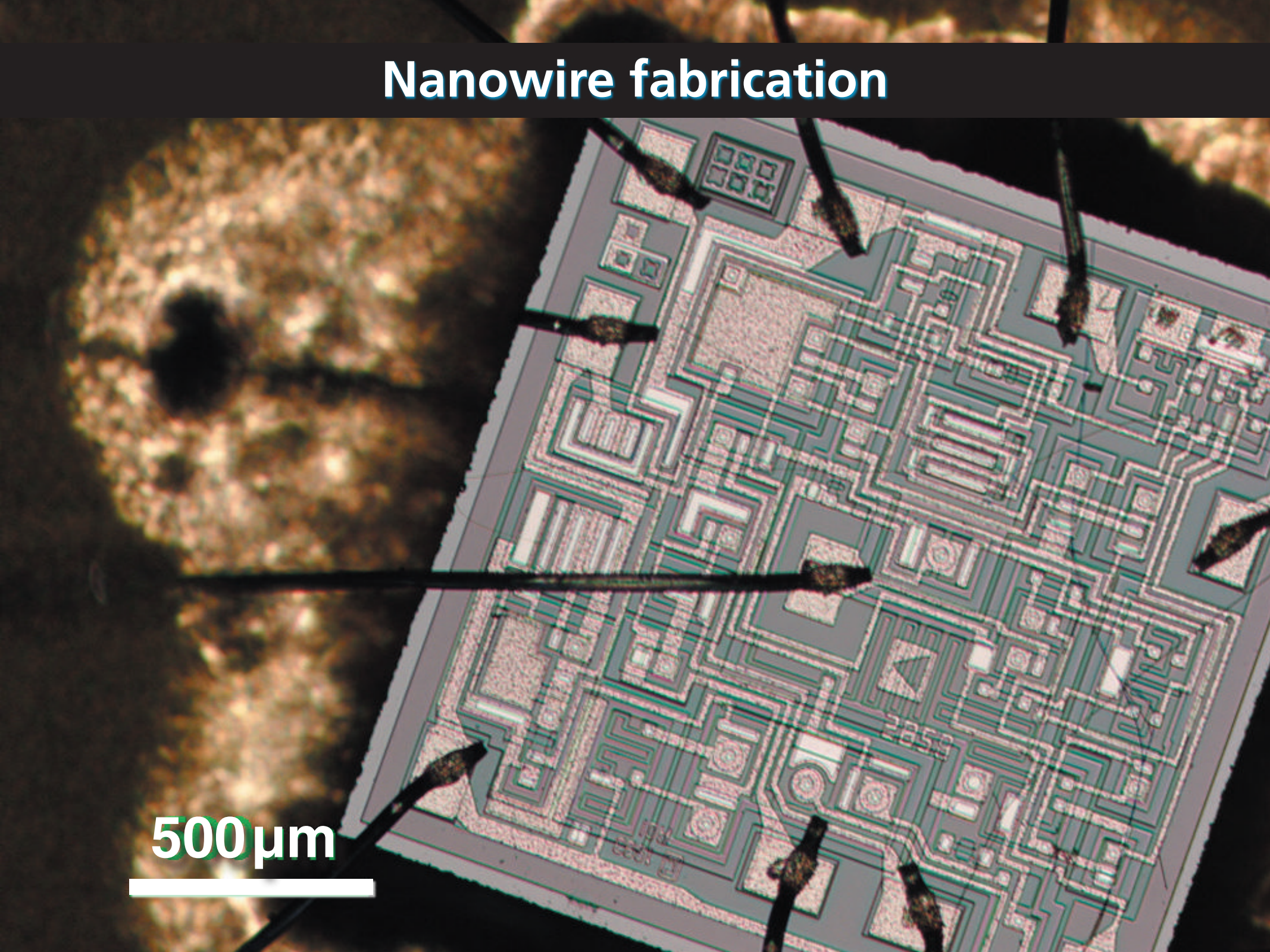

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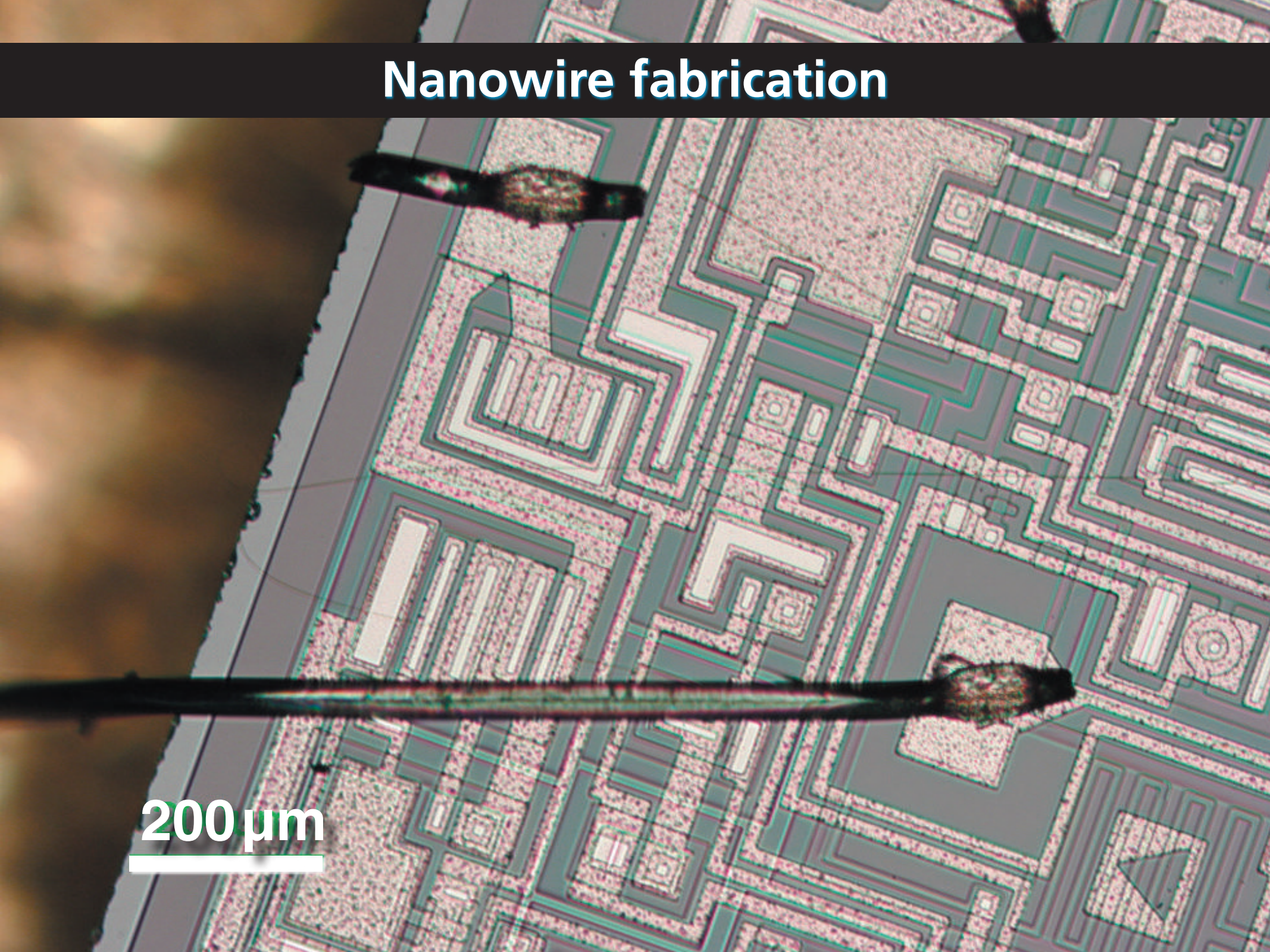

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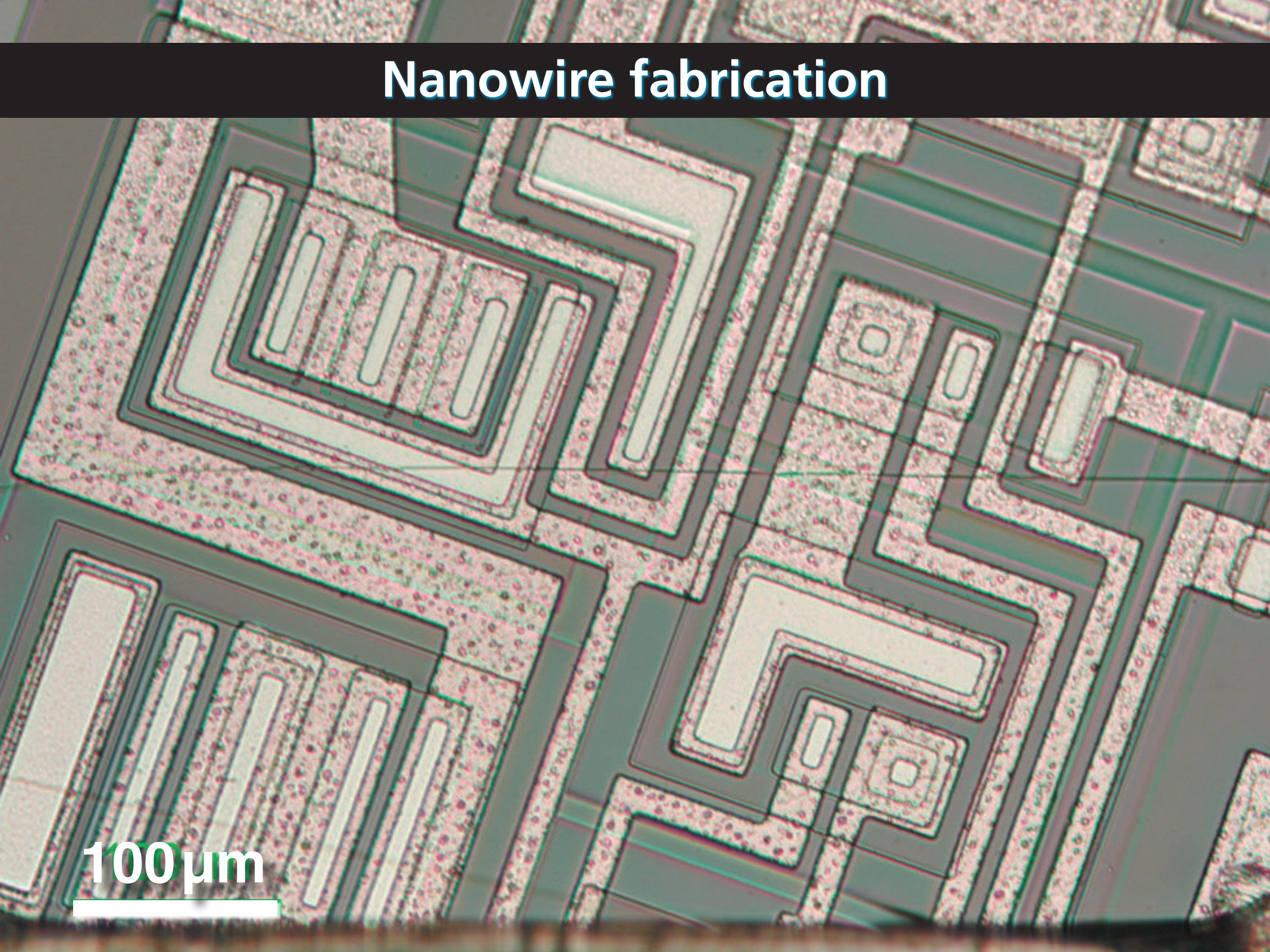
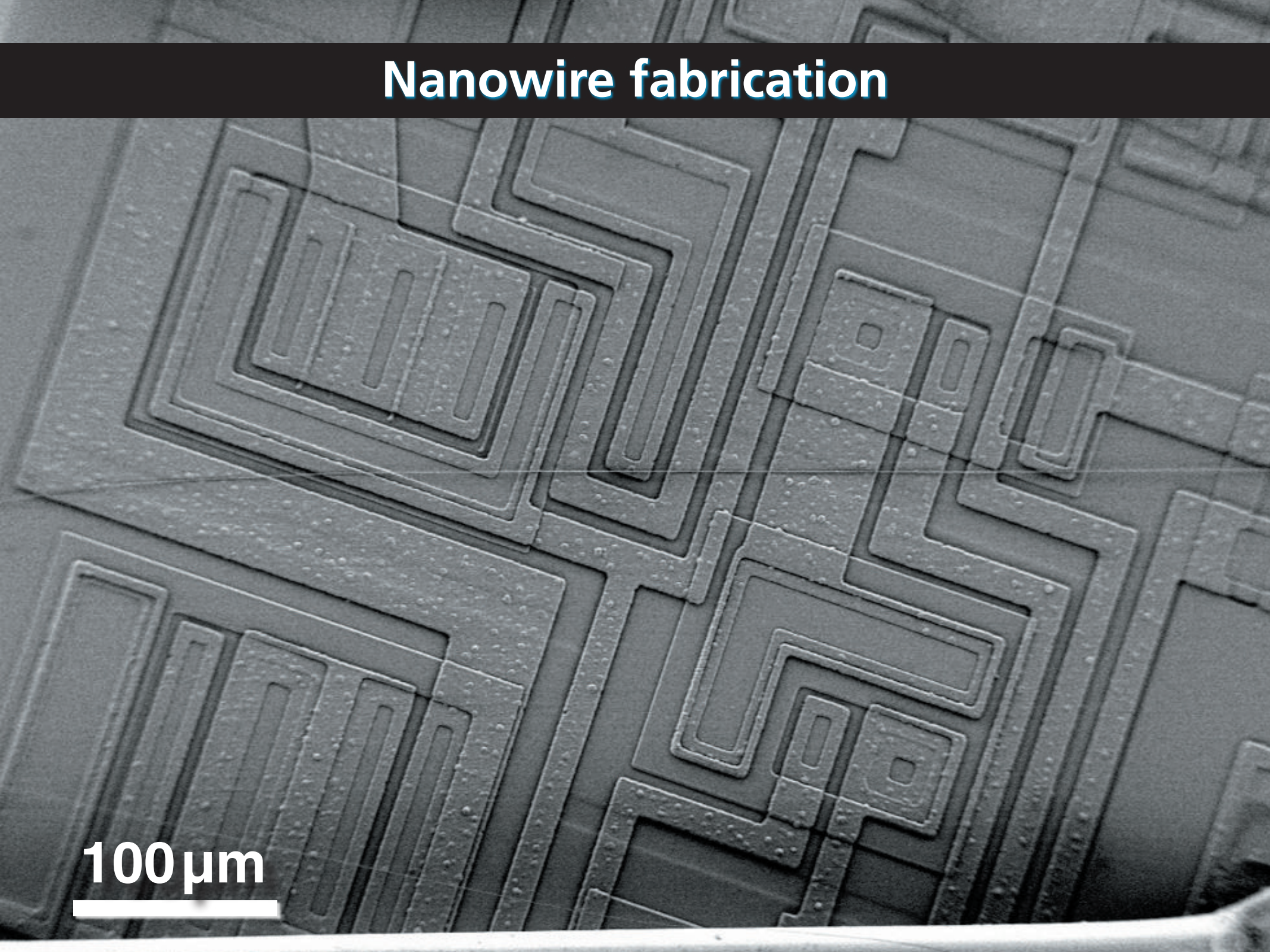


Nanowire fabrication



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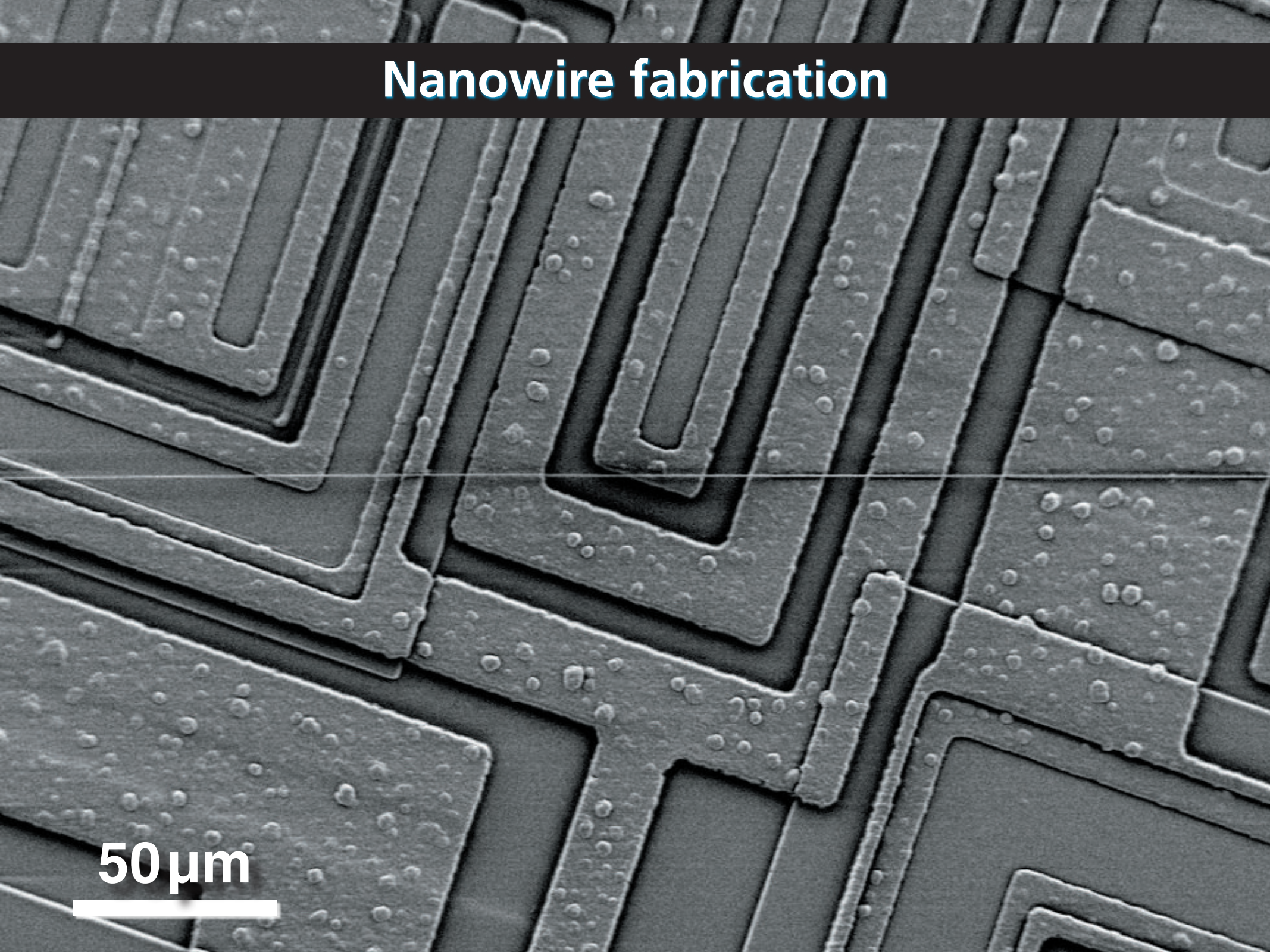

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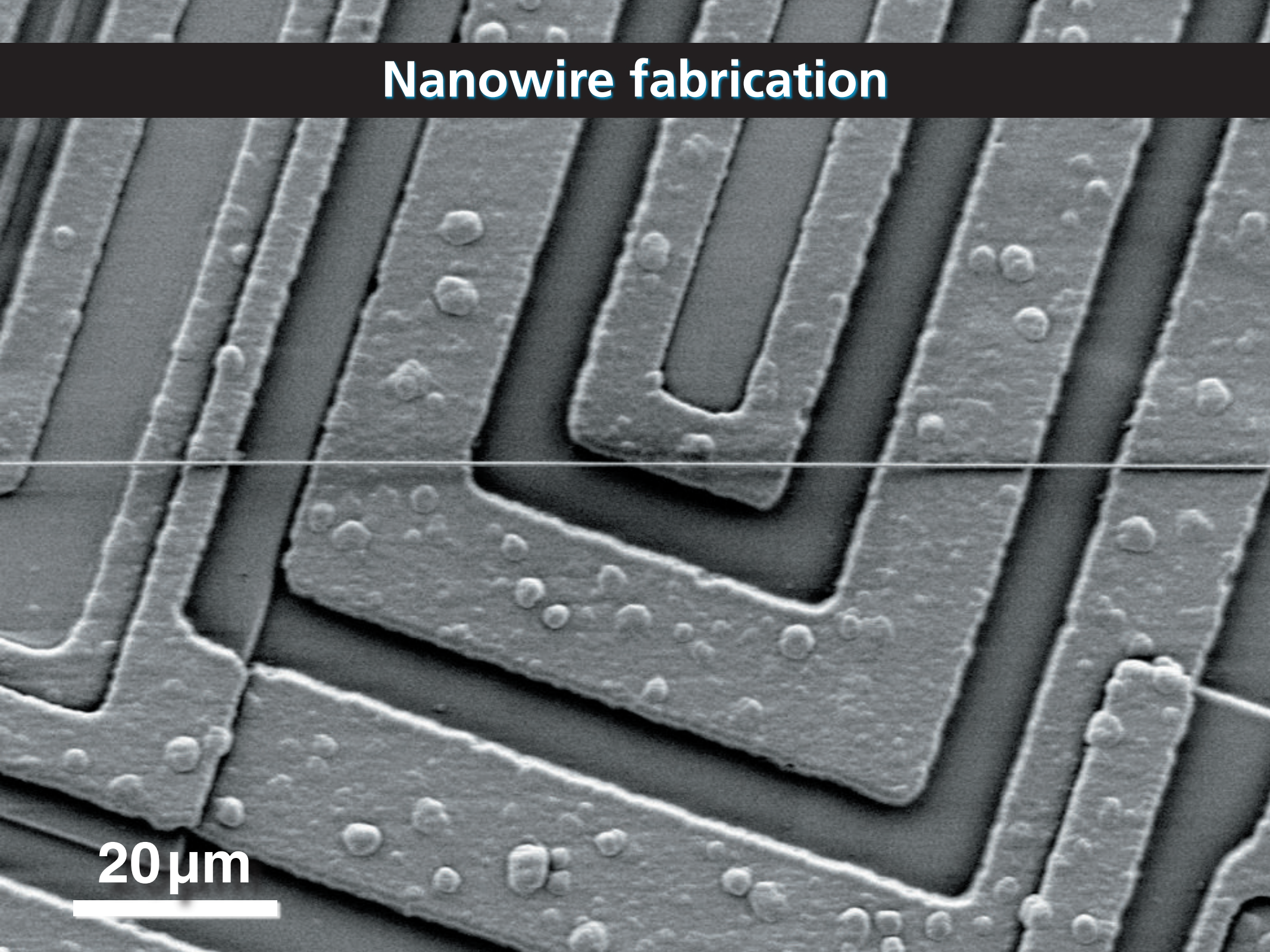

