TiO_2 nanophotonic waveguides for on-chip nonlinear optical devices

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Introduction

TiO_2 Material Properties

Large ultrafast nonlinearity:	30 x silica
High index of refraction:	2.5
Wide bandgap:	3.1 eV
Low two-photon absorption:	≥ 800 nm

Several polymorphs:

Rutile, Anatase, Brookite and Amorphous

Outline

Fabrication

Linear device properties

Nonlinear measurement

Conclusions

Material

Deposition

Reactive Sputtering

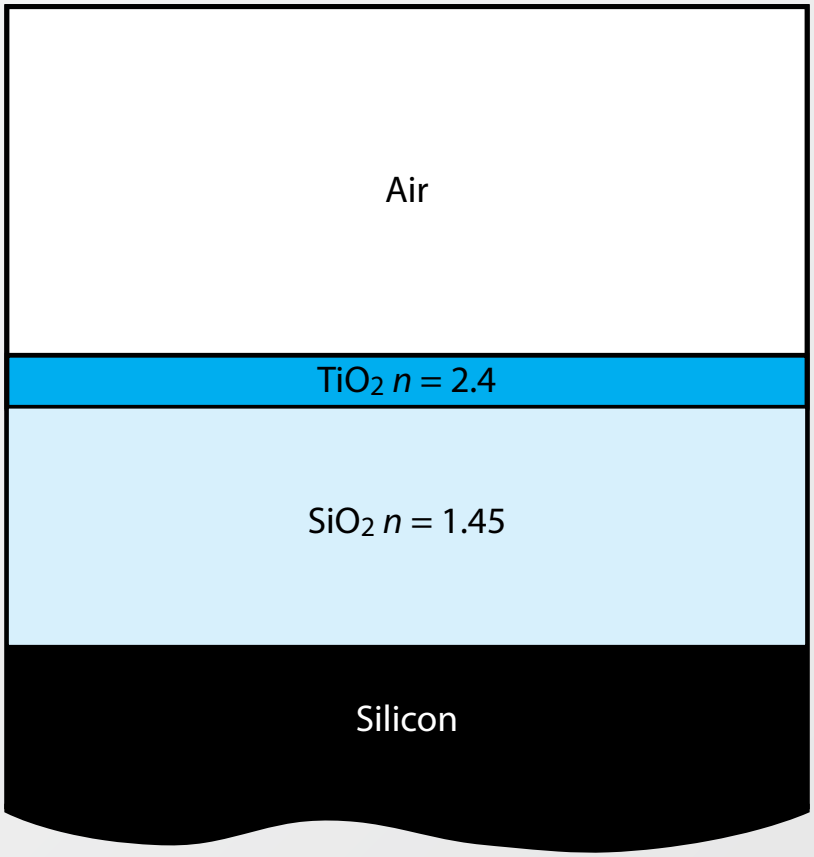
Titanium with Oxygen

Temp: 20–350° C

