Submicrometer-width TiO_2 waveguides

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CLEO

San Jose, CA, 7 May 2012

and also....

Katia Shtrykova

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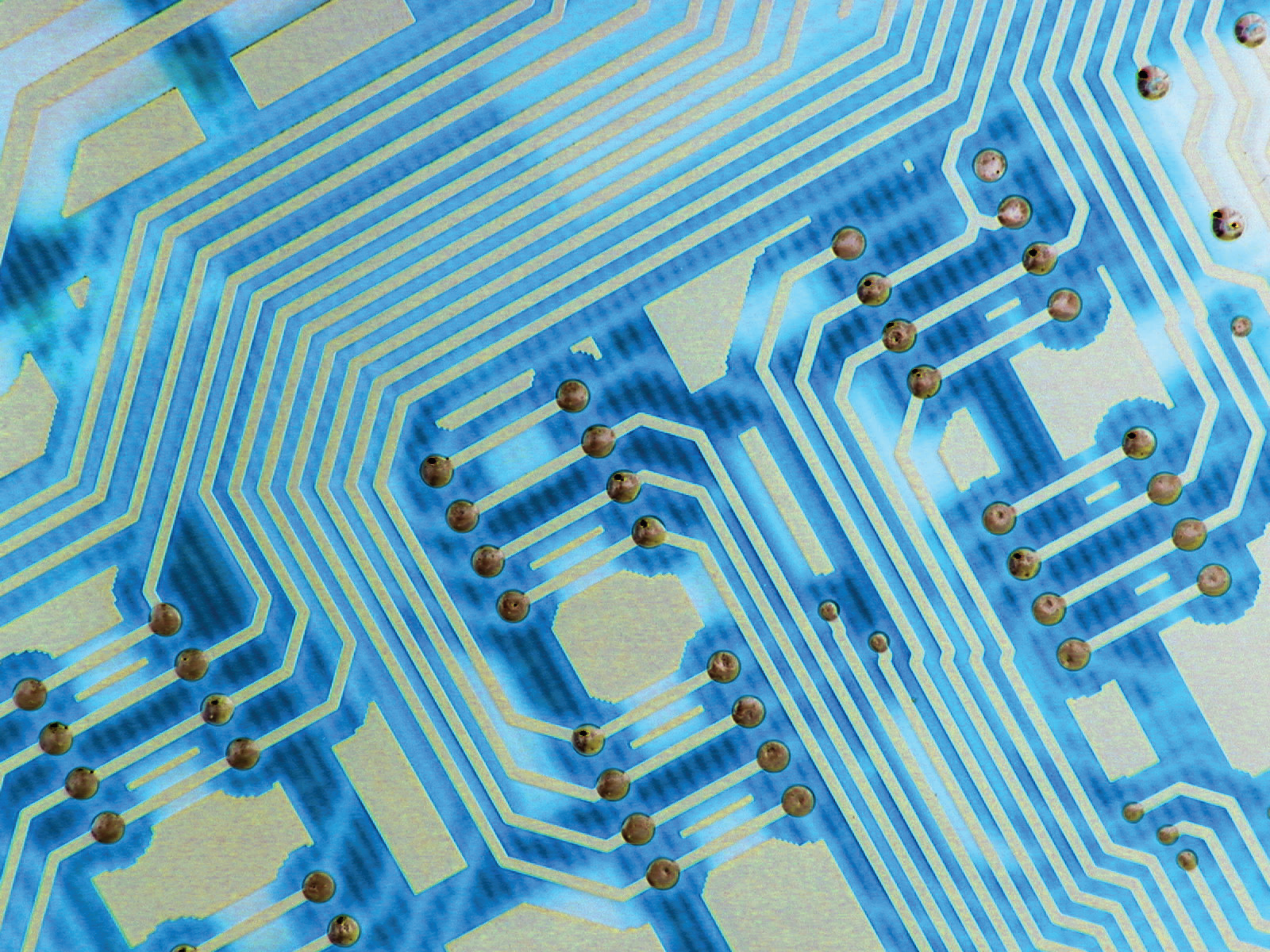
Grisel Rivera Batista

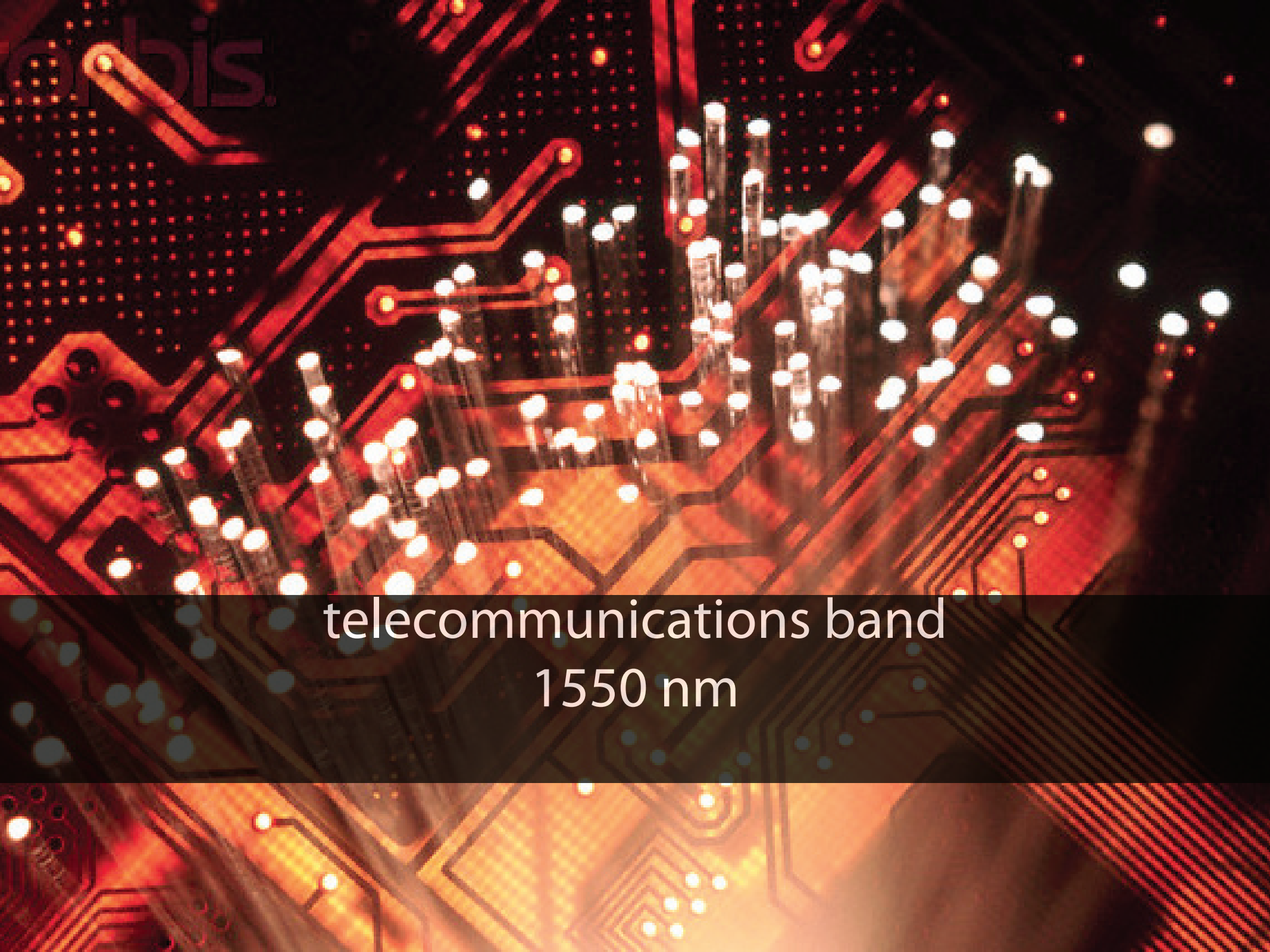
Stephanie Scwartz

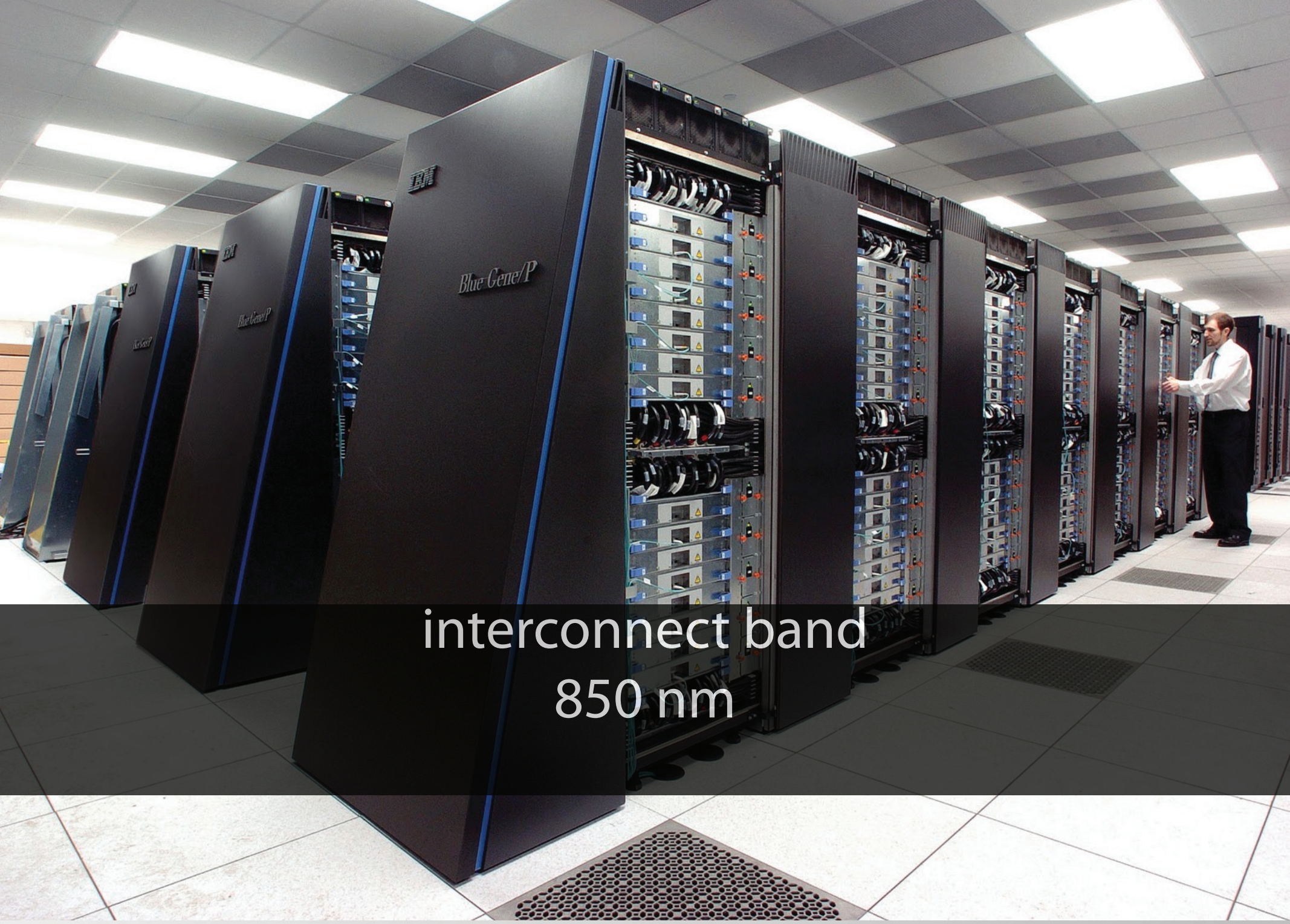
Prof. Erich Ippen (MIT)

Prof. Erwin Martí-Panameño (BUAP)

Prof. Markus Pollnau (Twente)




telecommunications band
1550 nm



interconnect band
850 nm

Titanium dioxide (TiO_2)

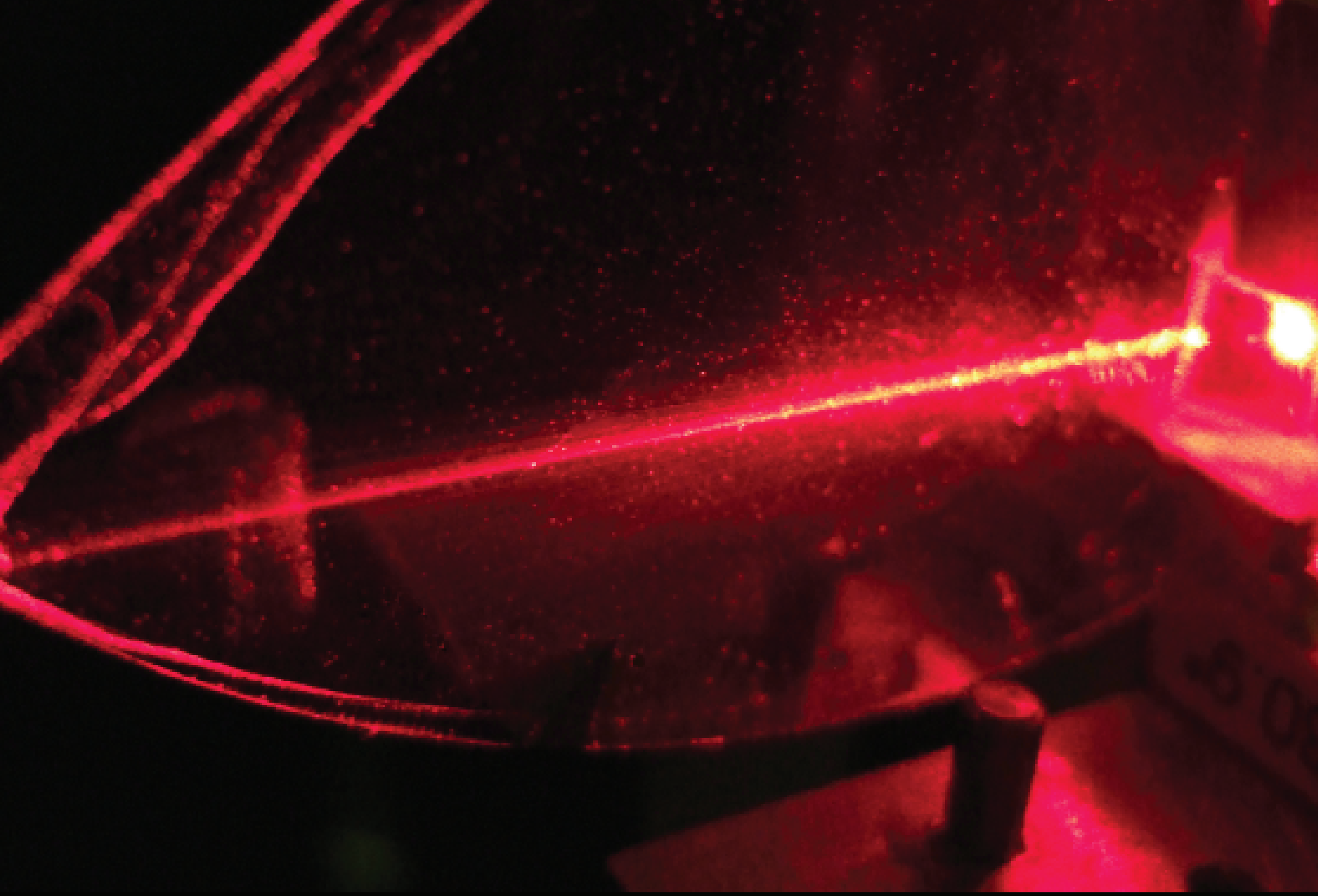
TiO_2 material properties

high index of refraction:	2.5
wide bandgap:	3.1 eV
large nonlinearity:	25 x silica
low two-photon absorption:	≥ 800 nm

several phases:

rutile, anatase, brookite and amorphous

Evans et. al., Opt. Express 20, 3118-3128 (2012).