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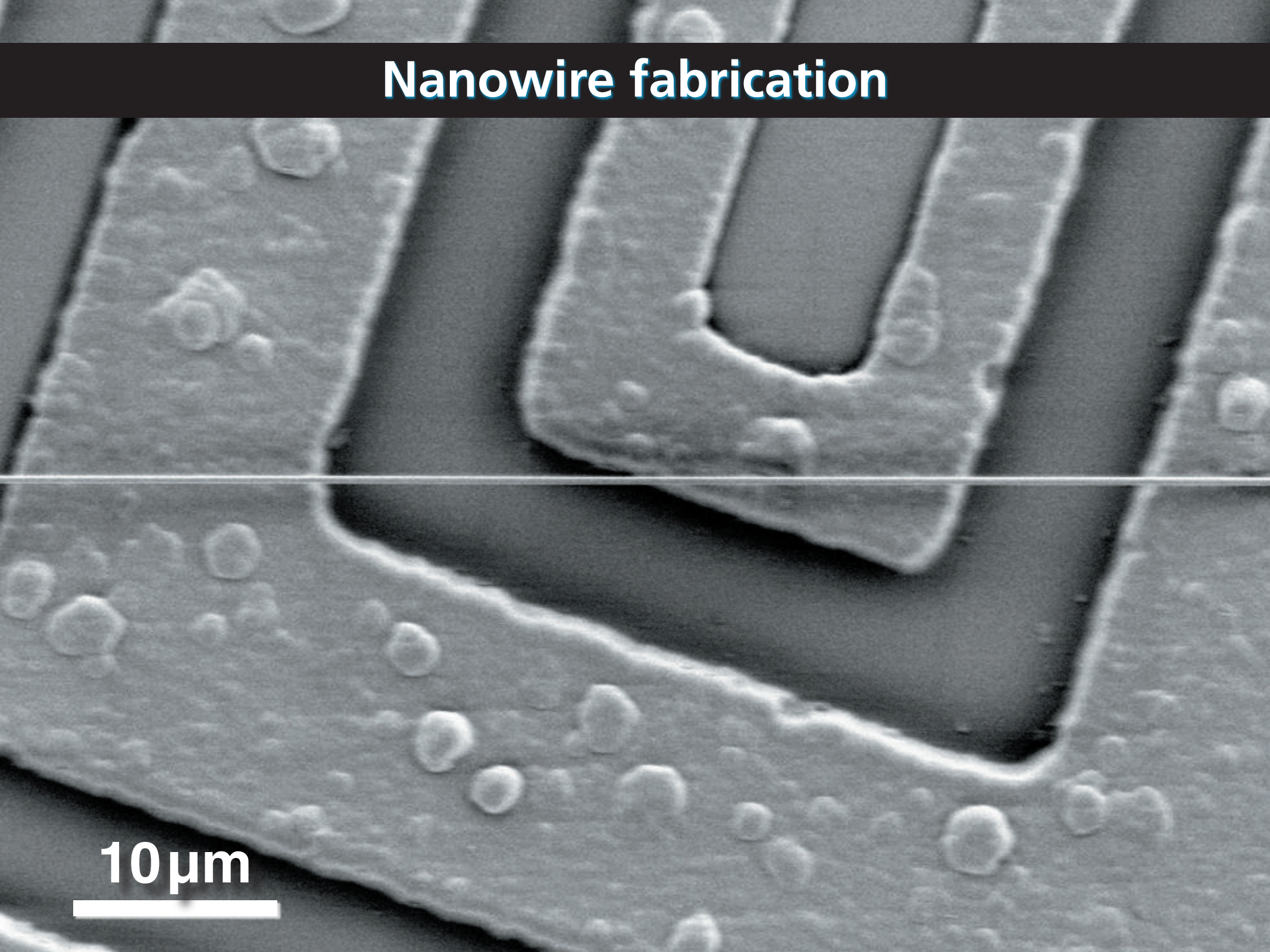

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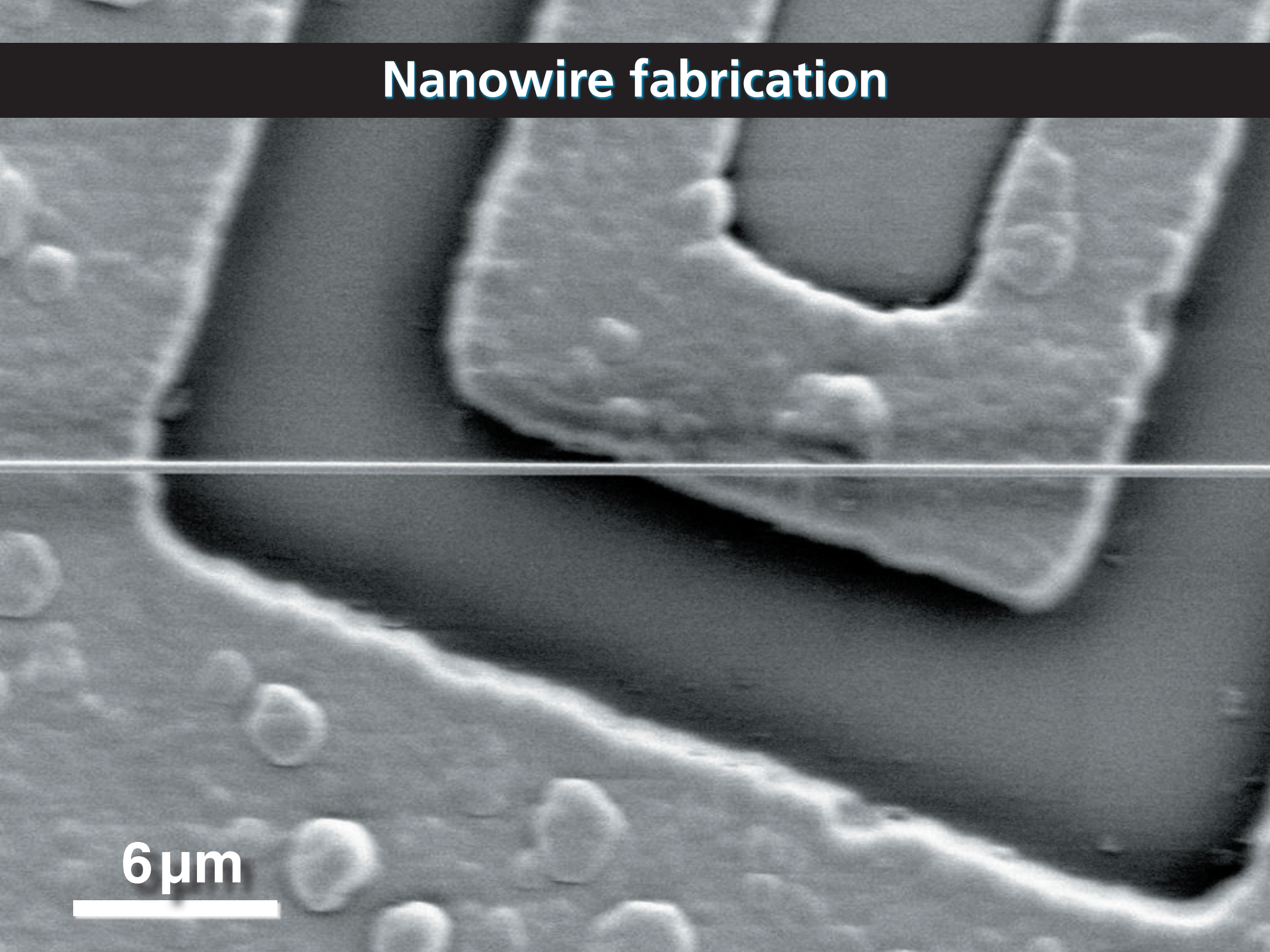

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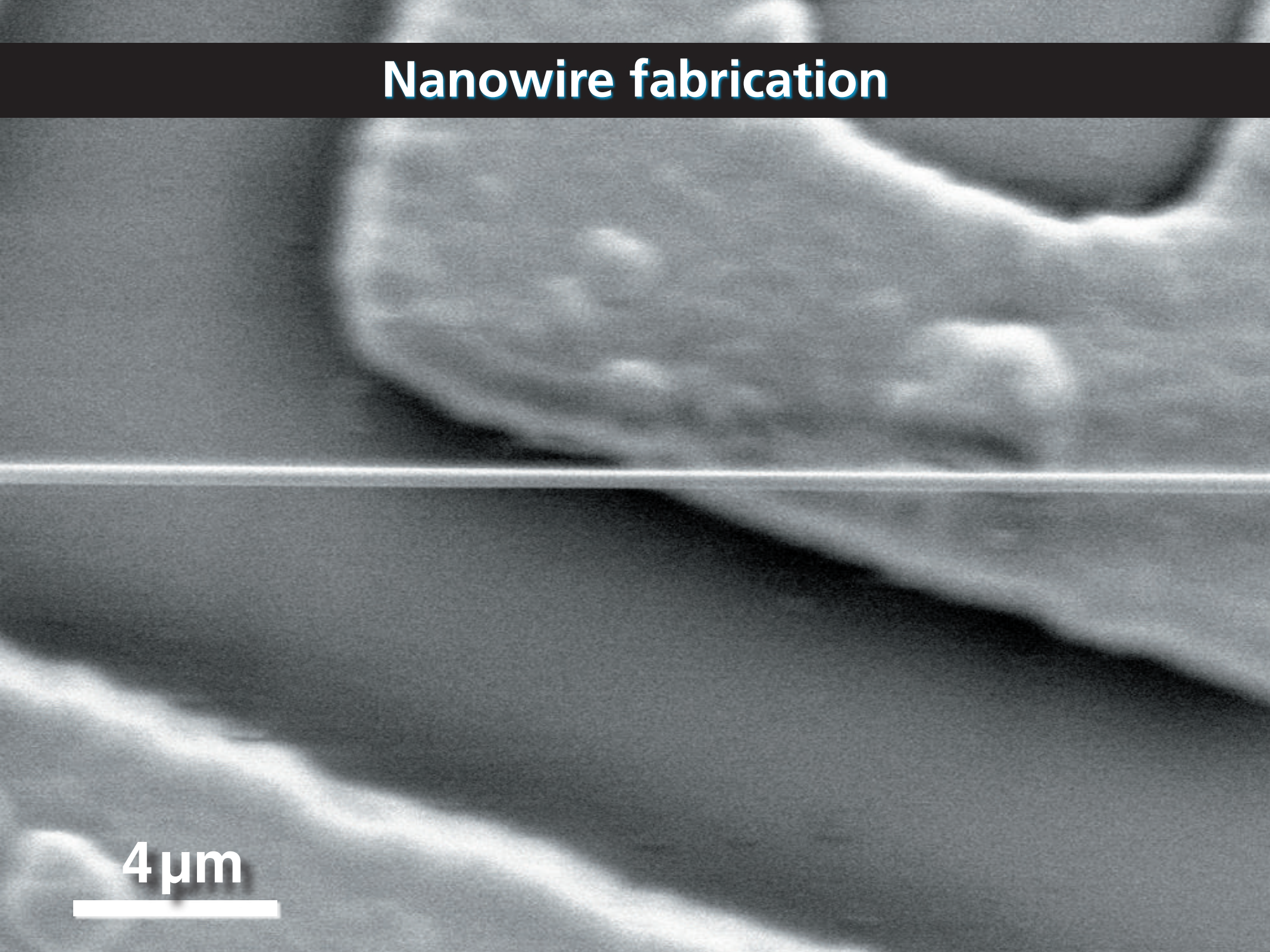

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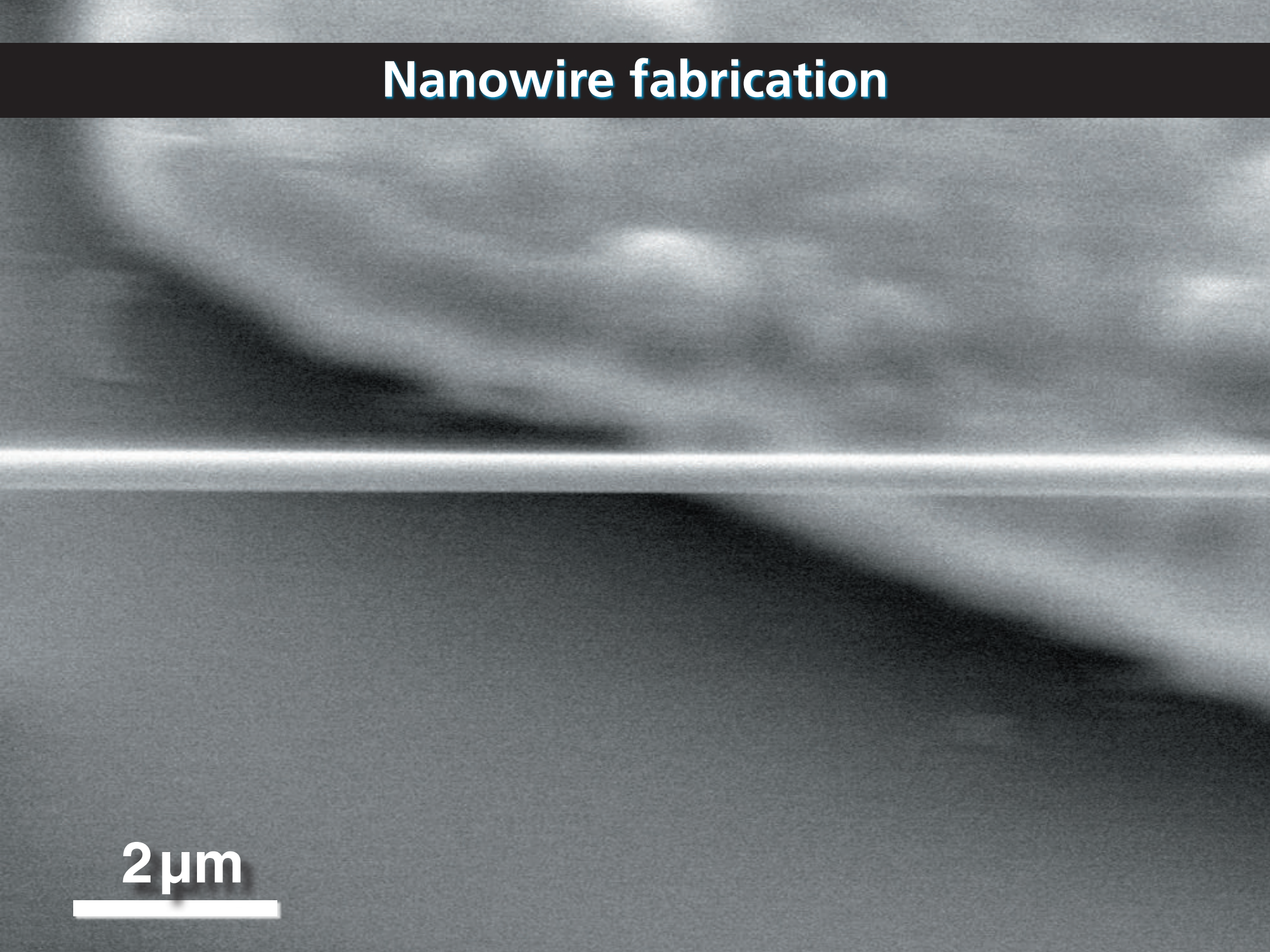

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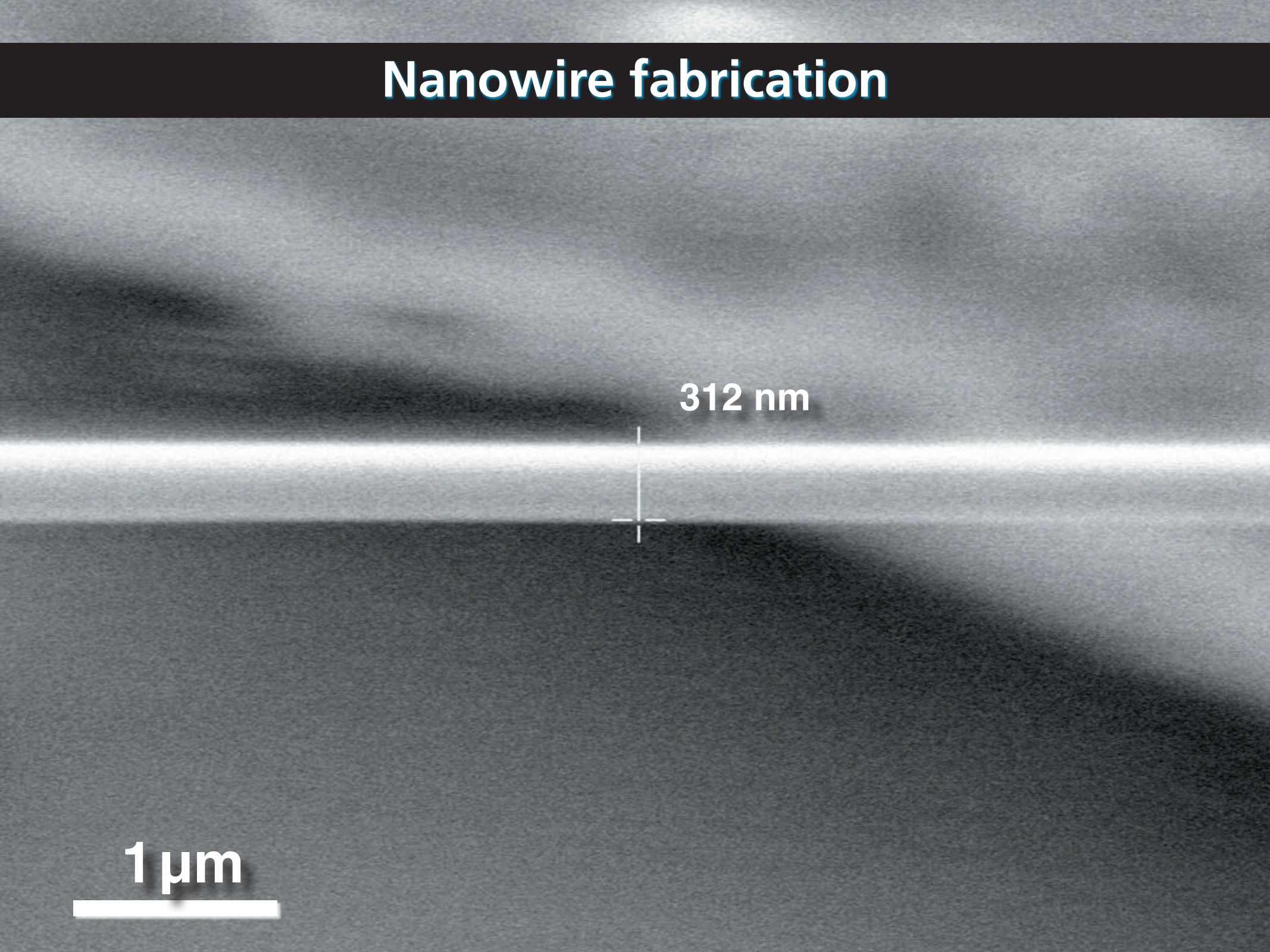
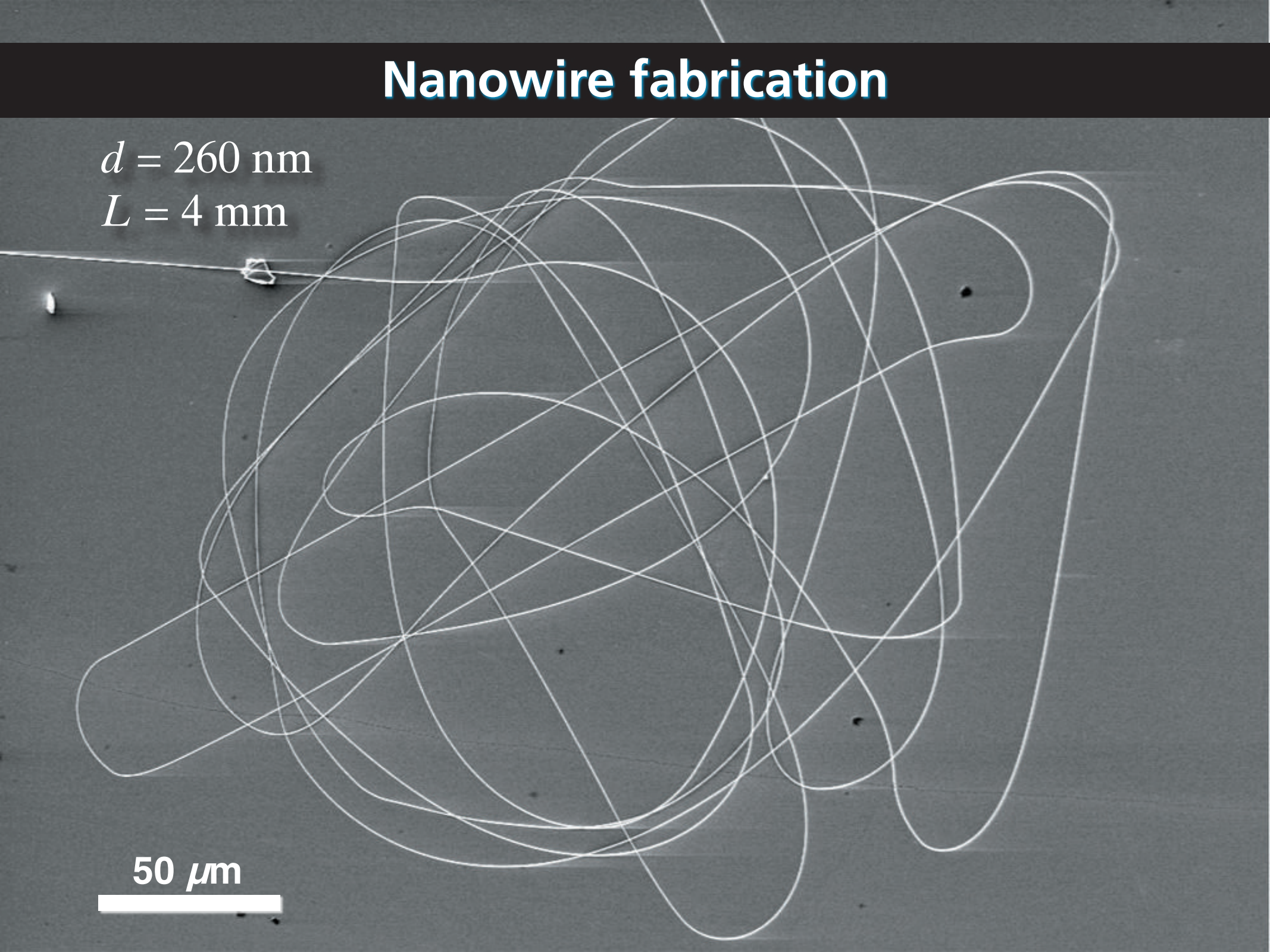