Pressure: 2 mTorr

O_2 flow: 4.4–20 sccm

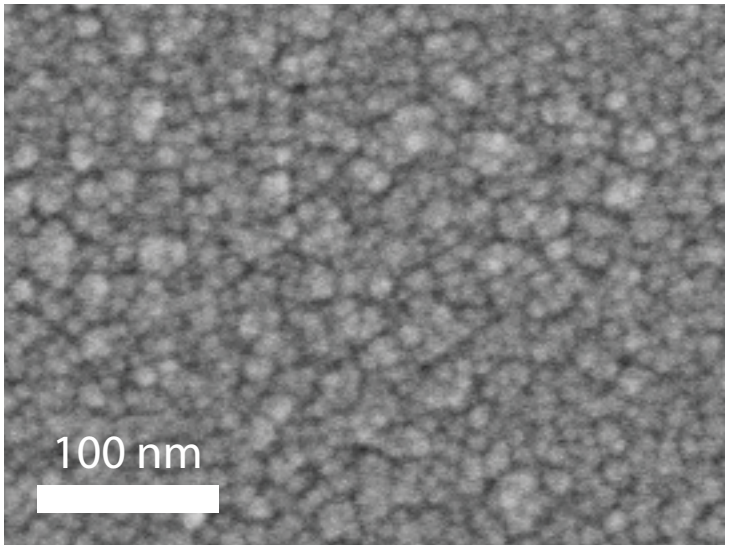
Material



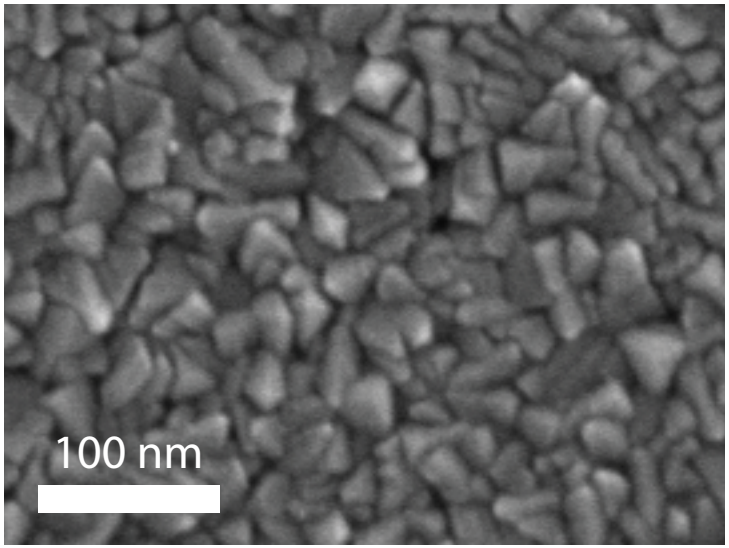
Material

Sputtering

Deposition Temperature: 20° C

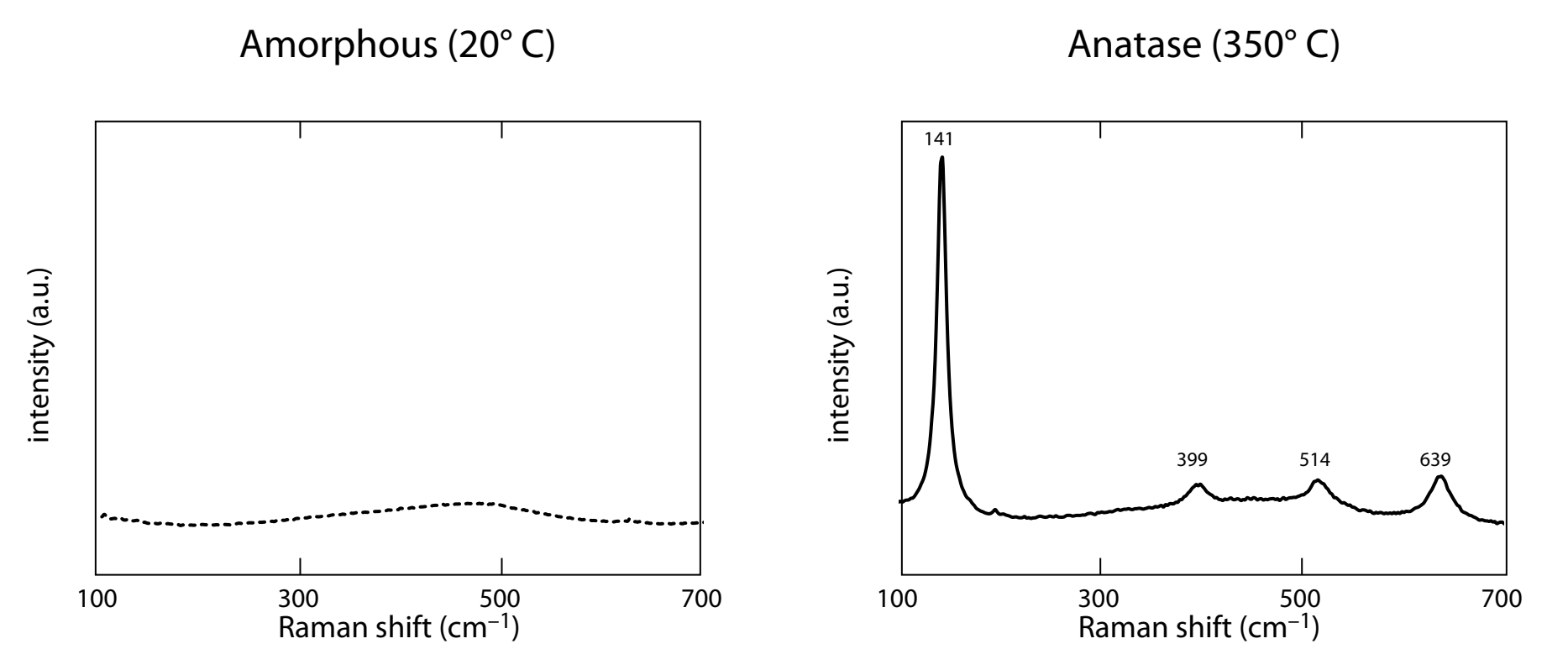


Depostion Temperature 350° C



Material

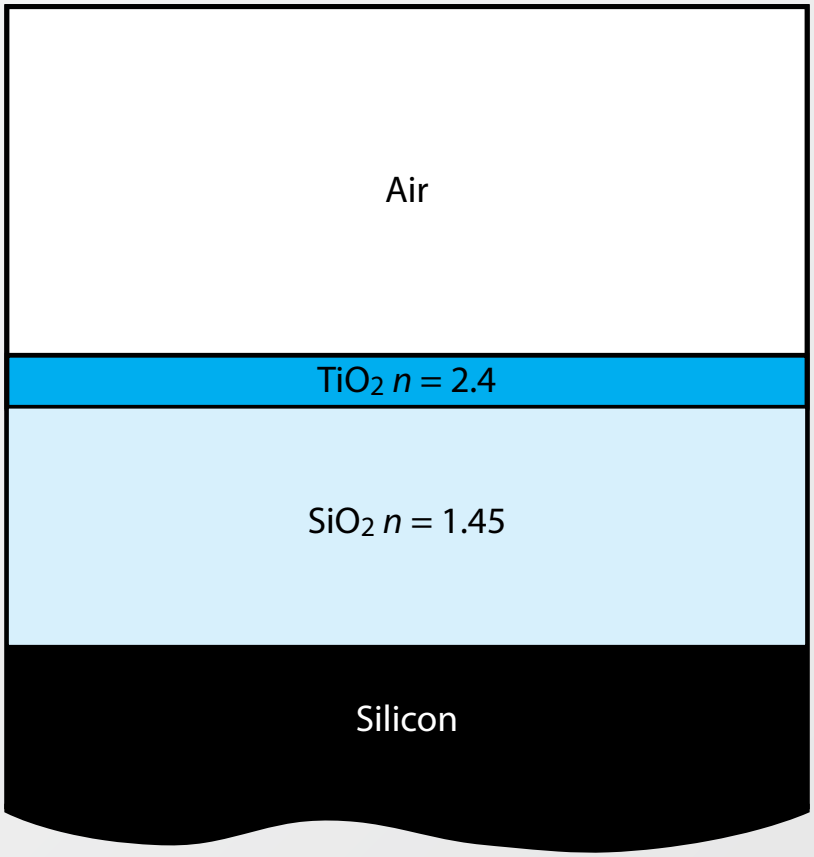
Sputtering



Material

Amorphous

240 nm thick

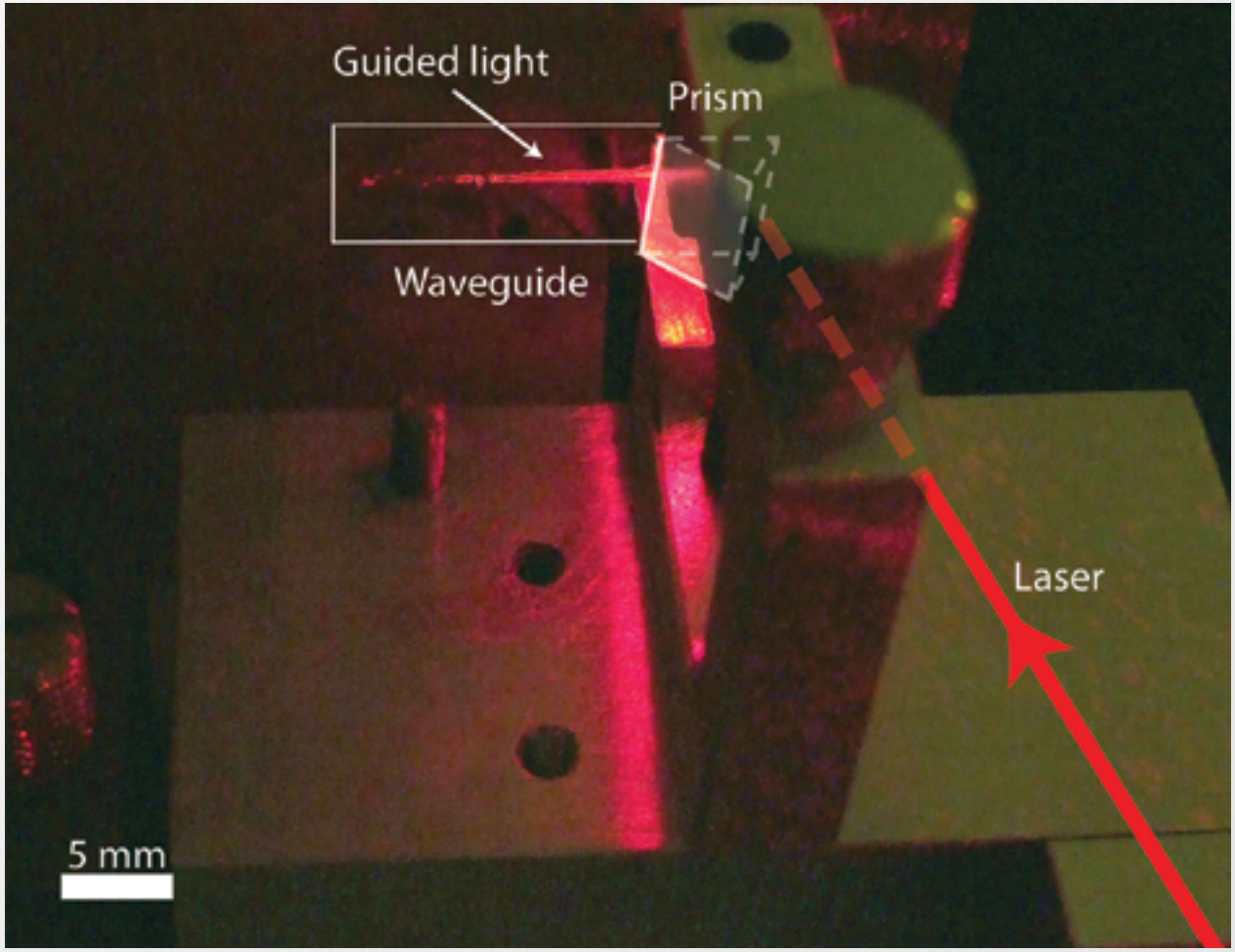


Anatase

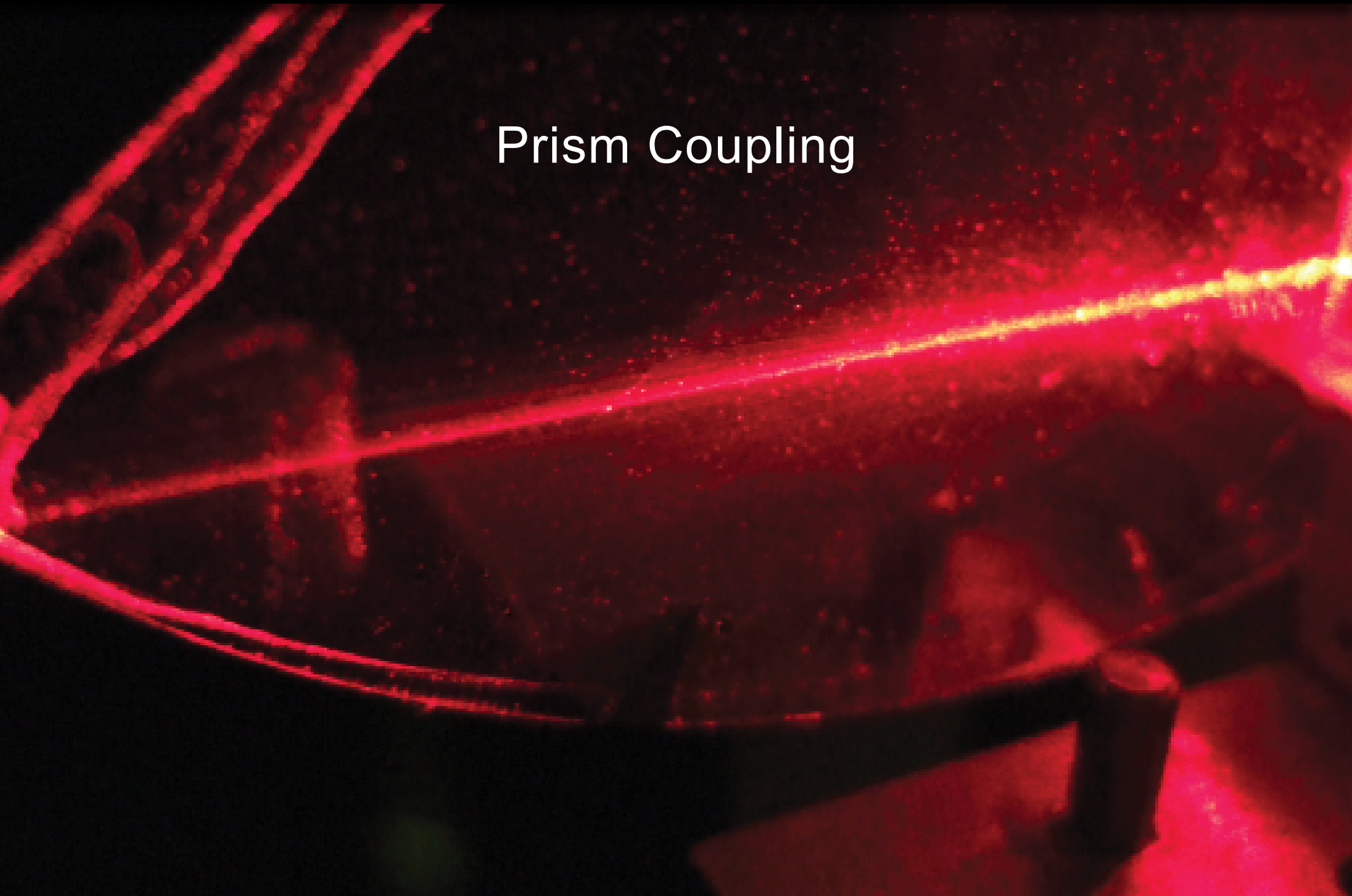
80 nm thick

Material

Prism Coupling

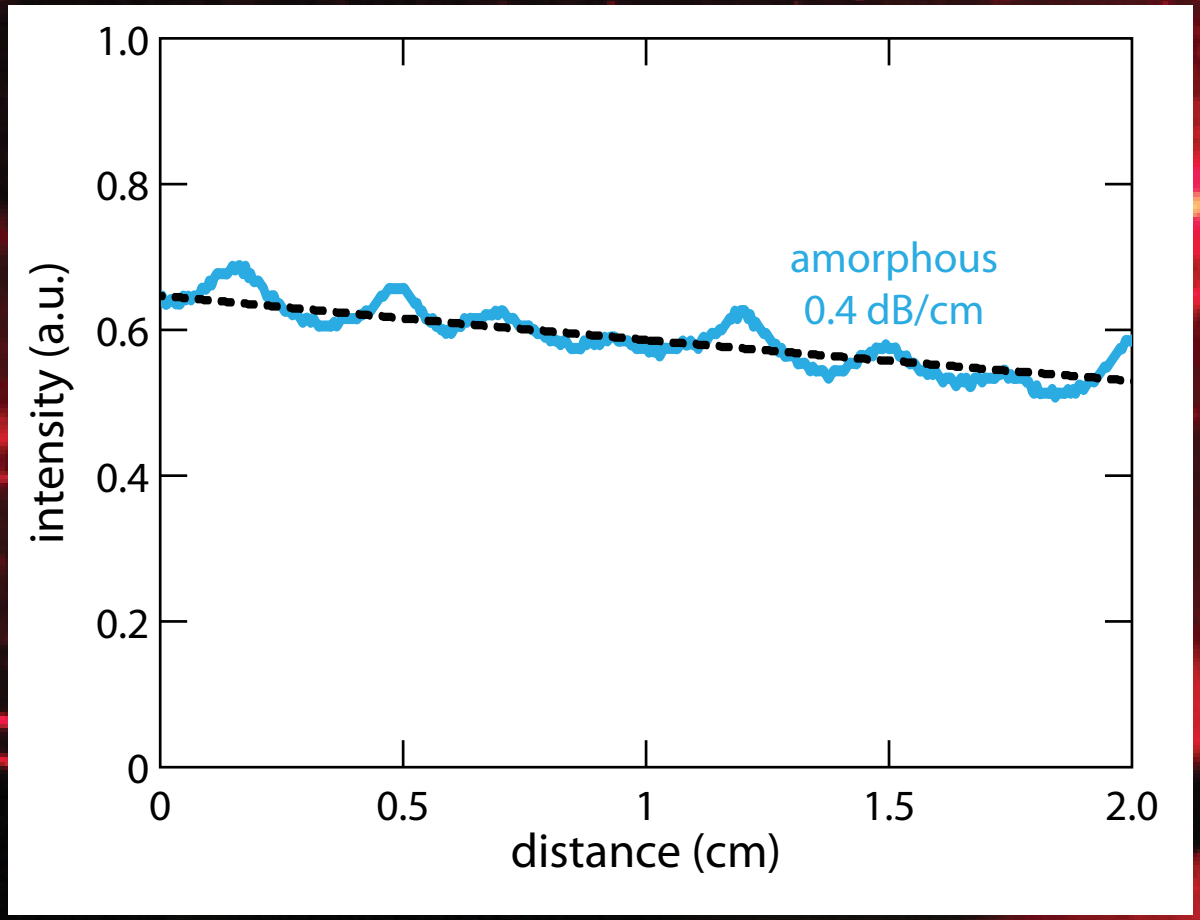


Material