1 fabrication

2 linear devices

3 NL properties

deposition

reactive sputtering

titanium with oxygen

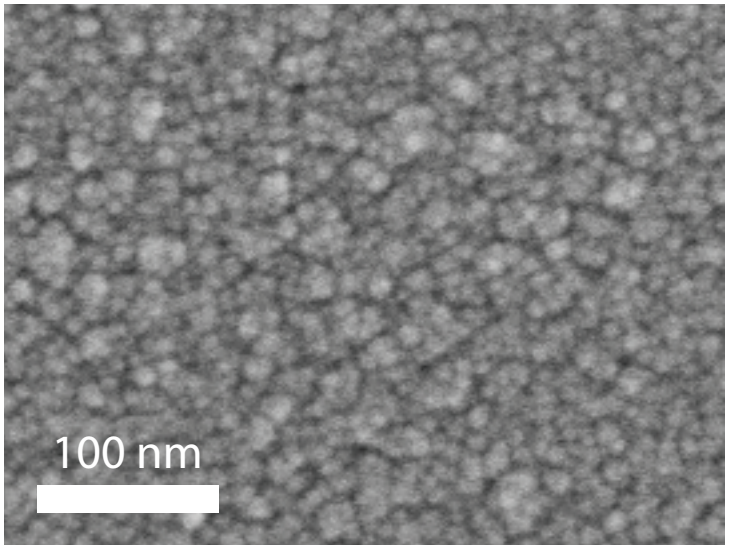
temp: 20–350° C

pressure: 2 mTorr

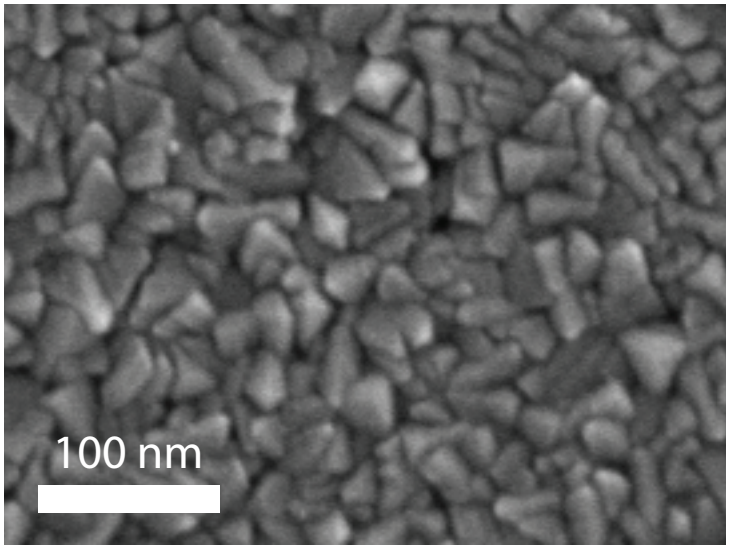
O_2 flow: 4.4–20 sccm

deposition

deposition temperature: 20° C

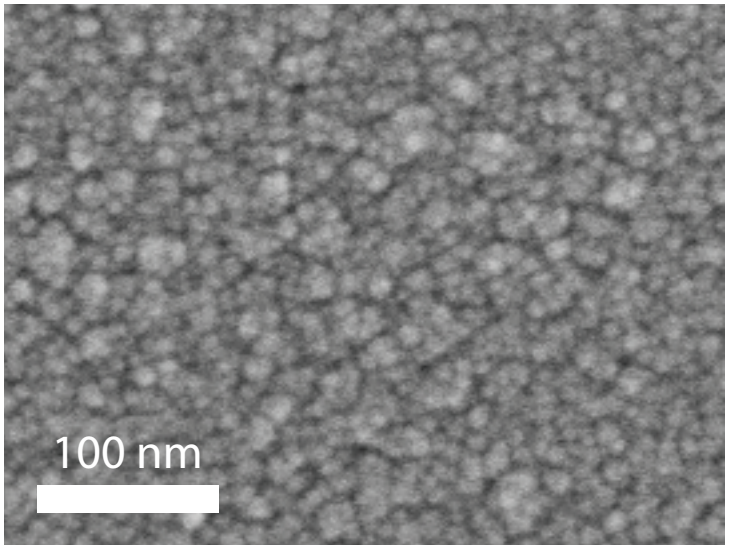


deposition temperature 350° C



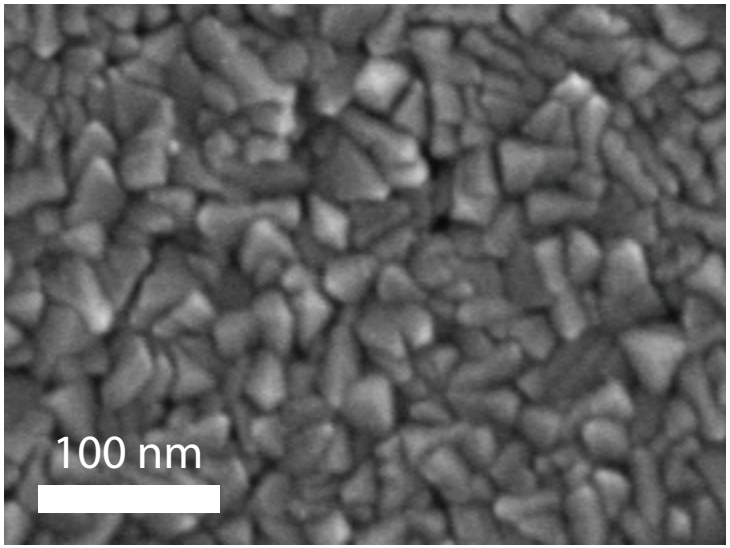
deposition

deposition temperature: 20° C



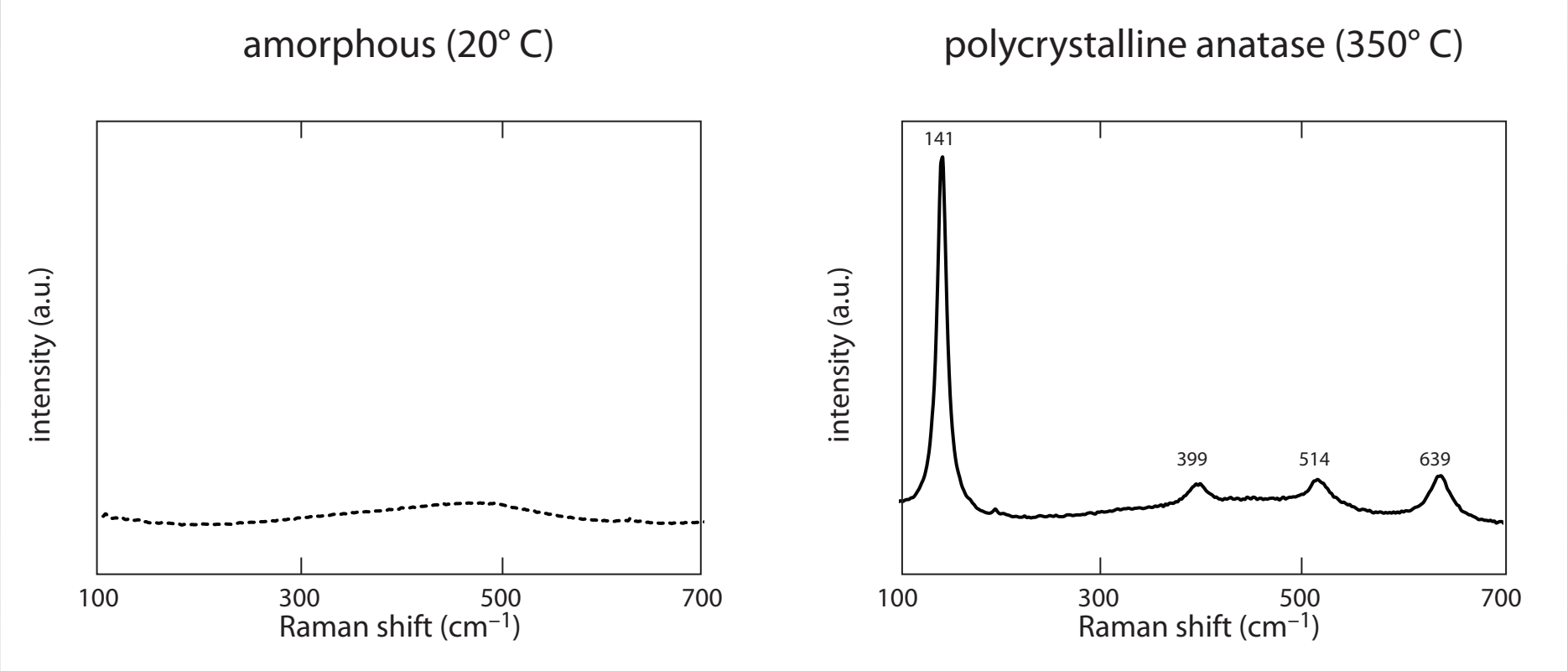
n = 2.32 (1550 nm)

deposition temperature 350° C



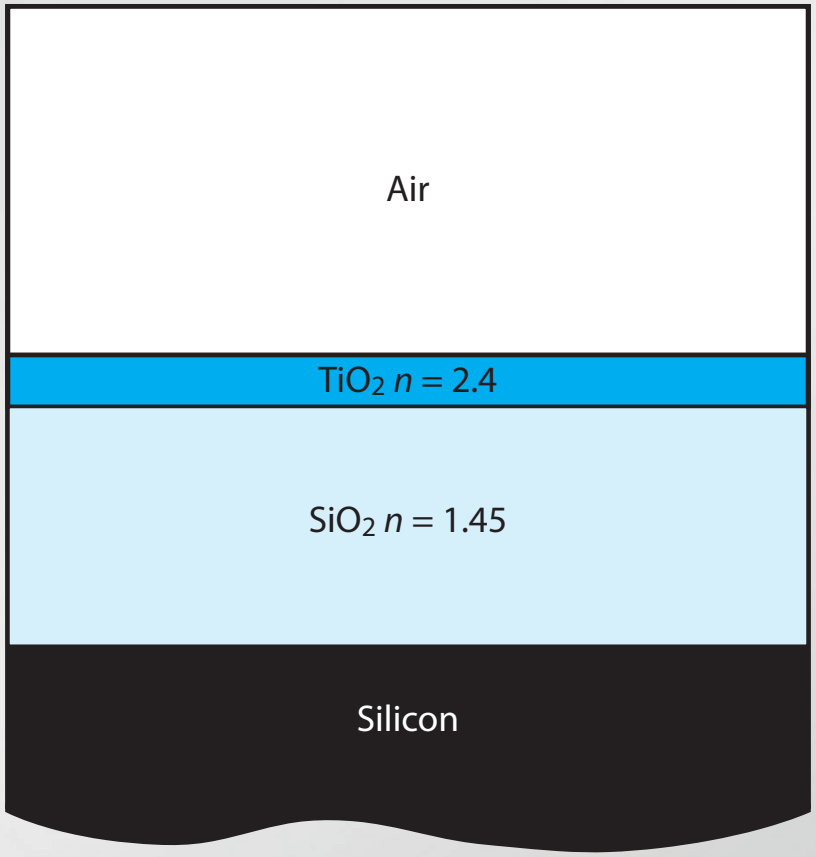
n = 2.37 (1550 nm)

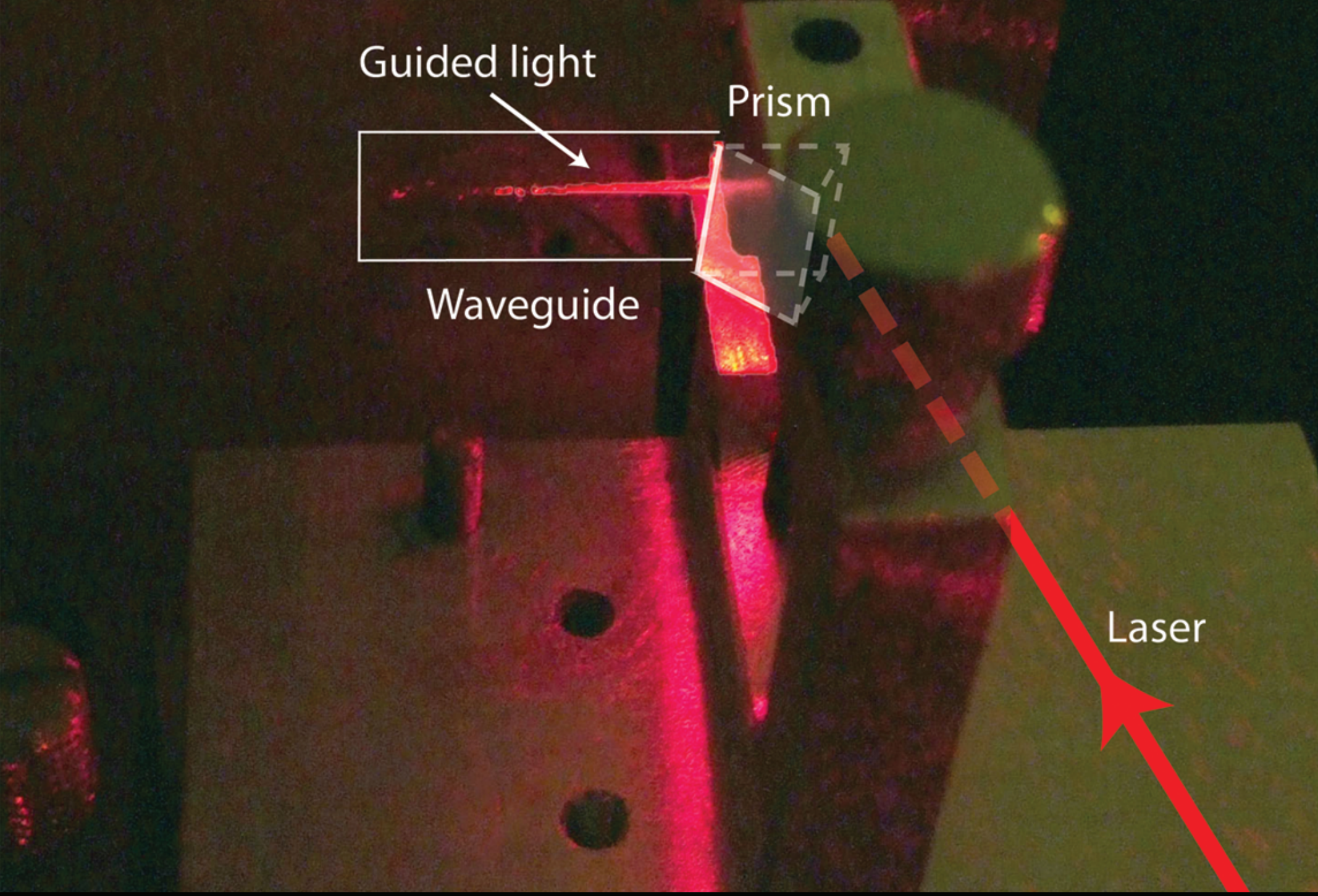
deposition


amorphous (20° C)
intensity (a.u.)
100
300
500
700
Raman shift (cm^{-1})
polycrystalline anatase (350° C)
intensity (a.u.)
141
399
514
639
100
300
500
700
Raman shift (cm^{-1})

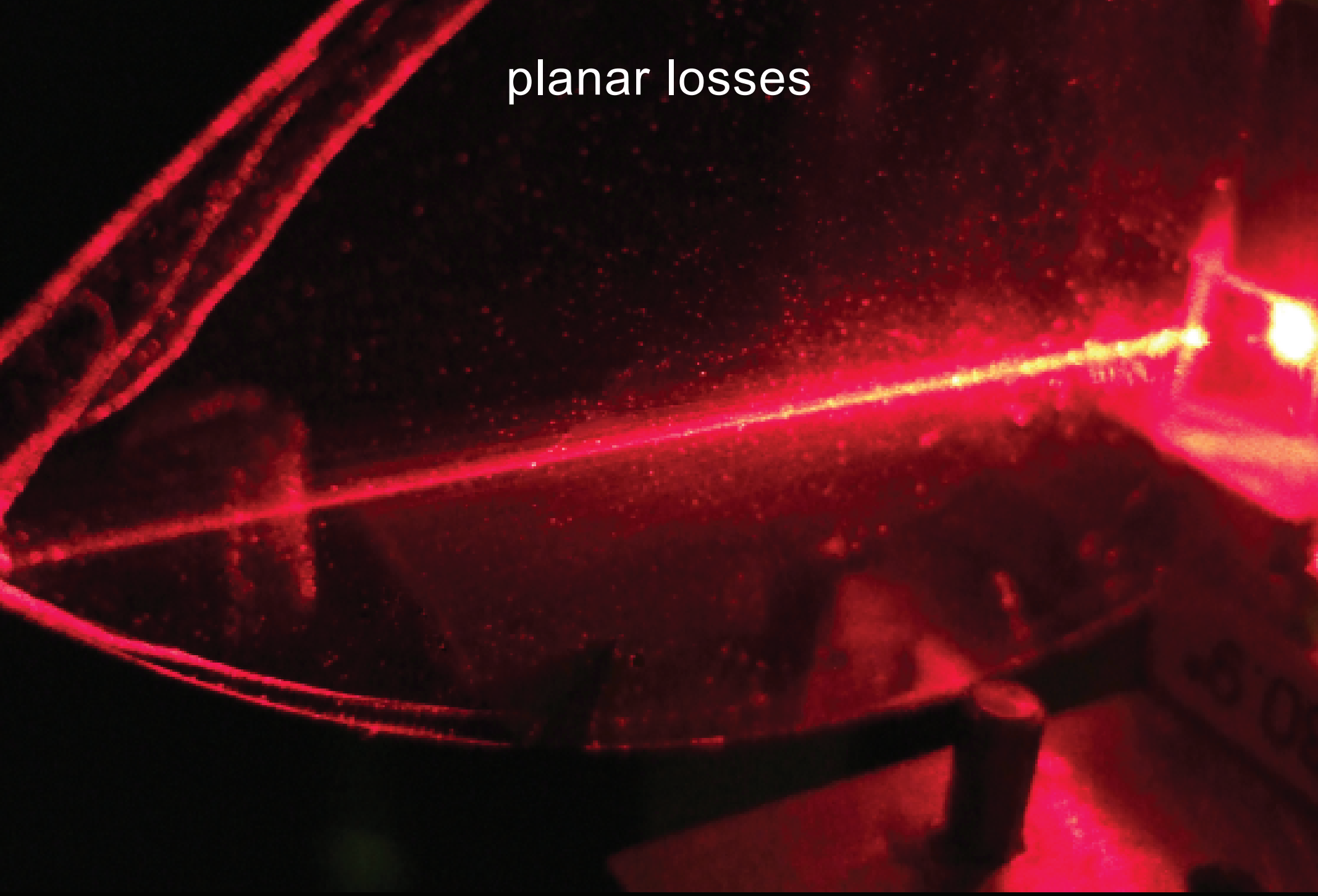
What about losses?