Waveguiding

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 x 10^{-6}

Nanowire fabrication



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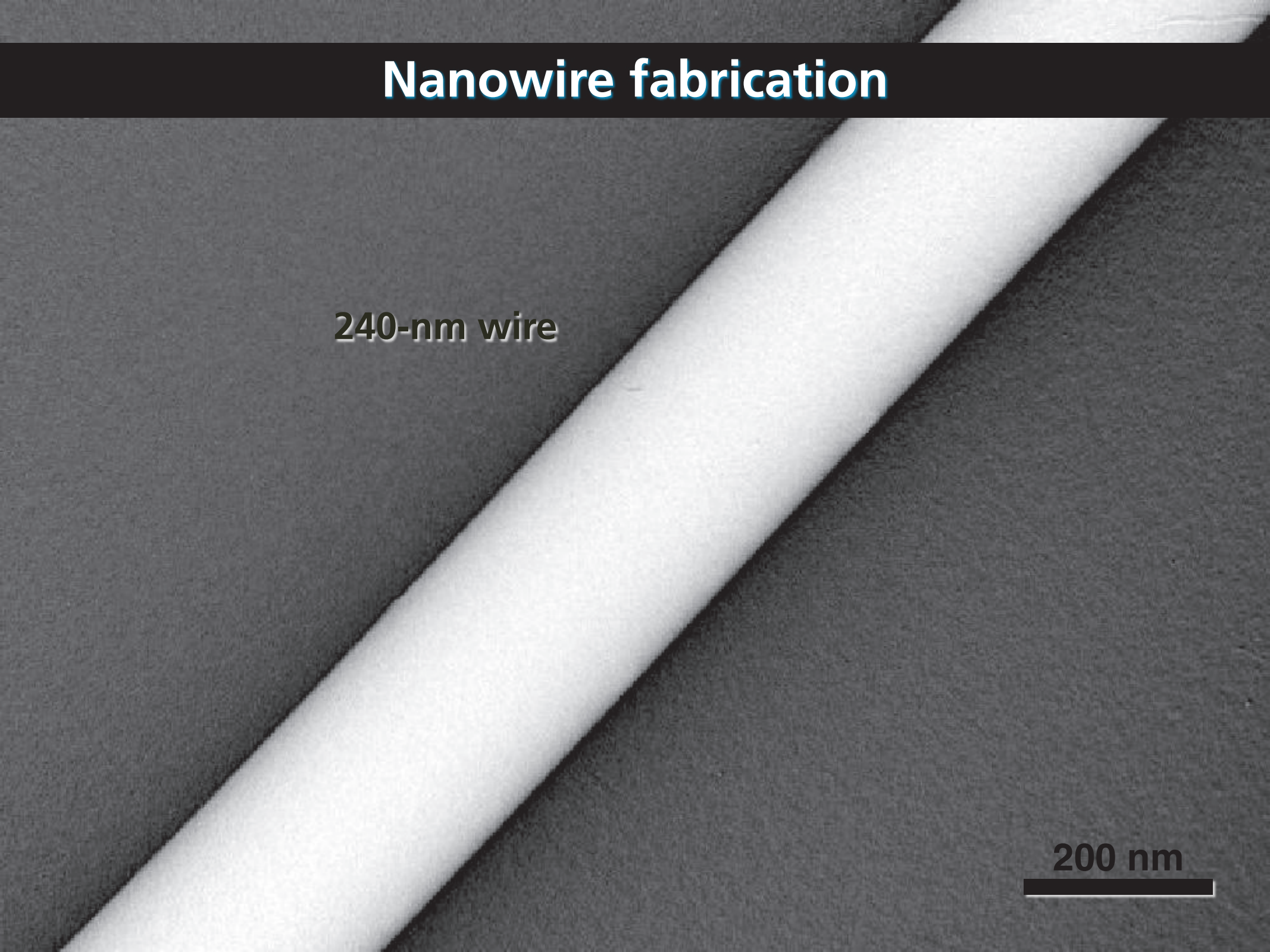
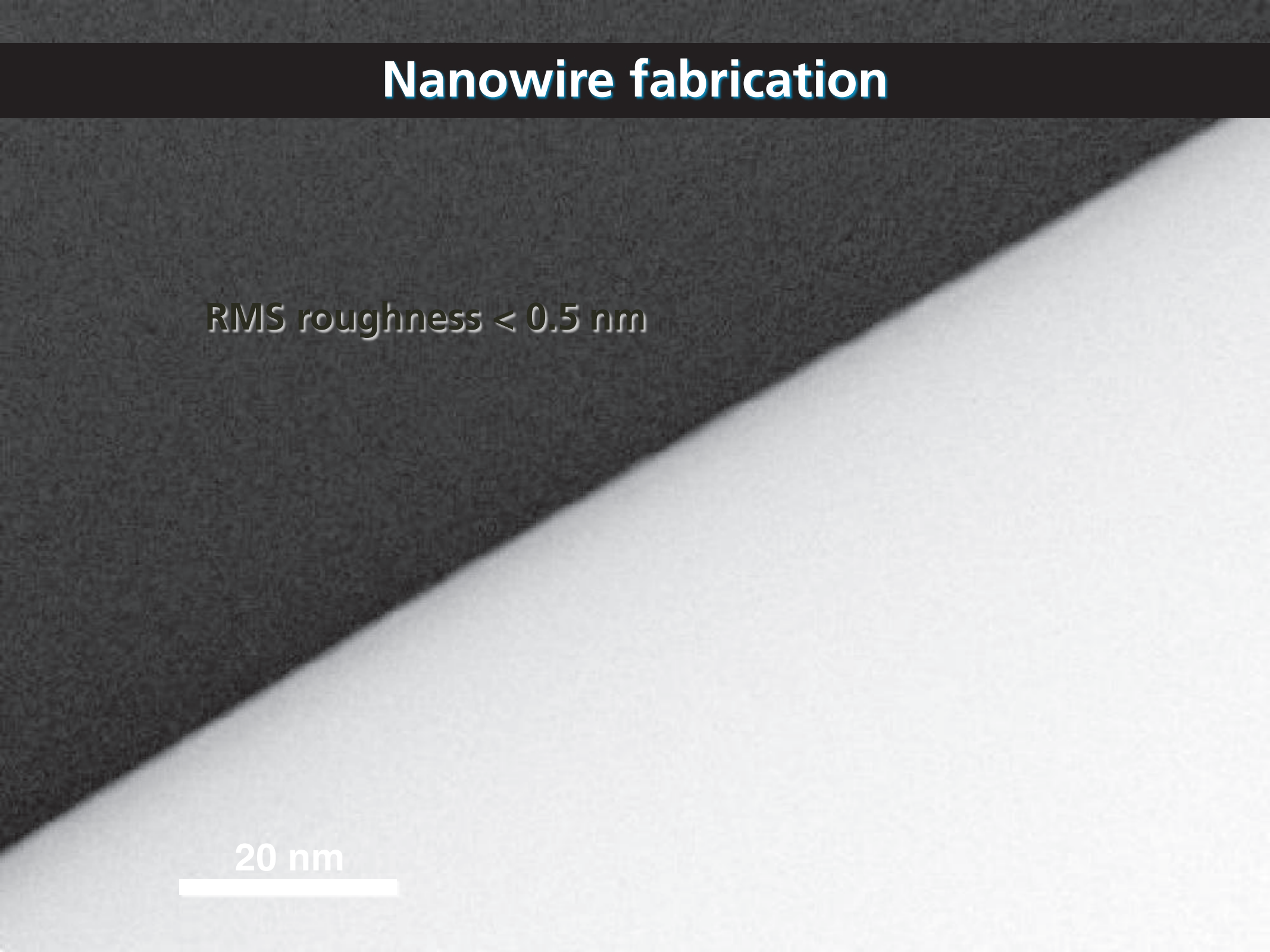


Nanowire fabrication



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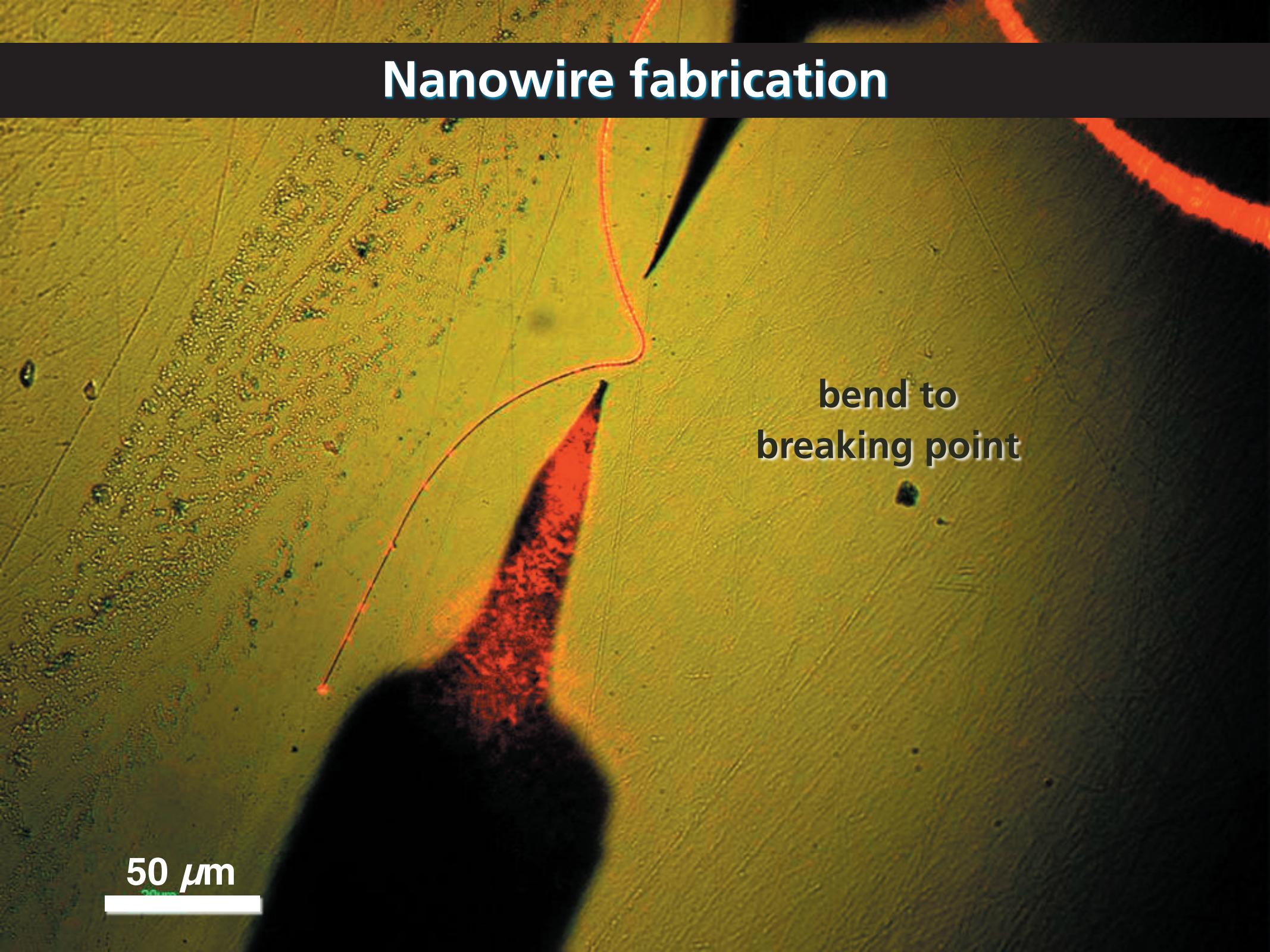
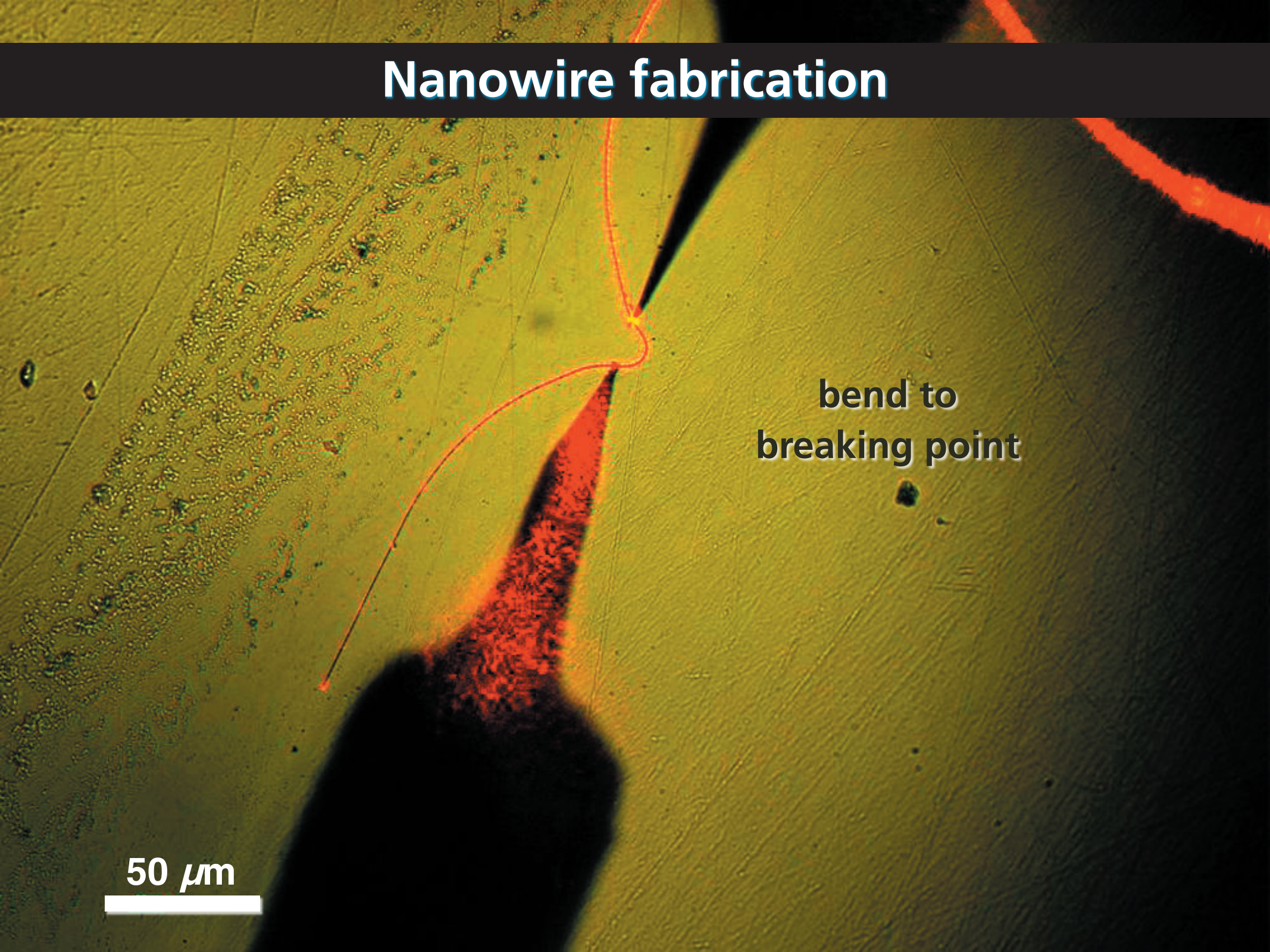
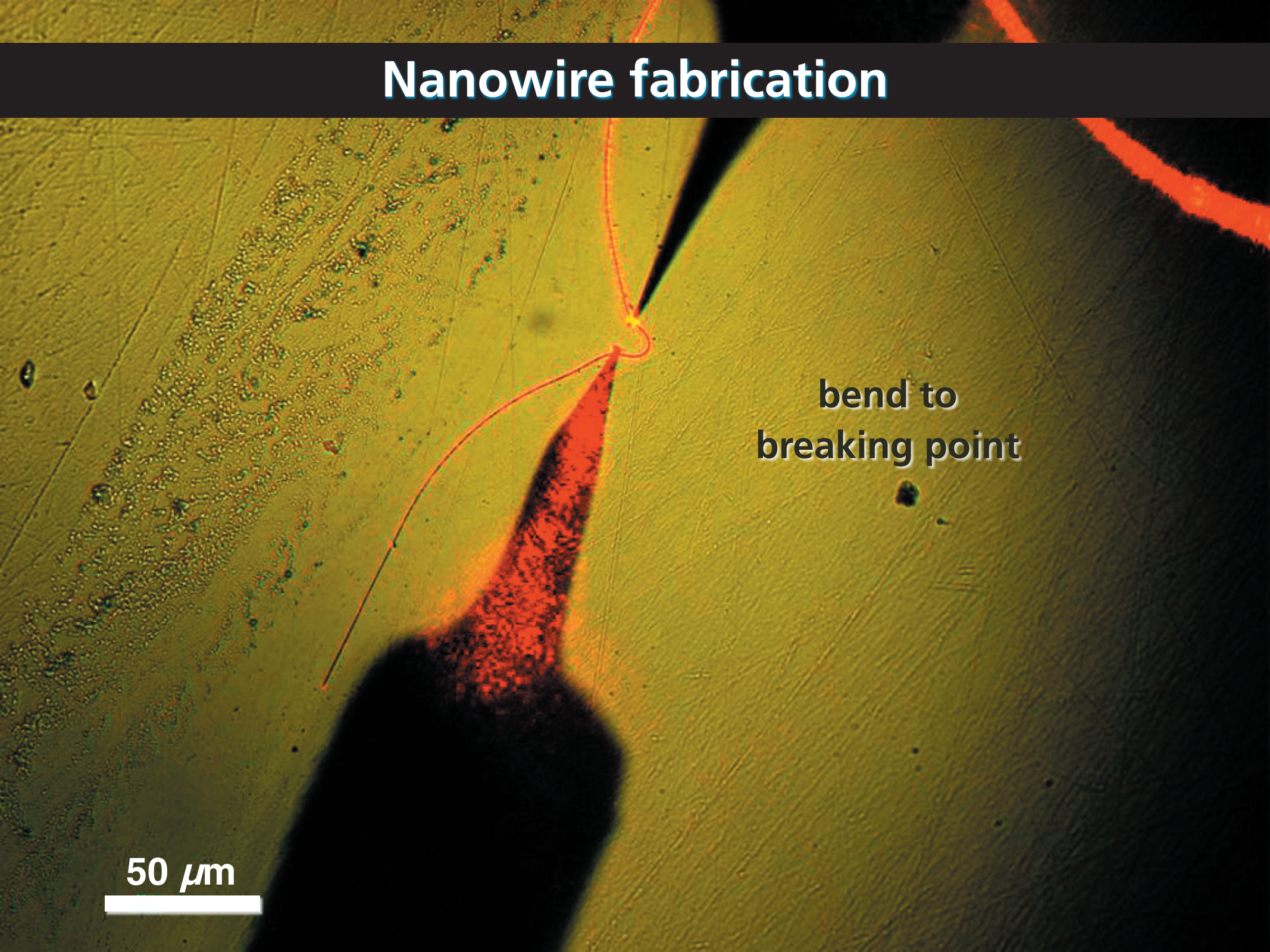