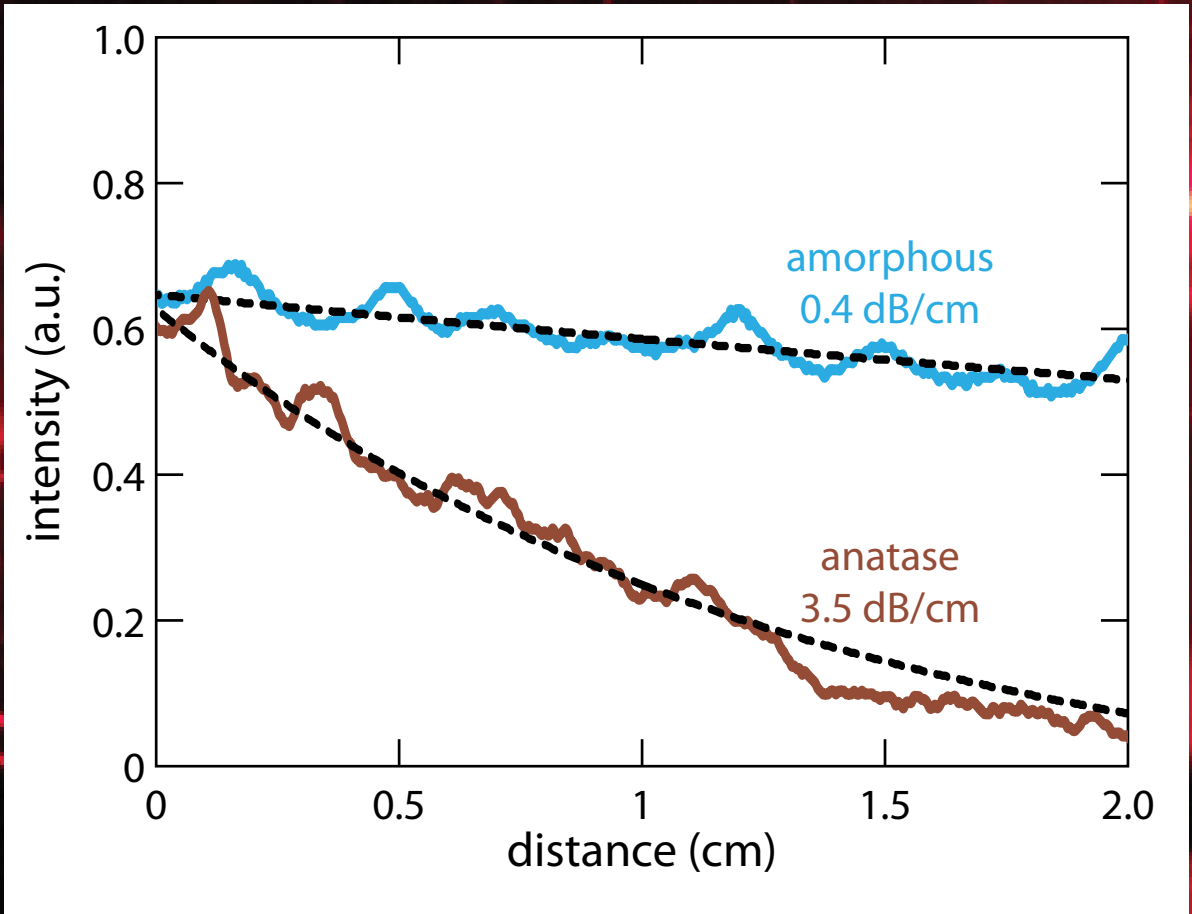
Material

Prism Coupling



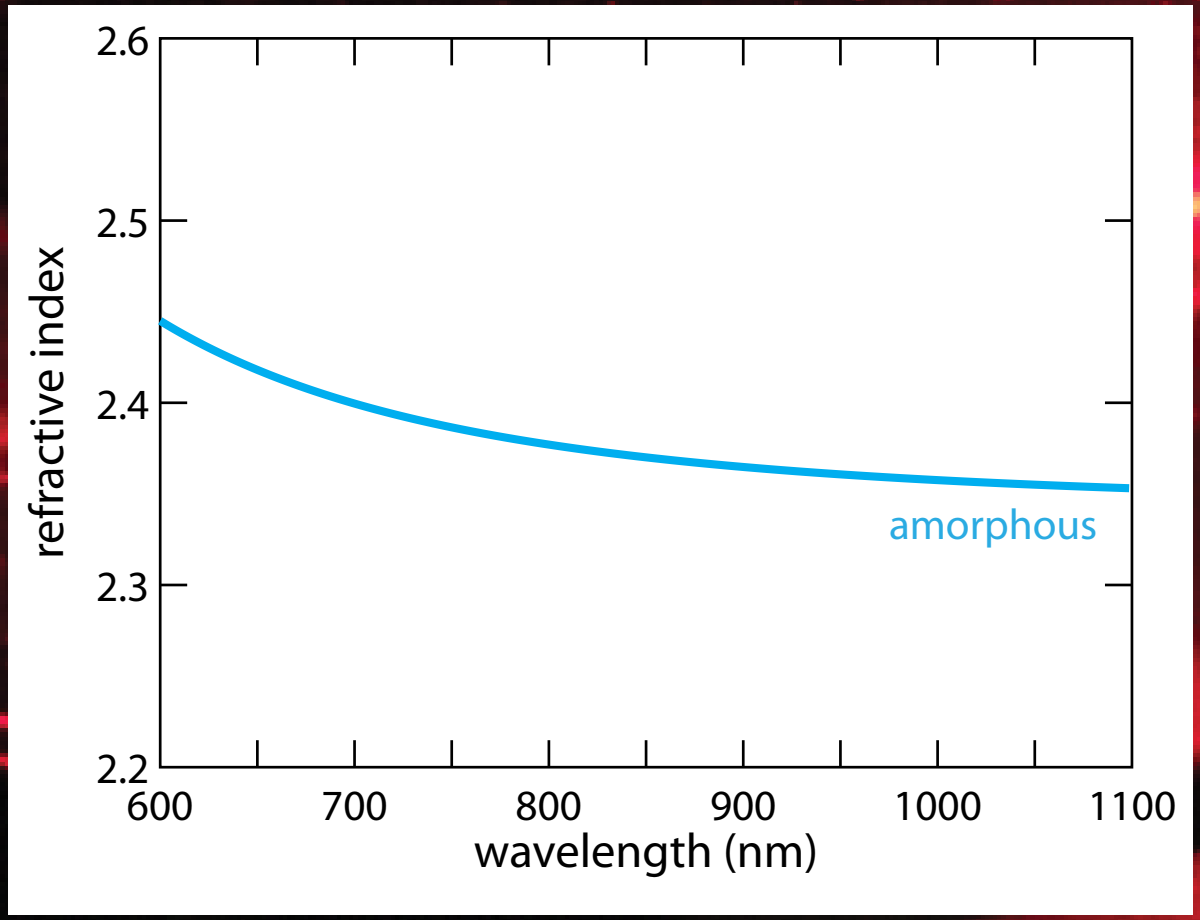
Material

Prism Coupling



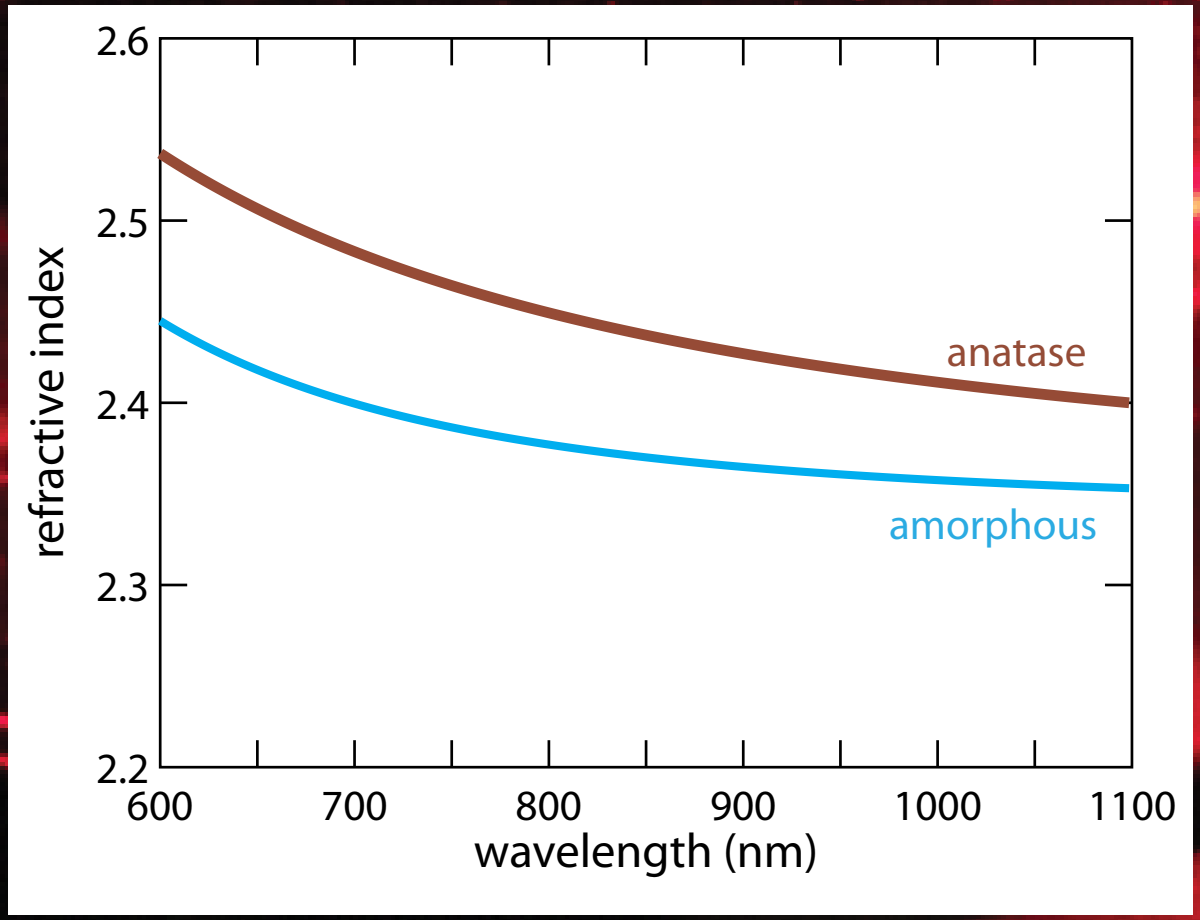
Material

Prism Coupling

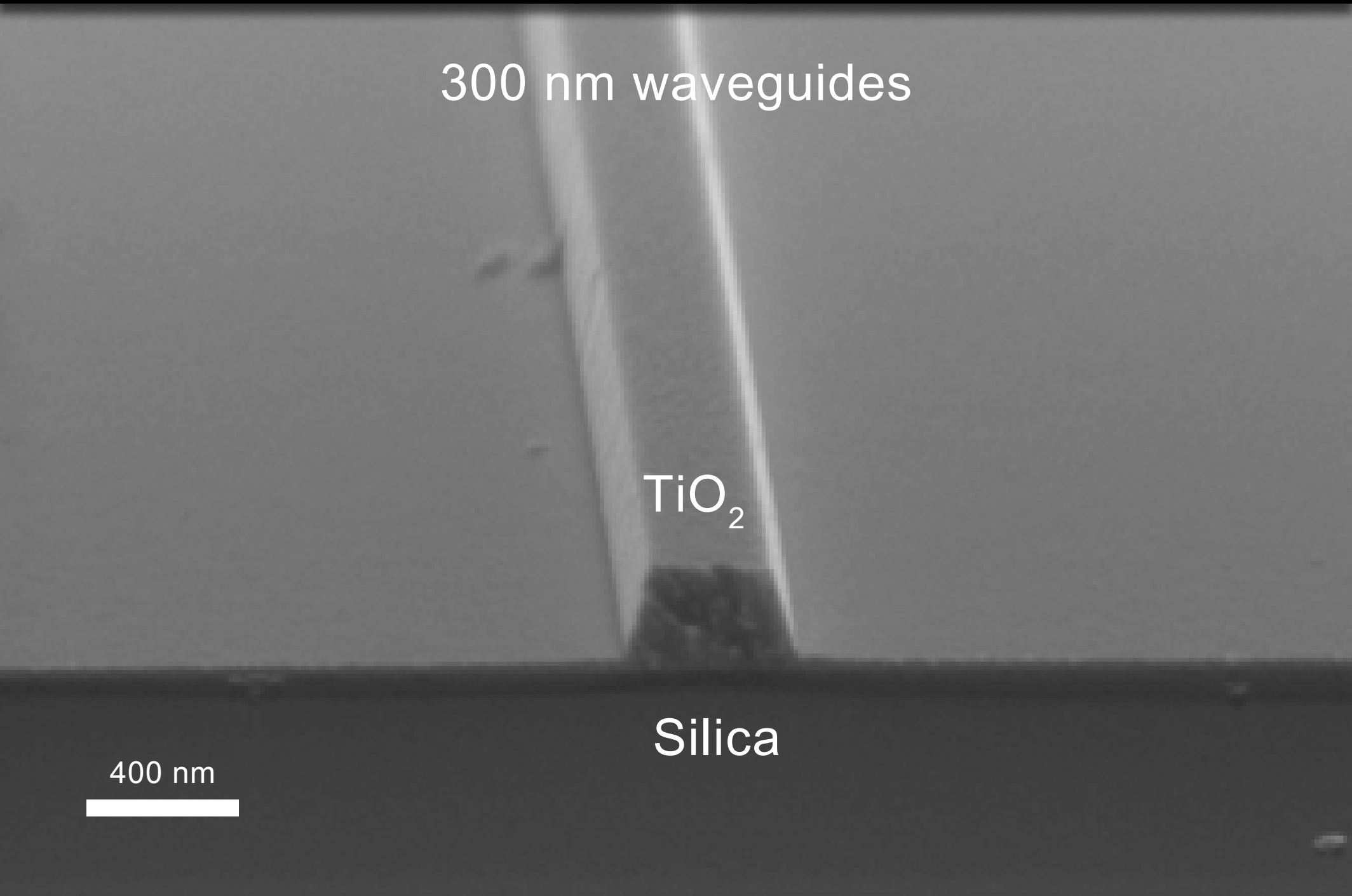


Material

Prism Coupling



Material



Outline

Fabrication

Linear device properties

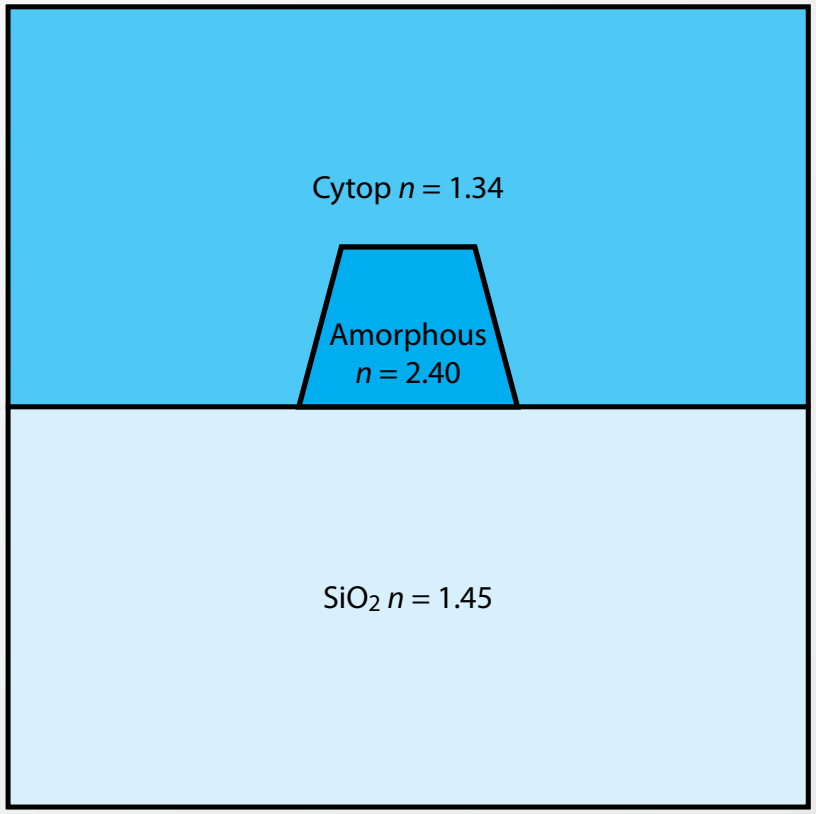
Nonlinear measurement

Conclusions

Linear device properties

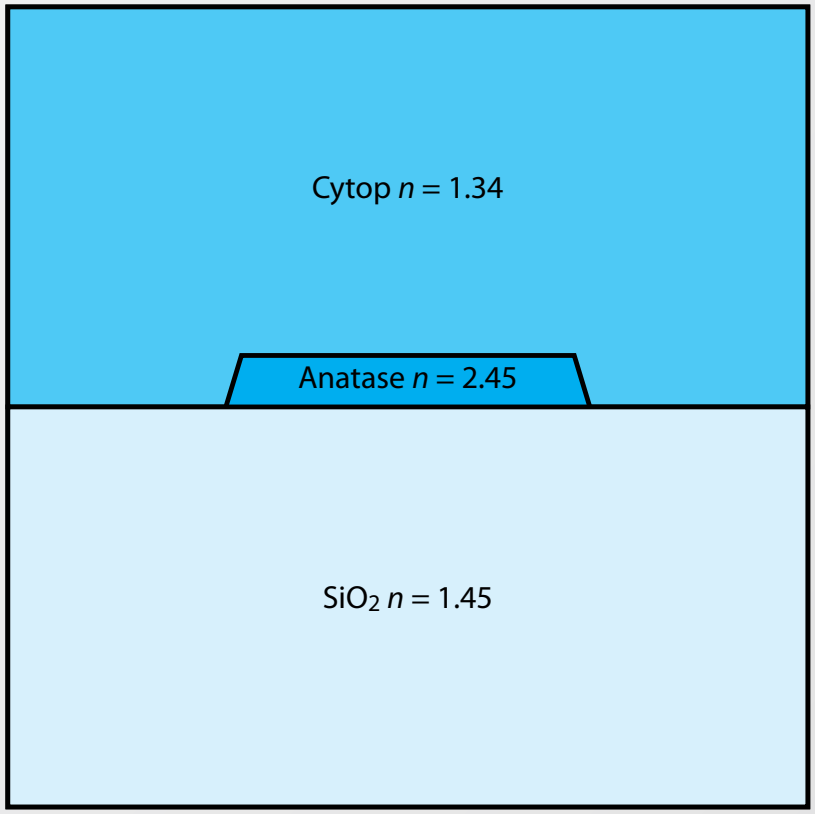
Waveguide cross sections

Amorphous



240 x 200 nm

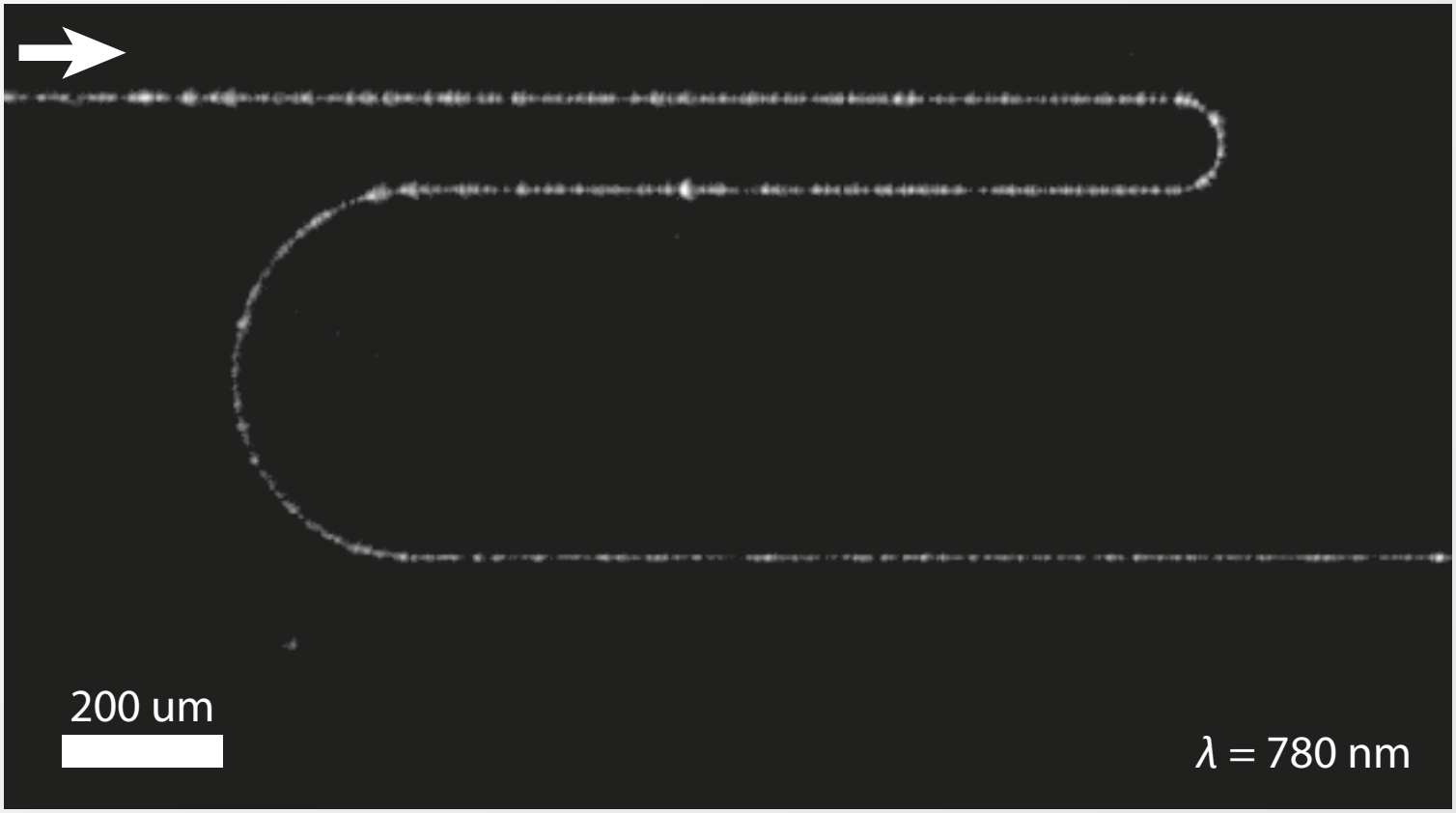
