Low-loss TiO_2 planar waveguides for nanophotonic applications

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Applications of TiO_2 thin films:

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Photocatalysis

Solar cells

Reflective coatings

Dielectric layers

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High nonlinearity: $n_2 \geq 30 \times n_{2,SiO2}$ at 1064 nm*

*Adair et. al., *Phys Rev B.* **39**, 1989.

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High refractive index: $n_0 \cong 2.4$ at 800 nm

High nonlinearity: $n_2 \geq 30 \times n_{2,SiO2}$ at 1064 nm

Potential applications:

Photonic crystals, nonlinear optics,
passive devices, active devices

Introduction

Challenges:

TiO_2 has several phases: amorphous, anatase, brookite, rutile.

These phases result in a wide range of properties (refractive index, birefringence, nonlinearity, loss).

Introduction

Goal:

Exploit TiO_2 as a material for nanophotonic devices for real-world applications.

Requirements:

- Low losses
- Scalable technology
- Small dimensions

Deposition of TiO_2 Films

Reactive Sputtering

Deposition of TiO_2 Films

Reactive Sputtering

Excellent uniformity

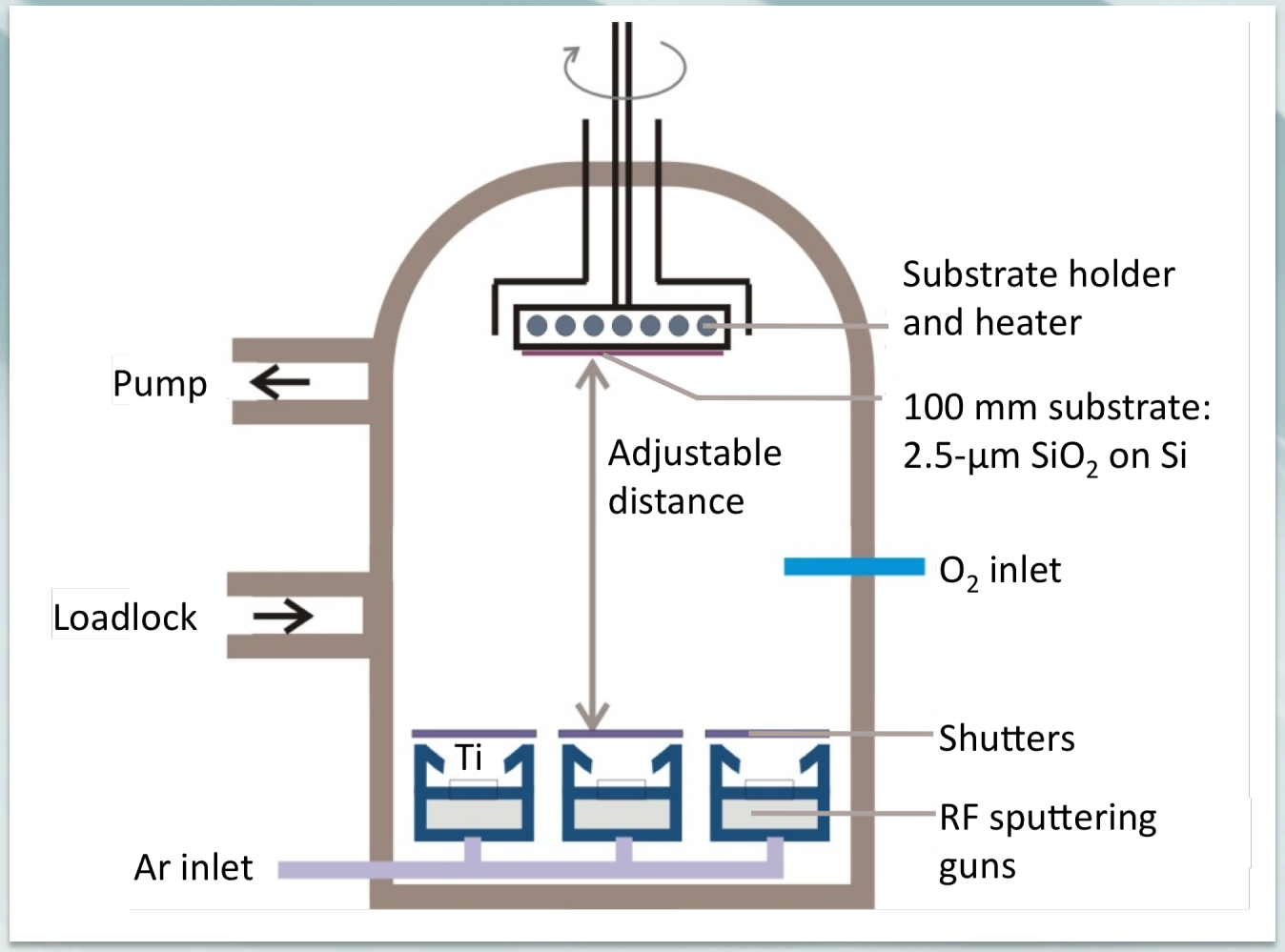
Large parameter space for control of film properties