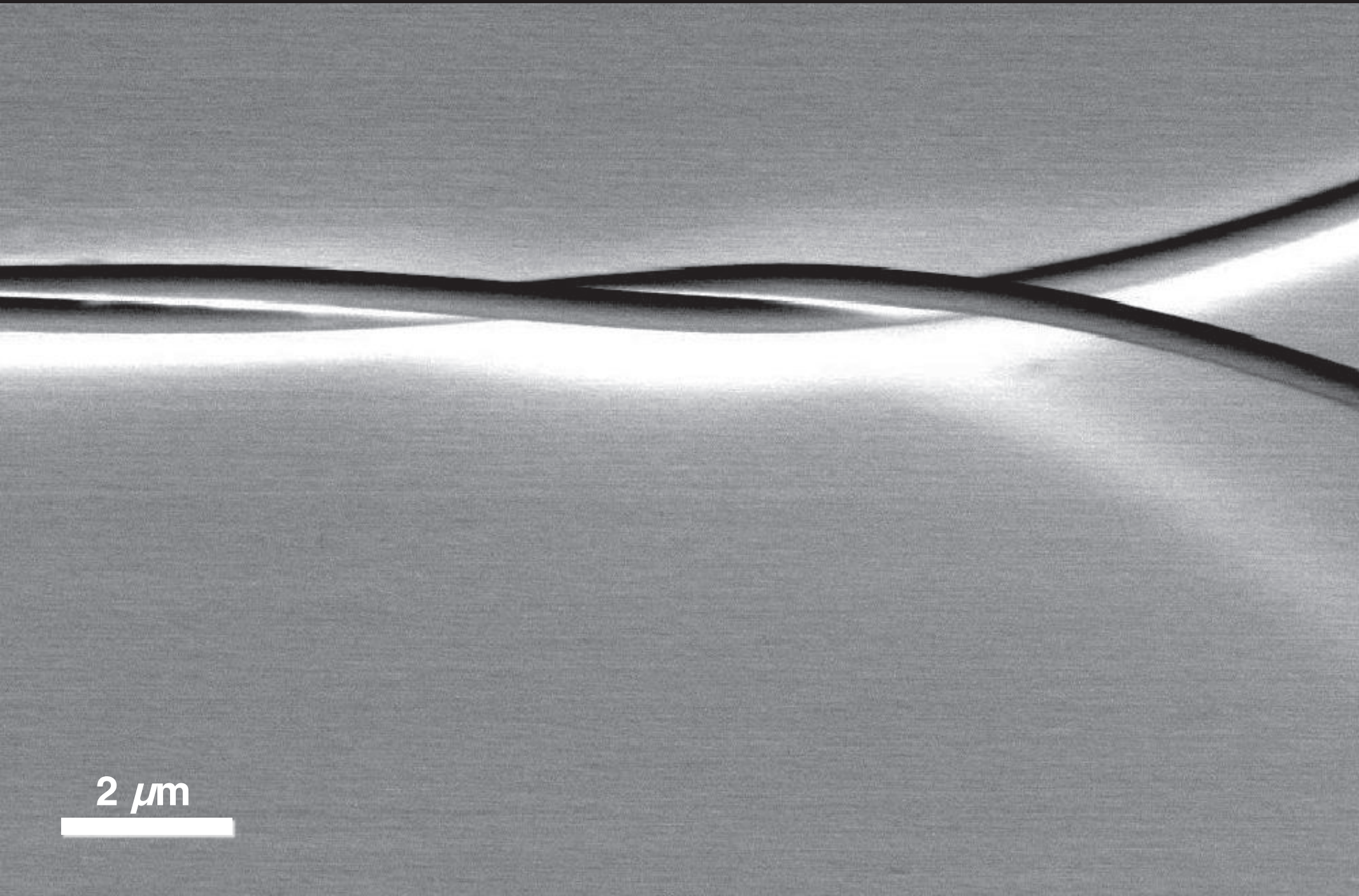
Nanowire fabrication



Nanowire fabrication



Nanowire fabrication



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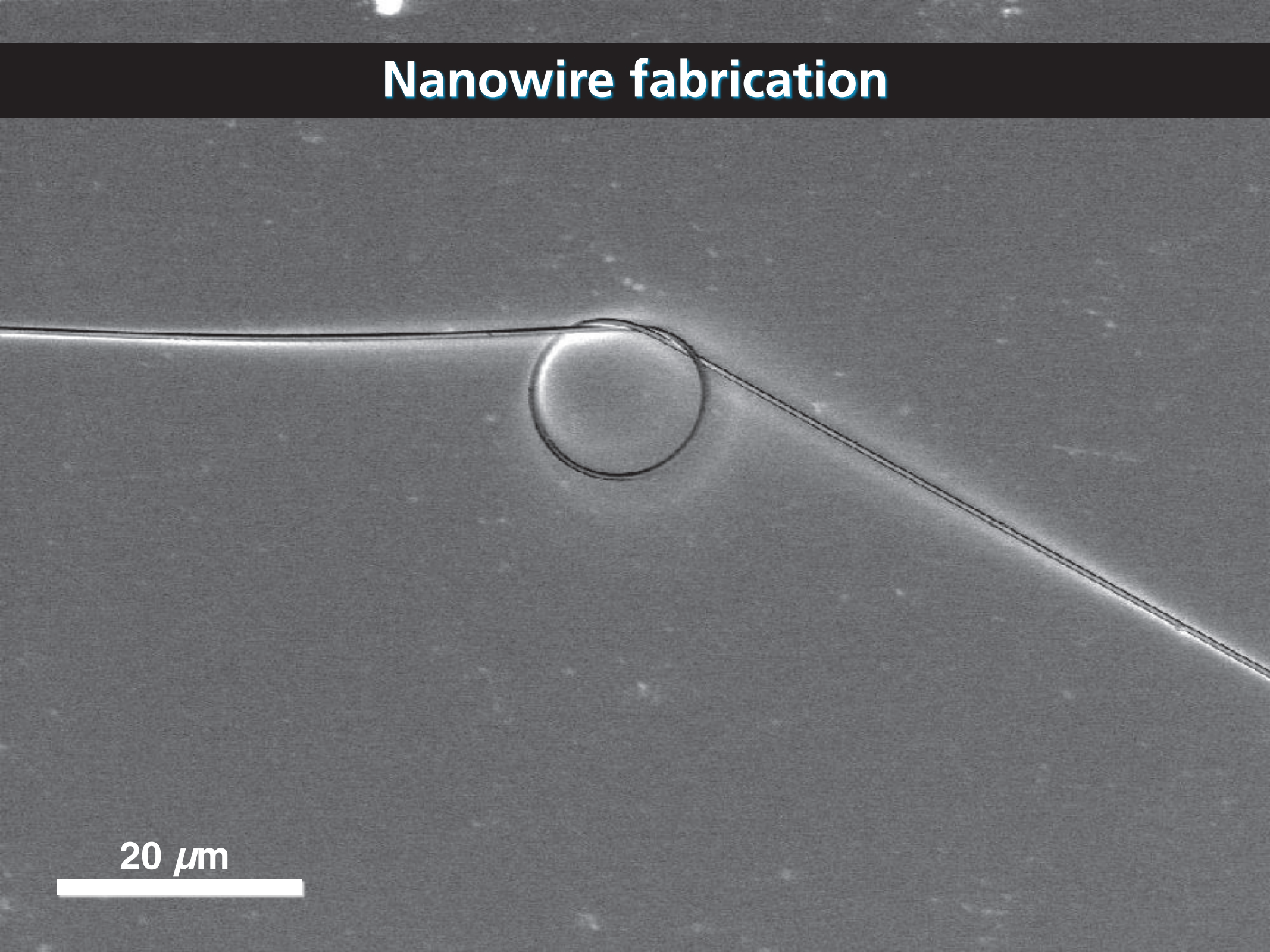
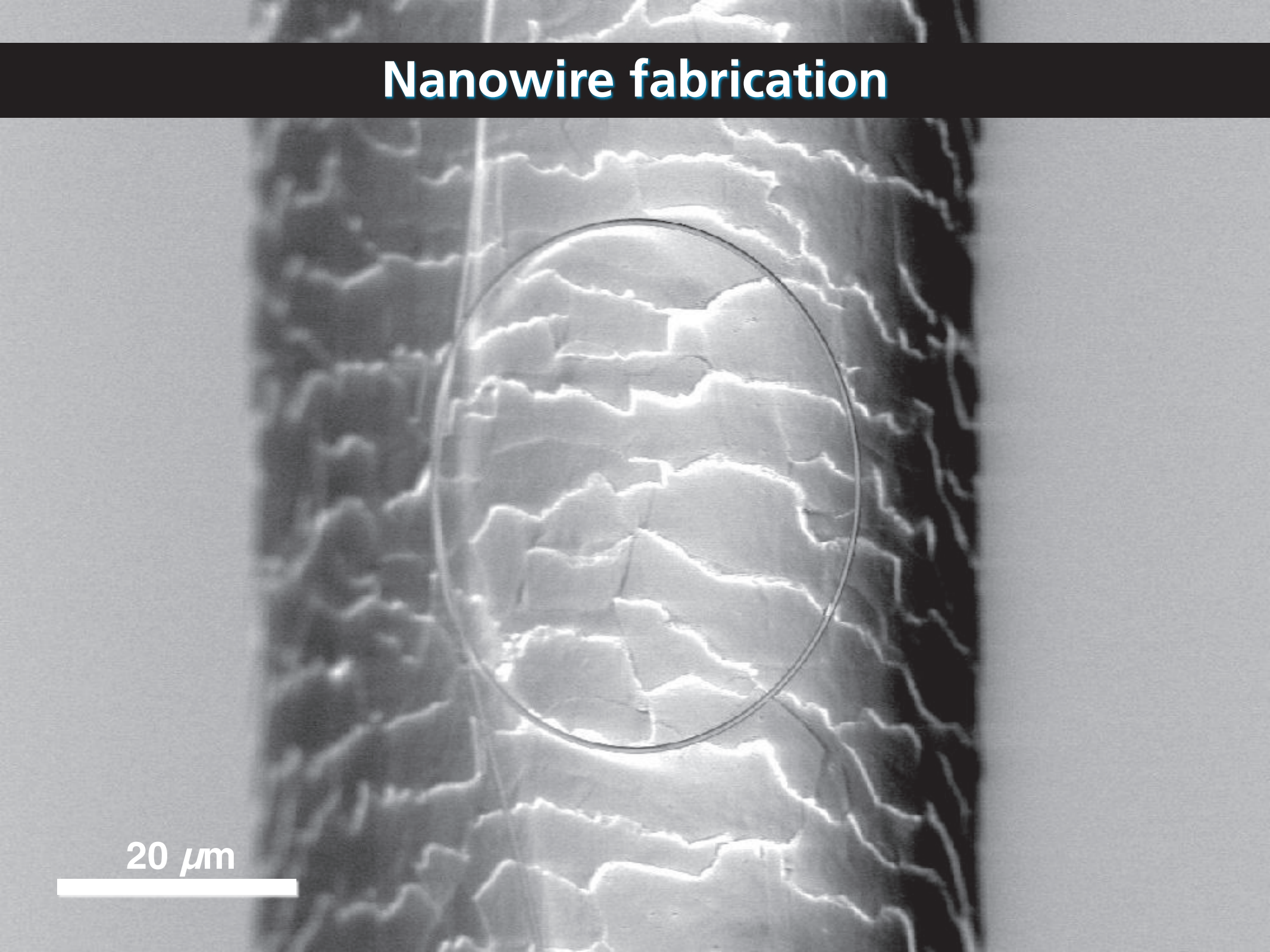