Anatase



80 x 500 nm

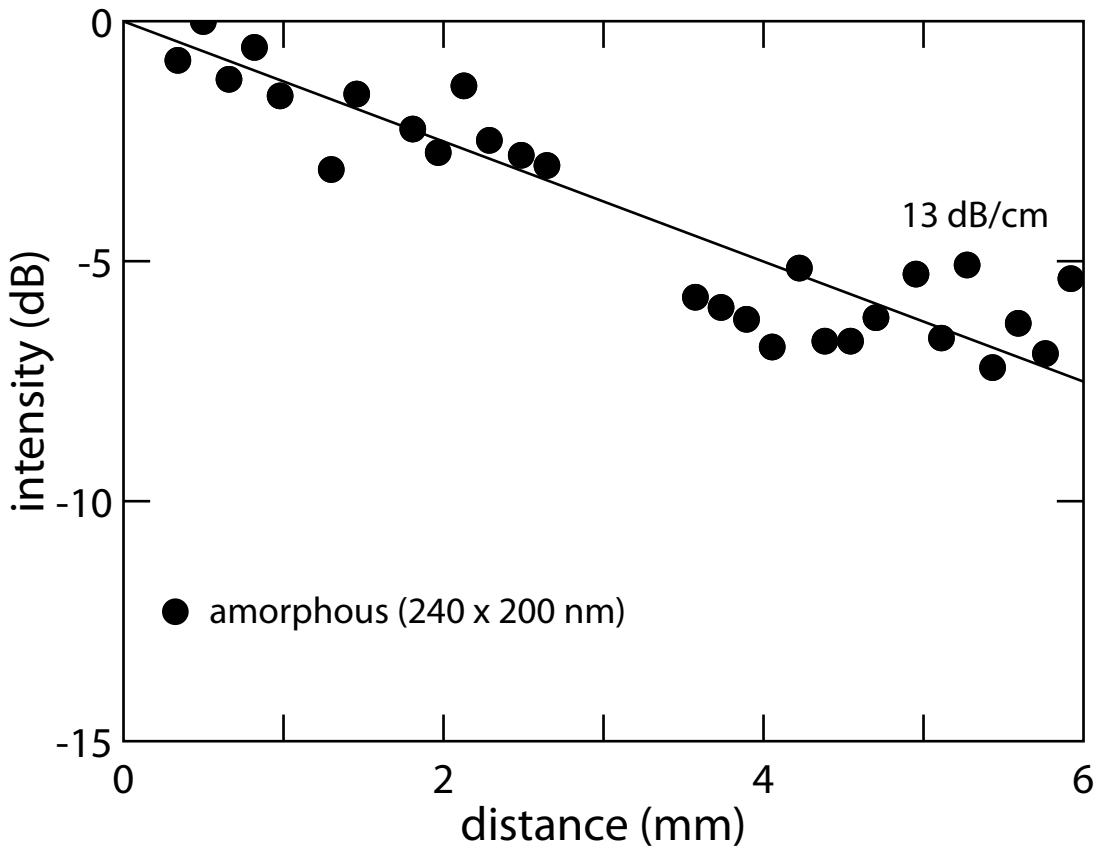
Linear device properties

Amorphous TiO_2



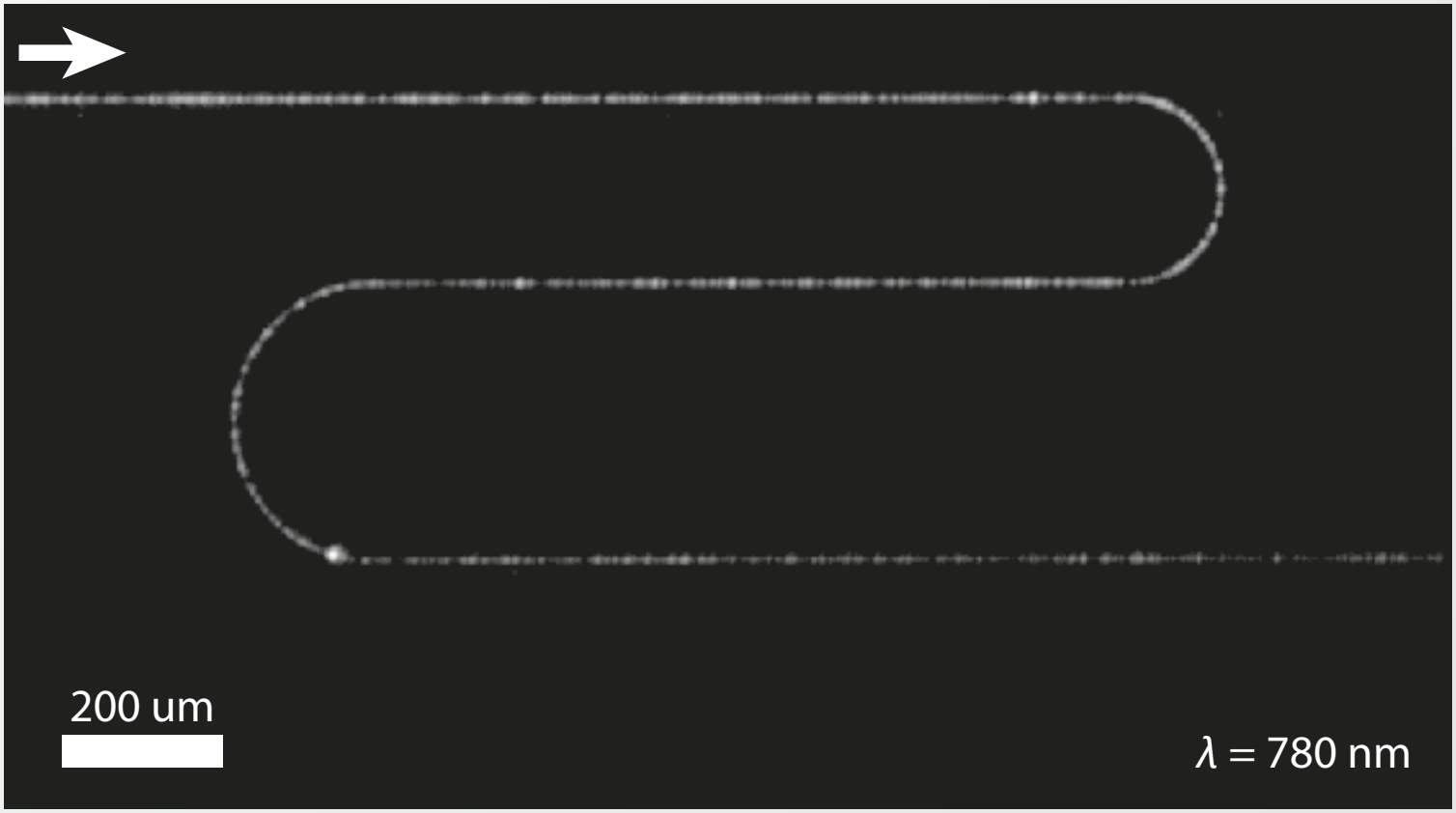
Linear device properties

Waveguiding losses



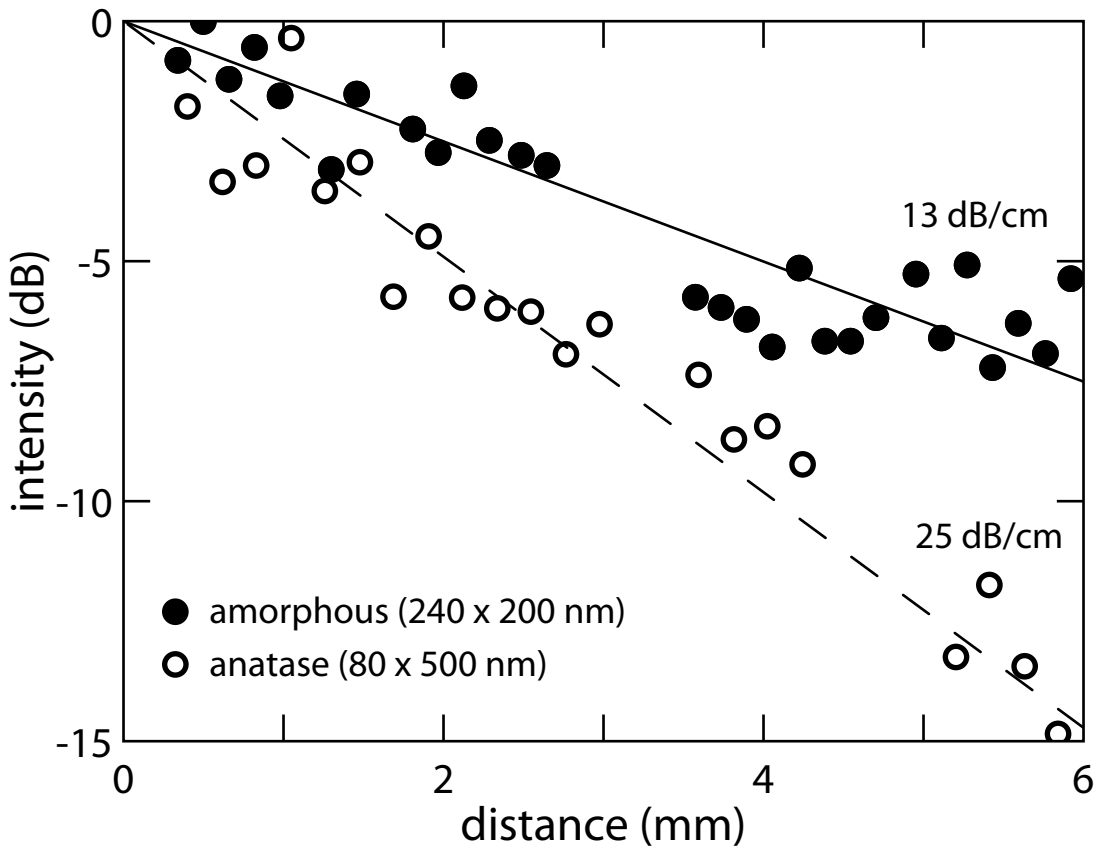
Linear device properties

Anatase TiO_2

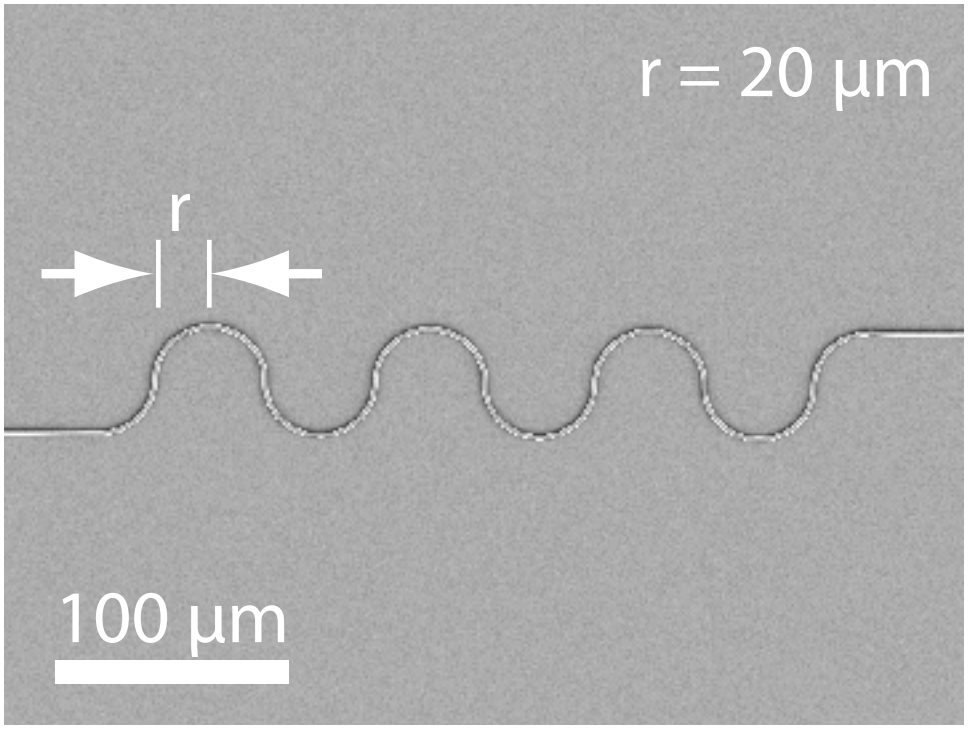


Linear device properties

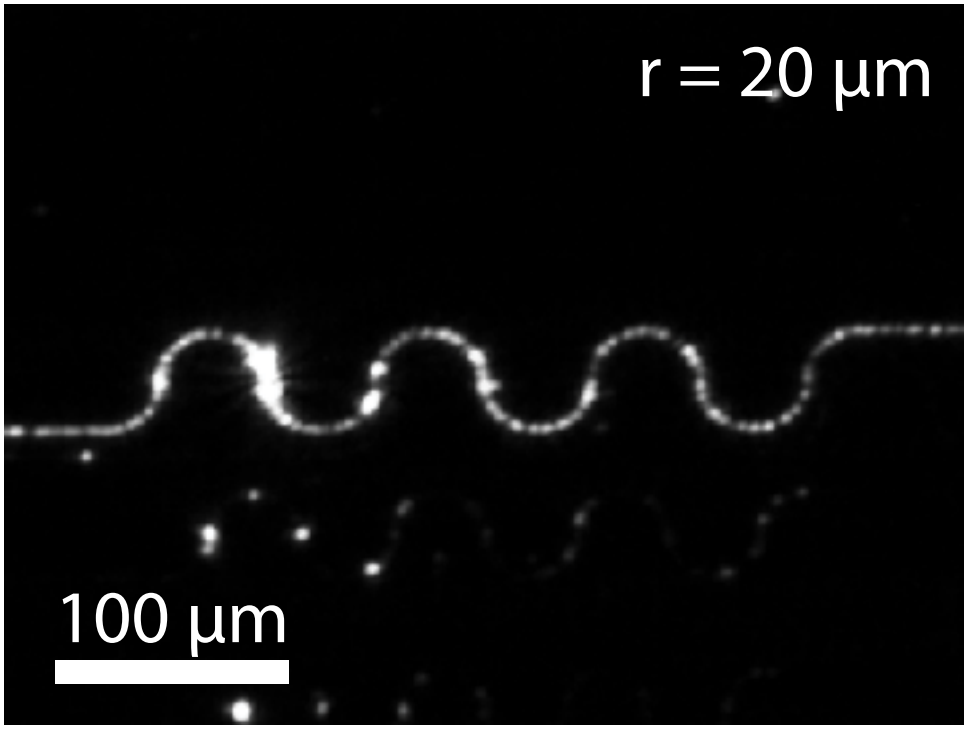
Waveguiding losses



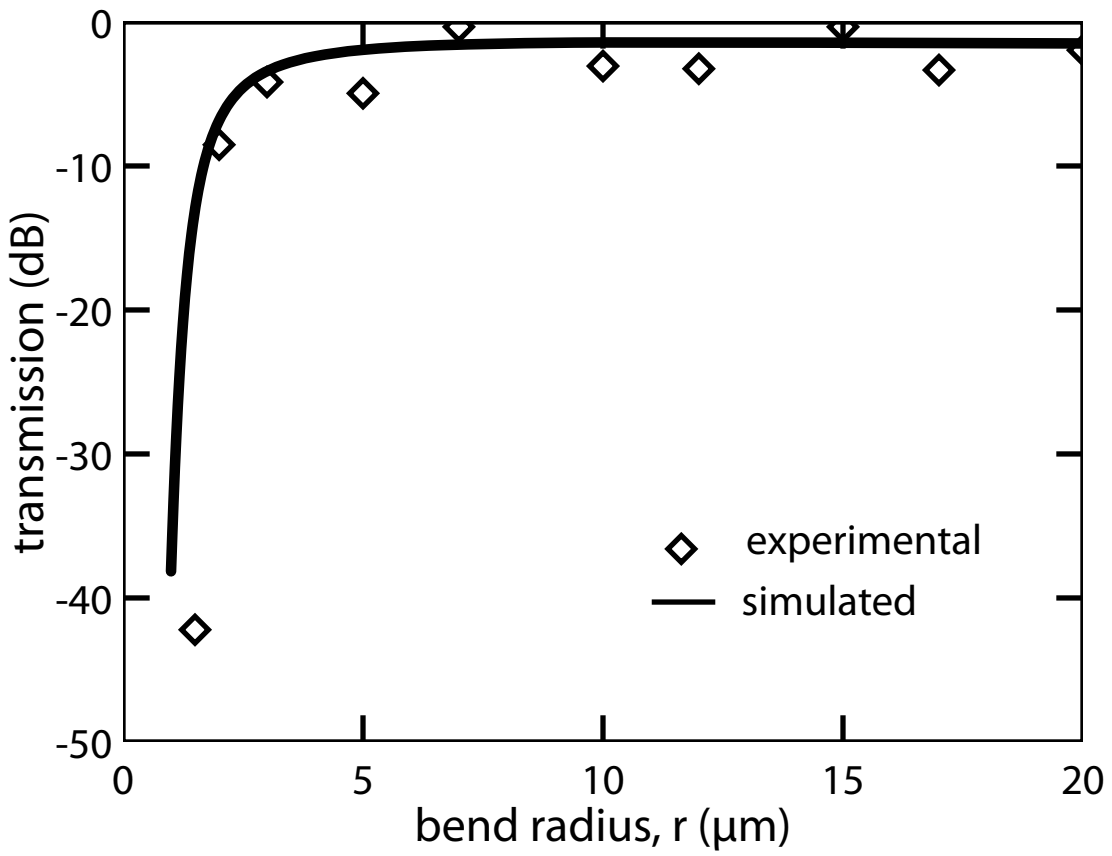
Linear device properties



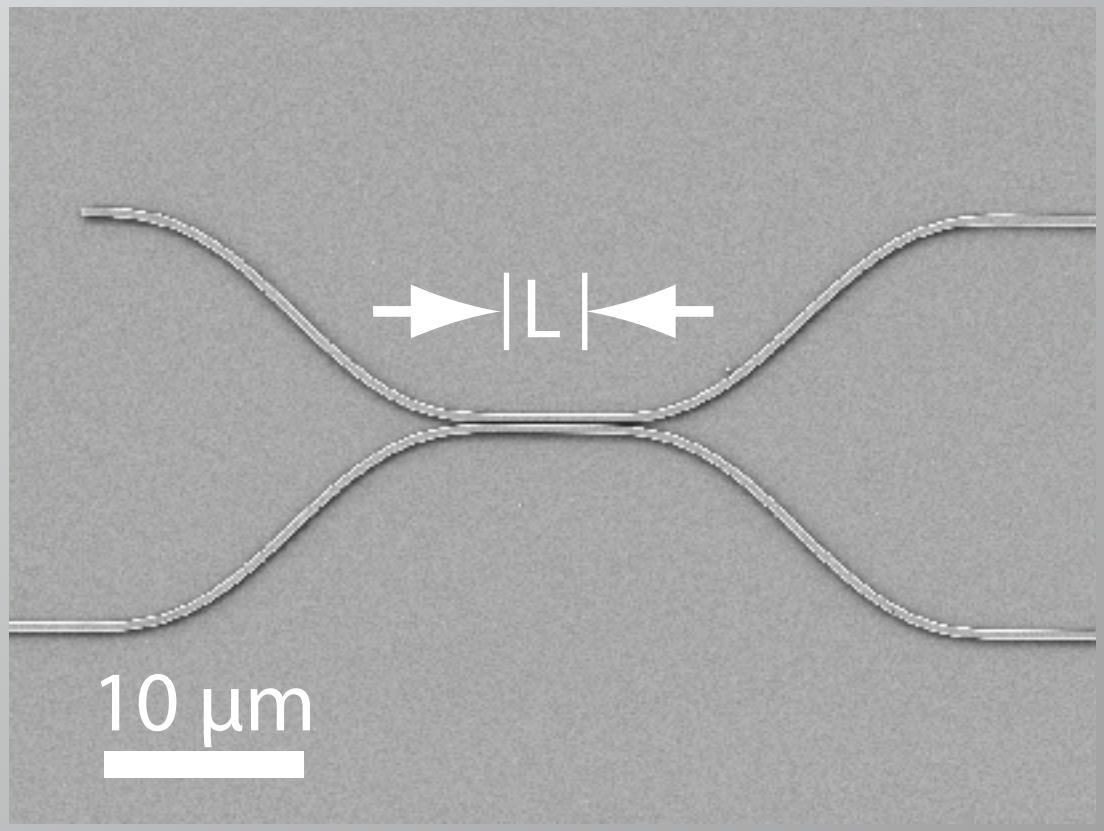
Linear device properties