planar waveguides: decoupling losses



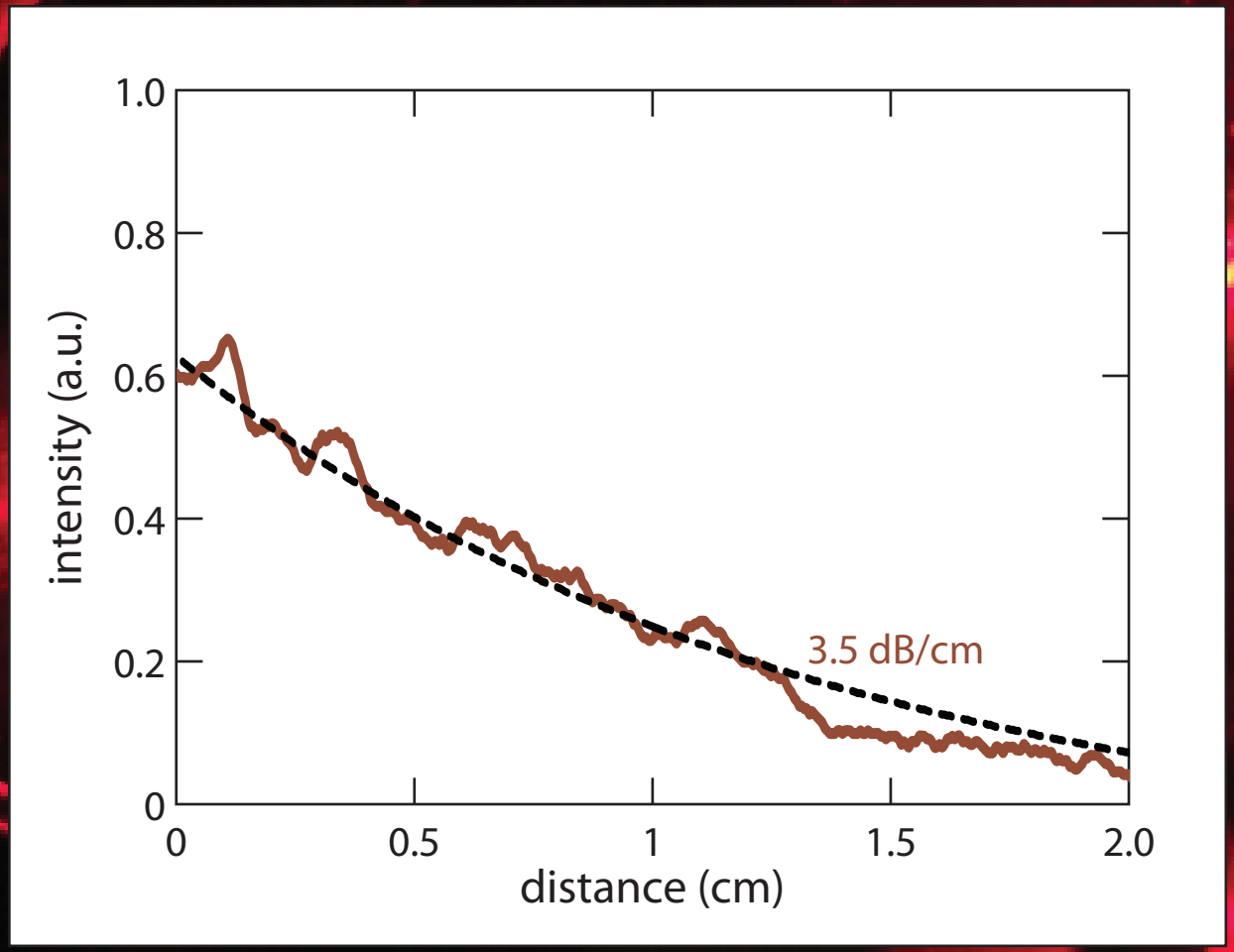


1 fabrication



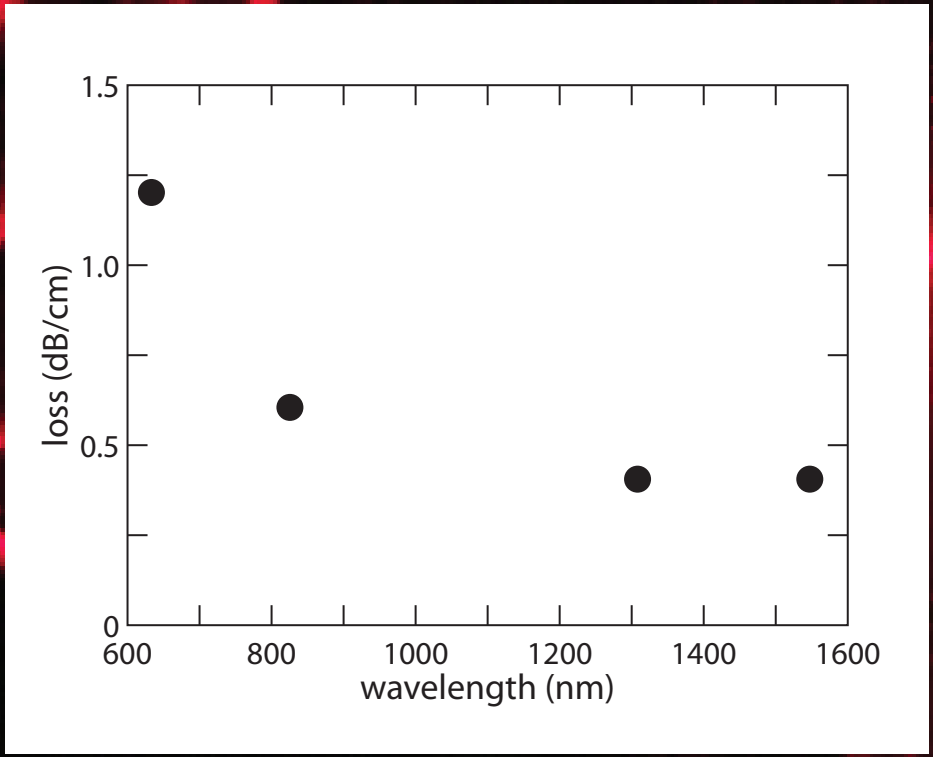
1 fabrication

planar losses

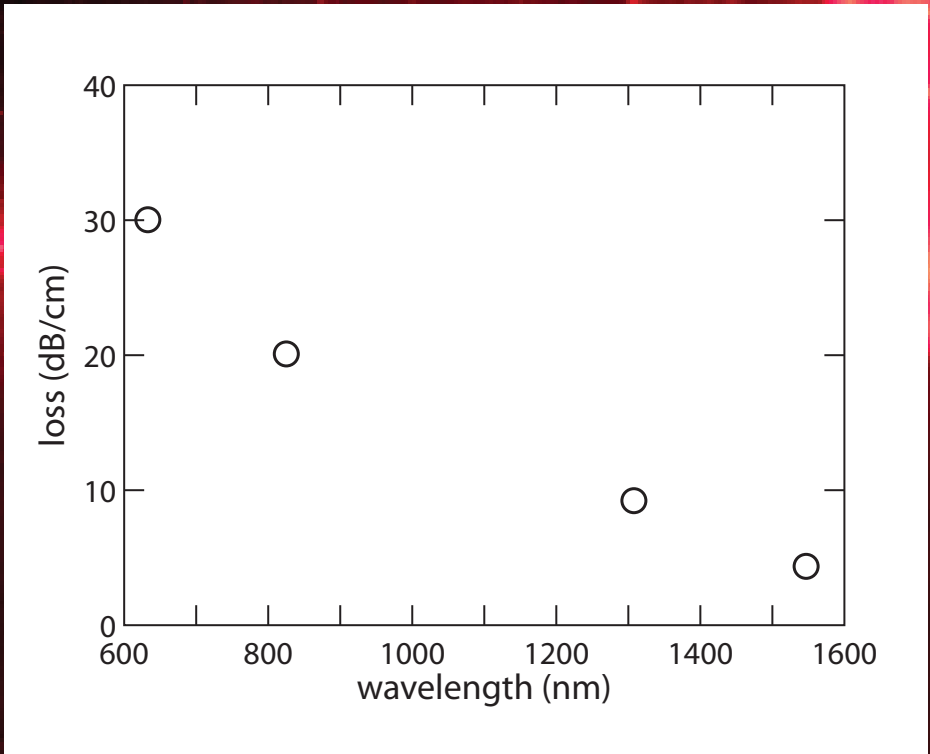


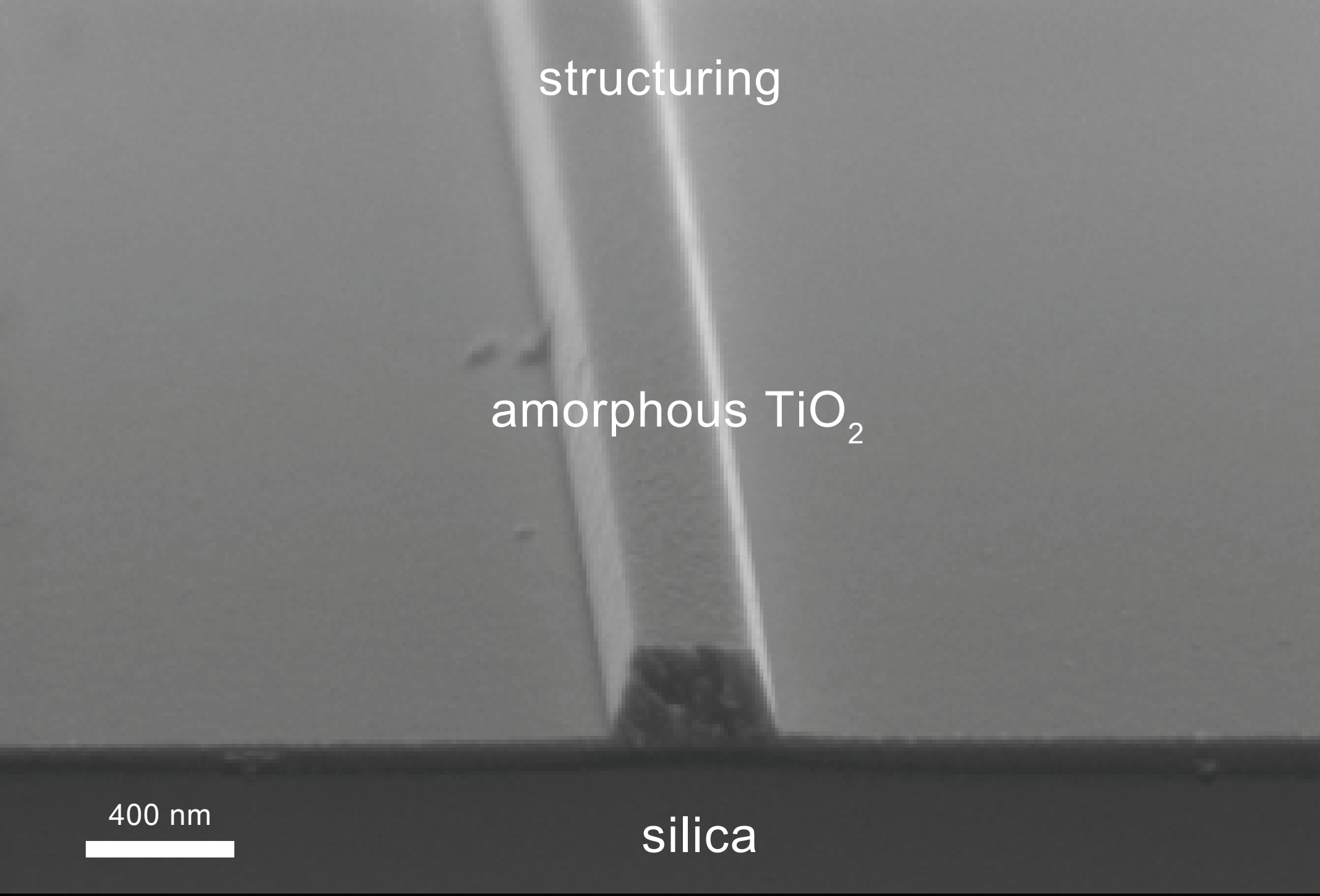
planar losses

amorphous

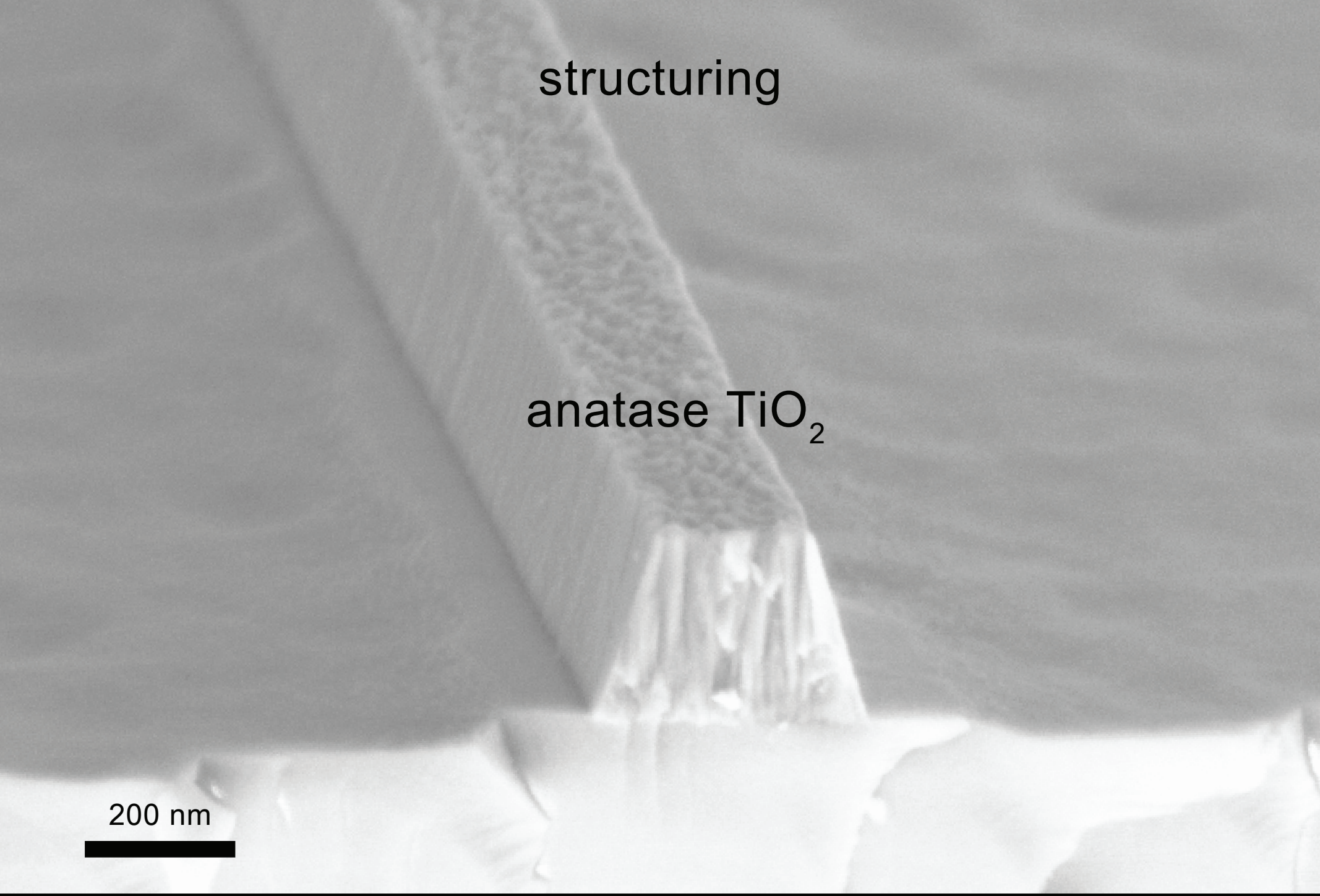


anatase

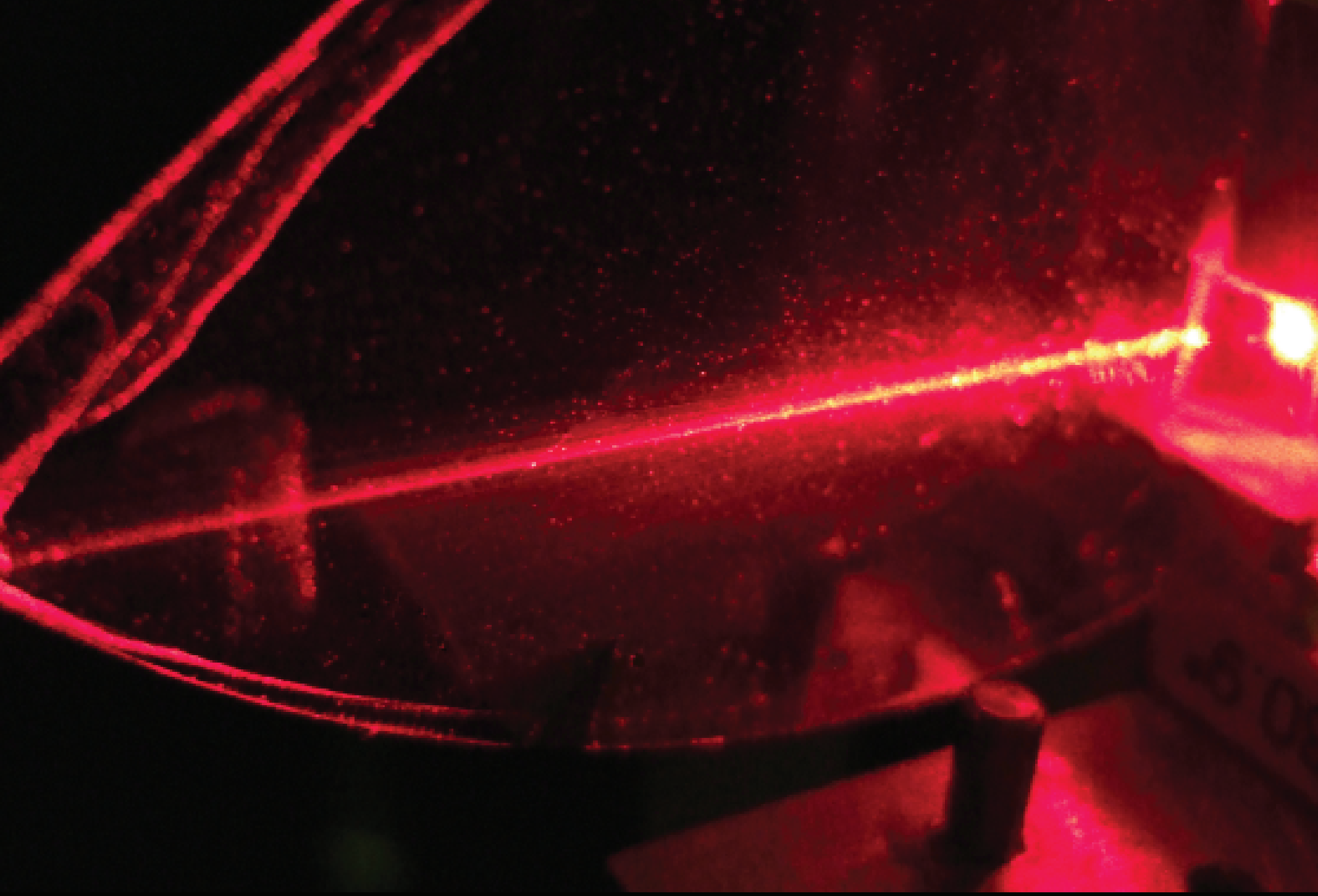




1 fabrication



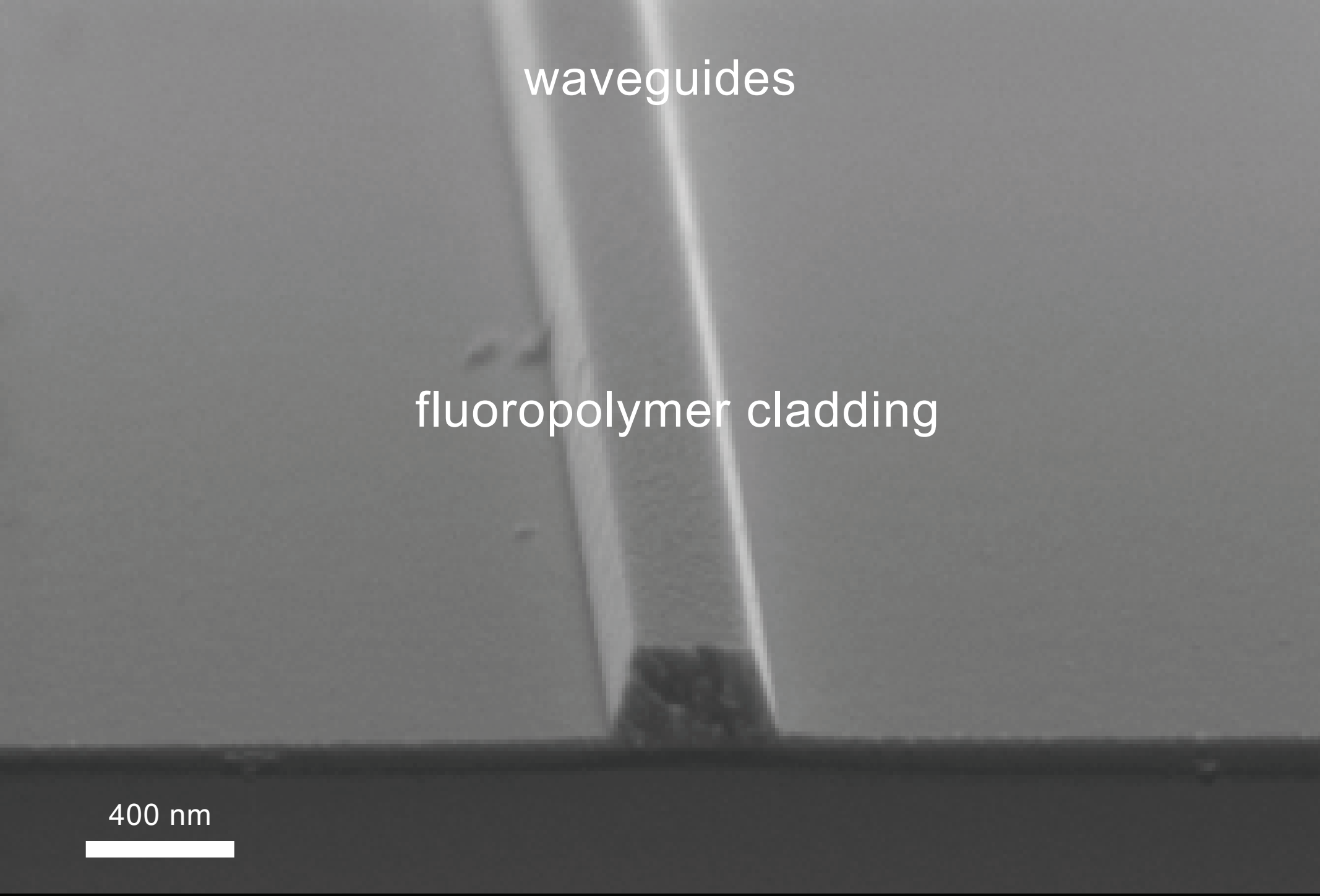
1 fabrication



1 fabrication