Nanowire fabrication

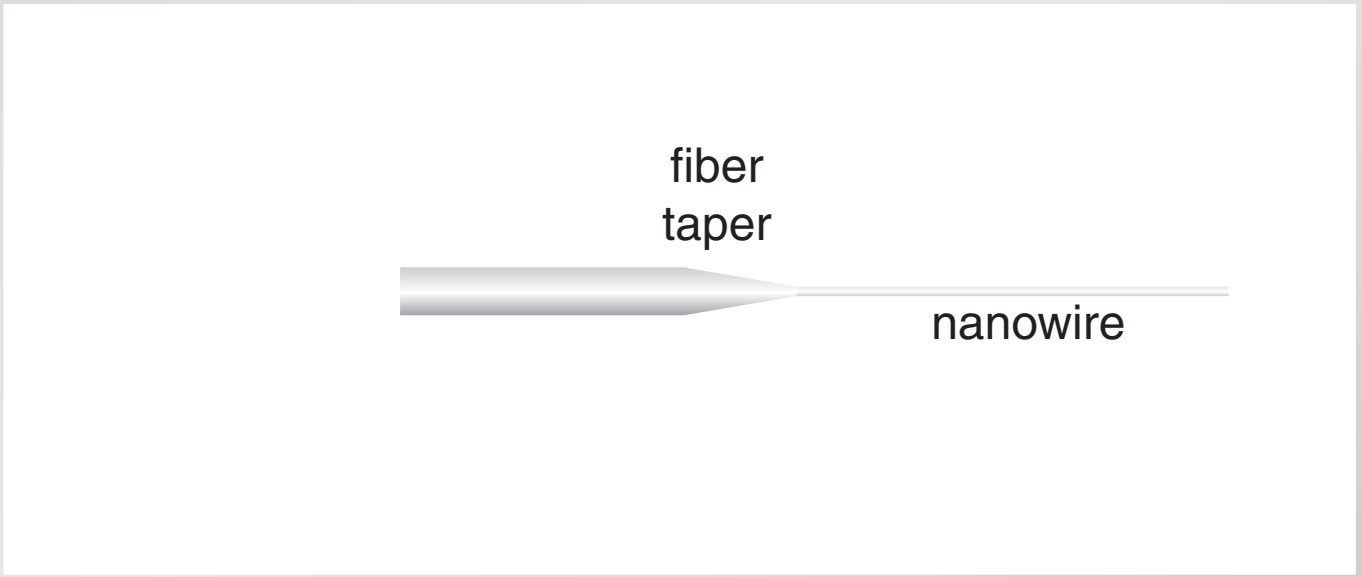


Outline

- waveguiding
- nanowire fabrication
- optical properties

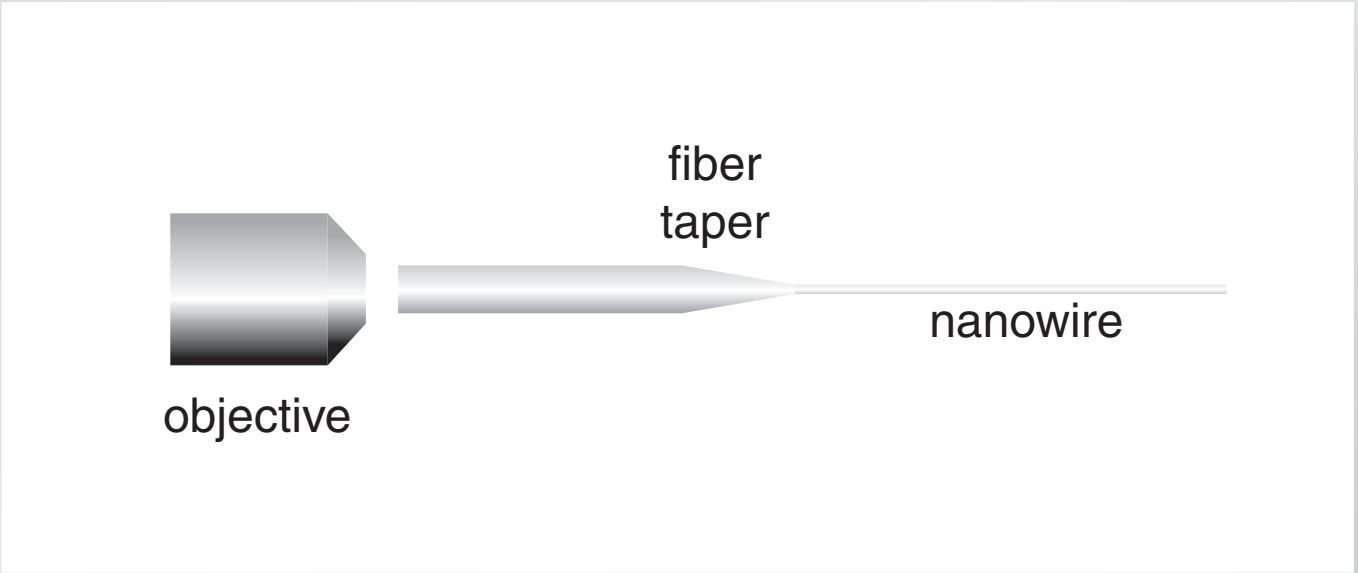
Optical properties

coupling light into nanowires



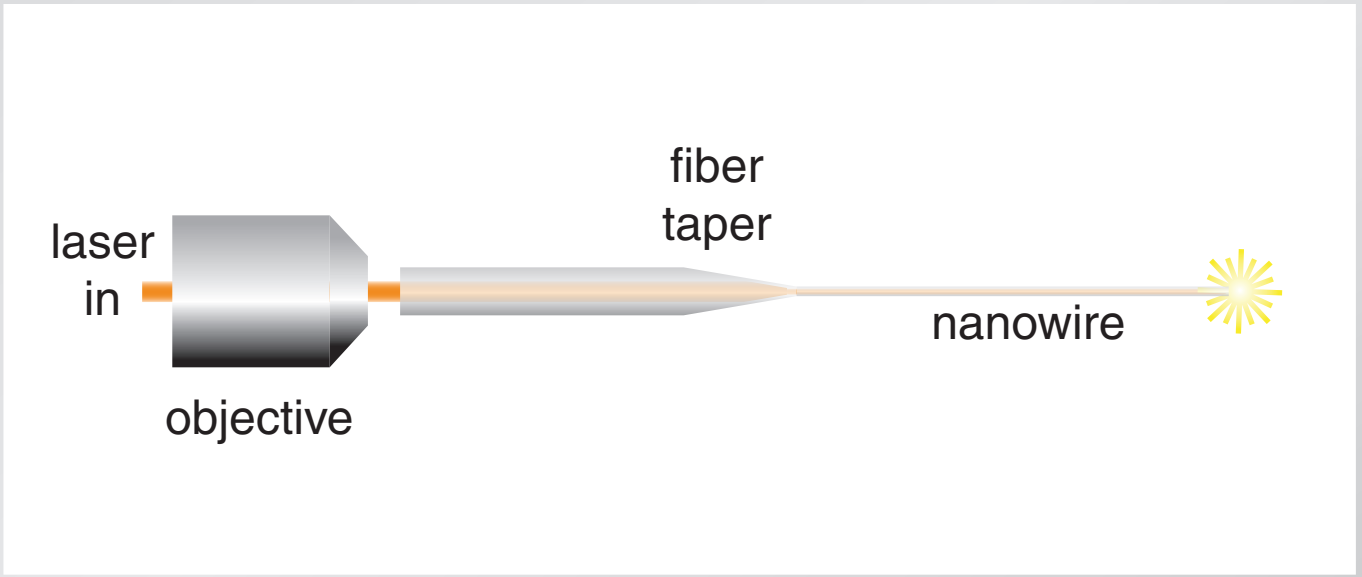
Optical properties

coupling light into nanowires

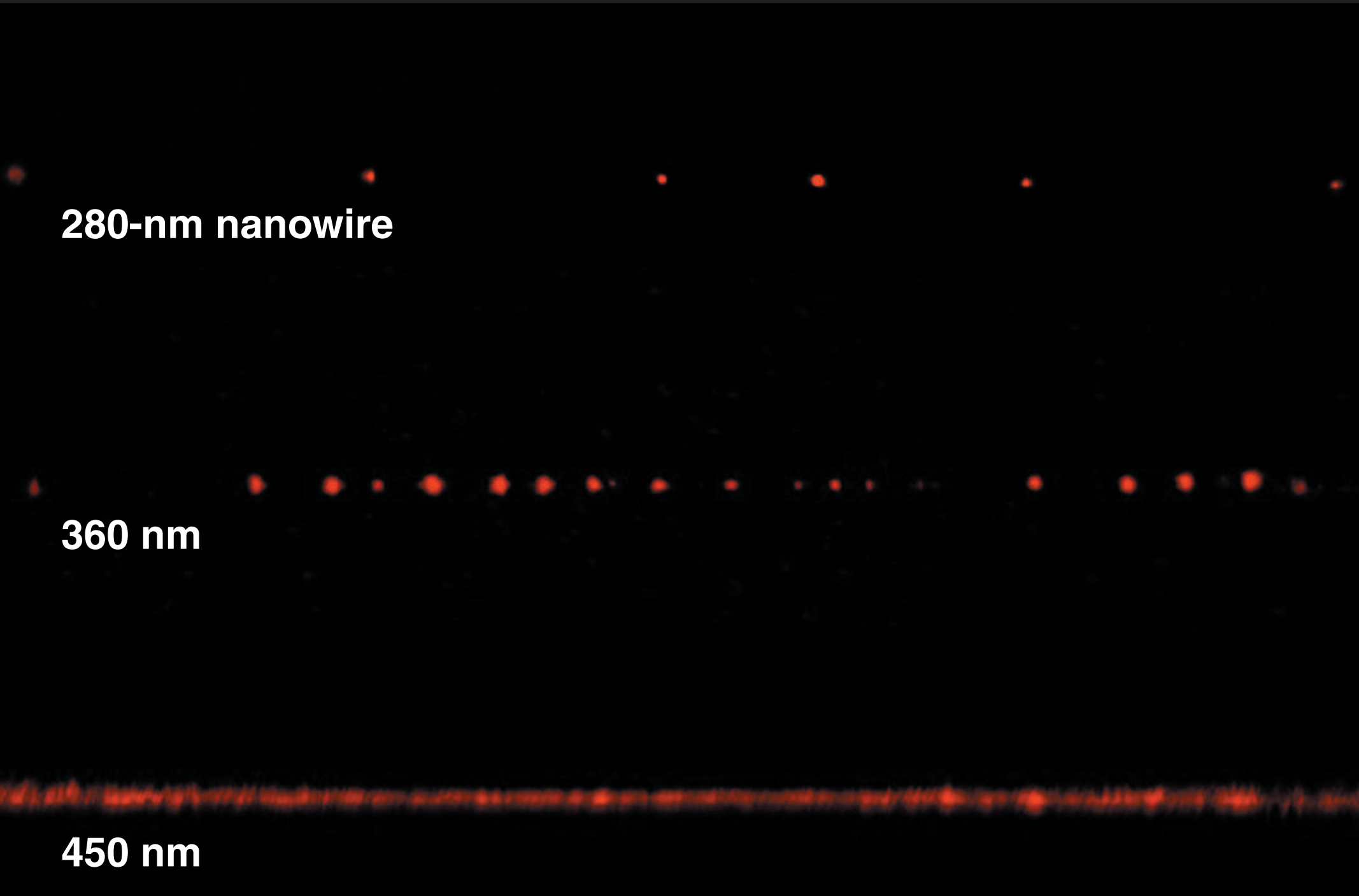


Optical properties

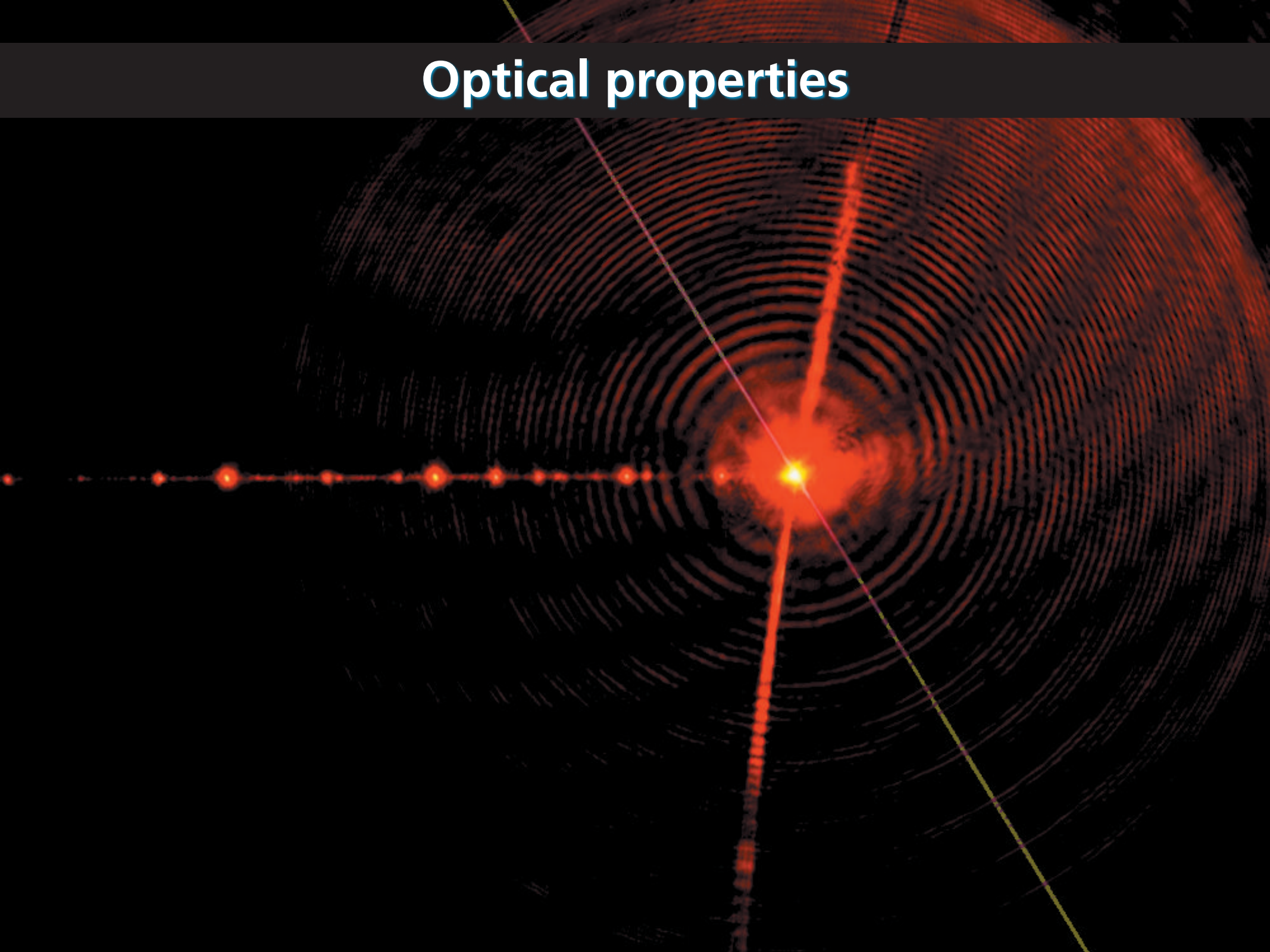
coupling light into nanowires



Optical properties



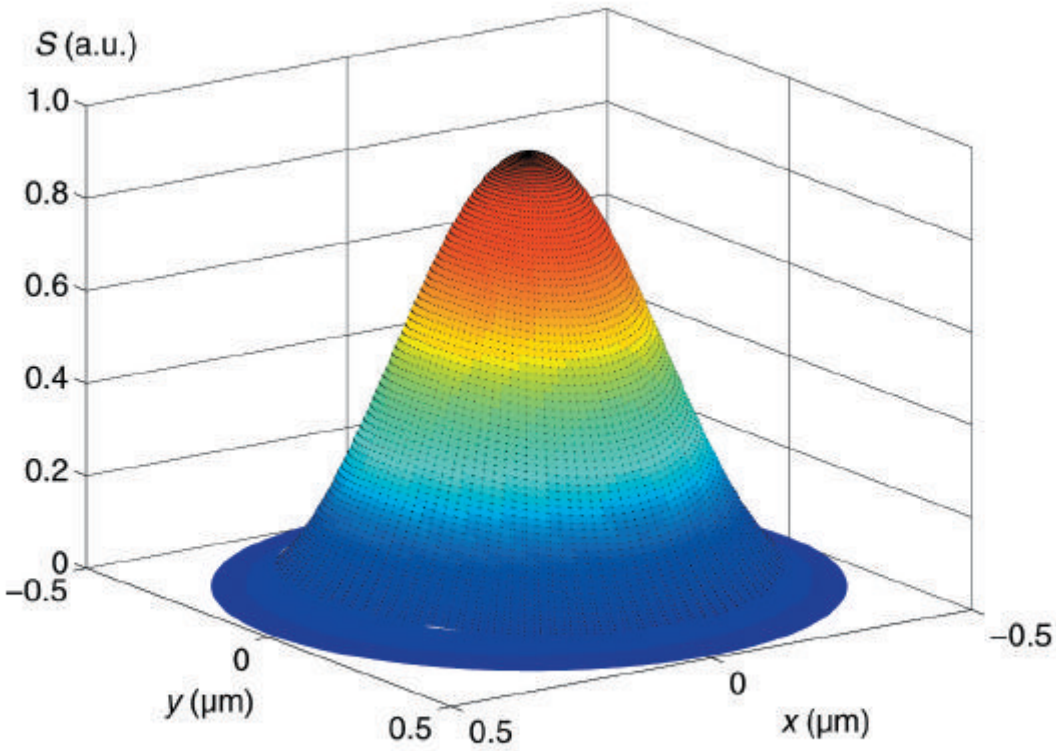
Optical properties



Optical properties

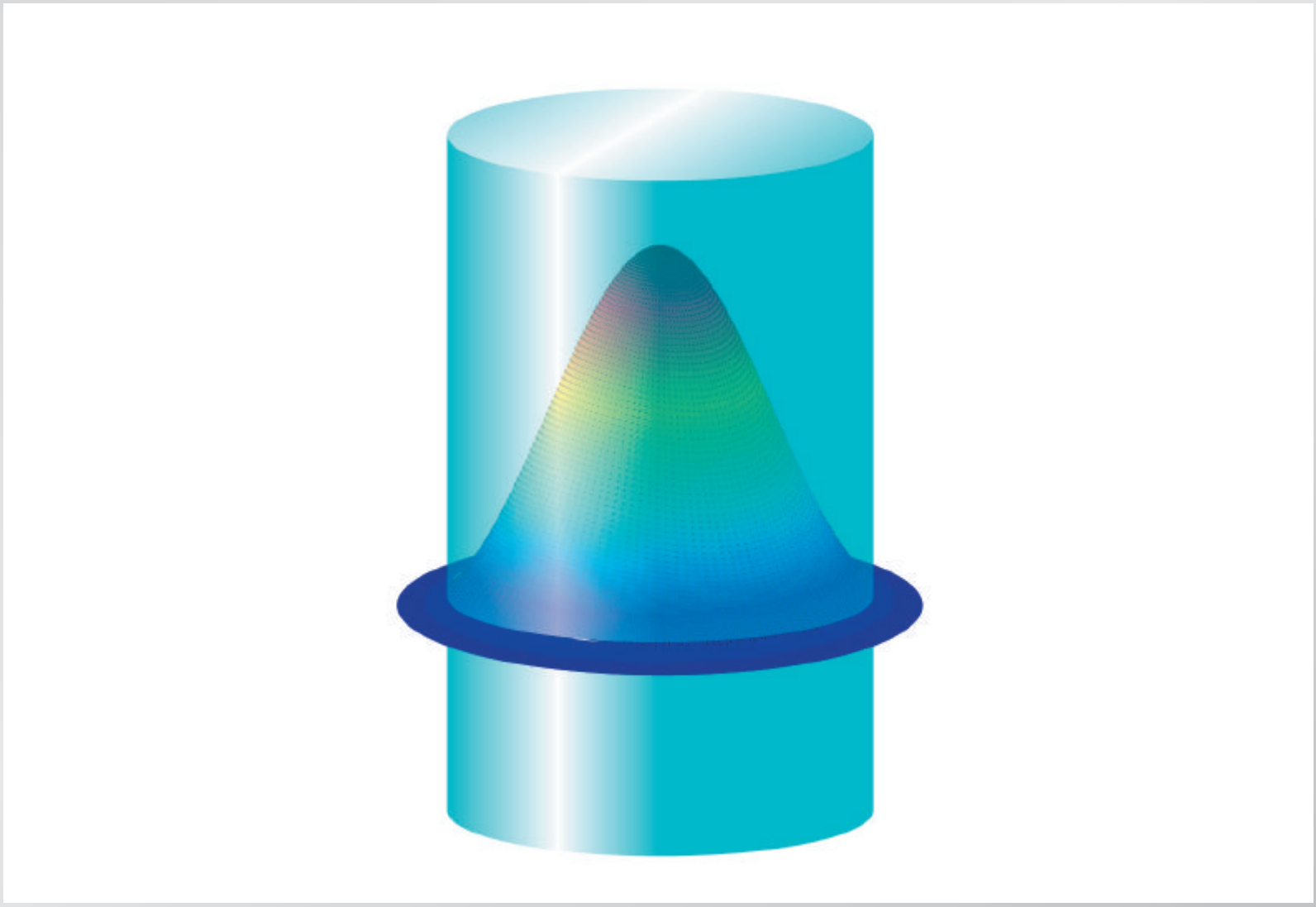
Optical properties

Poynting vector profile for 800-nm nanowire