Multiple targets: potential for doping

Compatible with Silicon Technology

Wörhoff et. al., *IEEE J. Quantum Electron.* **45**, 2009.

Deposition of TiO_2 Films



Deposition of TiO_2 Films

Process Parameters

Parameter	Range	Units
Temperature	20−600	°C
Pressure	2−5	mTorr
Power	100−200	W
Total Flow	40−60	sccm
O_2 Flow %	2−33	%

Results

Film Characterization Methods

Structure: scanning electron microscopy (SEM)

Composition: X-ray photoelectron spectroscopy (XPS)

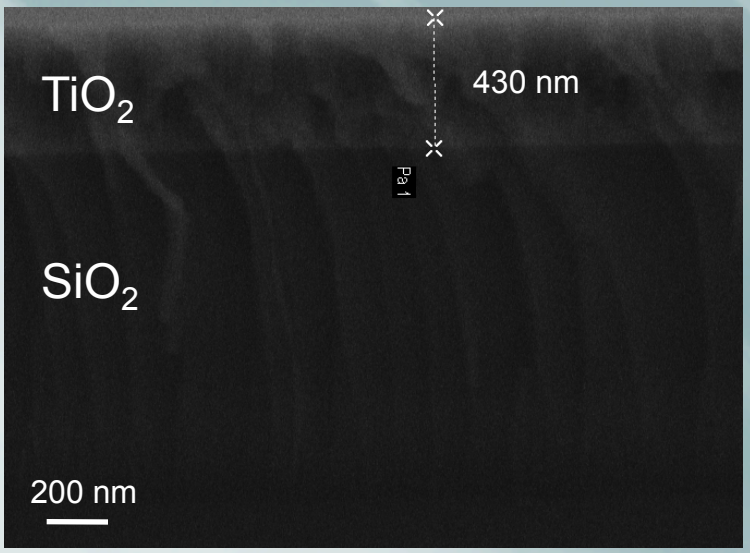
Crystalline phase: Raman spectroscopy

Optical properties: ellipsometry and prism coupling

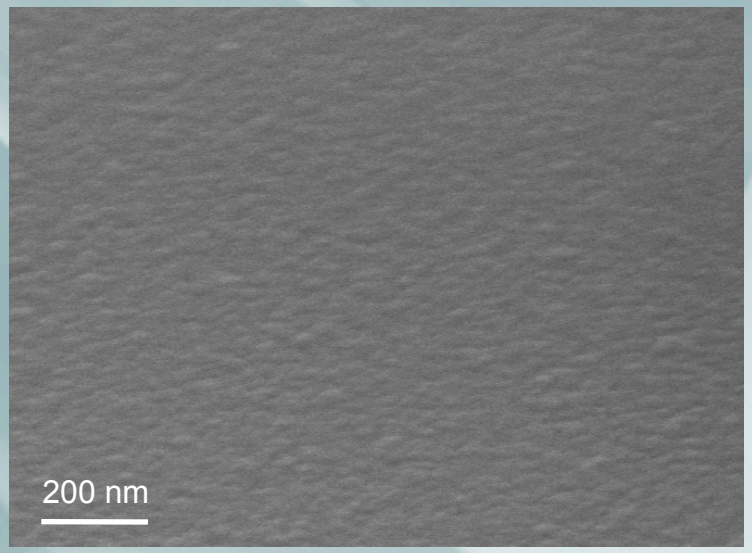
Results

Structure

Cross-section



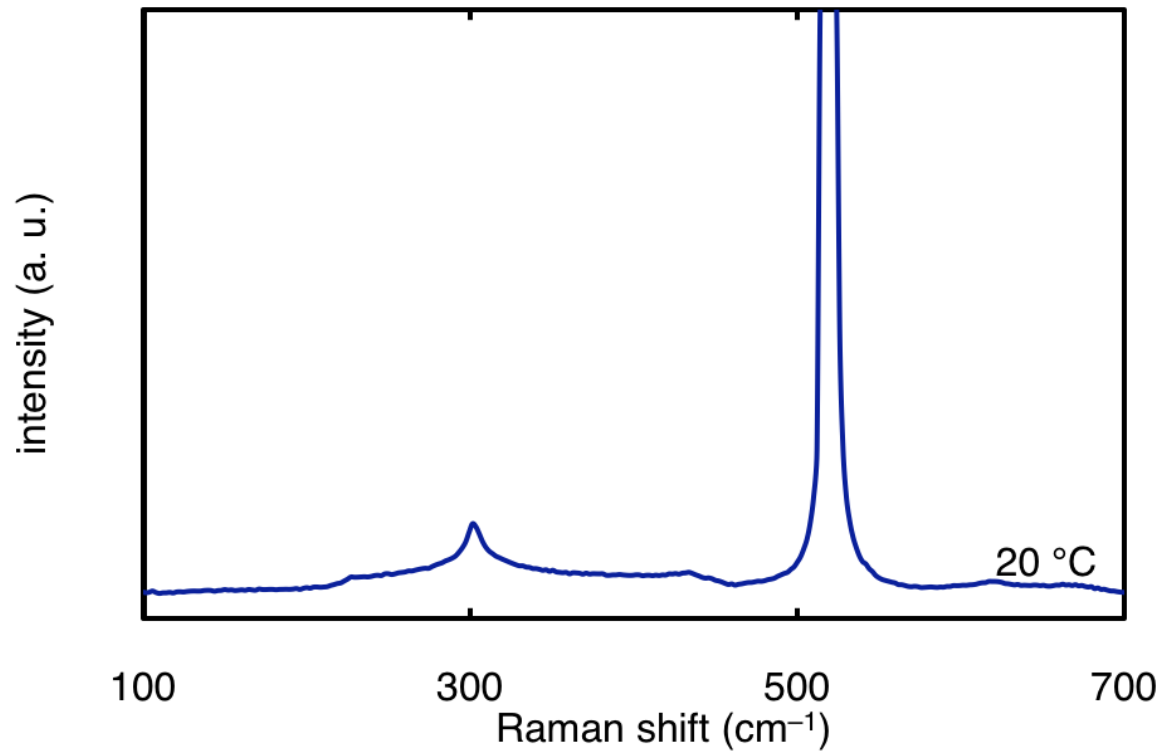
Surface



Stoichiometry confirmed via XPS measurements.