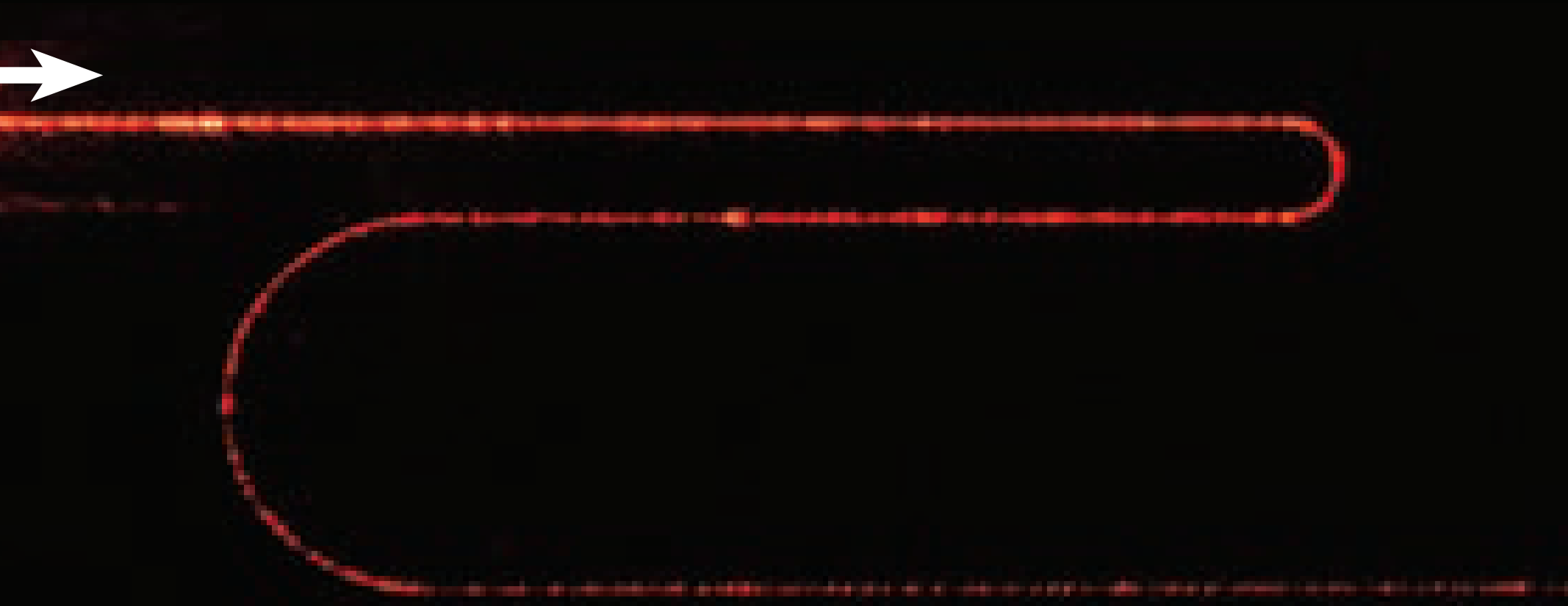
2 linear devices

3 NL properties



1 fabrication

amorphous waveguides



30 dB/cm

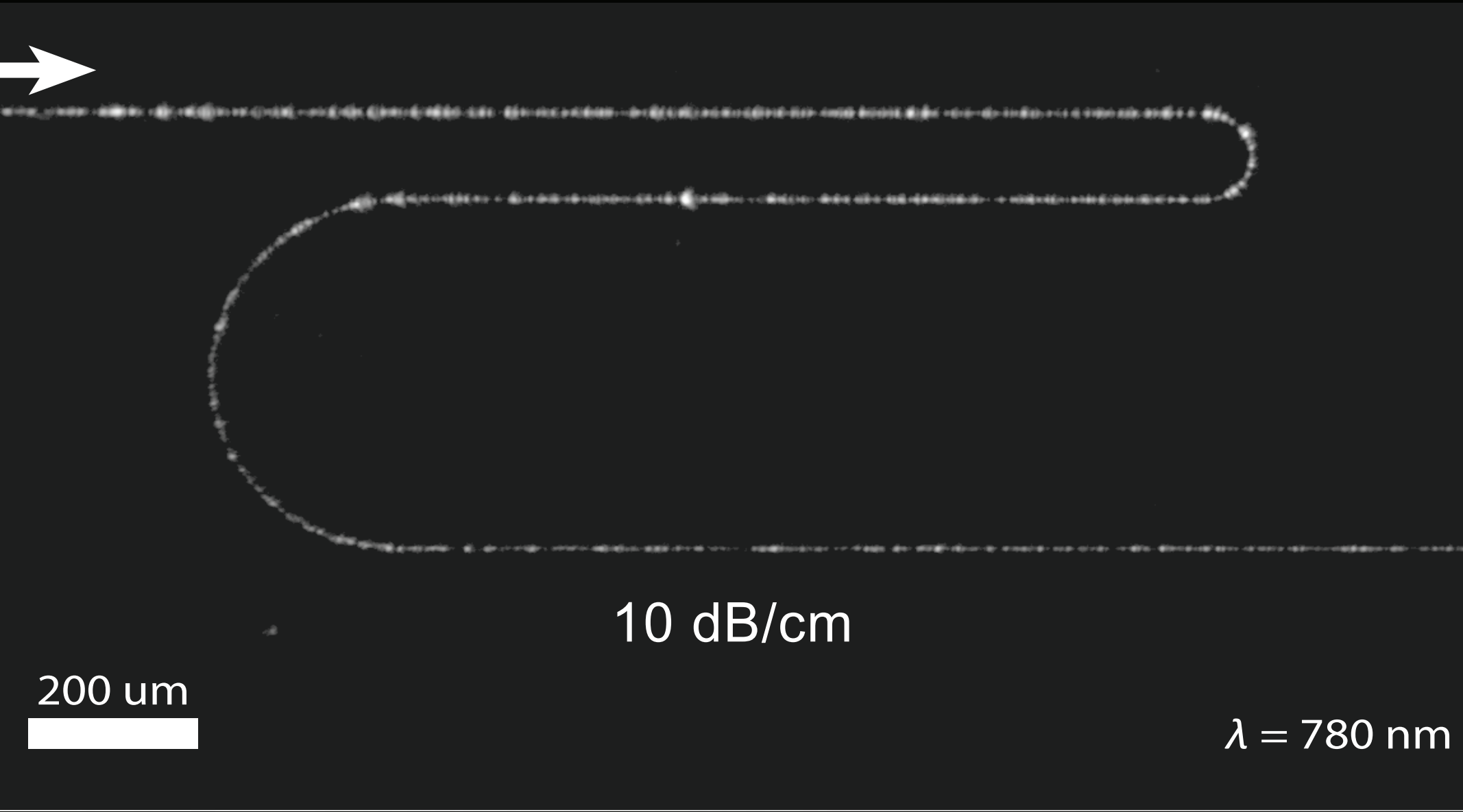
200 um

$\lambda = 632$ nm

1 fabrication

2 linear devices

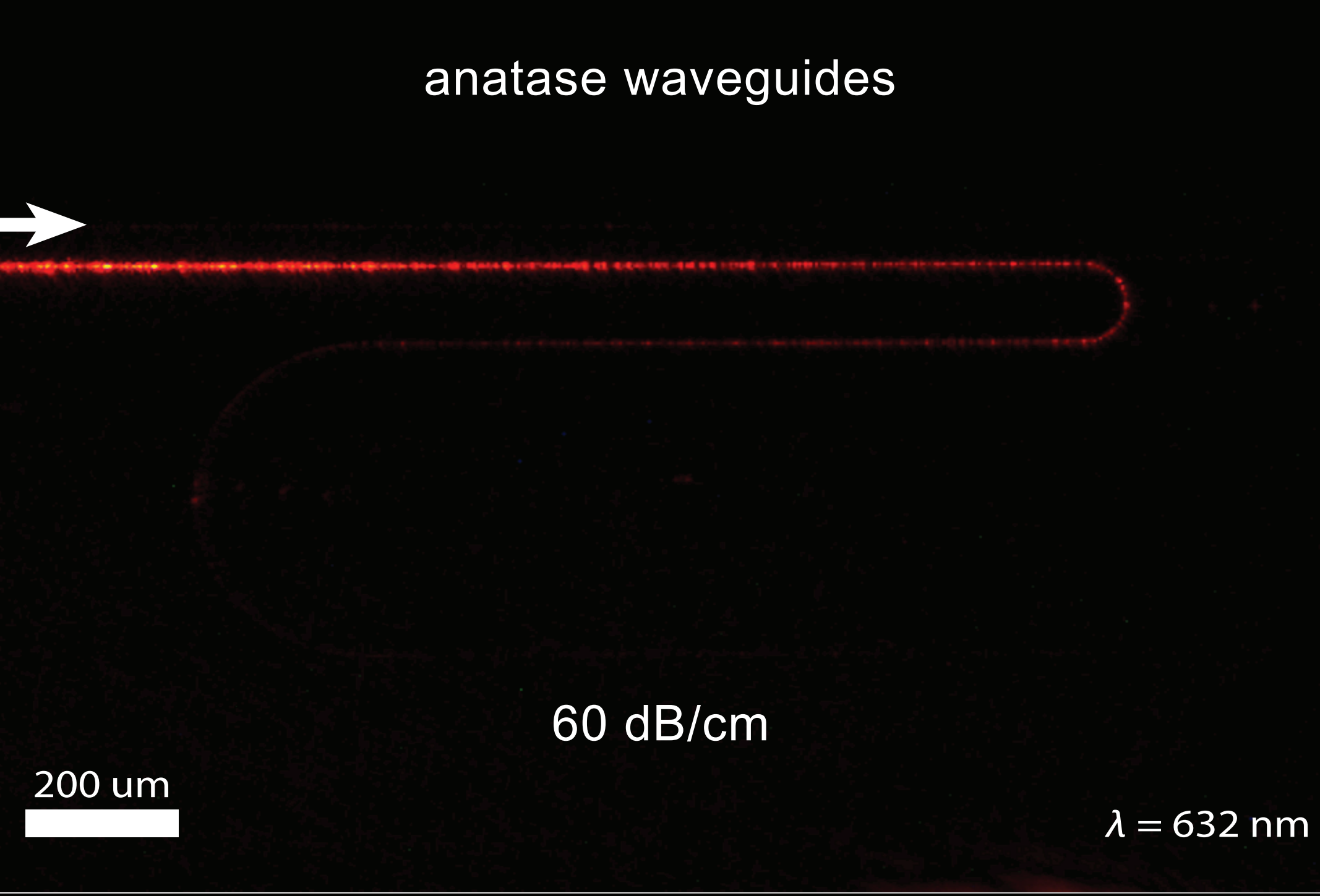
amorphous waveguides



1 fabrication

2 linear devices

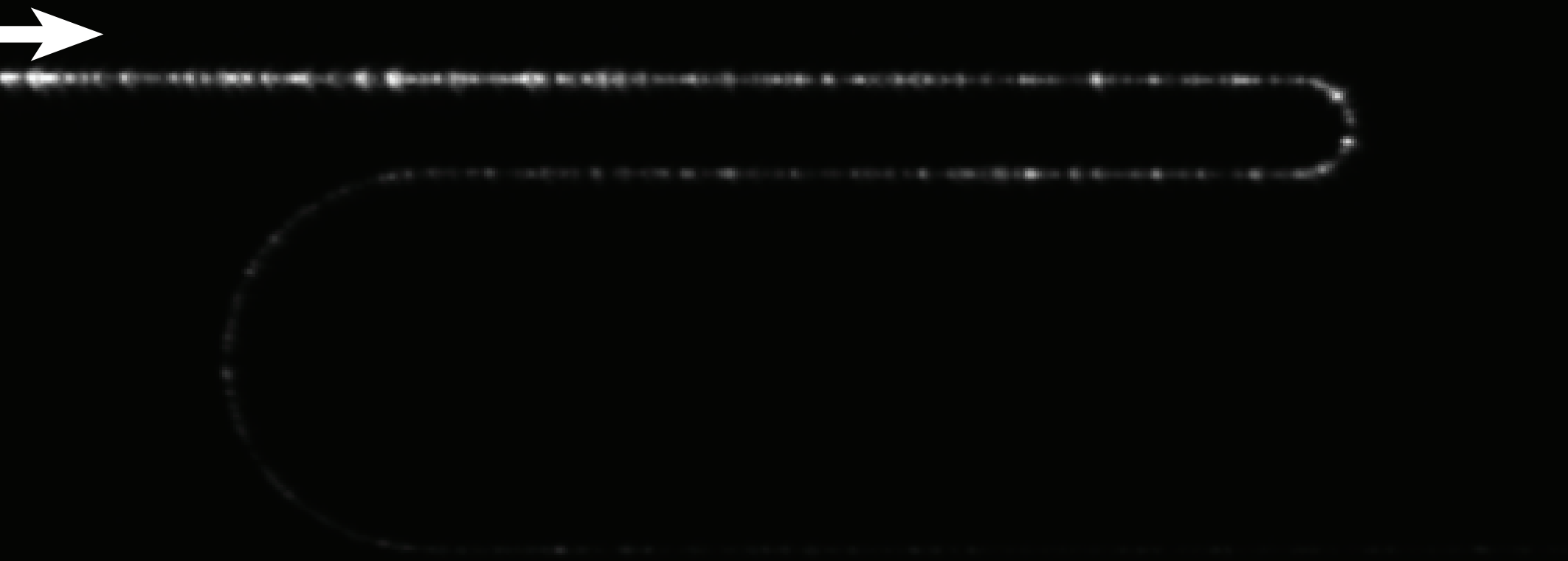
anatase waveguides



1 fabrication

2 linear devices

anatase waveguides



40 dB/cm

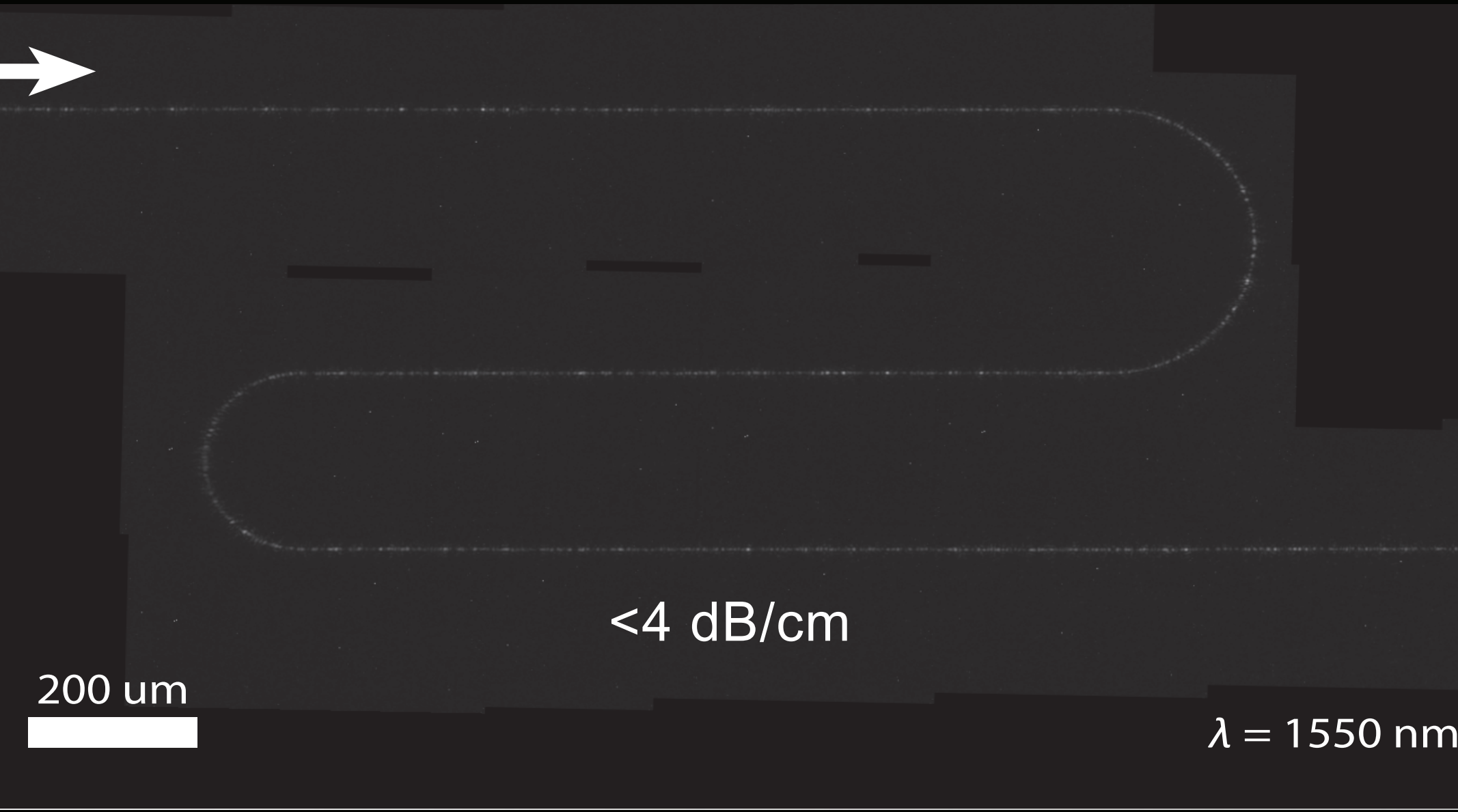