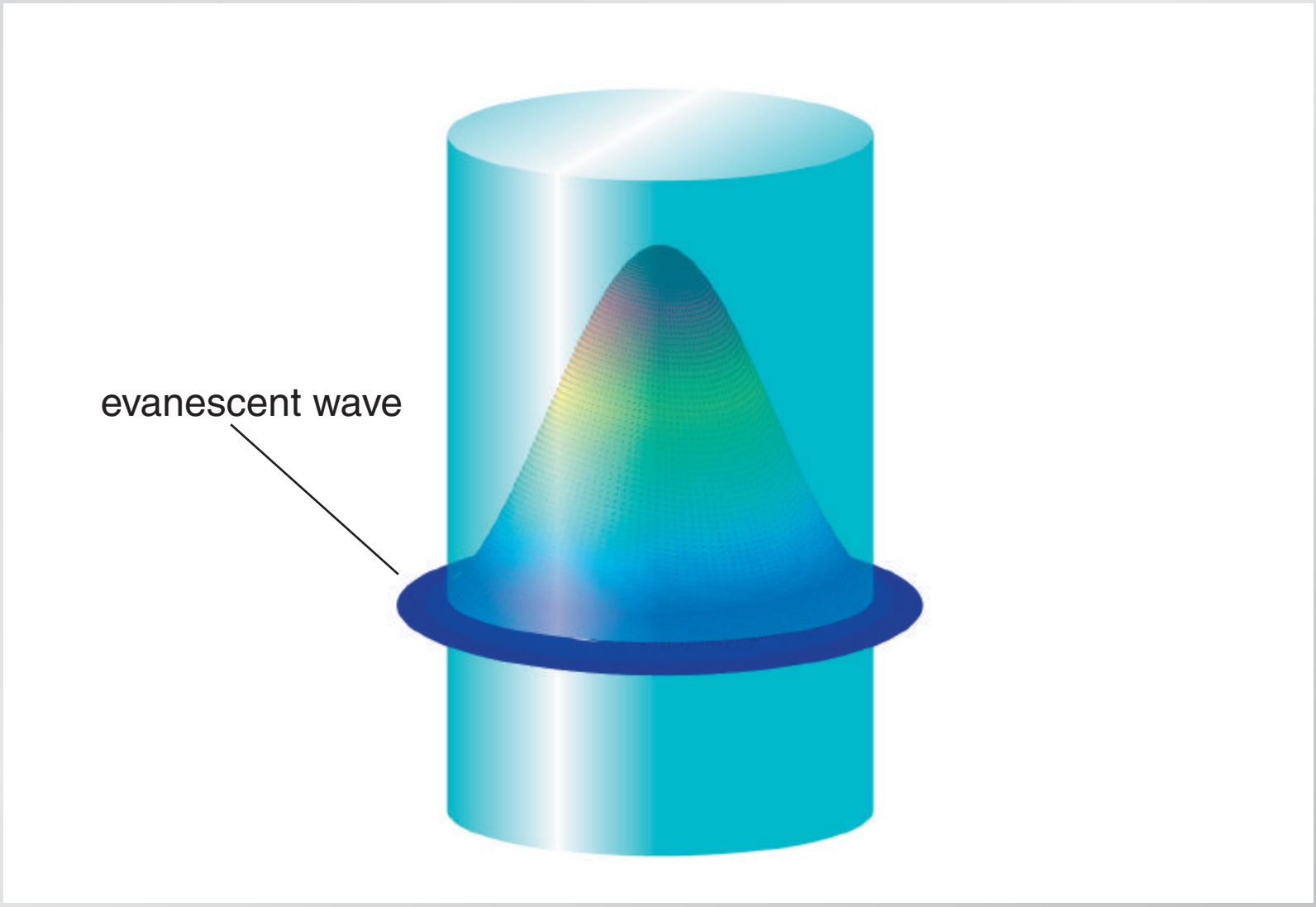
Optical properties

Poynting vector profile for 800-nm nanowire



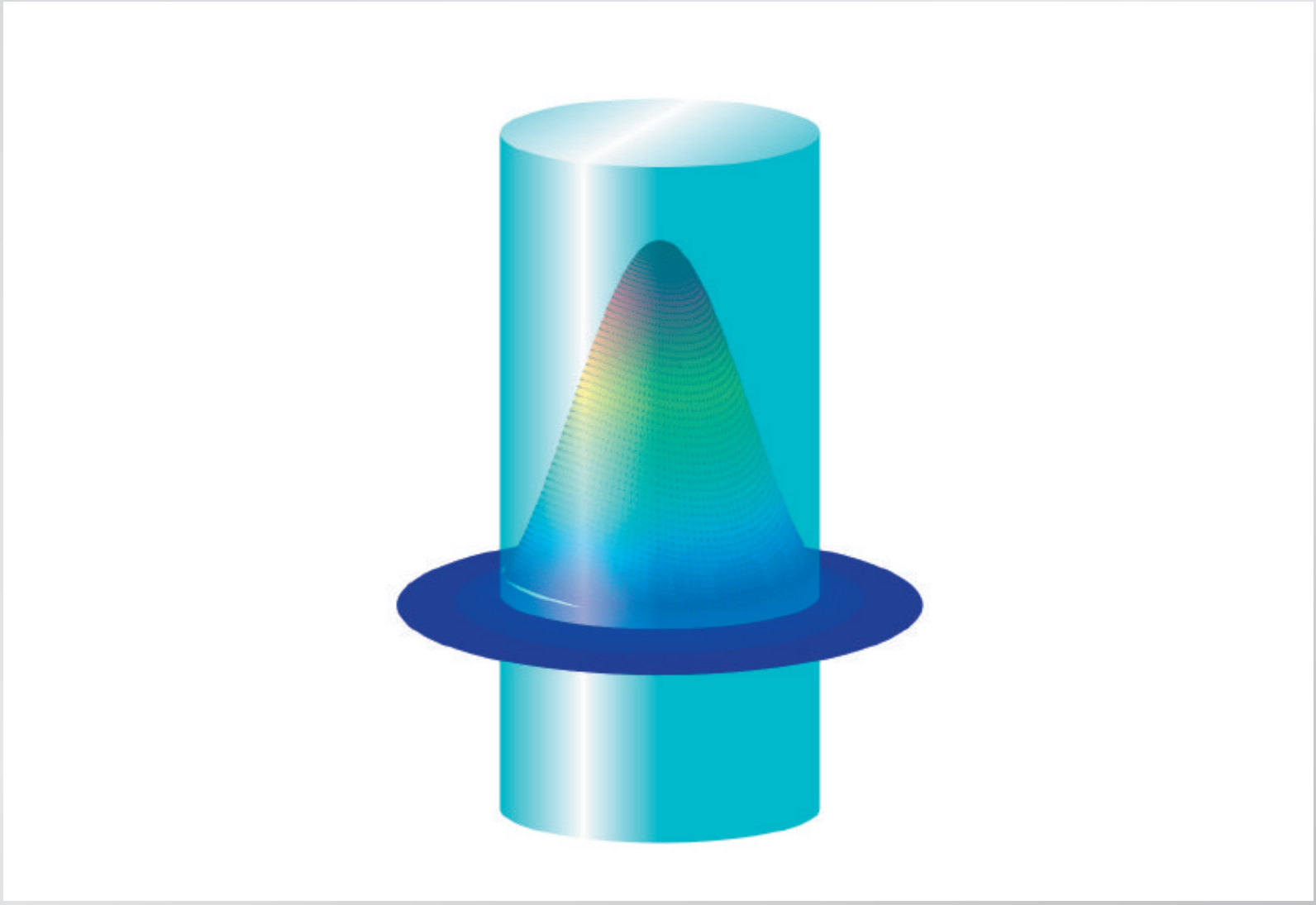
Optical properties

Poynting vector profile for 800-nm nanowire



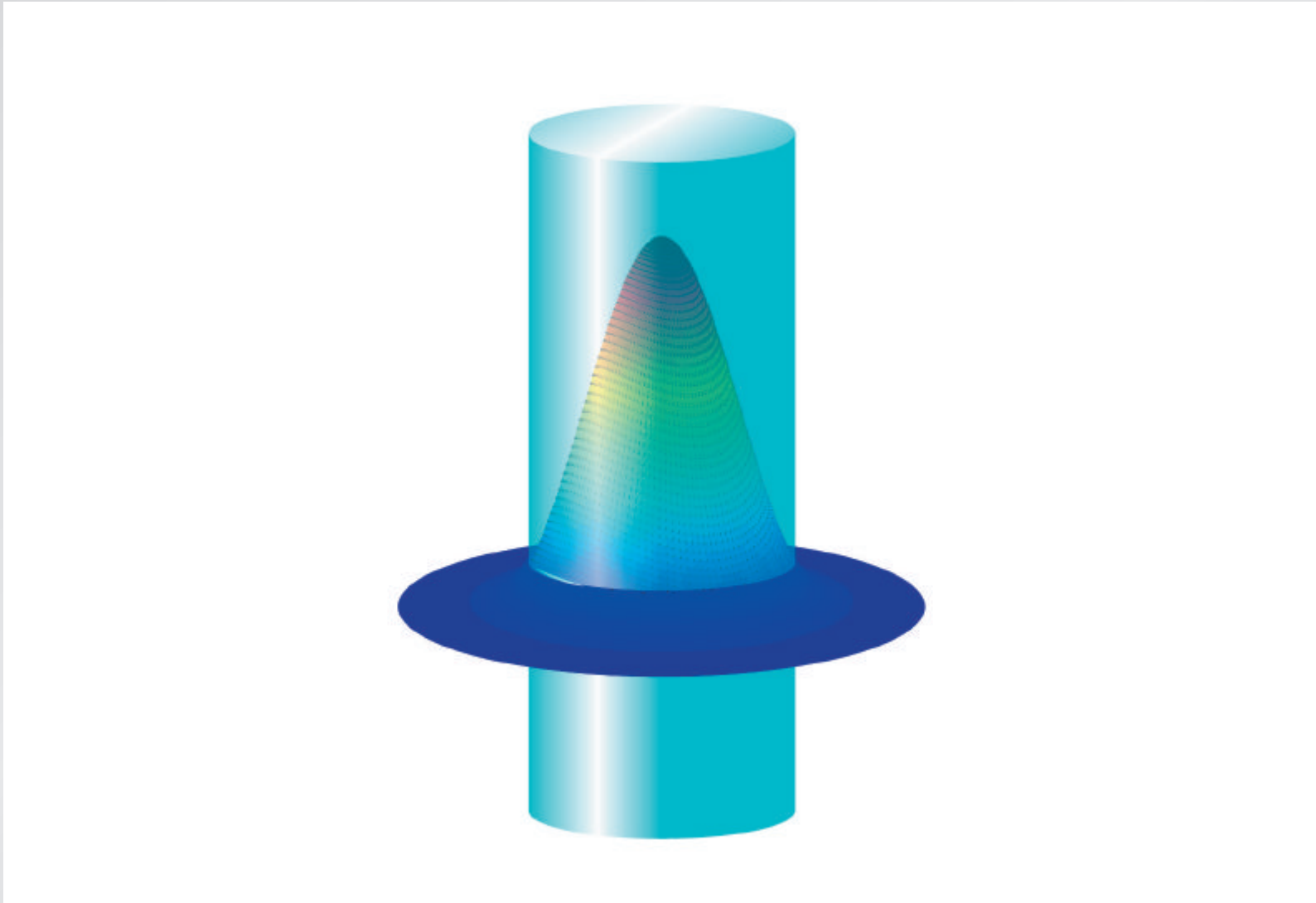
Optical properties

Poynting vector profile for 600-nm nanowire



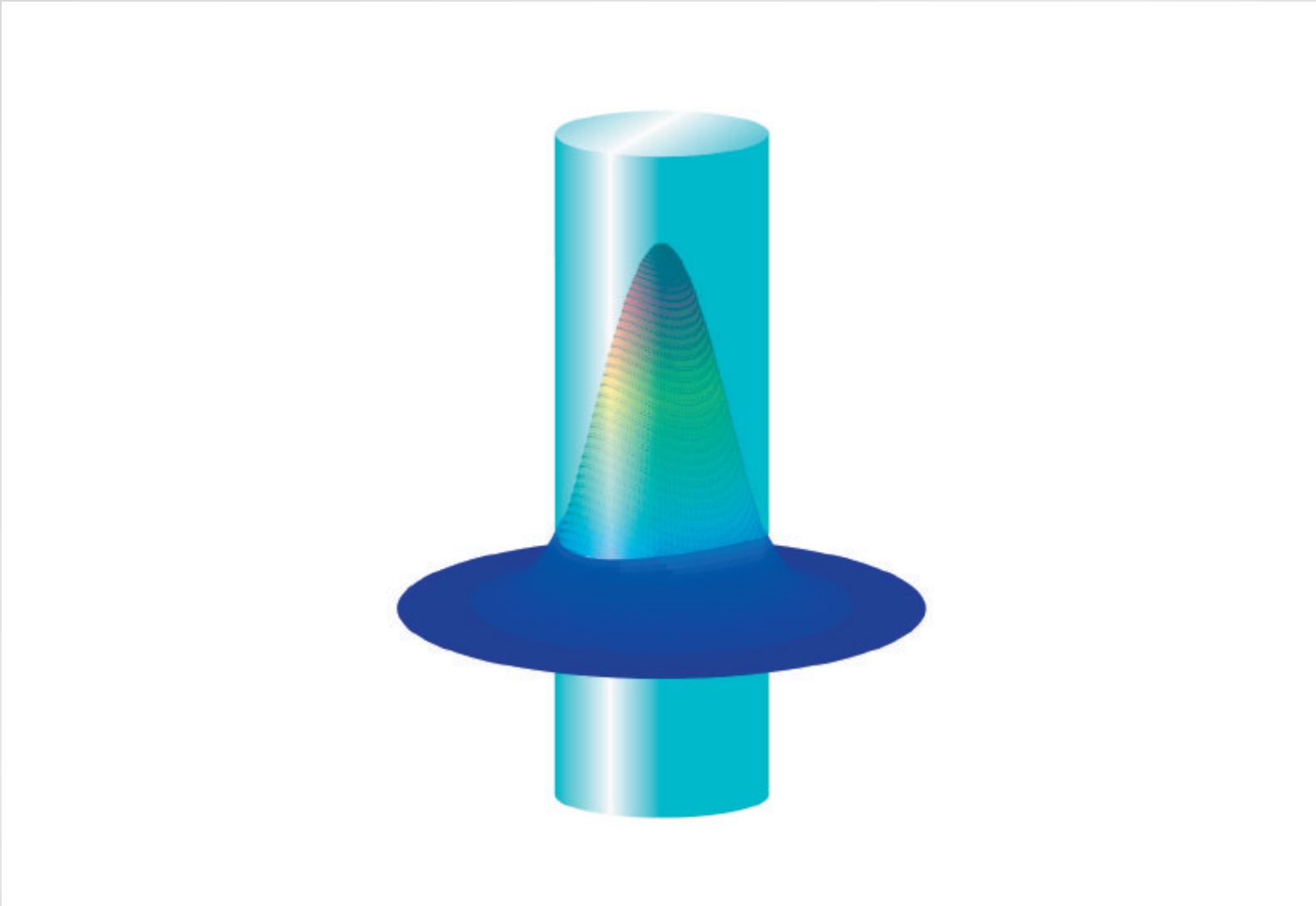
Optical properties

Poynting vector profile for 500-nm nanowire



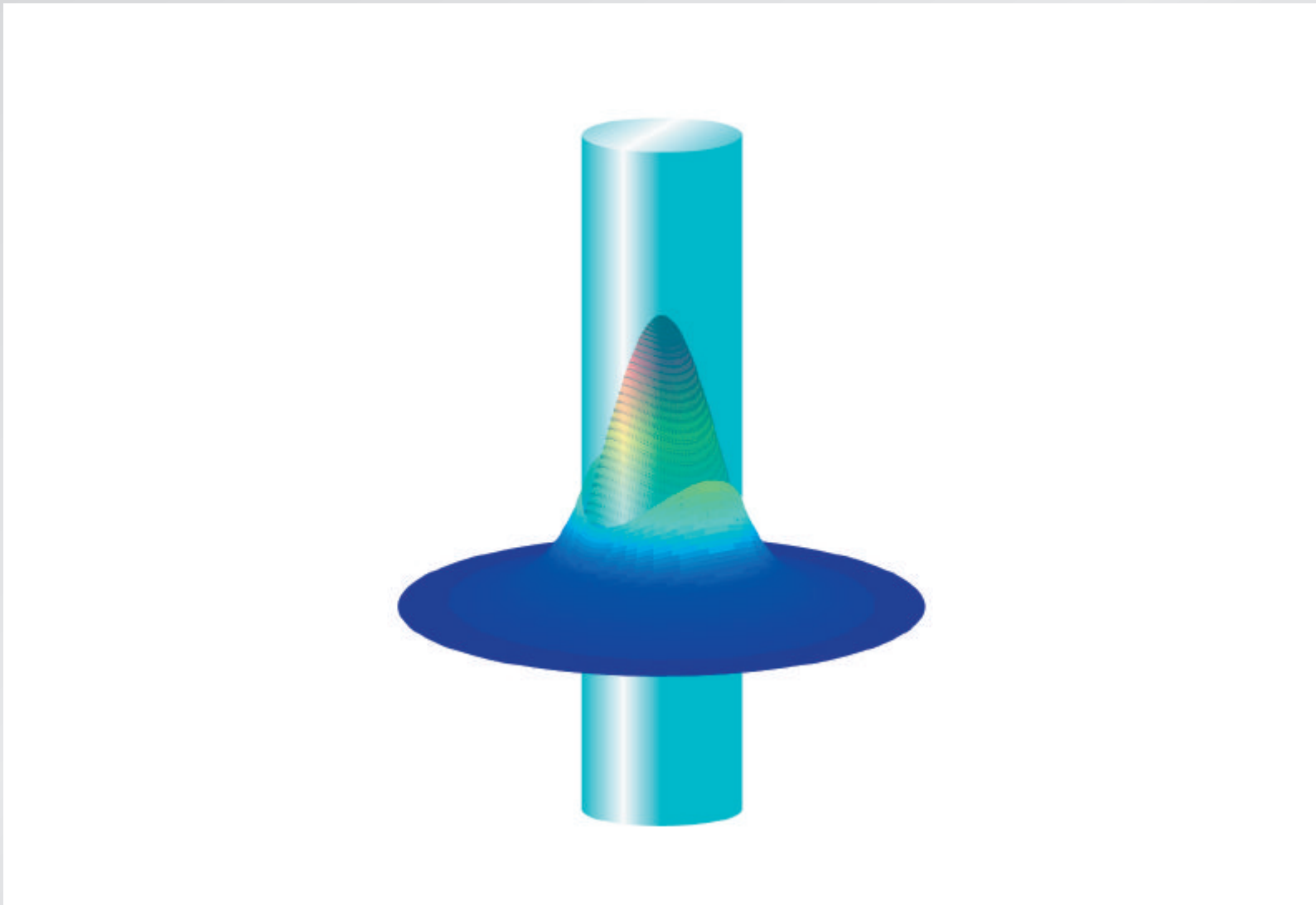
Optical properties

Poynting vector profile for 400-nm nanowire



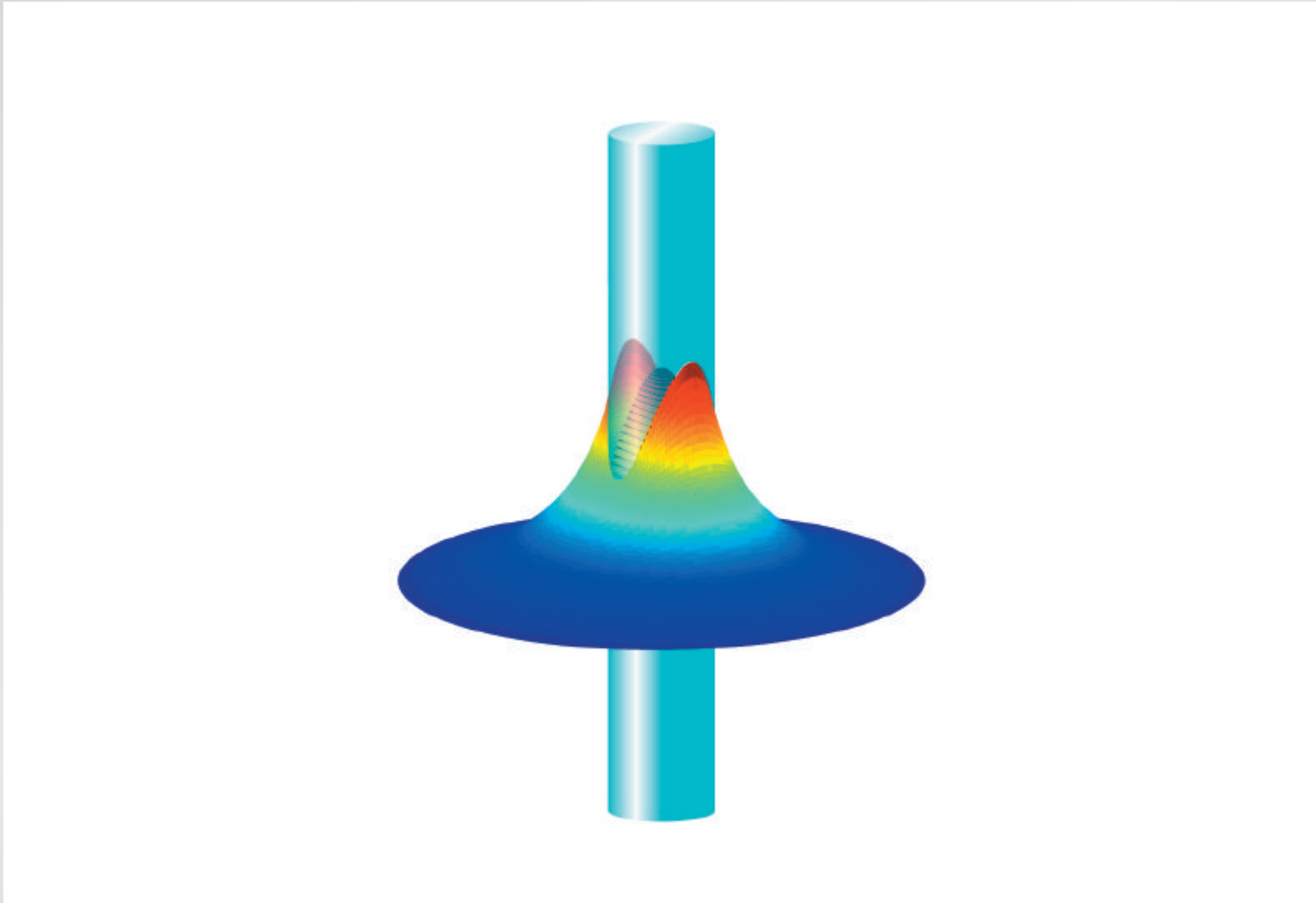
Optical properties

Poynting vector profile for 300-nm nanowire



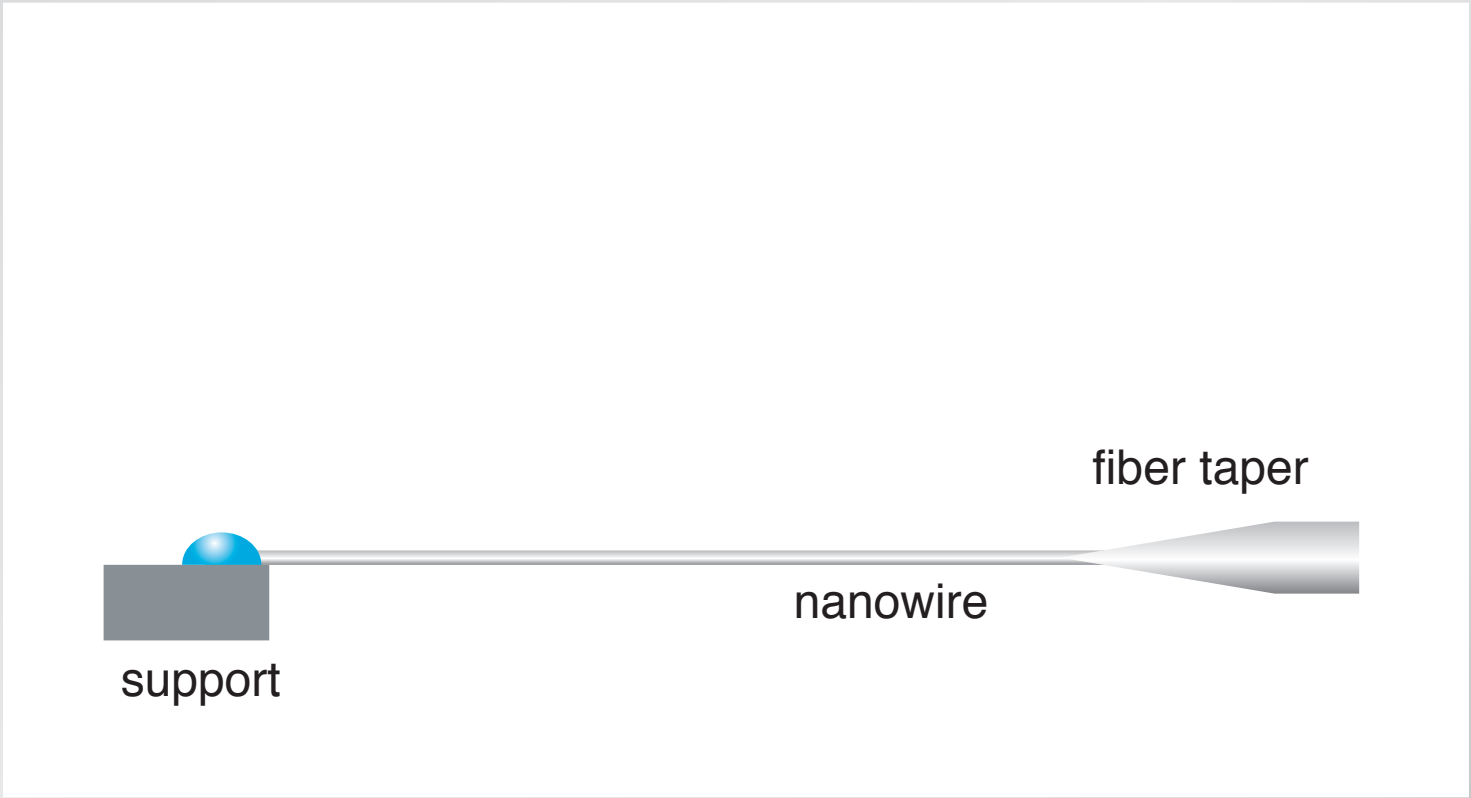