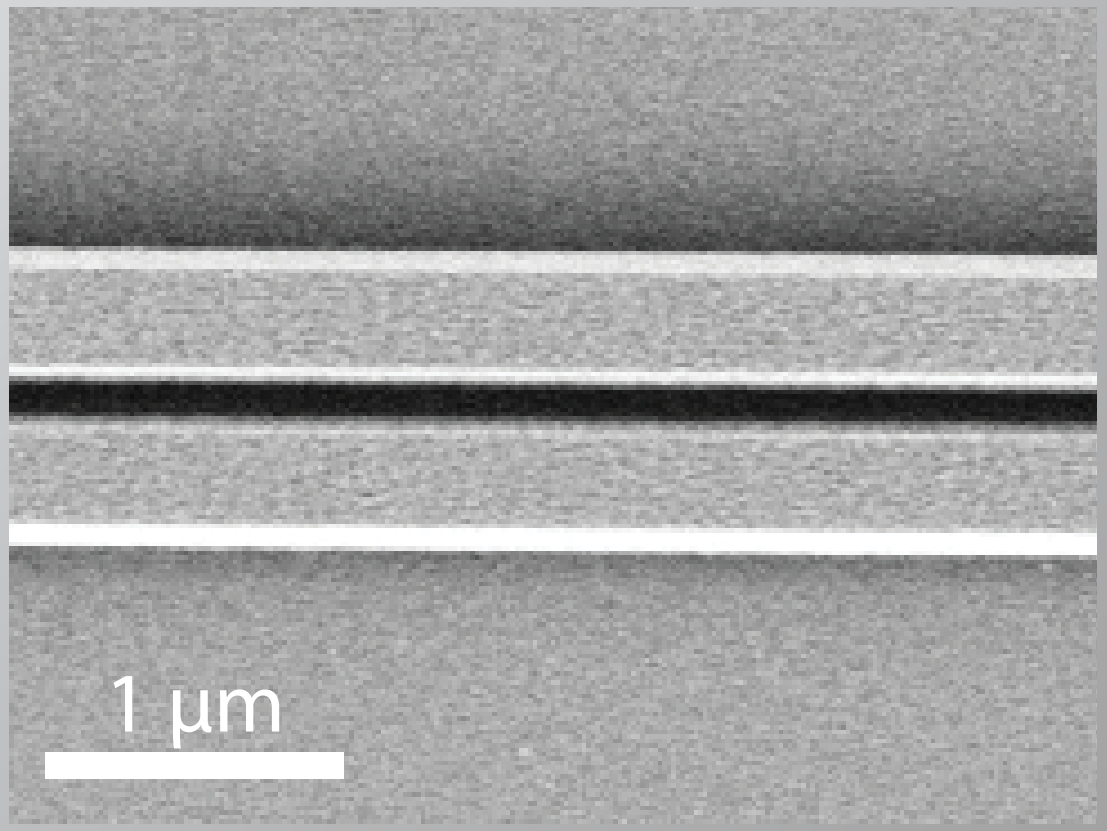
Linear device properties



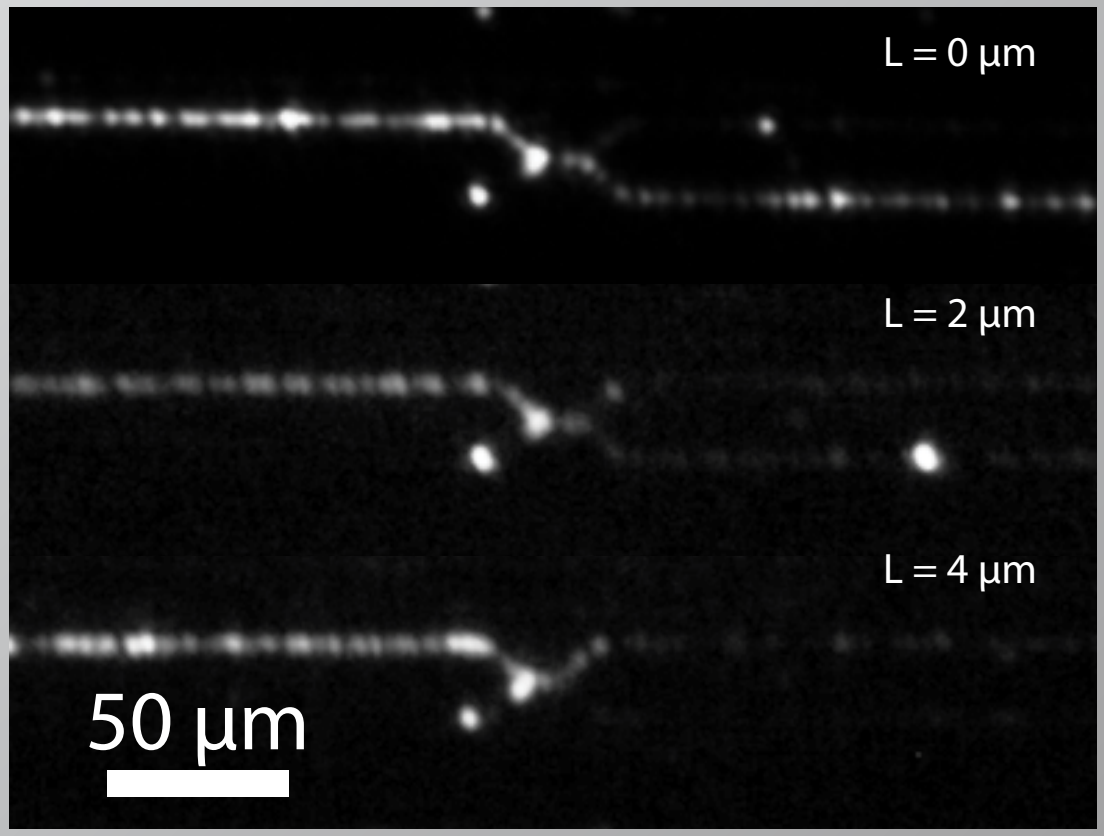
Linear device properties



Linear device properties



Linear device properties



Outline

Fabrication

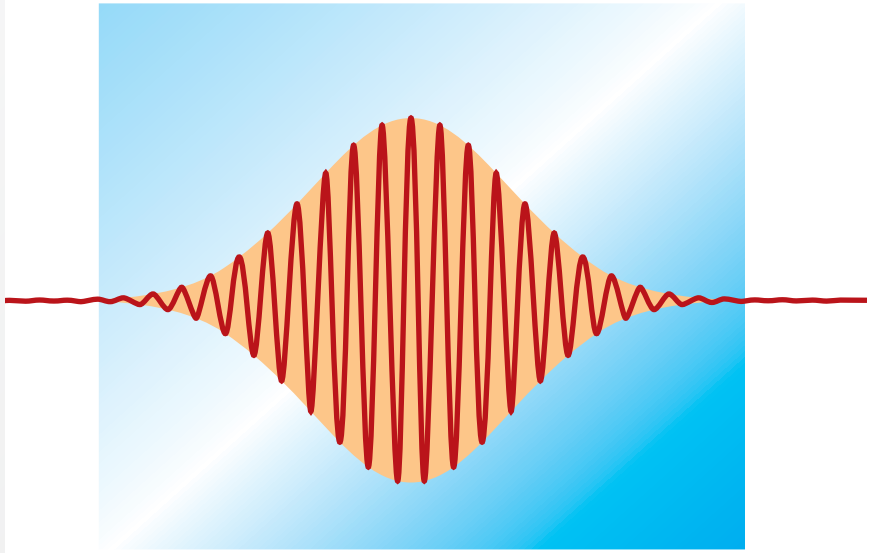
Linear device properties

Nonlinear measurement

Conclusions

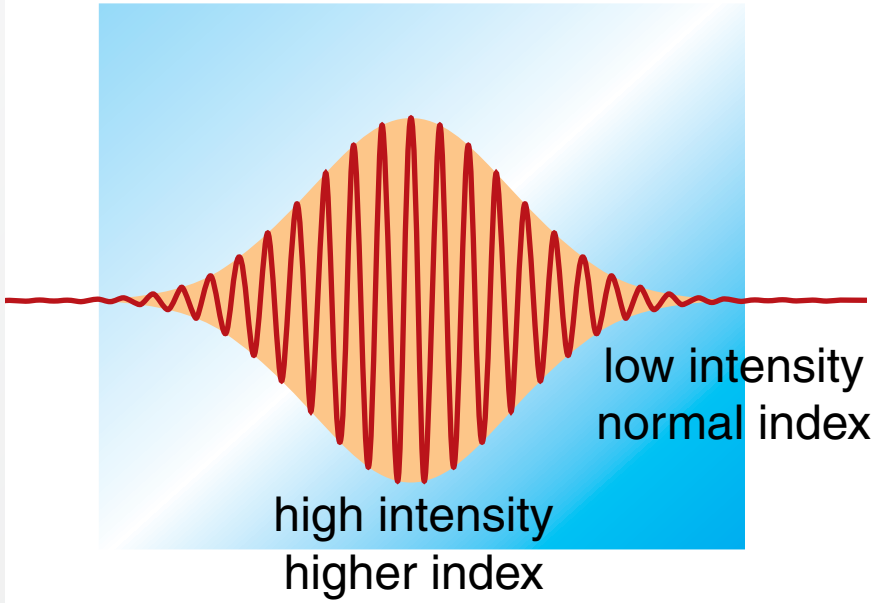
Nonlinear device properties

$$n = n_0 + n_2 I$$



Nonlinear device properties

$$n = n_0 + n_2 I$$



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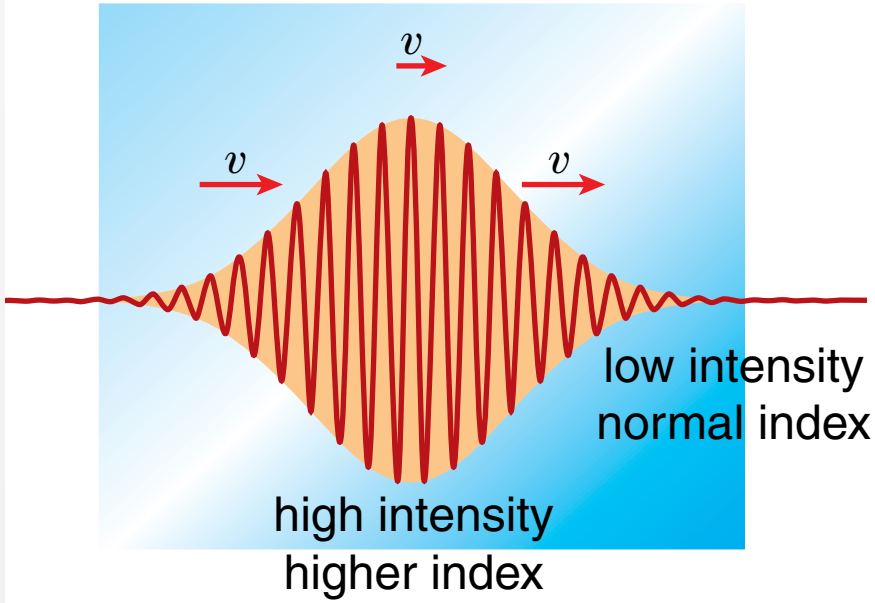