200 um

$\lambda = 780$ nm

1 fabrication

2 linear devices

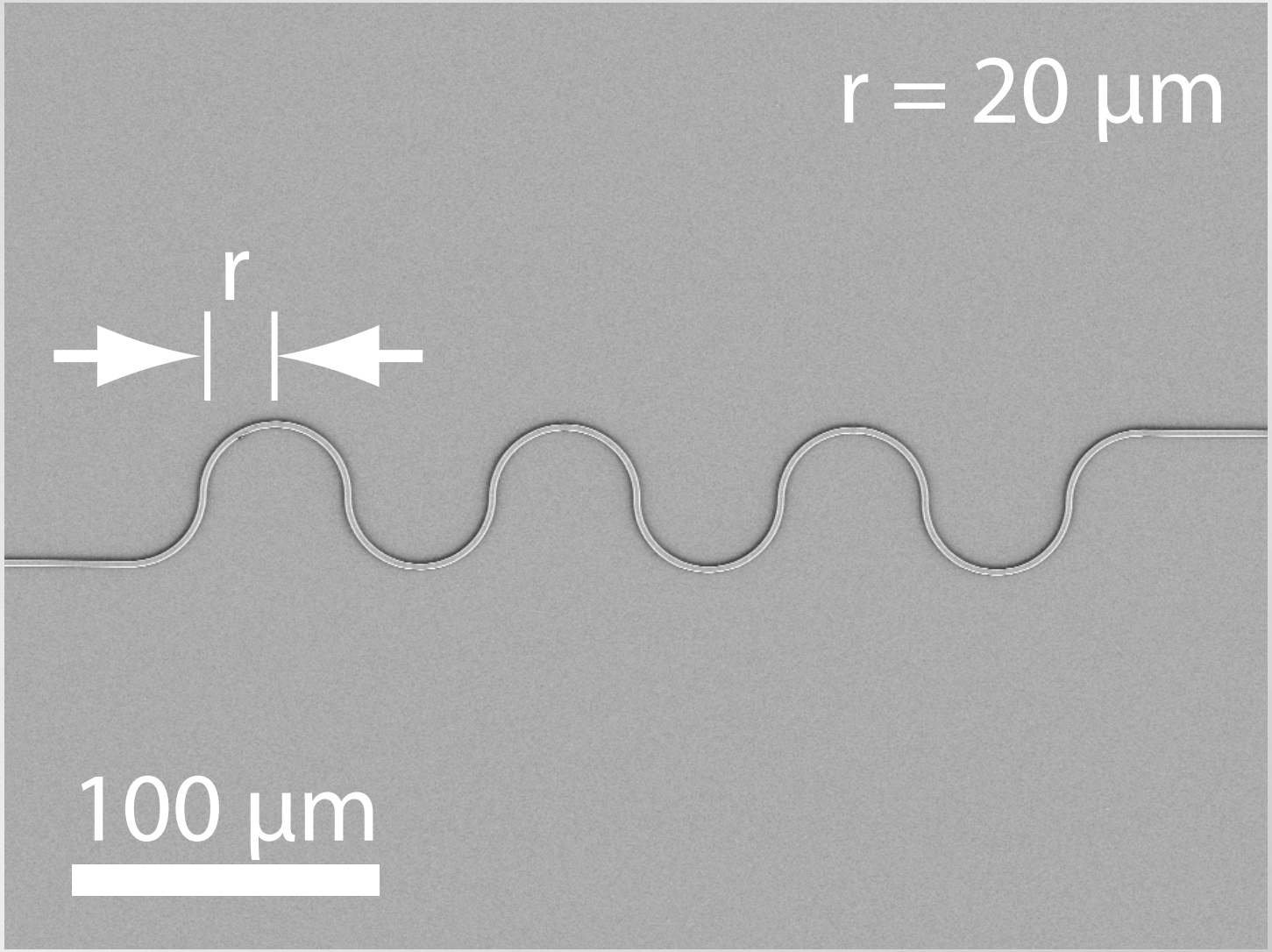
anatase waveguides



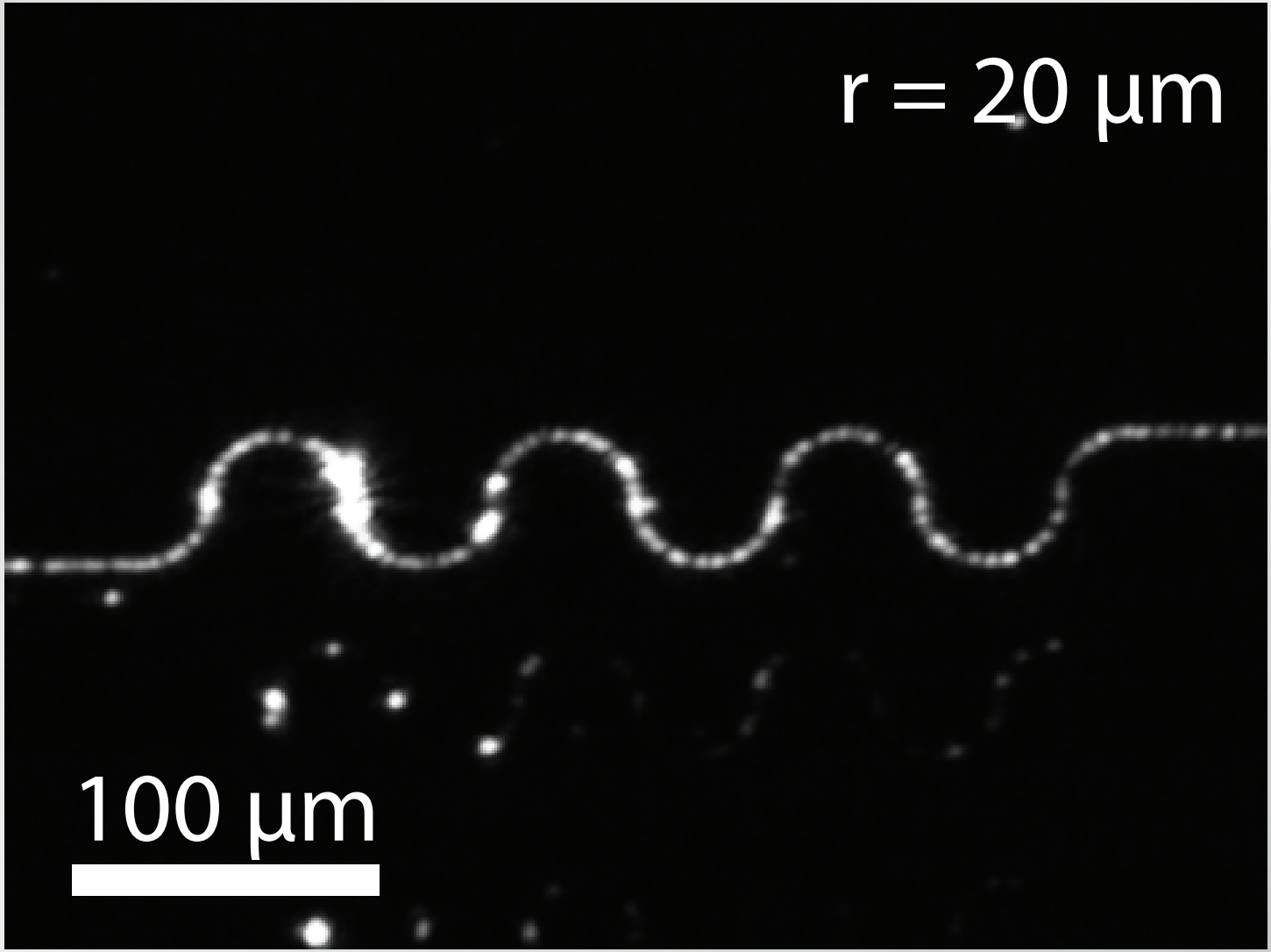
1 fabrication

2 linear devices

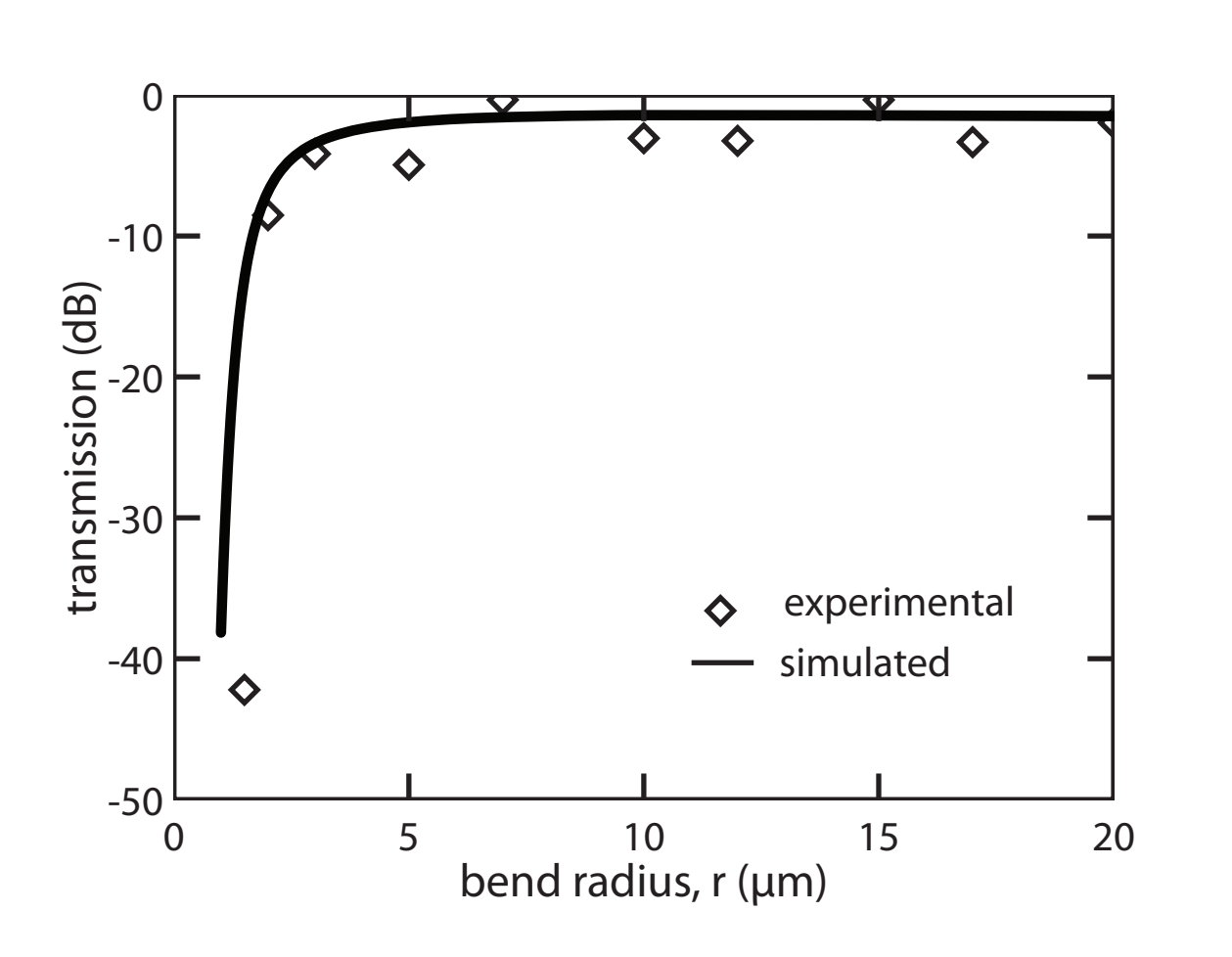
microbends



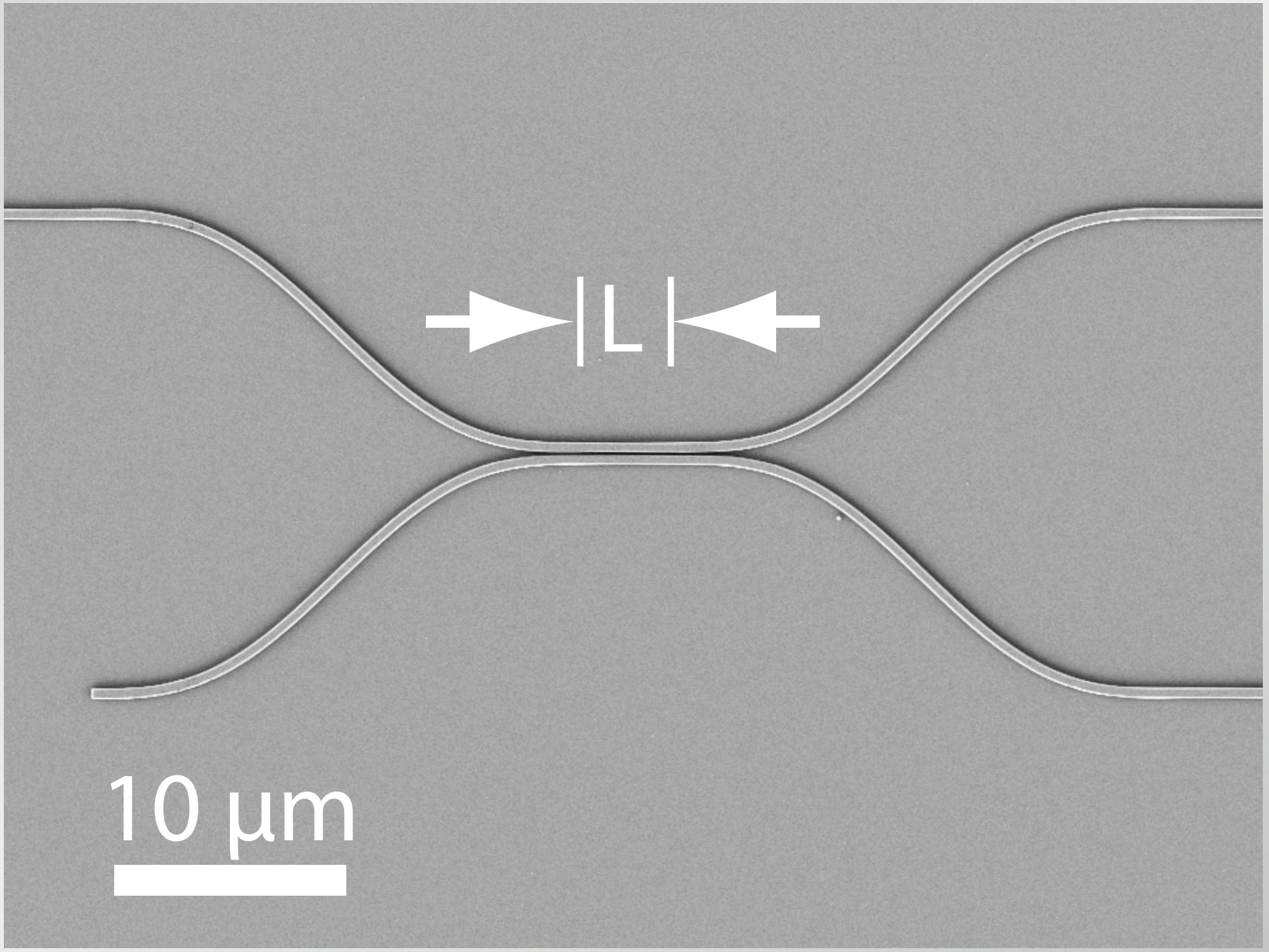
microbends



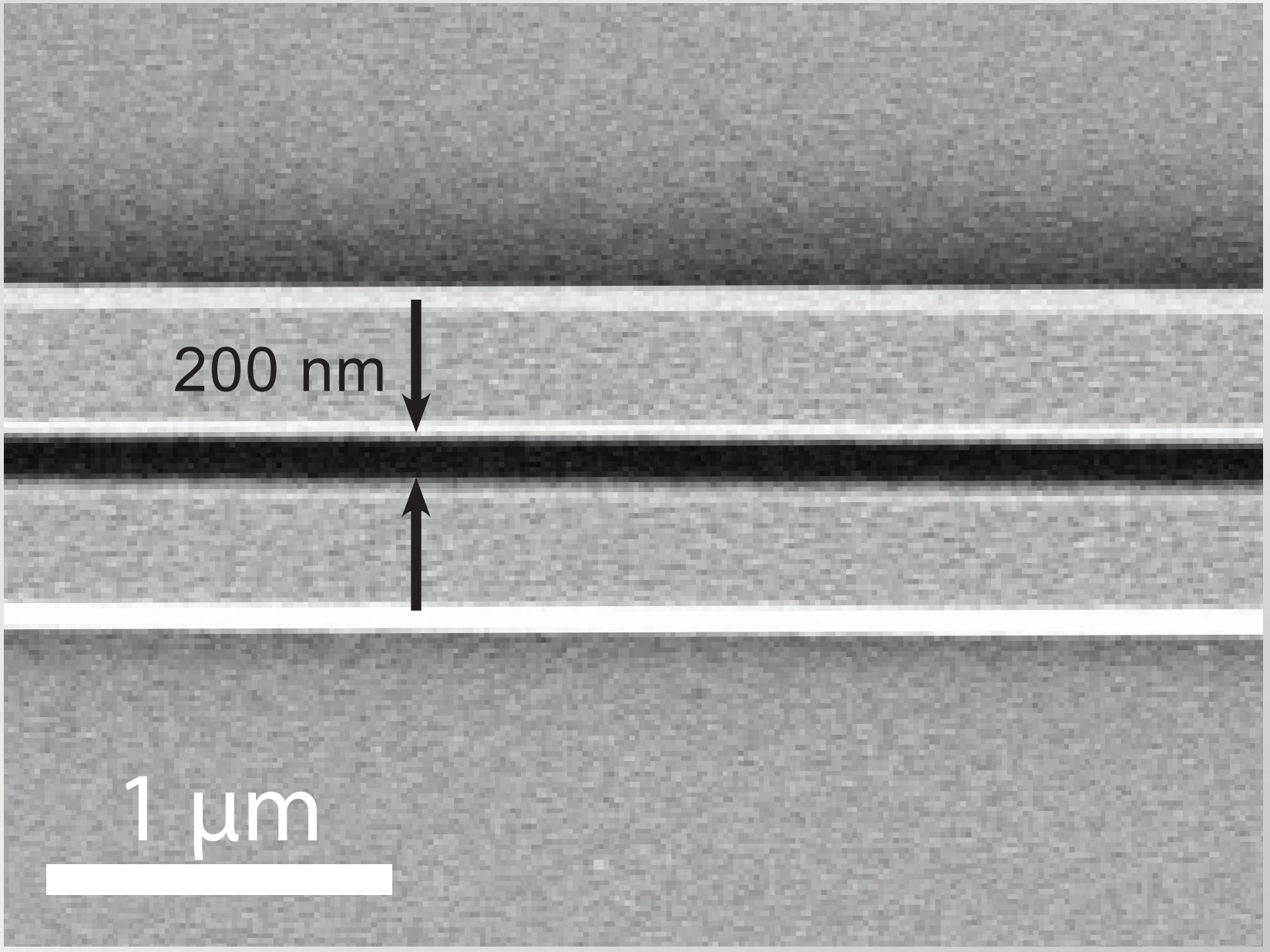
microbends


0
-10
-20
-30
-40
-50
transmission (dB)
0
5
10
15
20
bend radius, r (μm)
experimental
simulated