Optical properties

Poynting vector profile for 200-nm nanowire



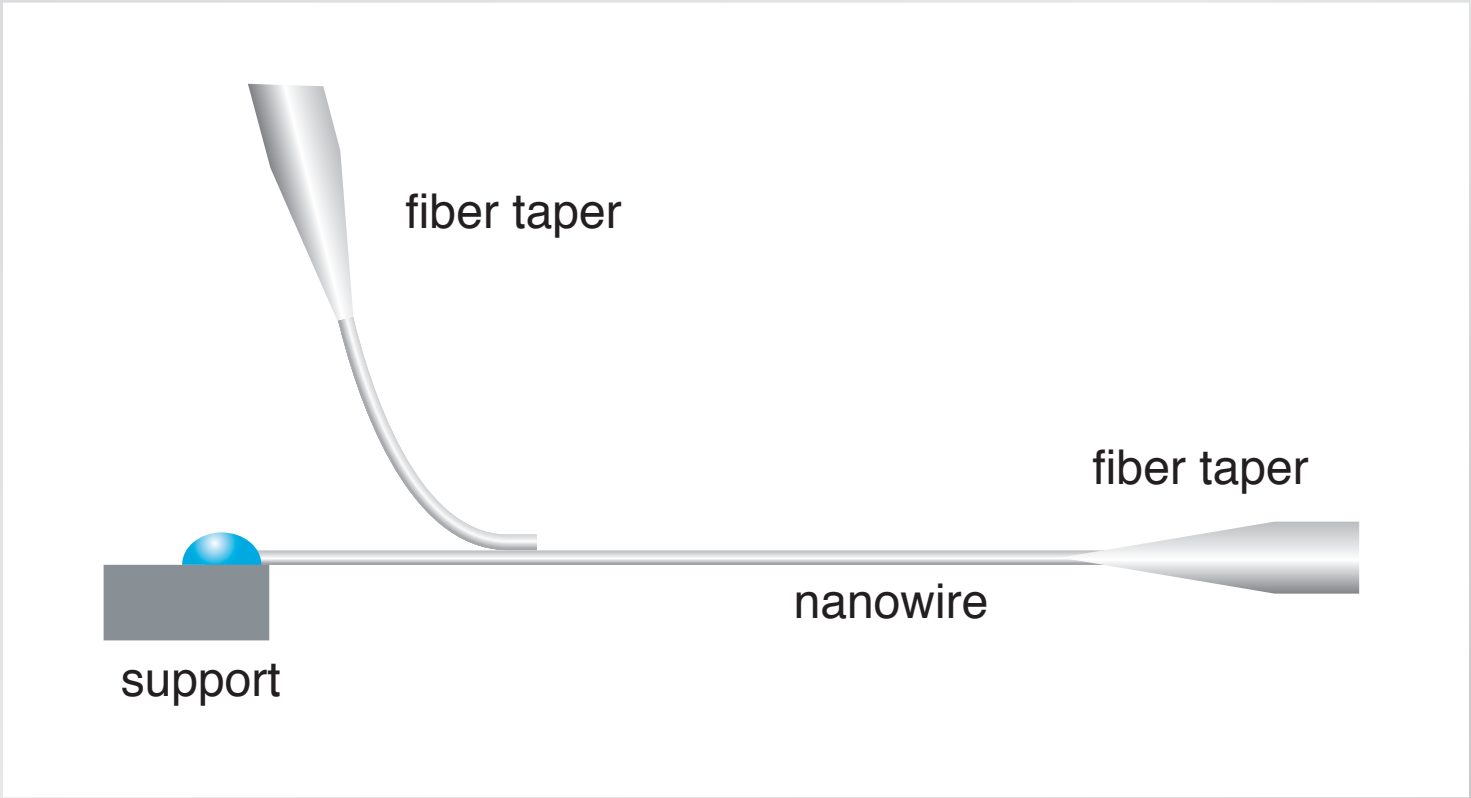
Optical properties

coupling light between nanowires



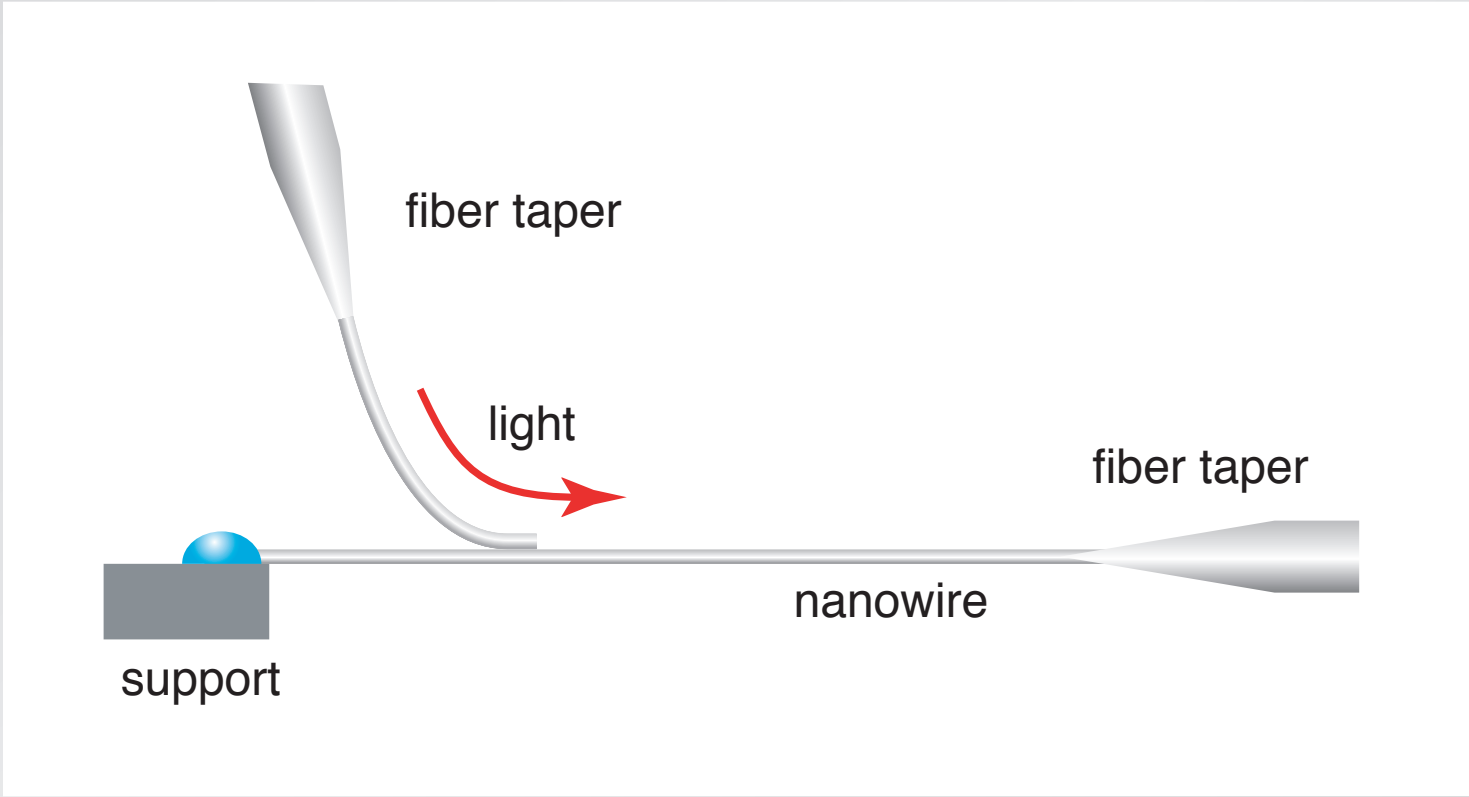
Optical properties

coupling light between nanowires

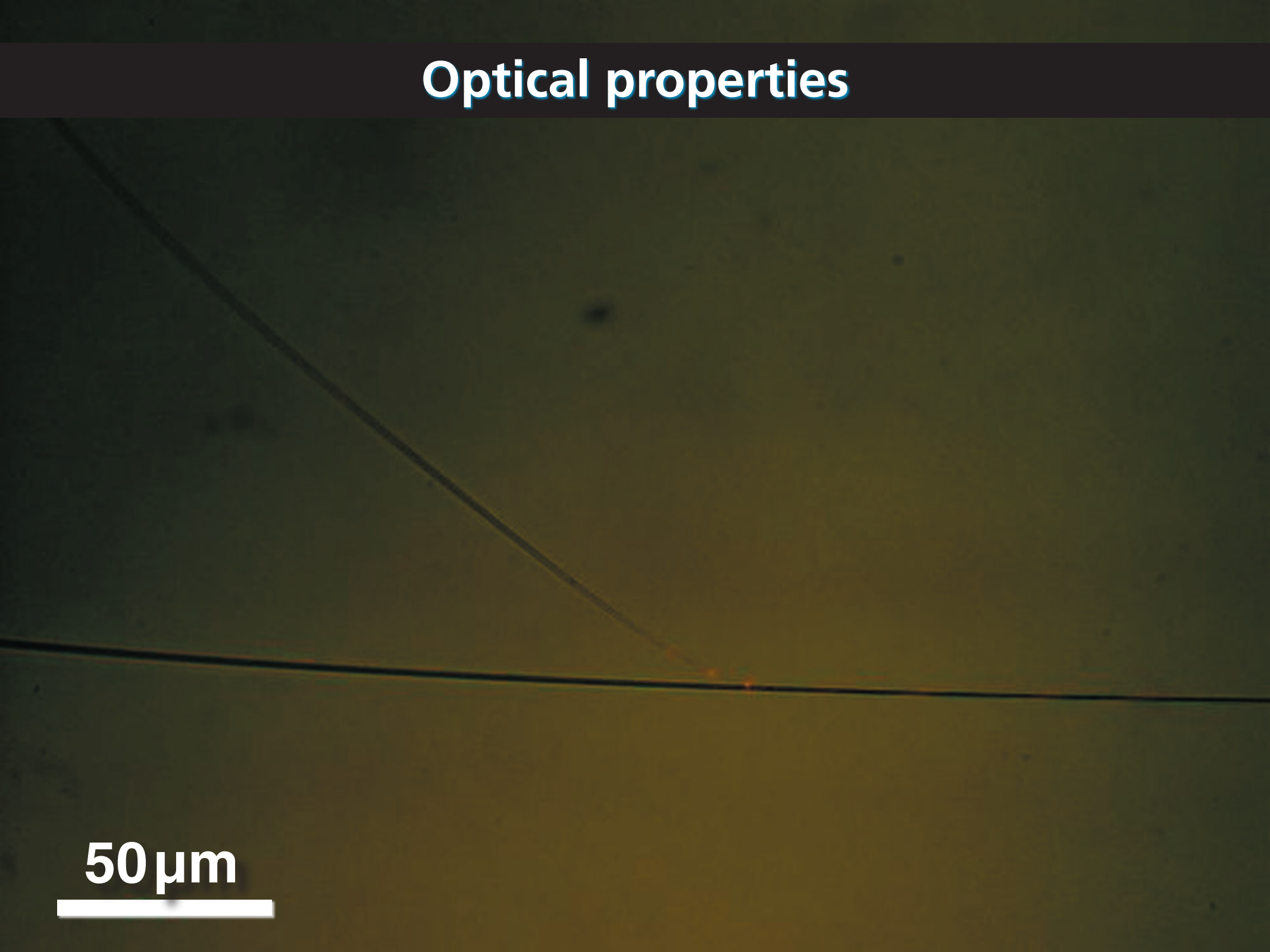


Optical properties

coupling light between nanowires



Optical properties



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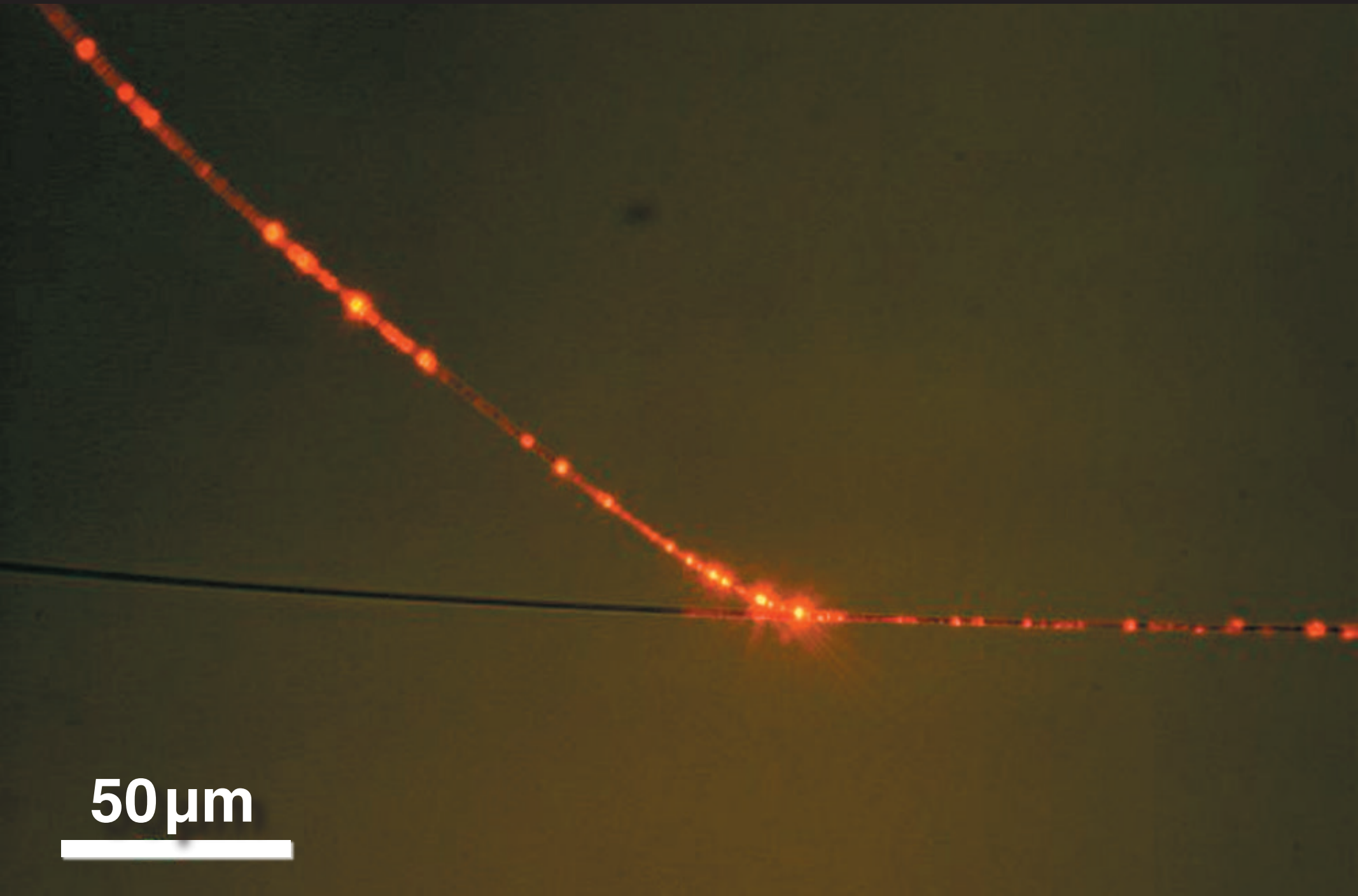

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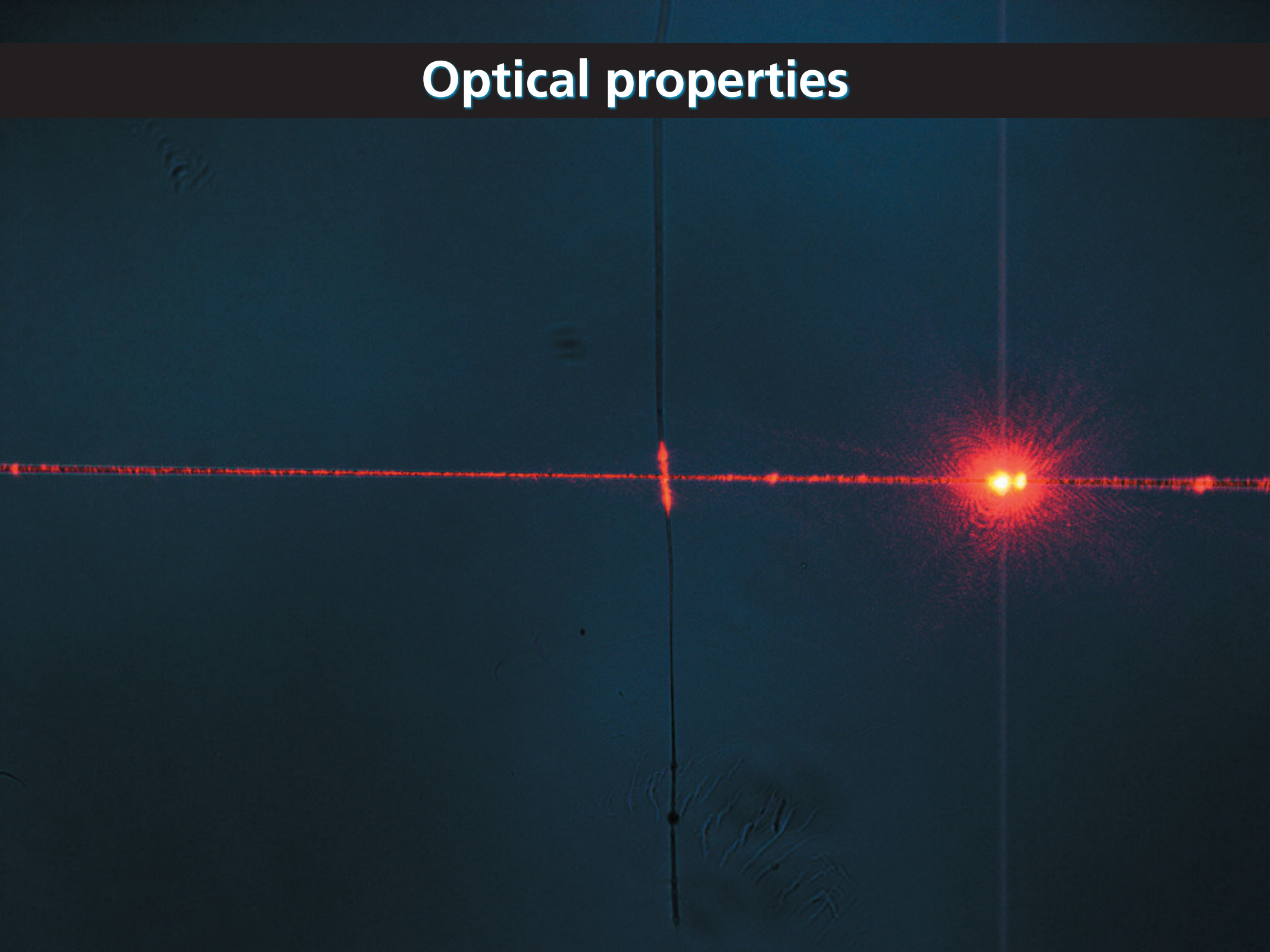

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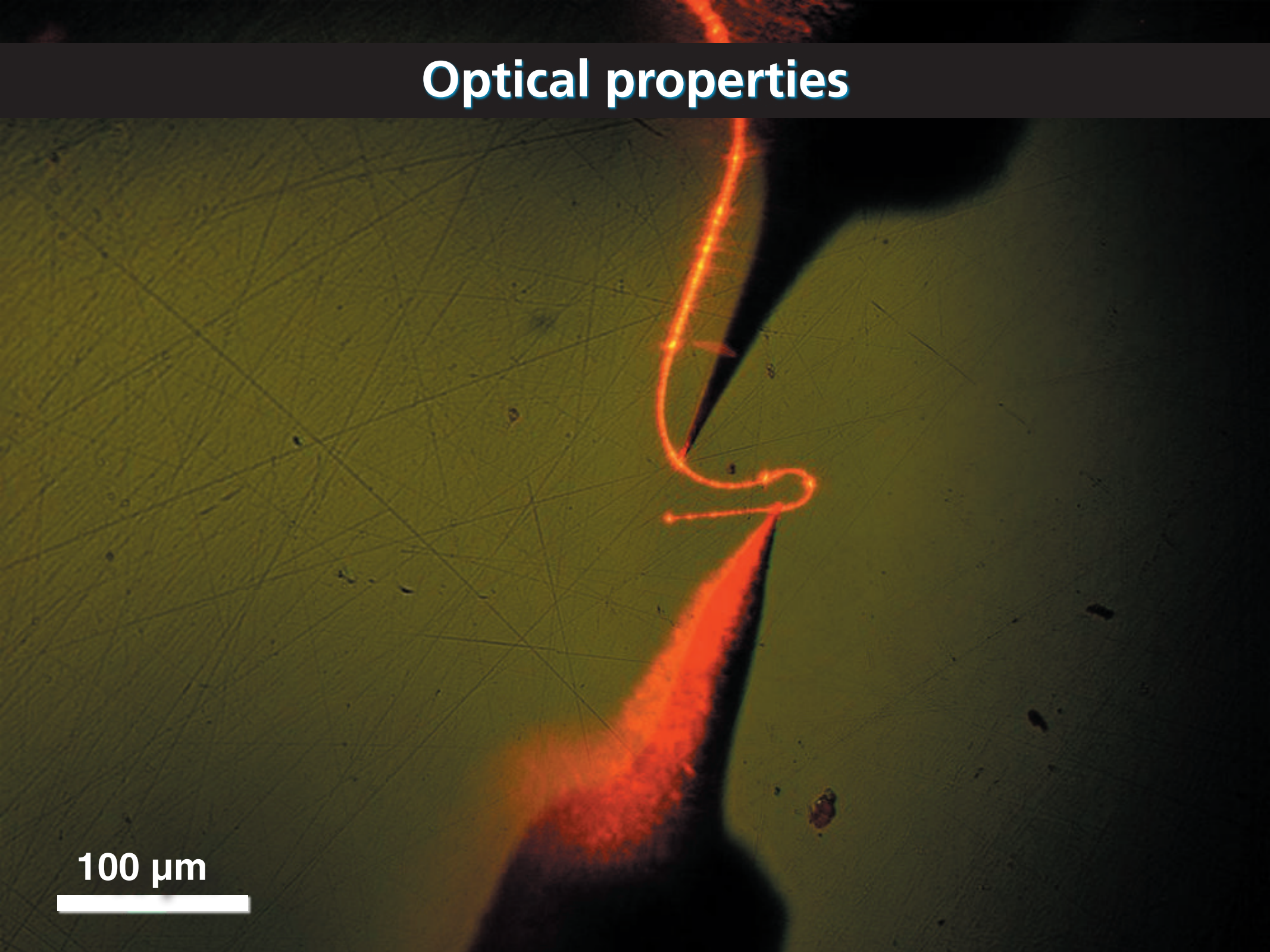