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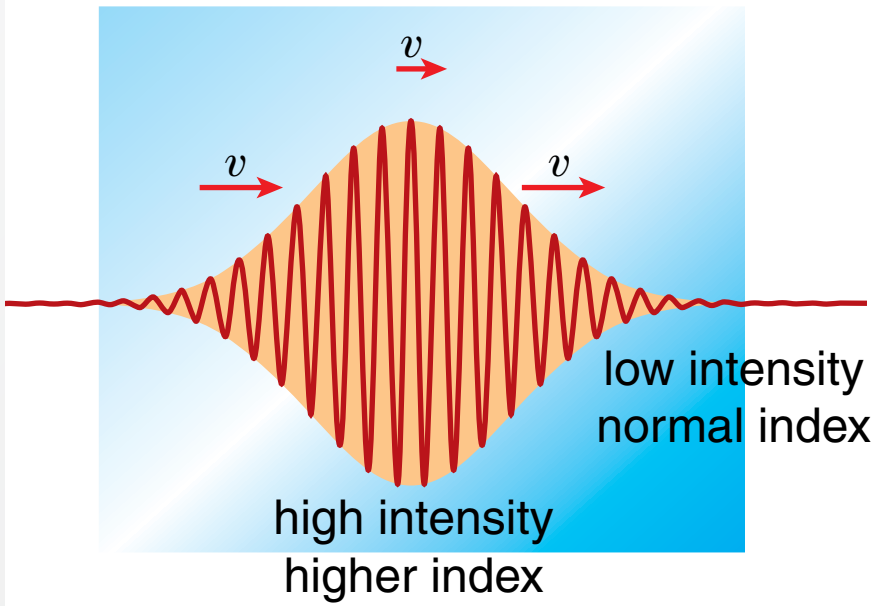

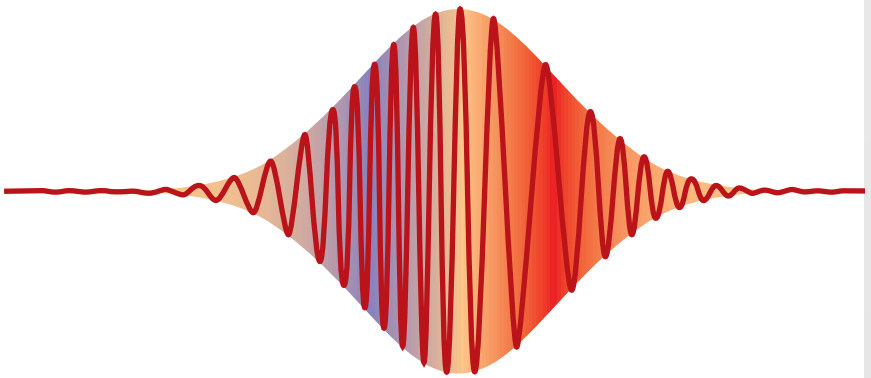

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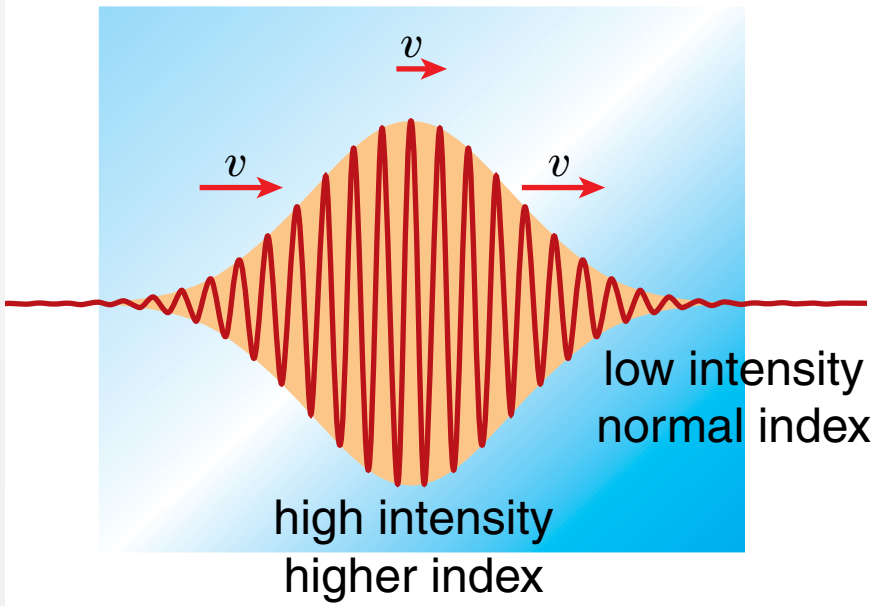
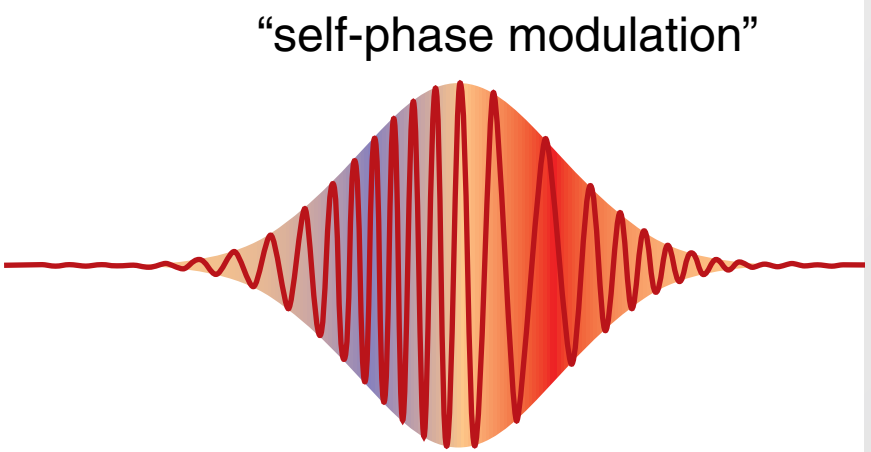
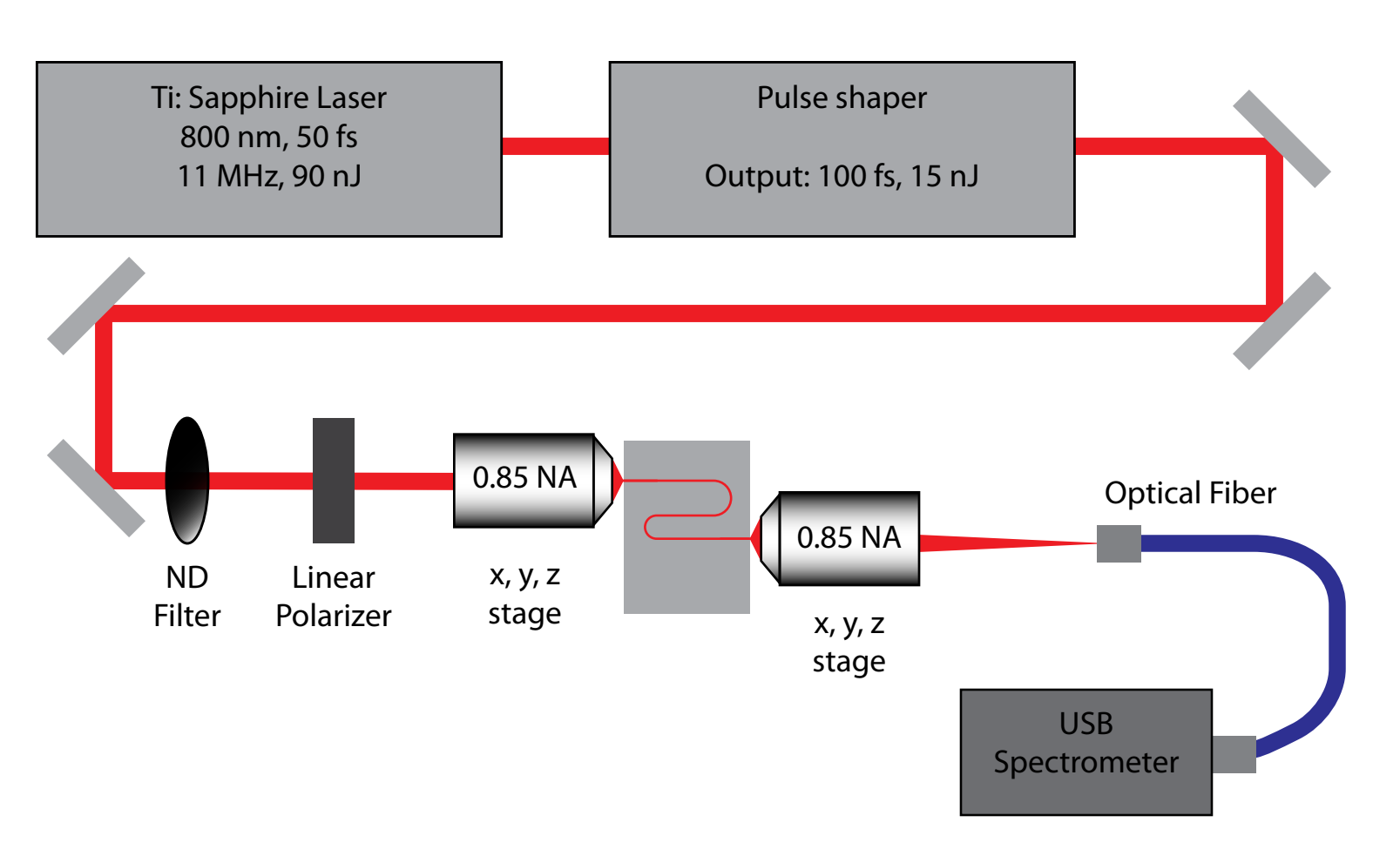