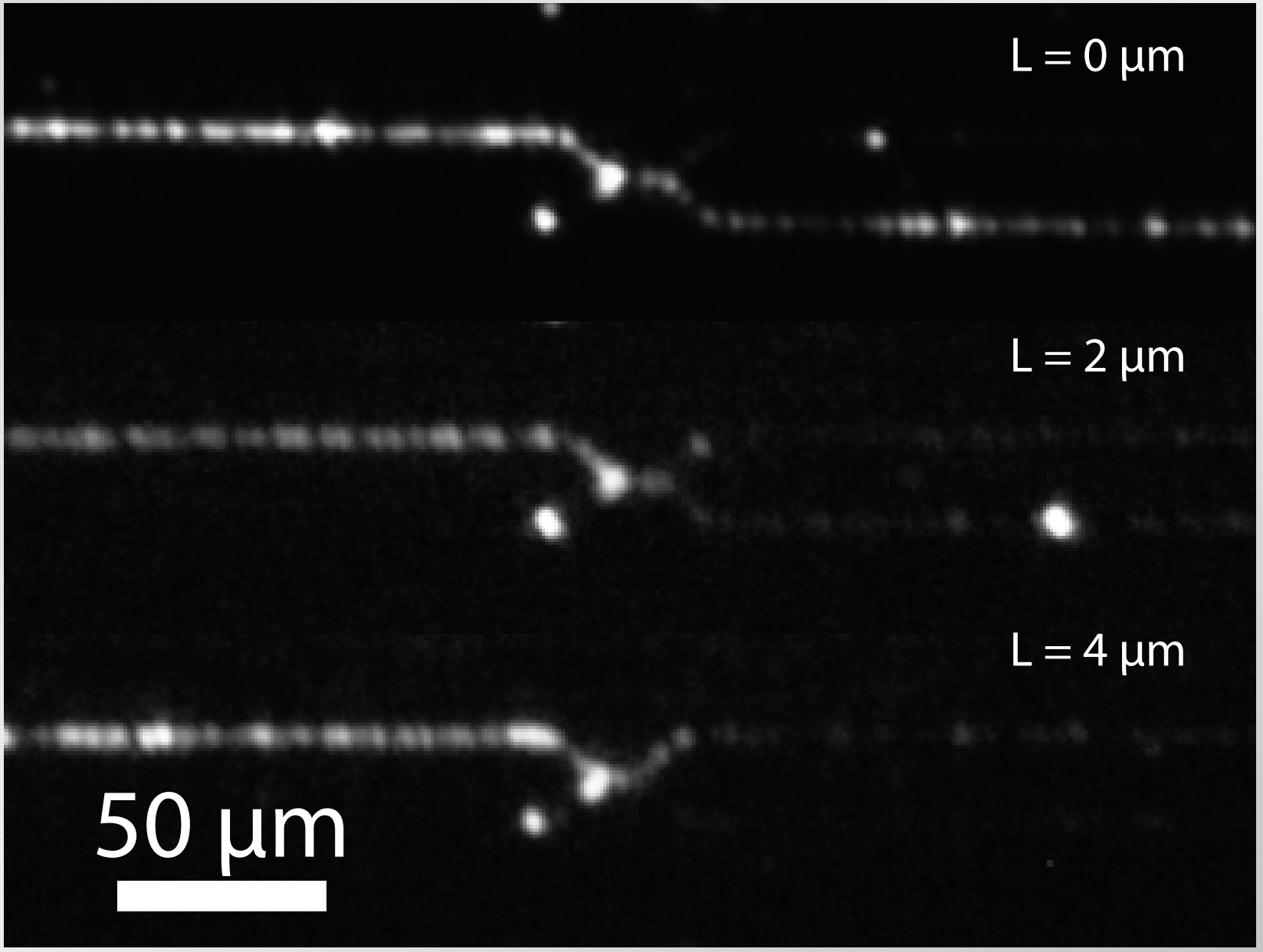
directional couplers

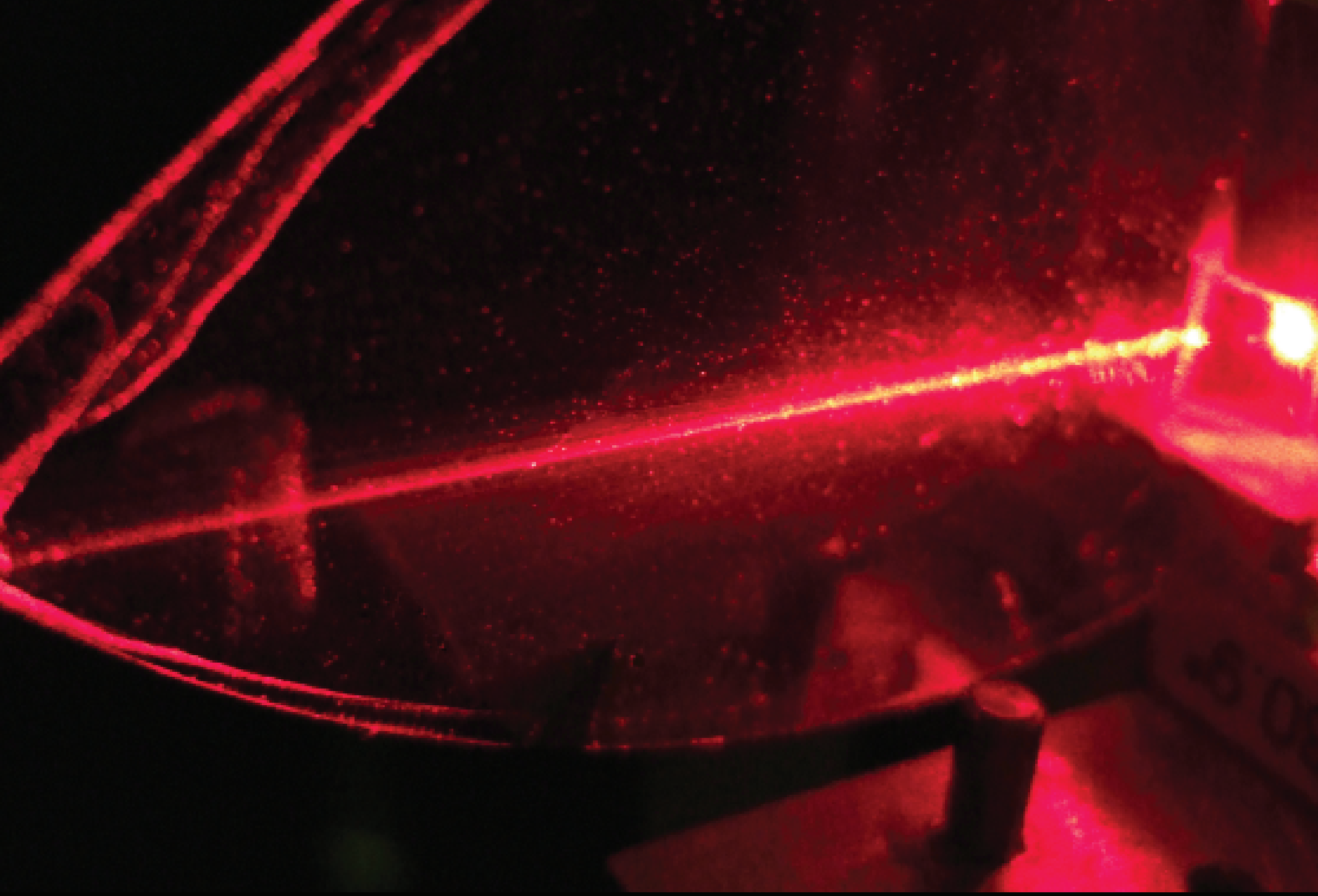


directional couplers



variable splitters



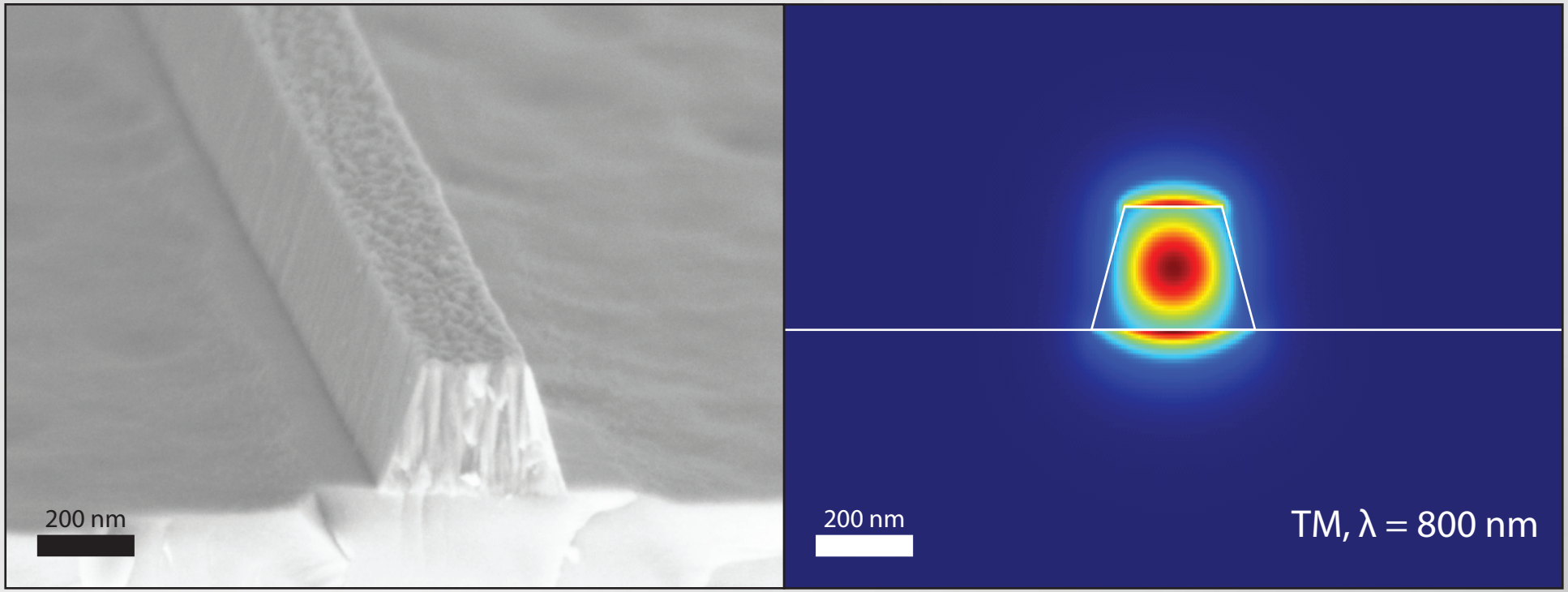


1 fabrication

2 linear devices

3 NL properties

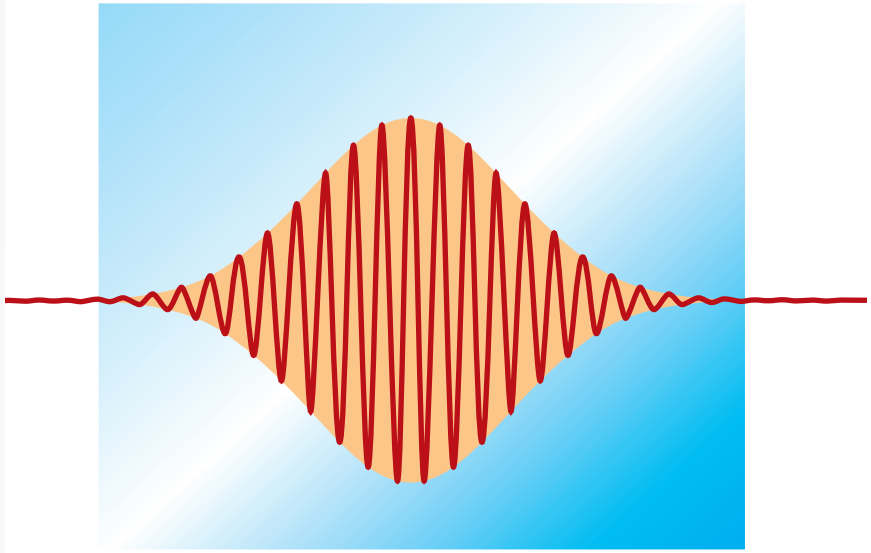
the first nonlinear optics in TiO_2



1 fabrication 2 linear devices 3 NL properties

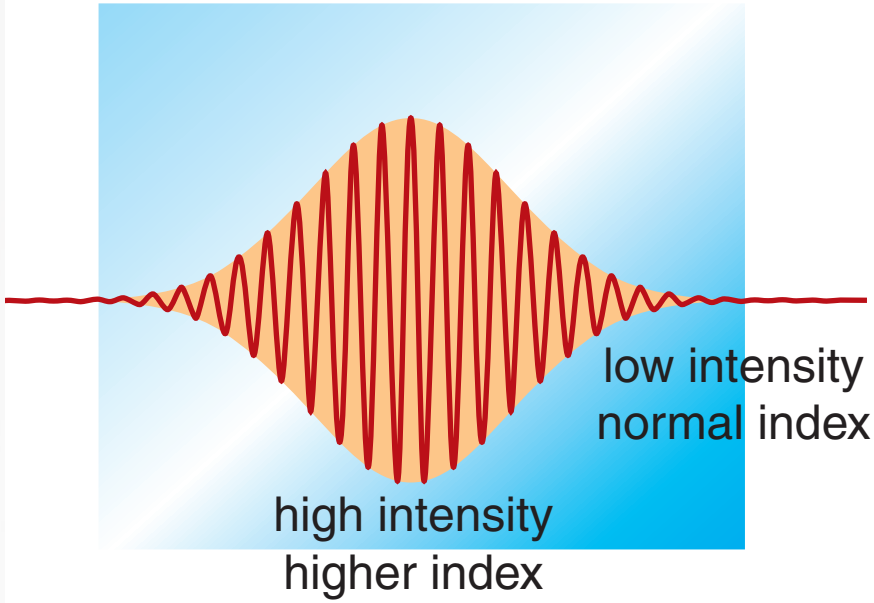
spectral broadening

$$n = n_0 + n_2 I$$



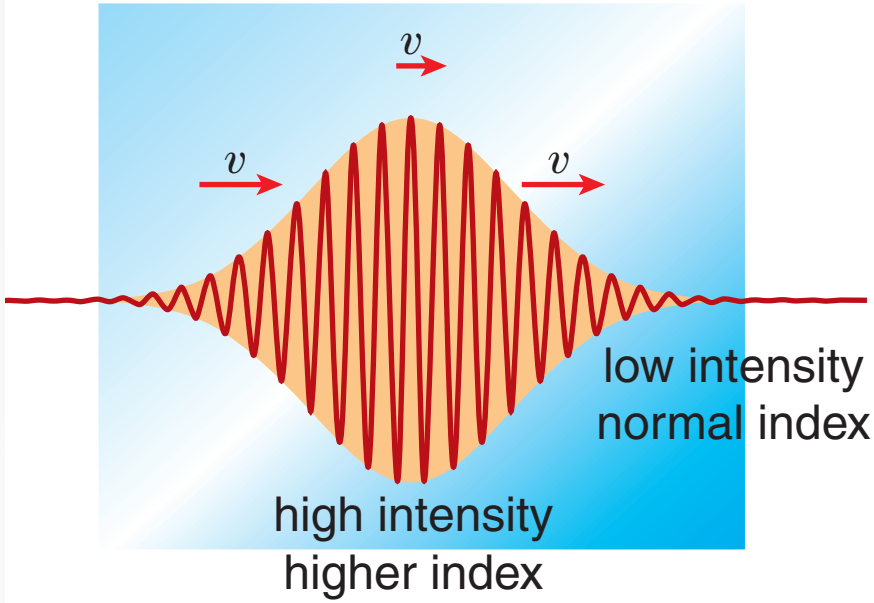
spectral broadening

$$n = n_0 + n_2 I$$



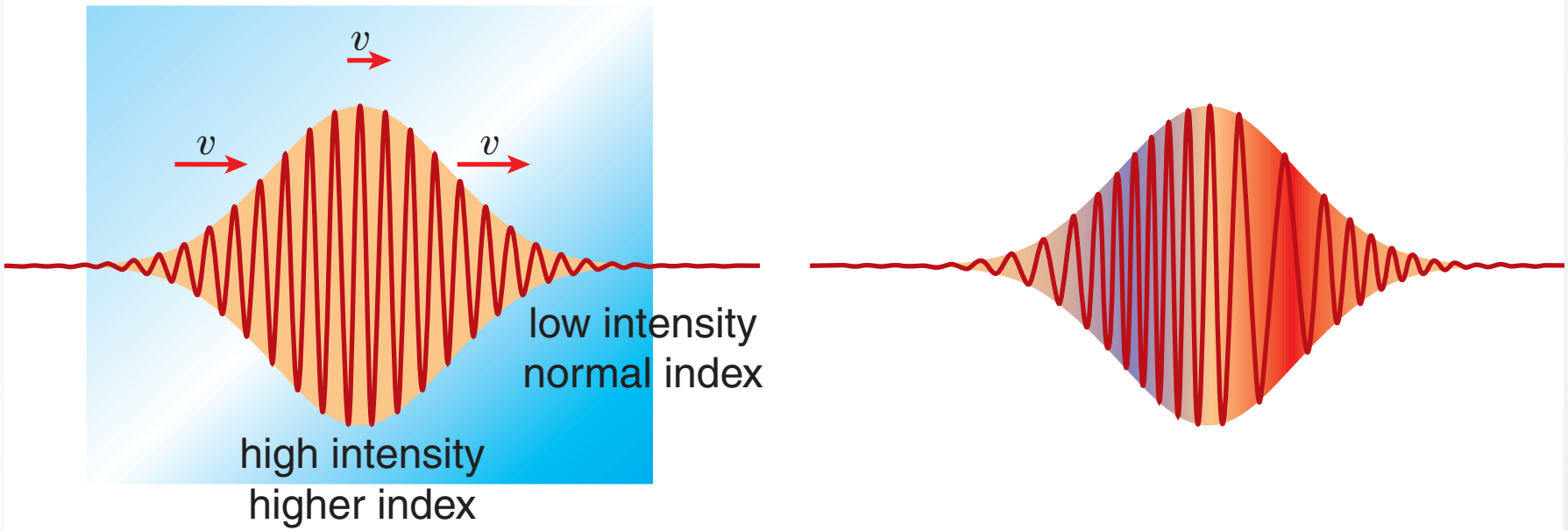