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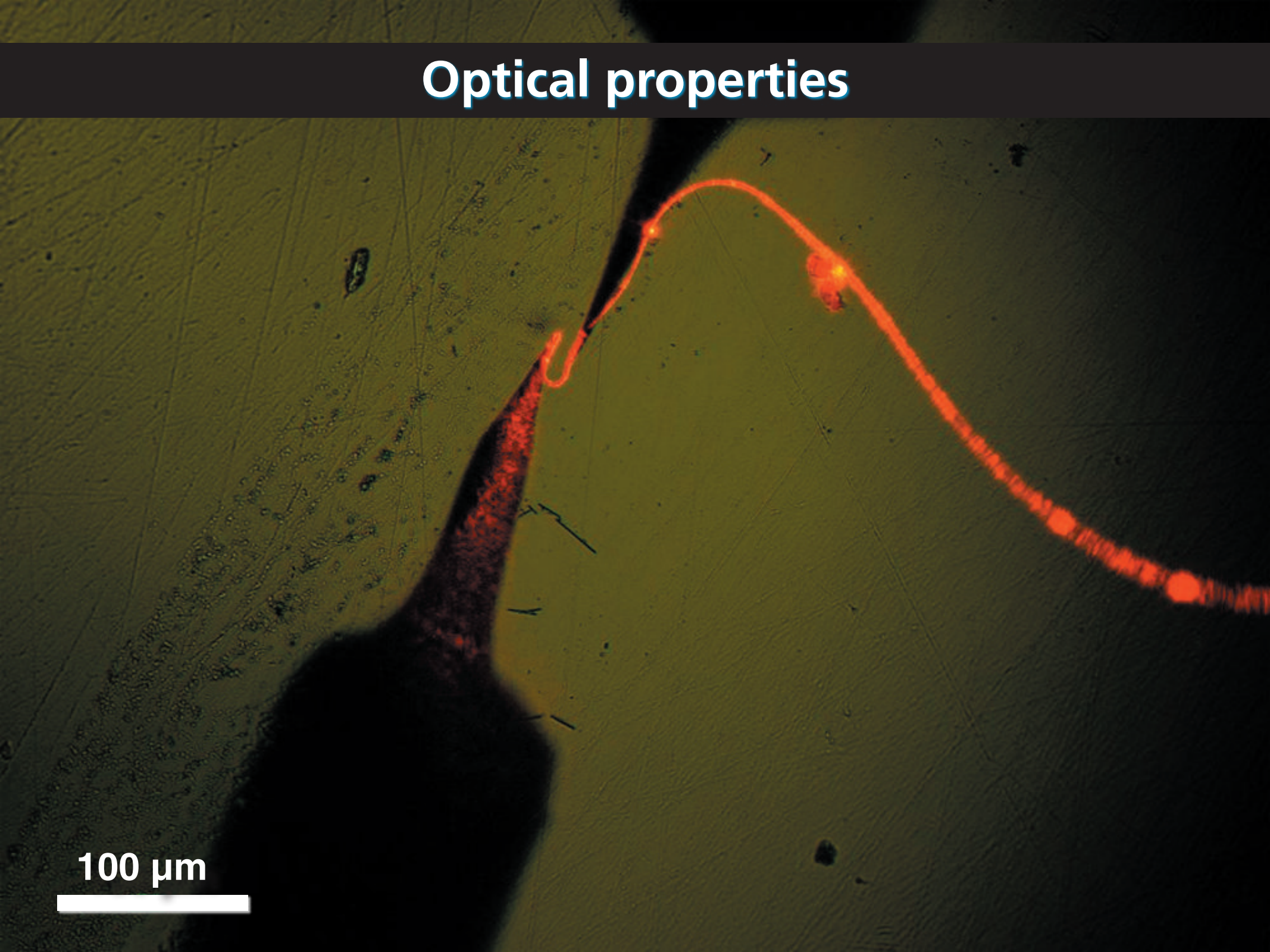

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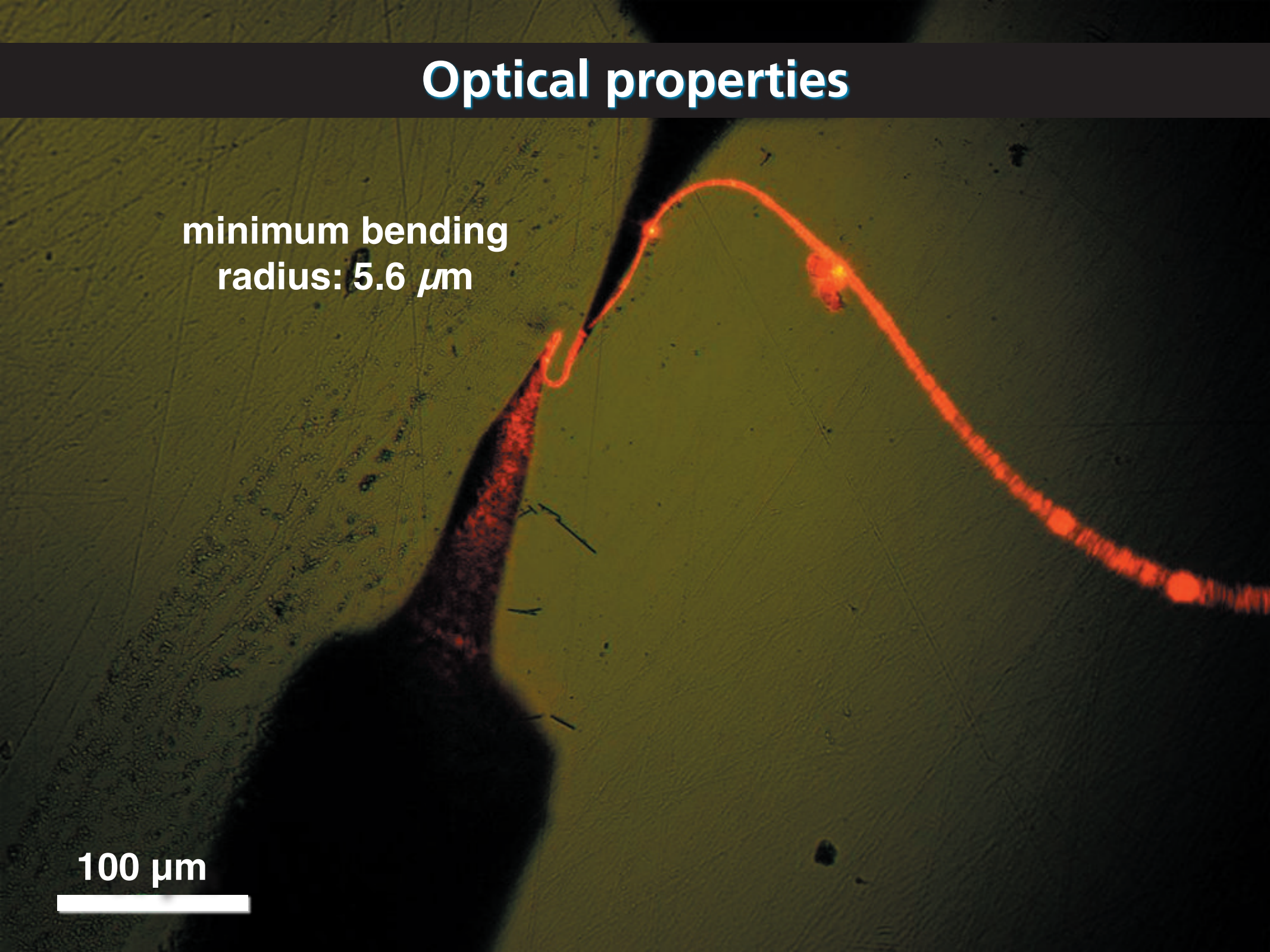
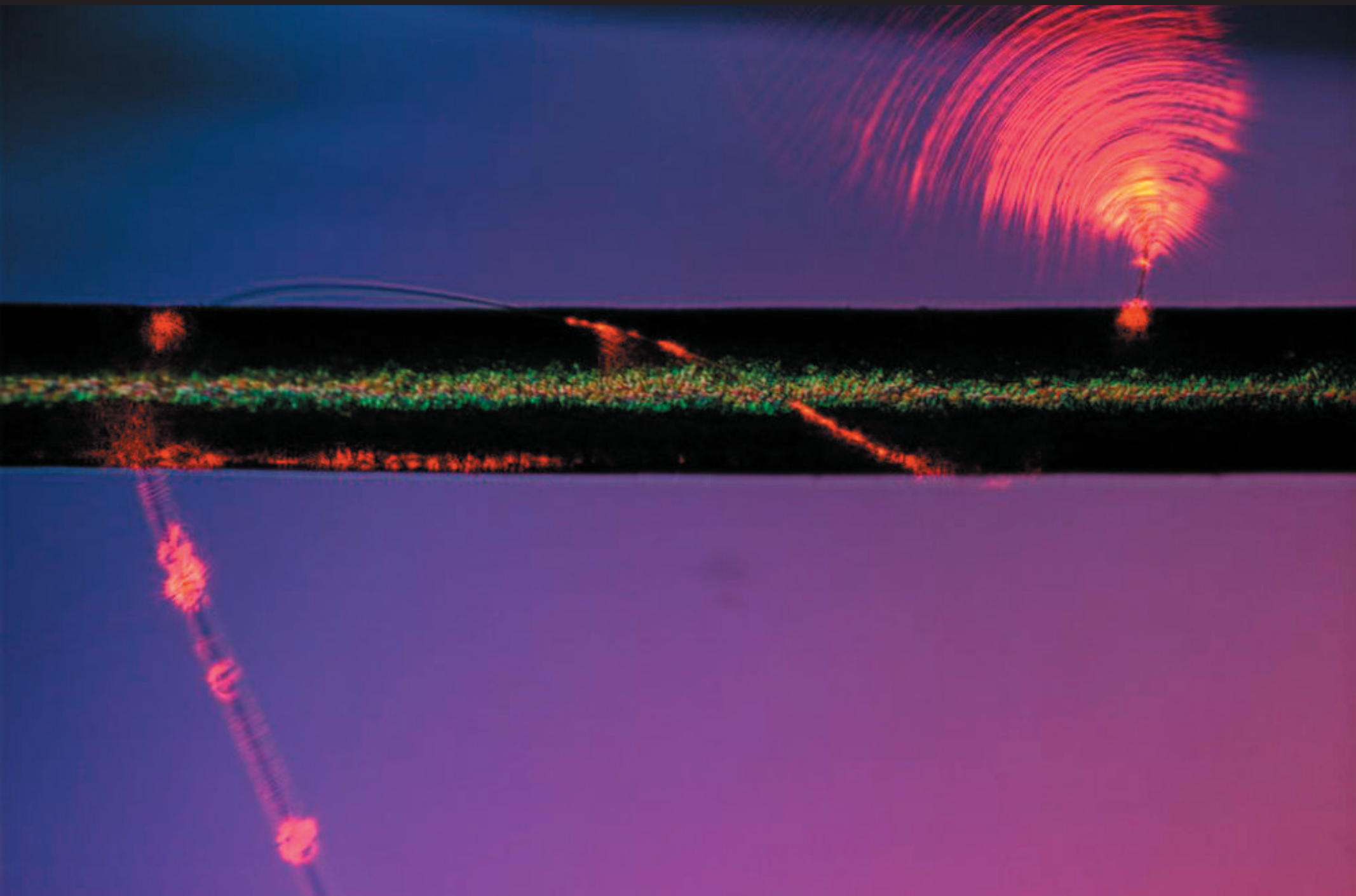
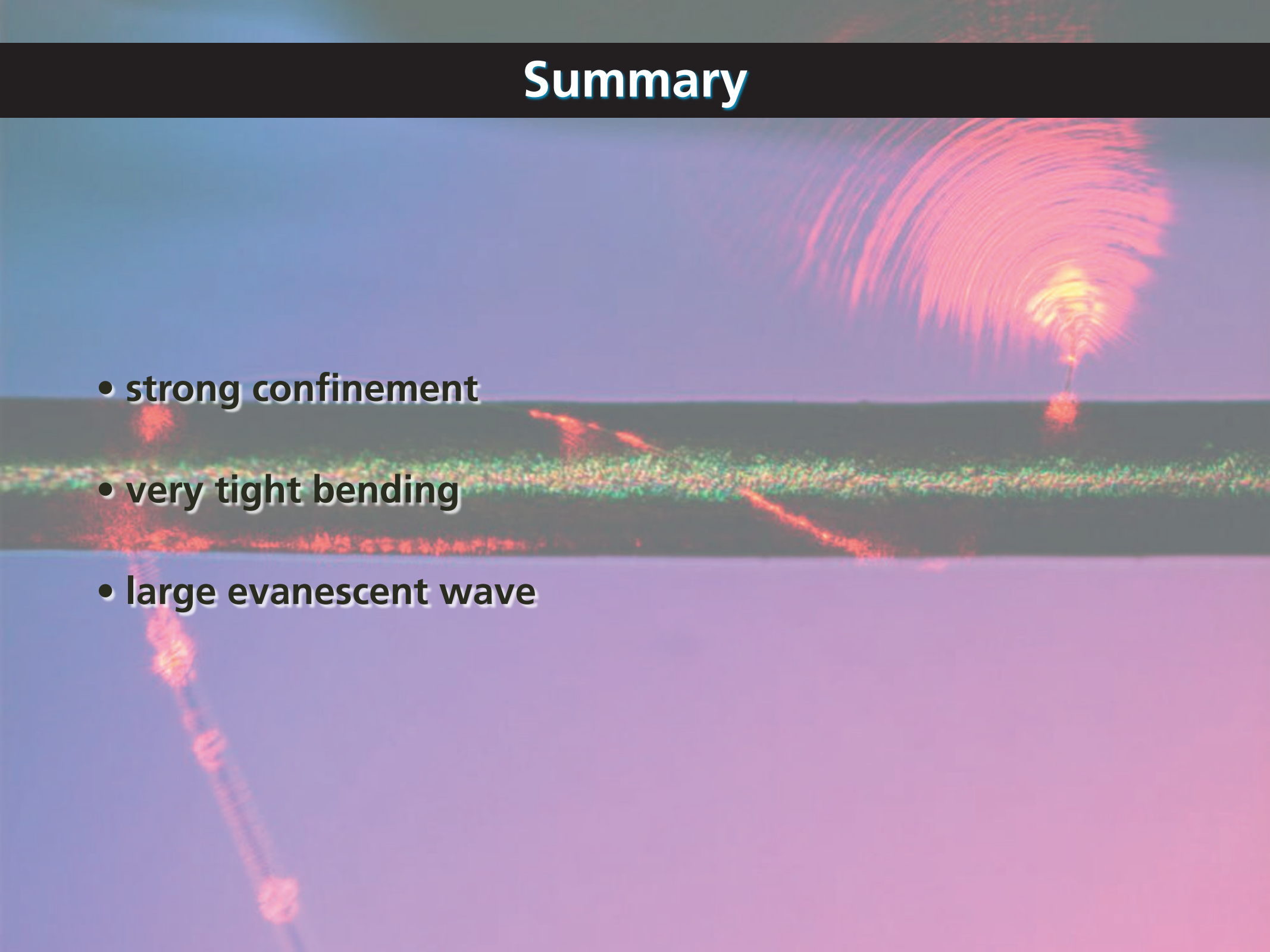


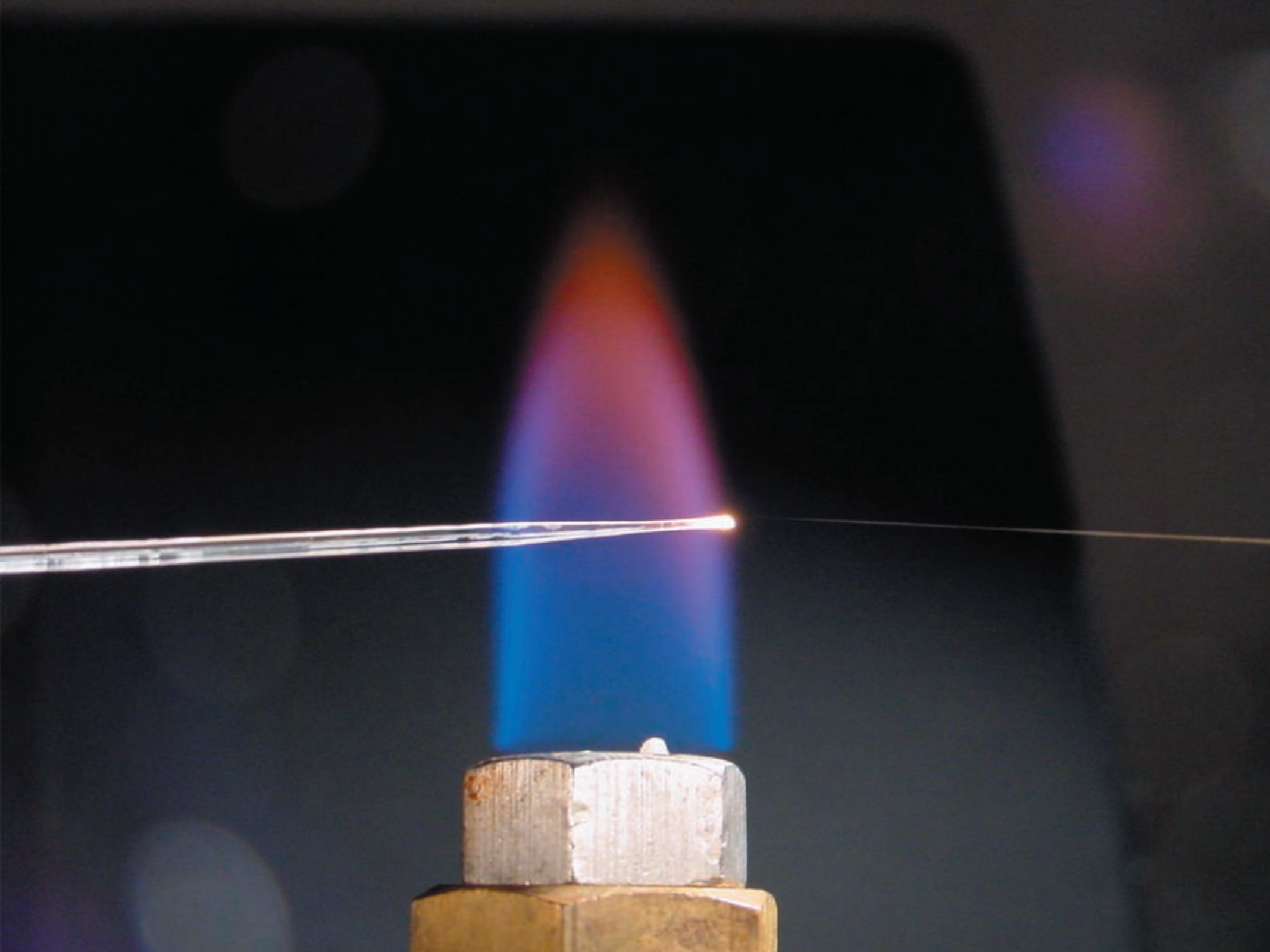
Summary



Summary



- strong confinement
- very tight bending
- large evanescent wave



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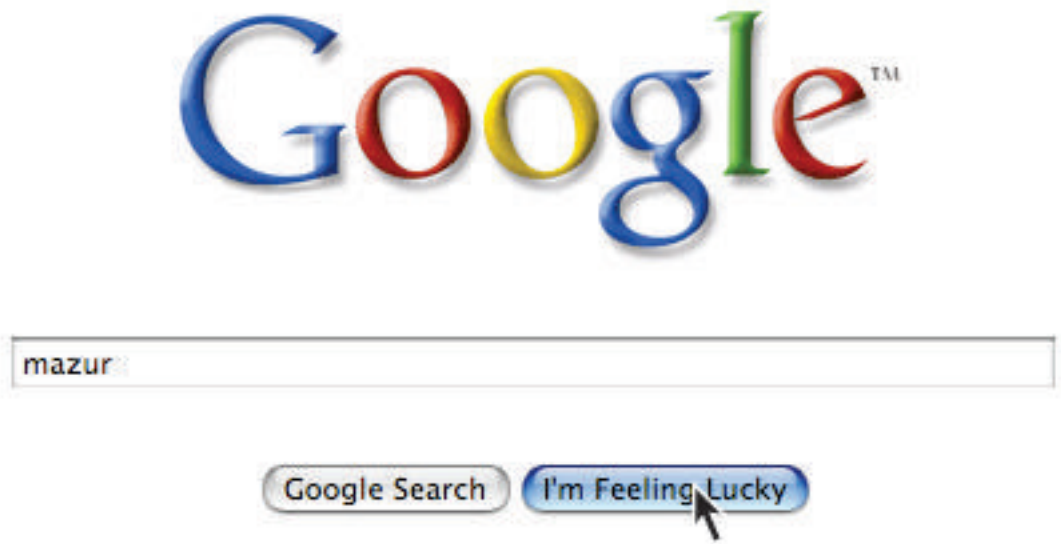
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