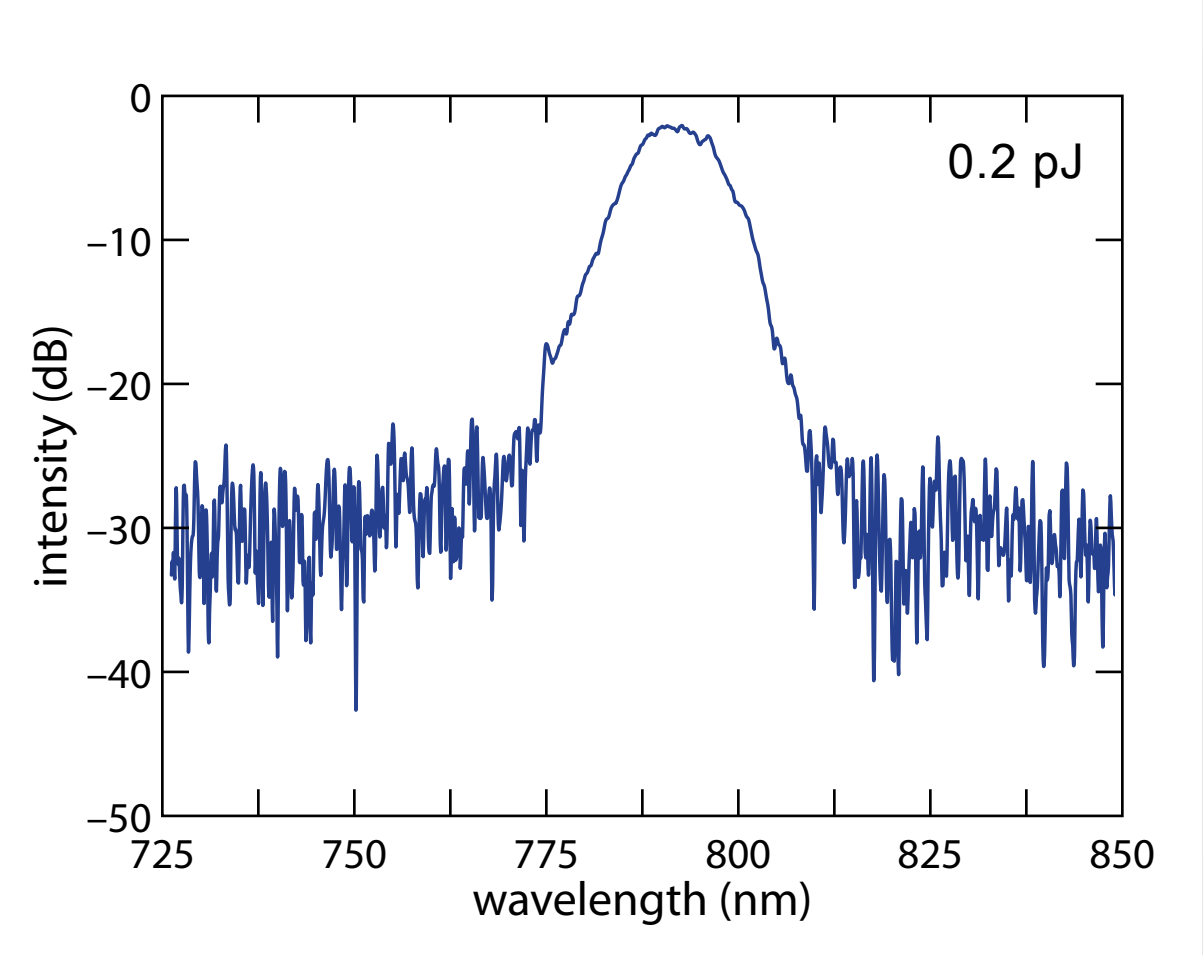
Nonlinear device properties

Diagram of setup



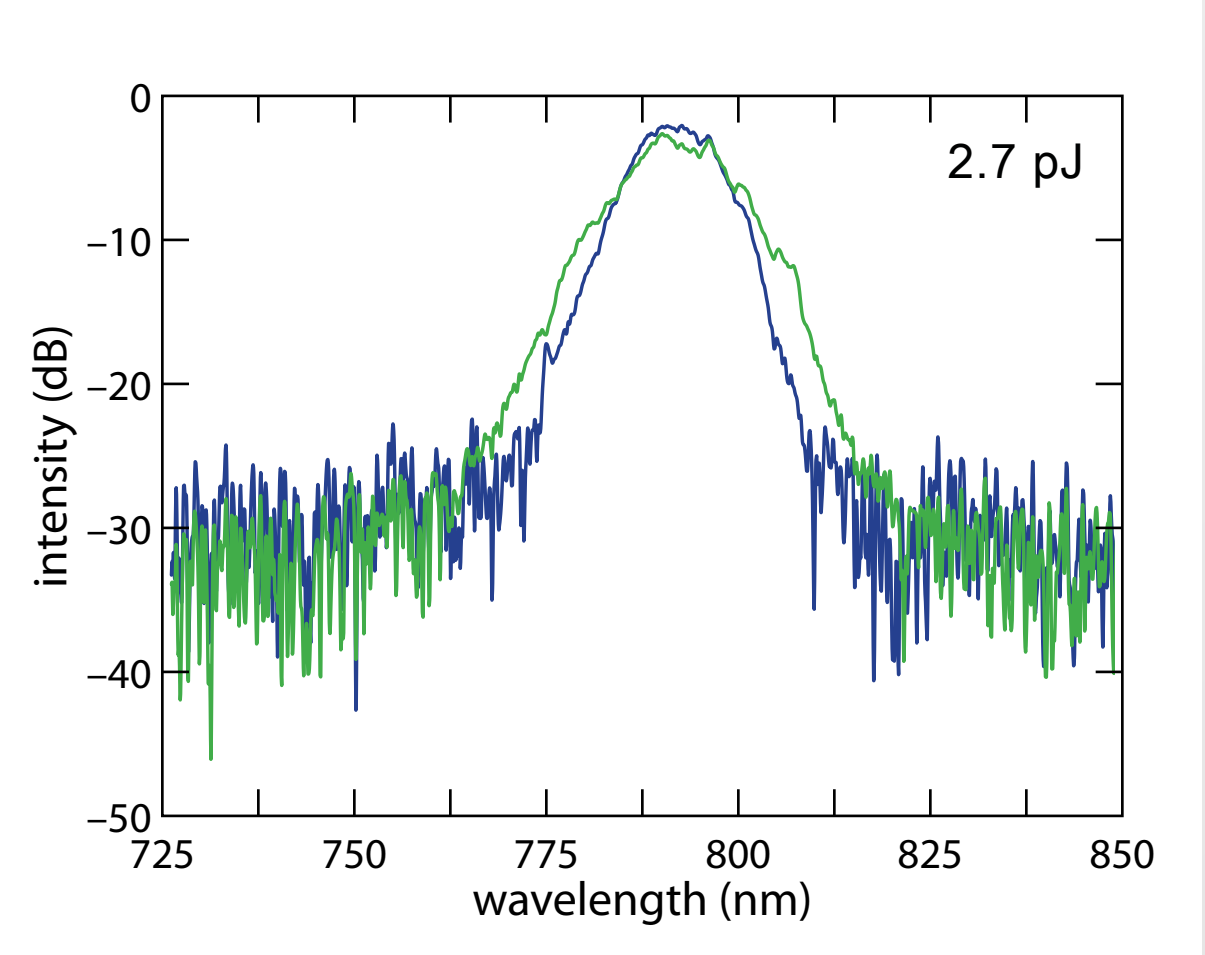
Nonlinear device properties

Spectral Broadening



Nonlinear device properties

Spectral Broadening



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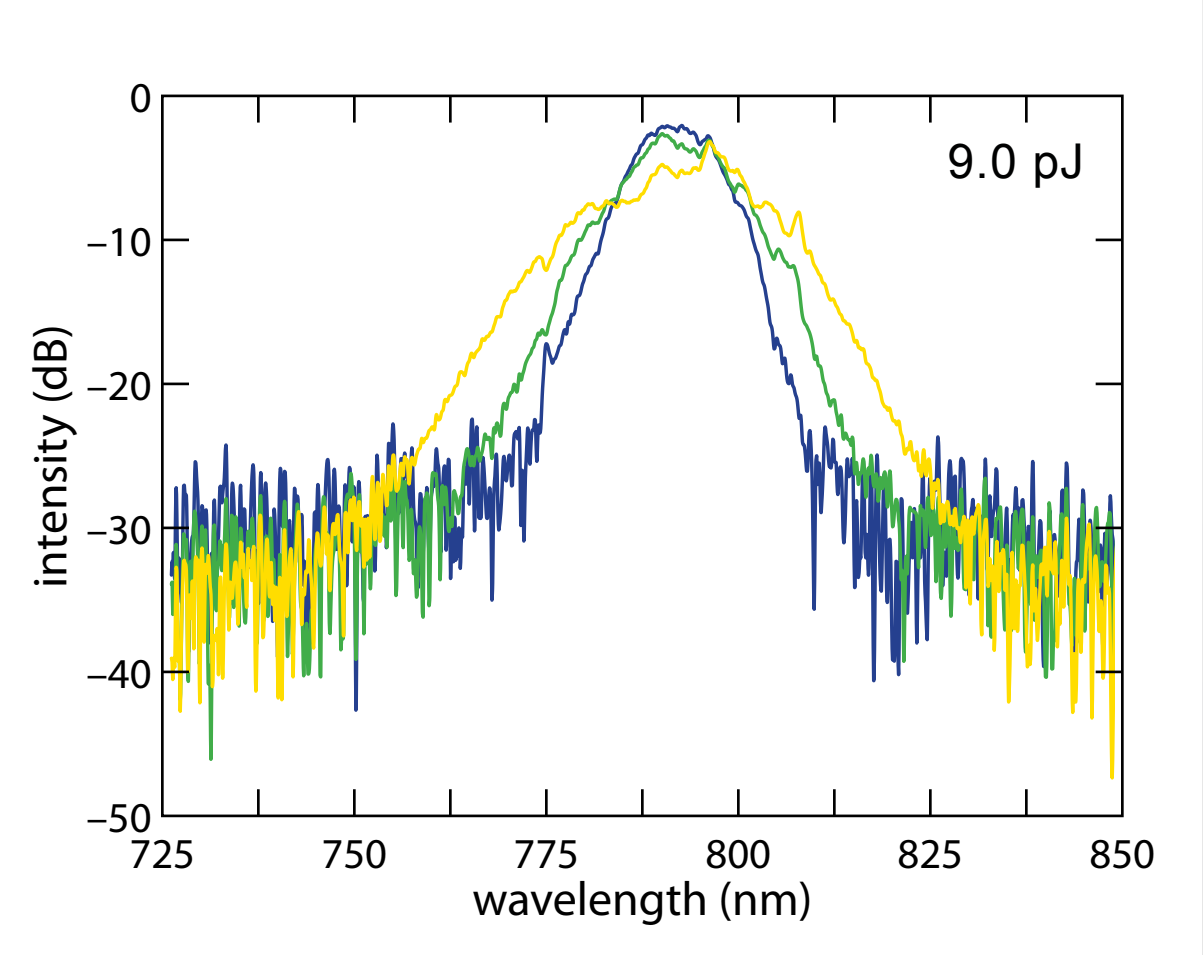
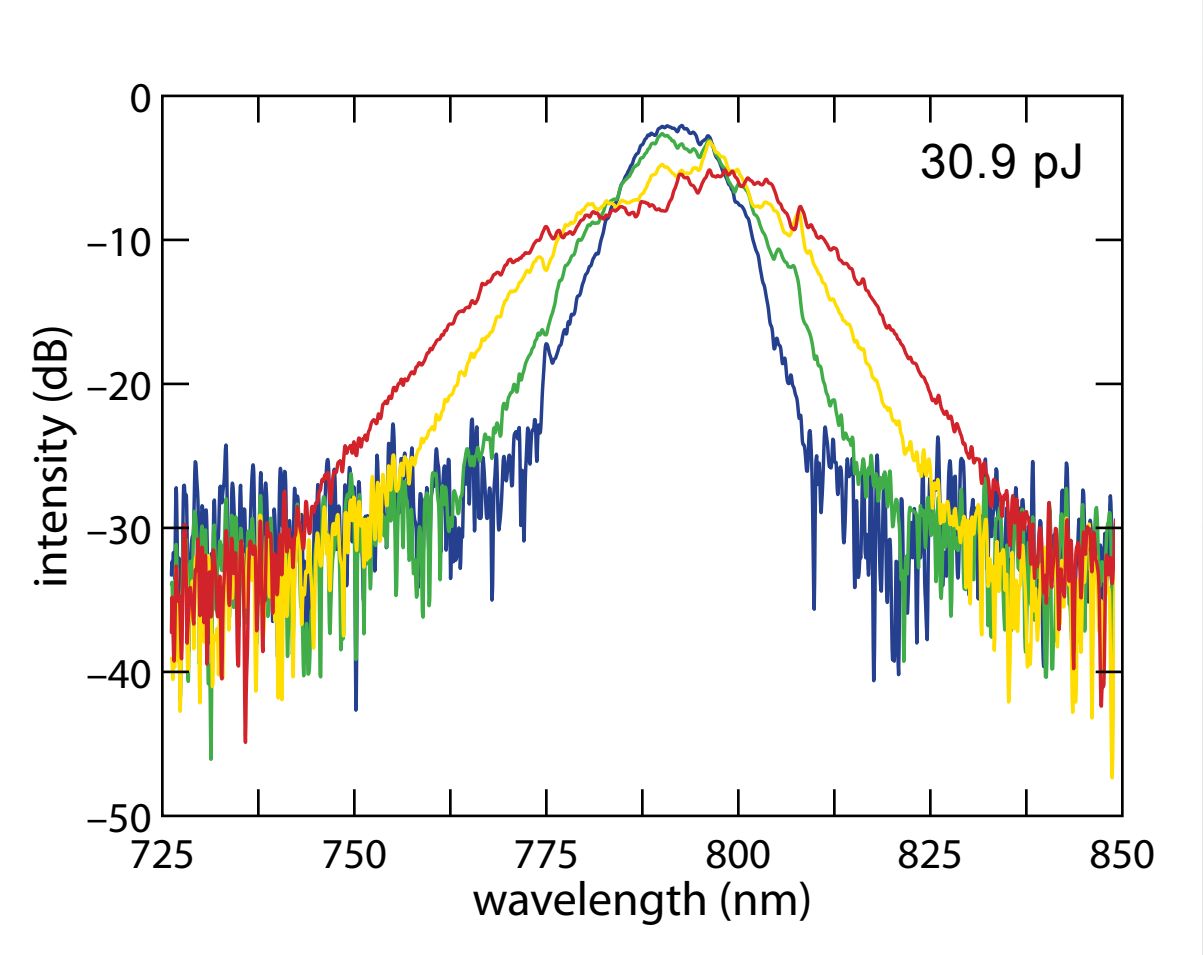
Spectral Broadening