spectral broadening

$$n = n_0 + n_2 I$$



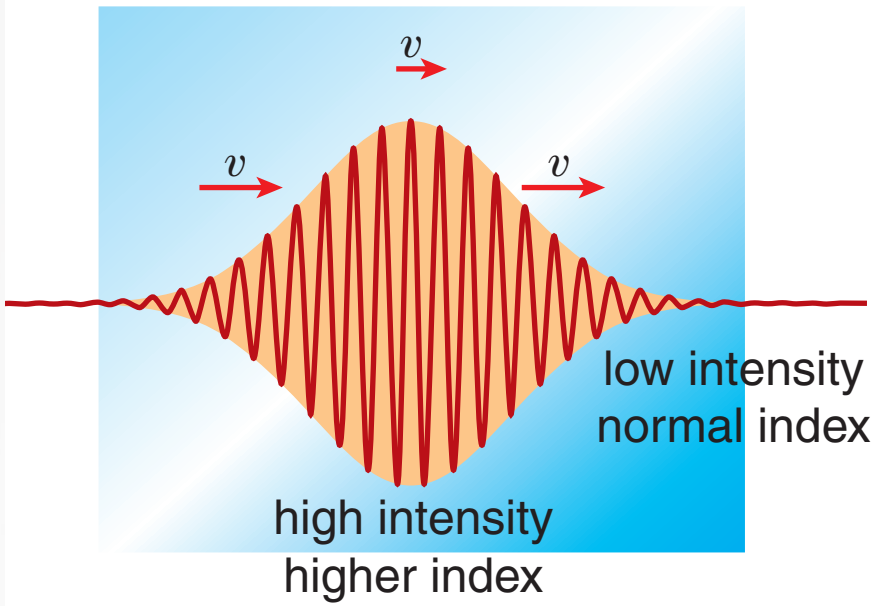
spectral broadening

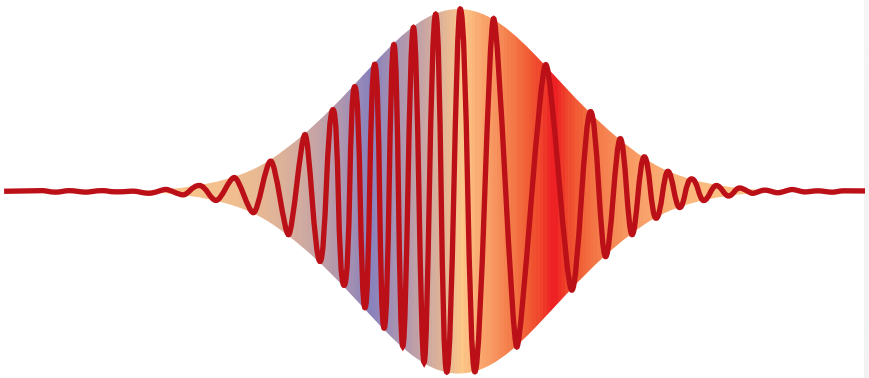
$$n = n_0 + n_2 I$$



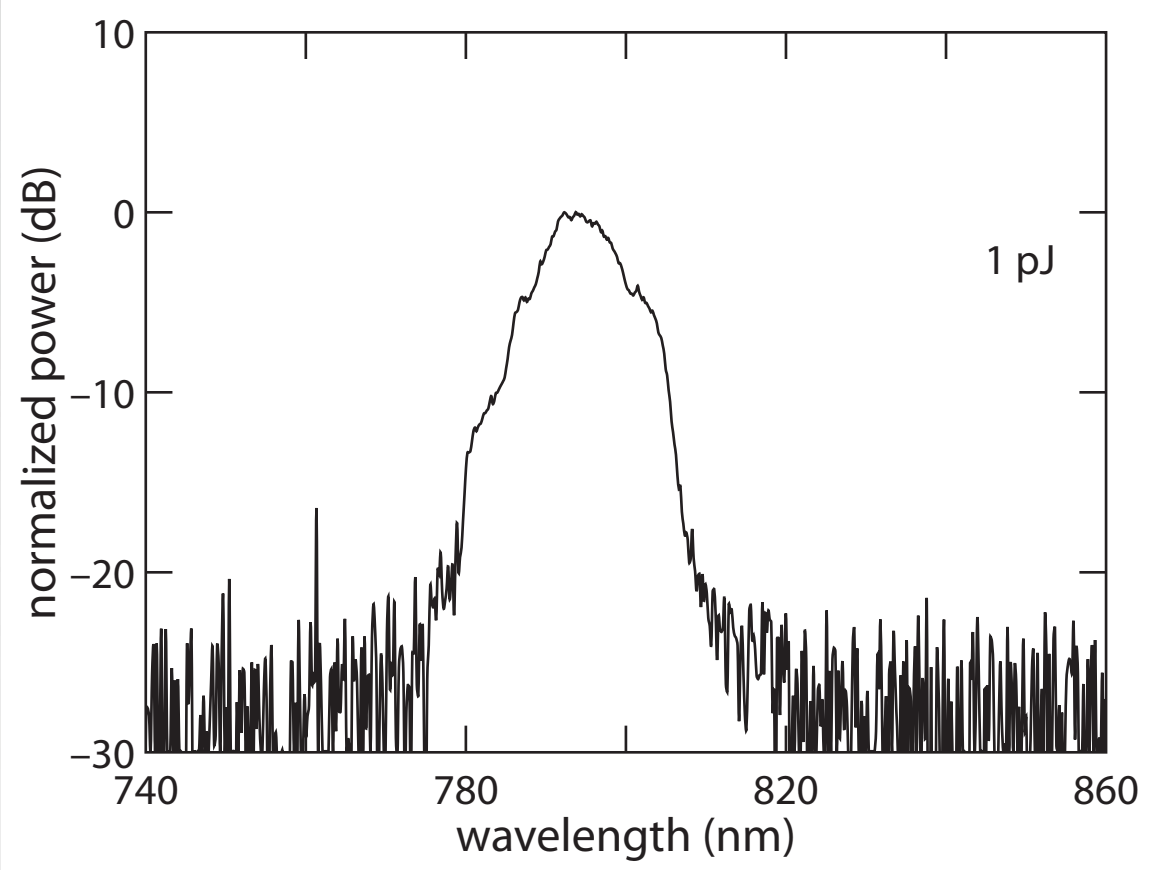
spectral broadening

$$n = n_0 + n_2 I$$





the first nonlinear optics in TiO_2



1 fabrication 2 linear devices 3 NL properties

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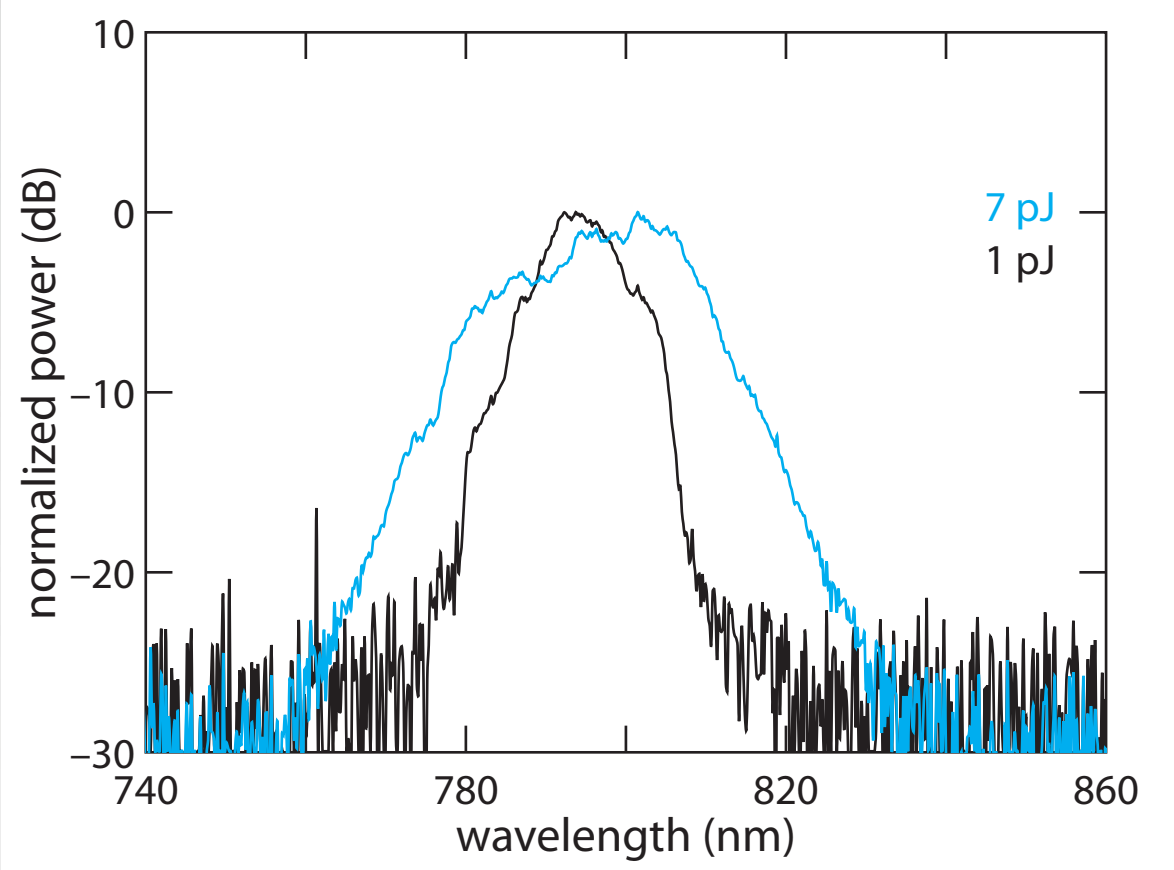

1 fabrication 2 linear devices 3 NL properties

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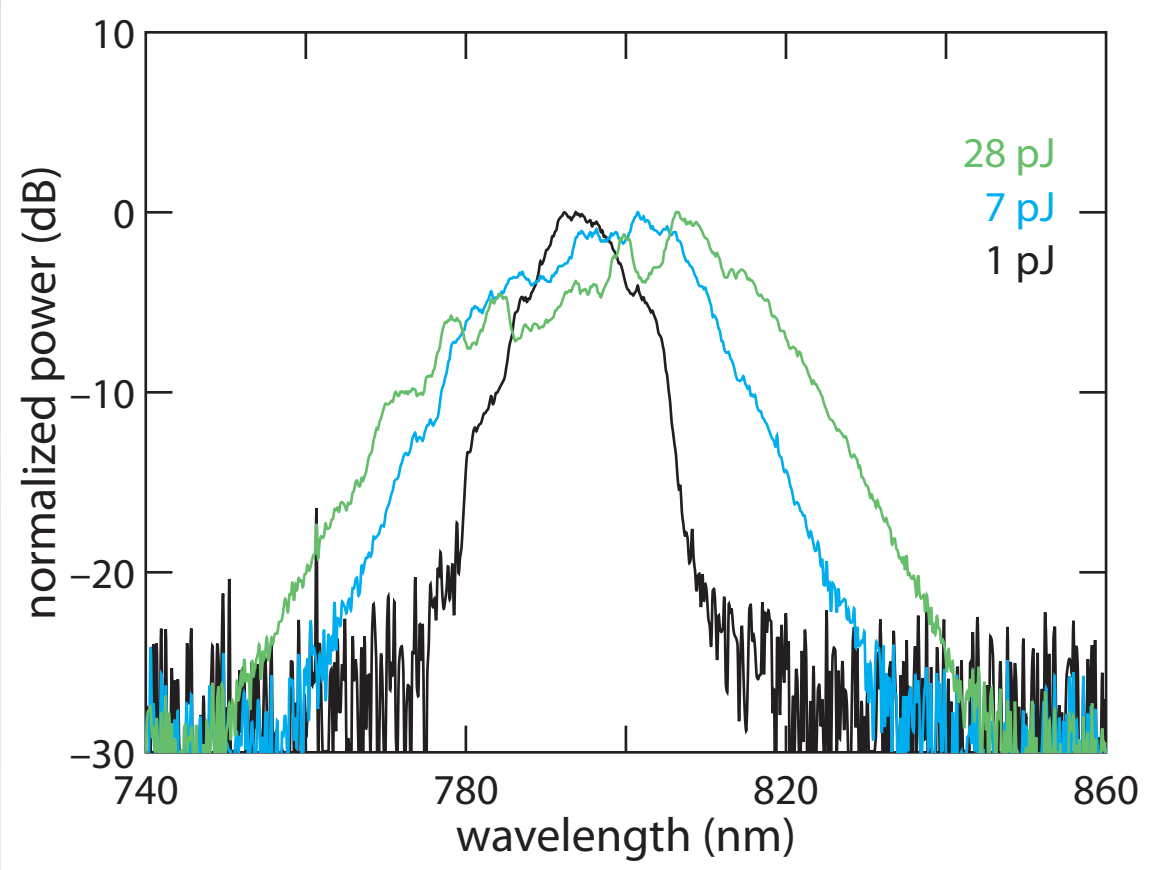

1 fabrication 2 linear devices 3 NL properties

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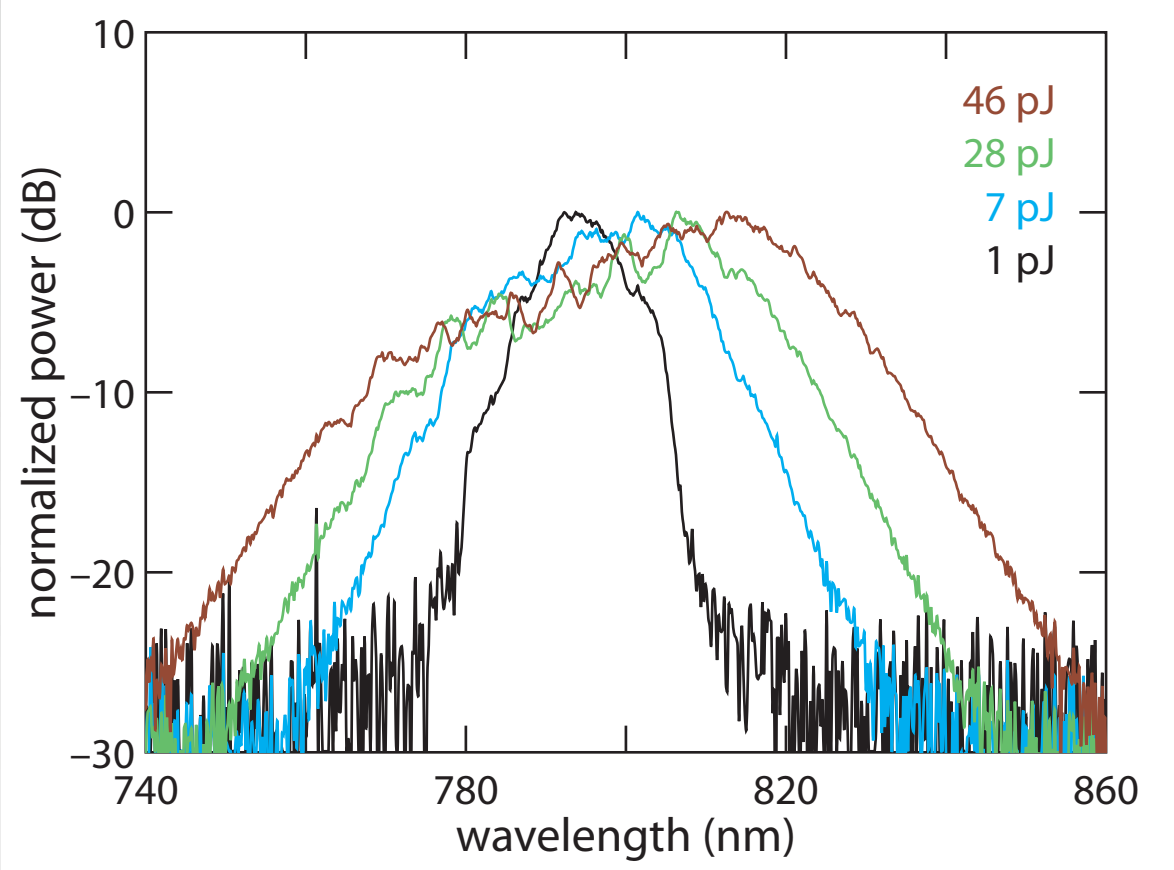
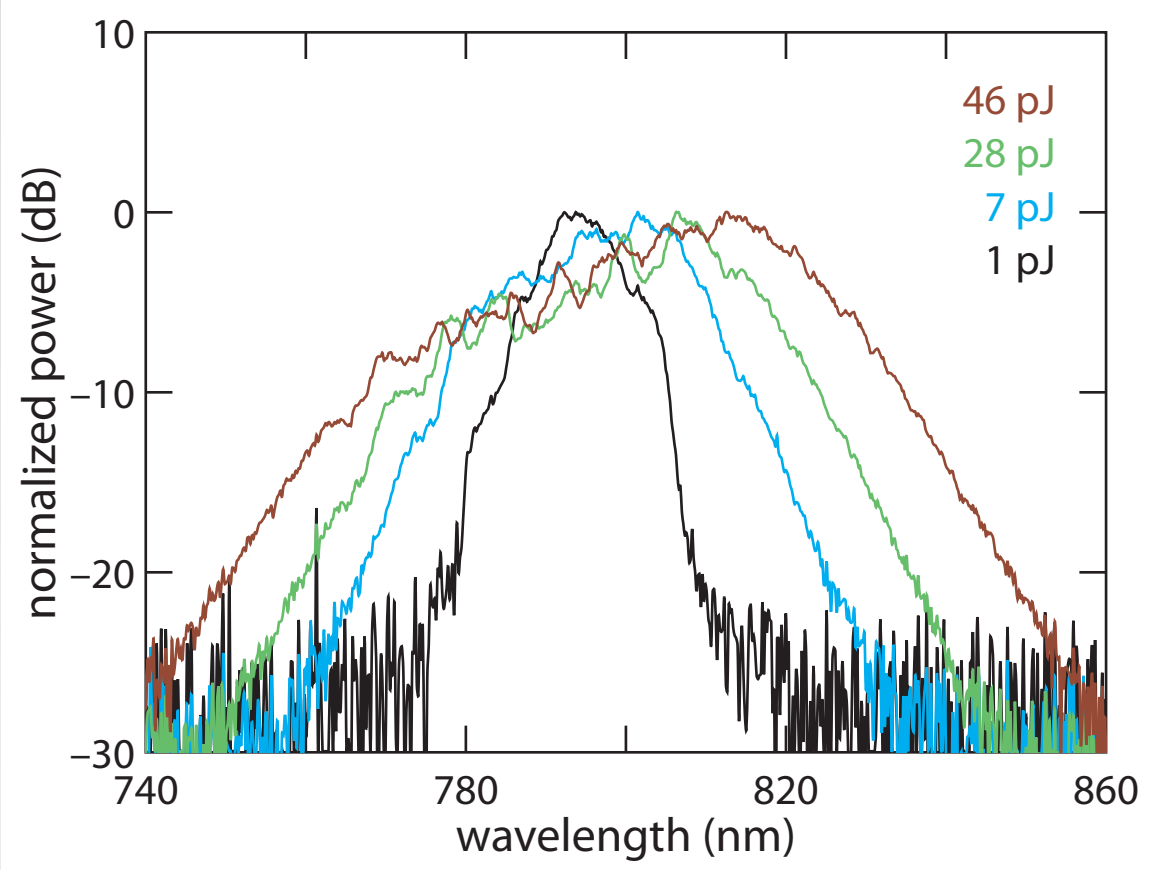


1 fabrication 2 linear devices 3 NL properties

the first nonlinear optics in TiO_2

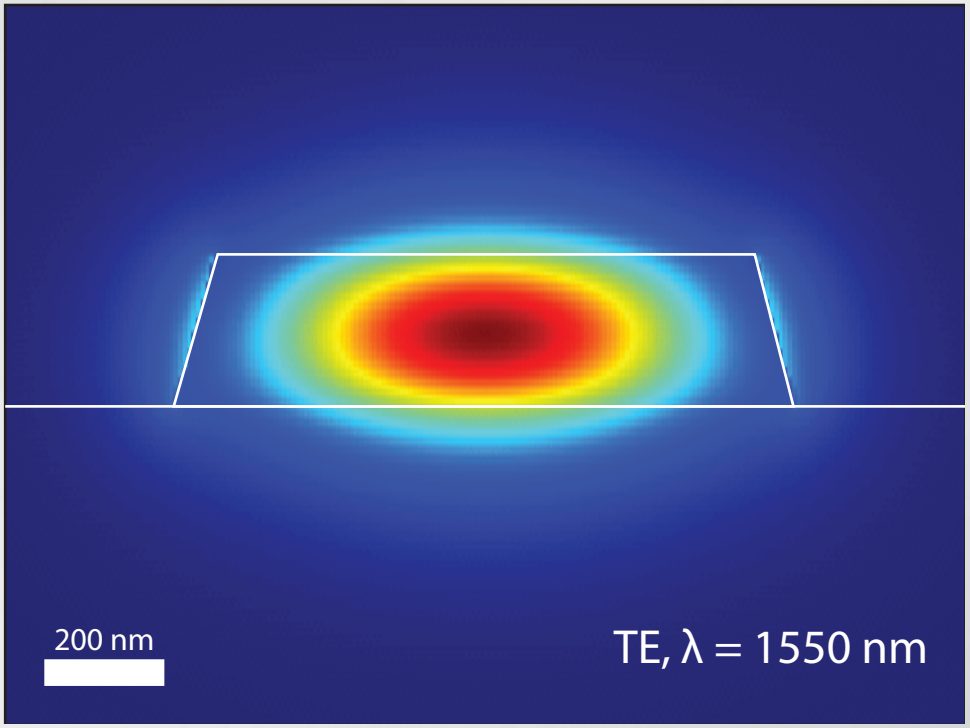


$\gamma \sim 40\ W^{-1}m^{-1}$

(~40,000 x silica fiber)

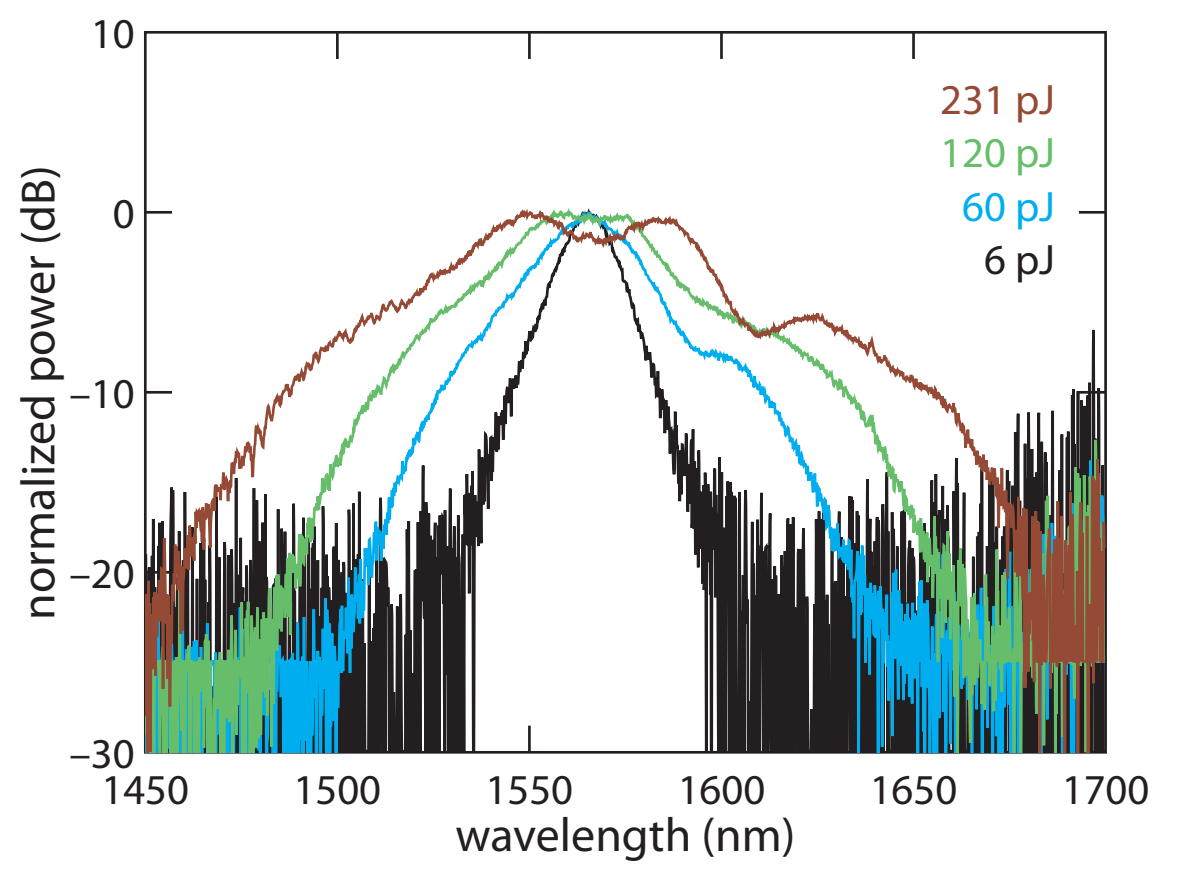
1 fabrication 2 linear devices 3 NL properties

the first nonlinear optics in TiO_2

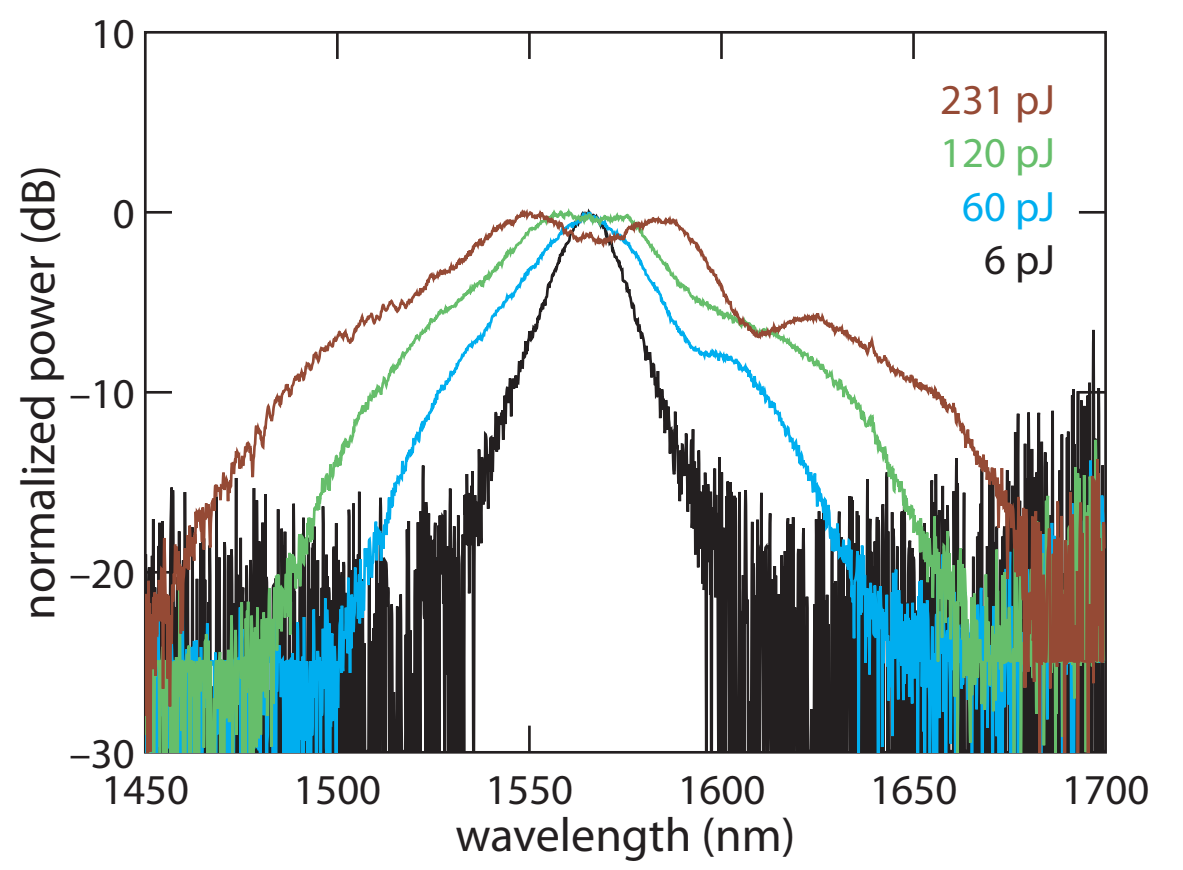


1 fabrication 2 linear devices 3 NL properties

... spanning the communications octave!



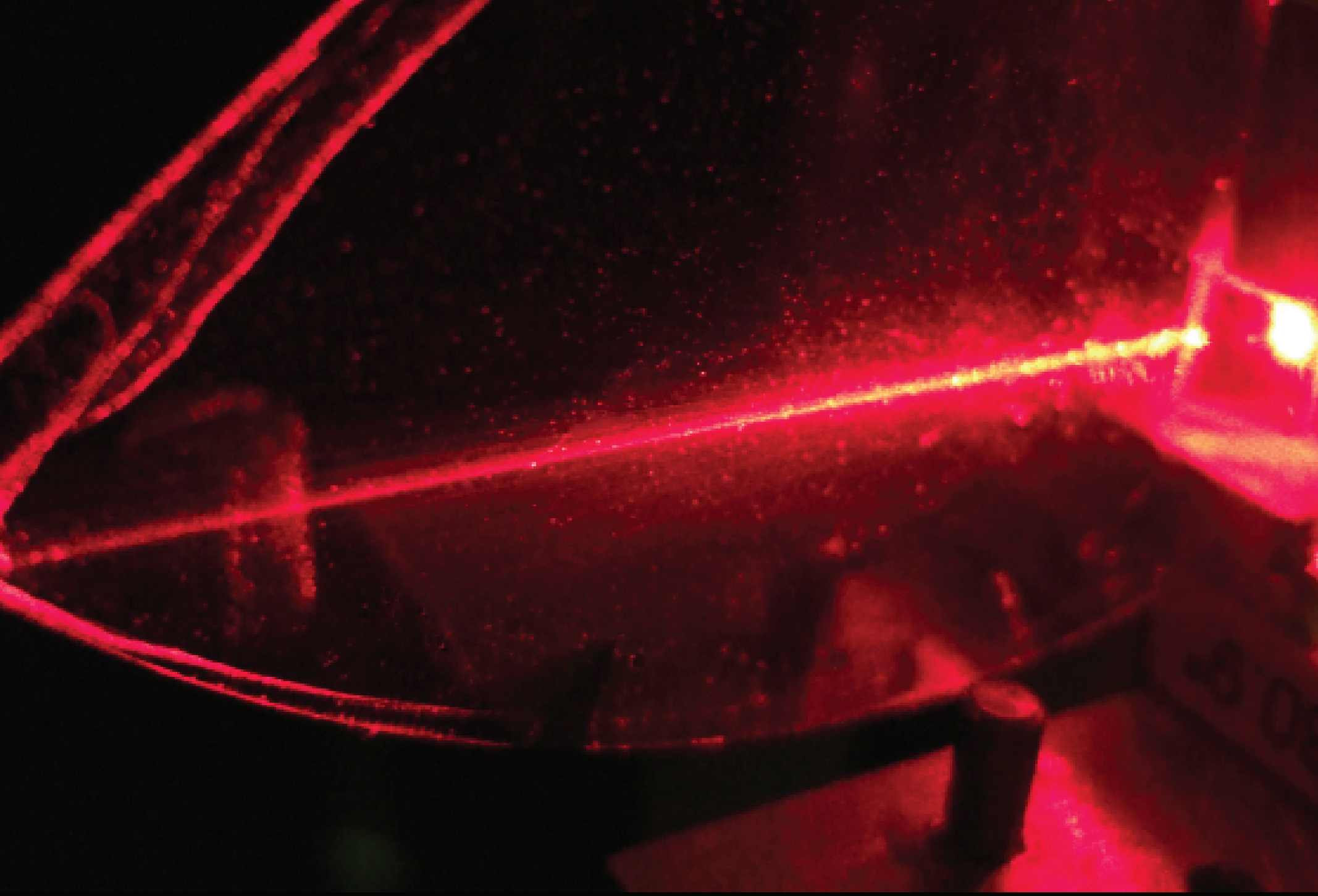
... spanning the communications octave!



$\gamma \sim 5\ W^{-1}m^{-1}$

(5,000x silica fiber)

1 fabrication 2 linear devices 3 NL properties



1 fabrication

2 linear devices

3 NL properties

Summary

established fabrication of TiO_2 waveguides

losses sufficient for mm-length devices

demonstrated optical nonlinearities in TiO_2

1 fabrication 2 linear devices 3 NL devices

Thank you

Any questions?

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National Science Foundation

Nanoscale Science and Engineering Center
Harvard Quantum Optics Center
Department of Energy

for more information and a copy of this presentation:

http://mazur.harvard.edu