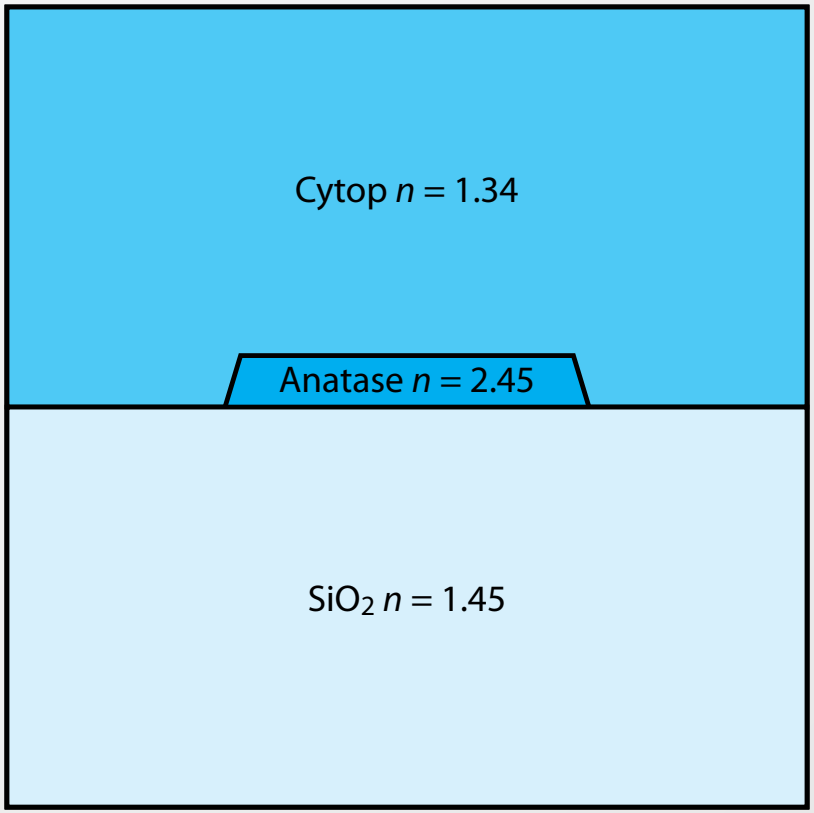
Nonlinear device properties

Spectral Broadening



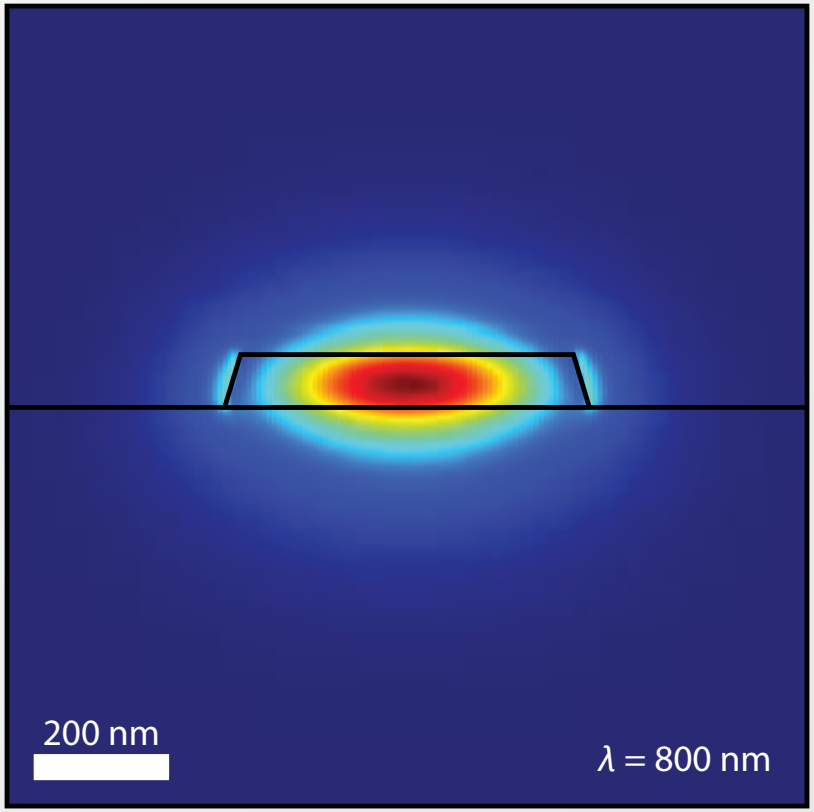
Nonlinear device properties

Mode profile



Nonlinear device properties

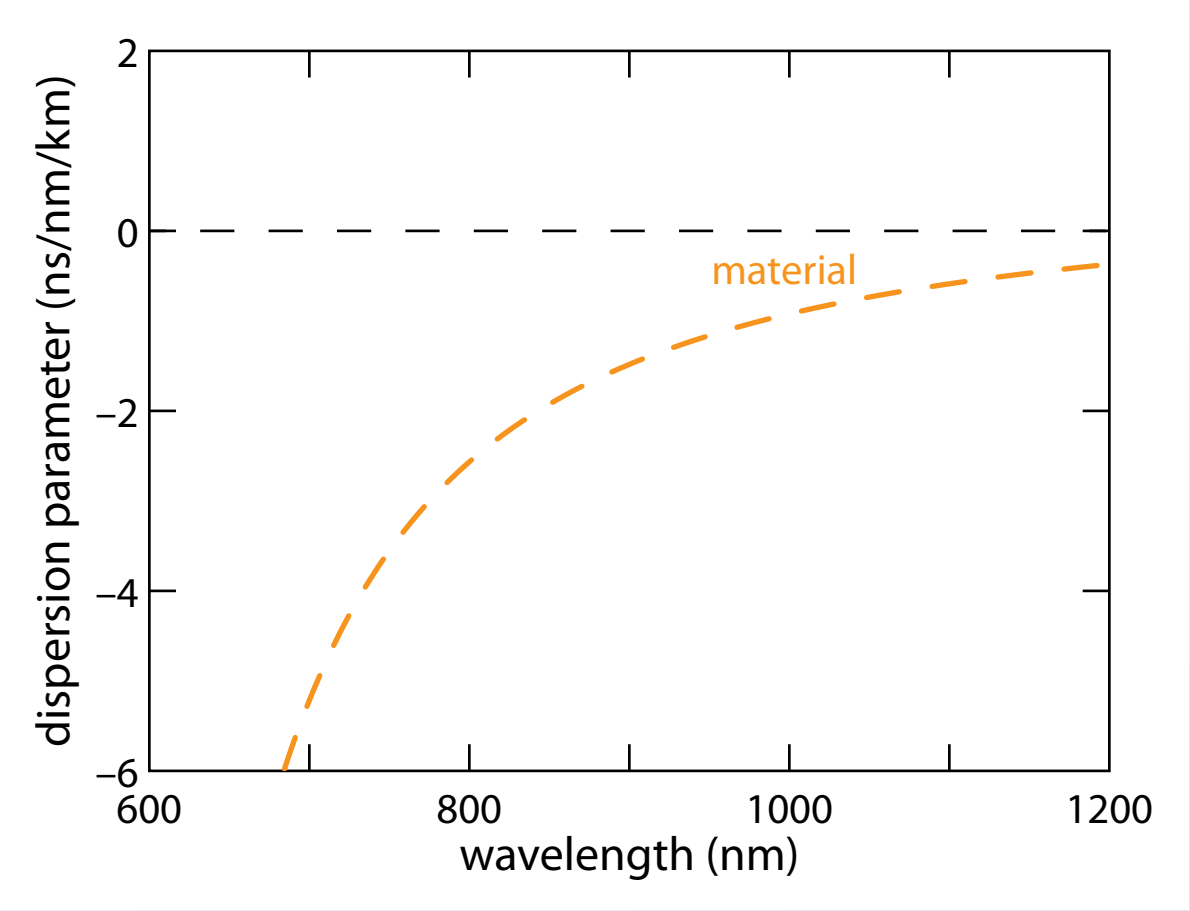
Mode profile



effective nonlinearity is 14 $W^{-1}\,m^{-1}$

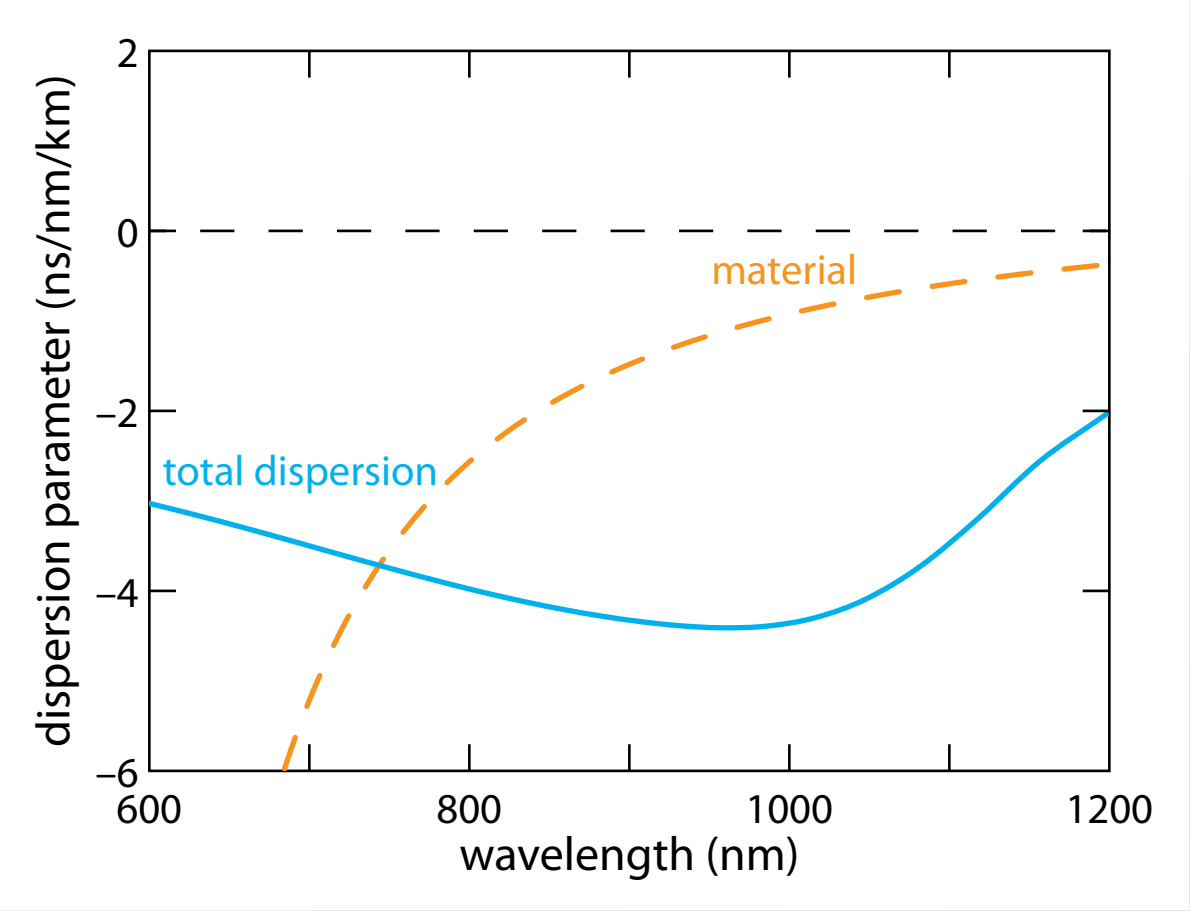
Nonlinear device properties

Dispersion



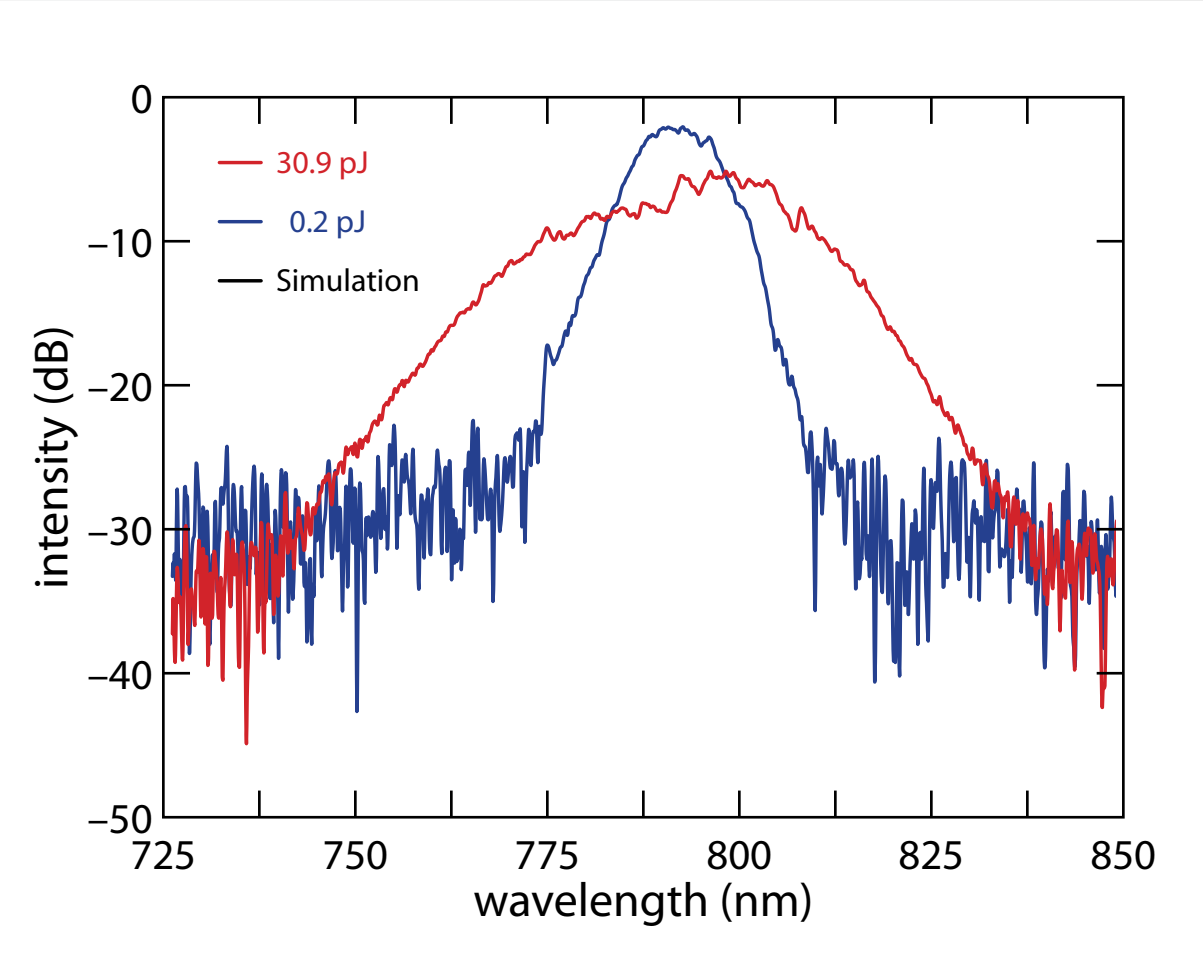
Nonlinear device properties

Dispersion



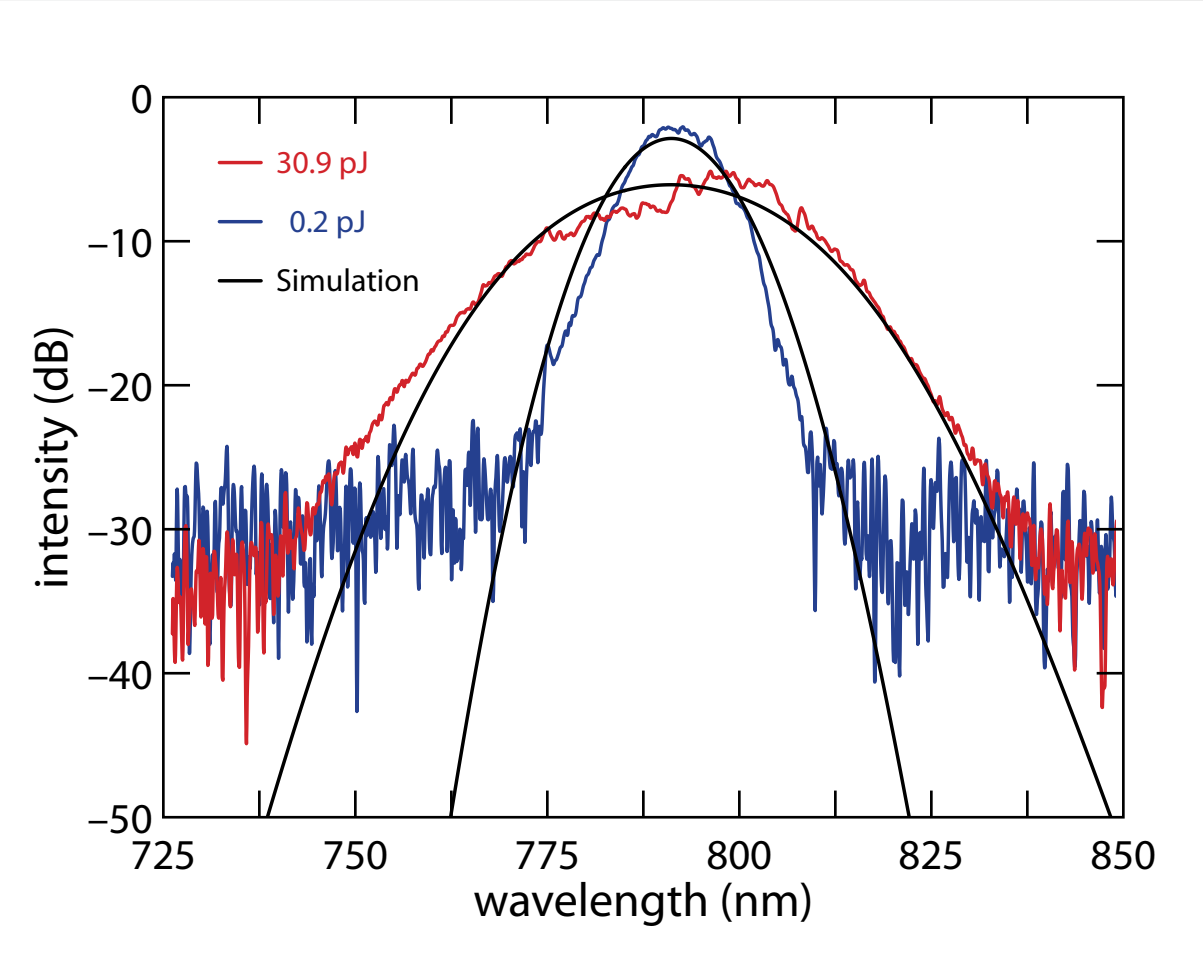
Nonlinear device properties

Nonlinear Simulation



Nonlinear device properties

Nonlinear Simulation



Nonlinear device properties

Nonlinear Simulation

Nonlinear pulse propagation at 800 nm

Effective nonlinearity: ~ 10 $W^{-1}m^{-1}$

Positive nonlinear index of refraction

Pulse energies of <u>only a few pJ</u>

Conclusions

Titanium Dioxide: material for Integrated Photonics

- Two-polymorphs: Amorphous and Anatase
- Deposition for low-loss planar waveguides
- Nanoscale structuring capabilities
- Waveguides with losses down to 13 db/cm
- Toolset of basic devices

Conclusions

Titanium Dioxide: material for Nonlinear Optics

Compatible with 800-nm nonlinear optics

Nonlinear pulse propagation in TiO_2 wavguides

High effective nonlinear index ~ 10 $W^{-1}m^{-1}$

Picojoule nonlinear optics

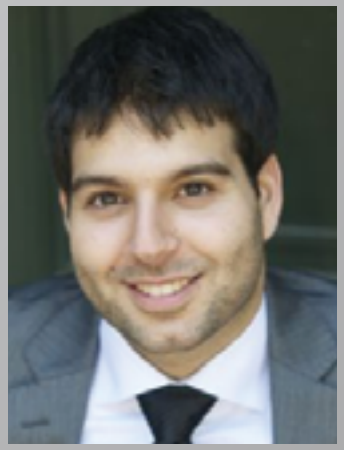
Conclusions

Titanium dioxide:

a novel material for integrated nonlinear optics

Funding provided by:

Chris Evans



Orad Reshef

Jon Bradley

Eric Mazur

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Erwin Marti
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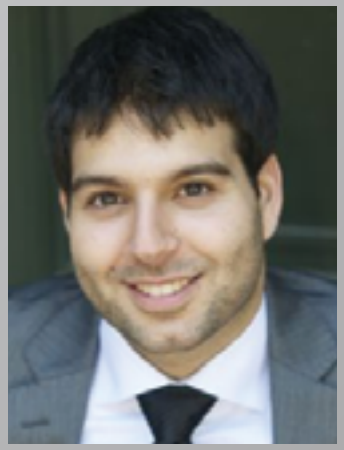
Grisel Rivera
Ruwan Senaratne
Stephanie Scwartz

Chris Evans



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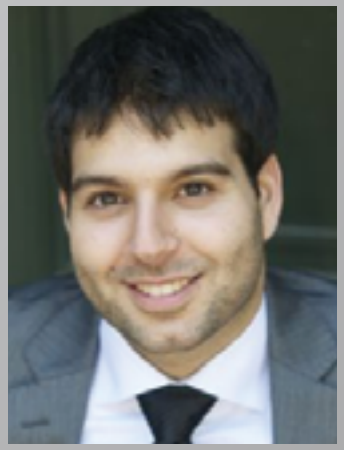
Any questions?

Chris Evans



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