Results

Phase



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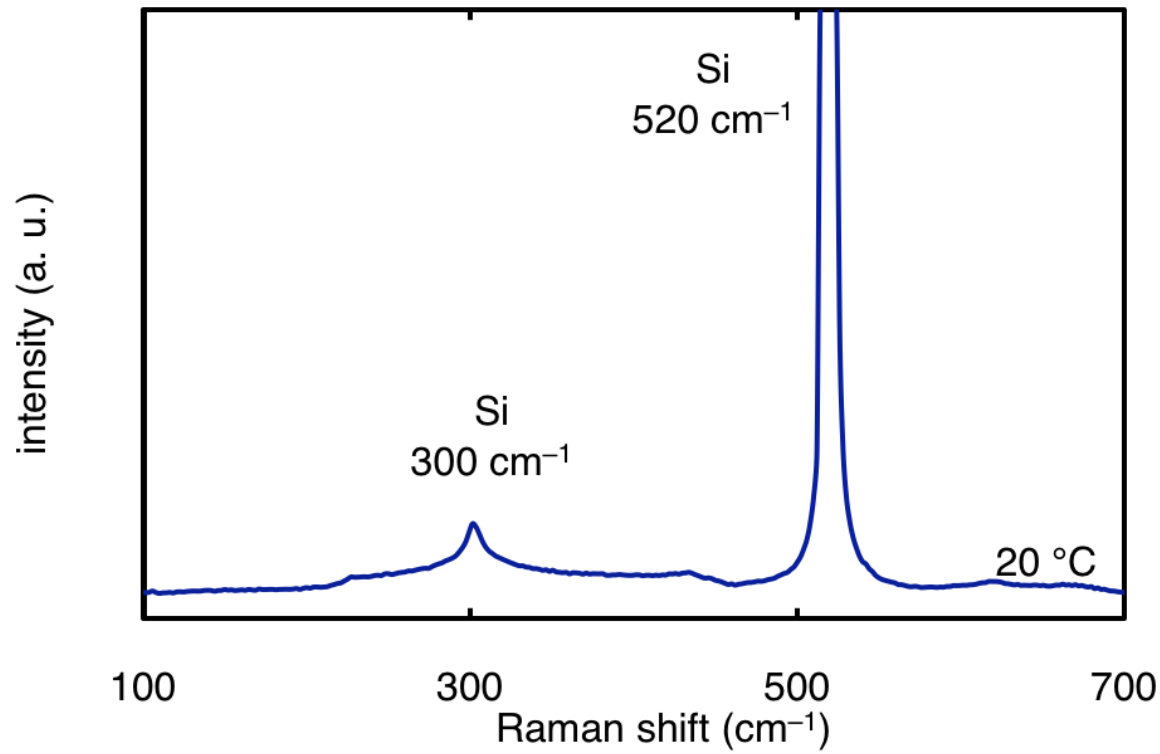

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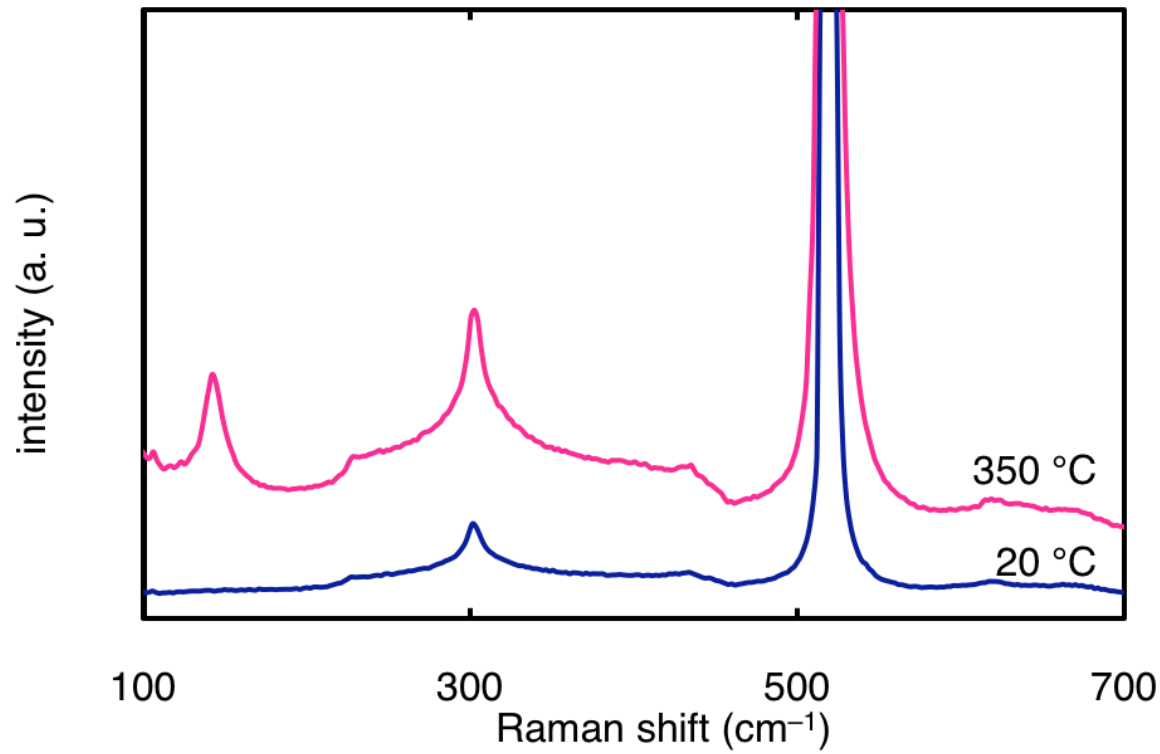

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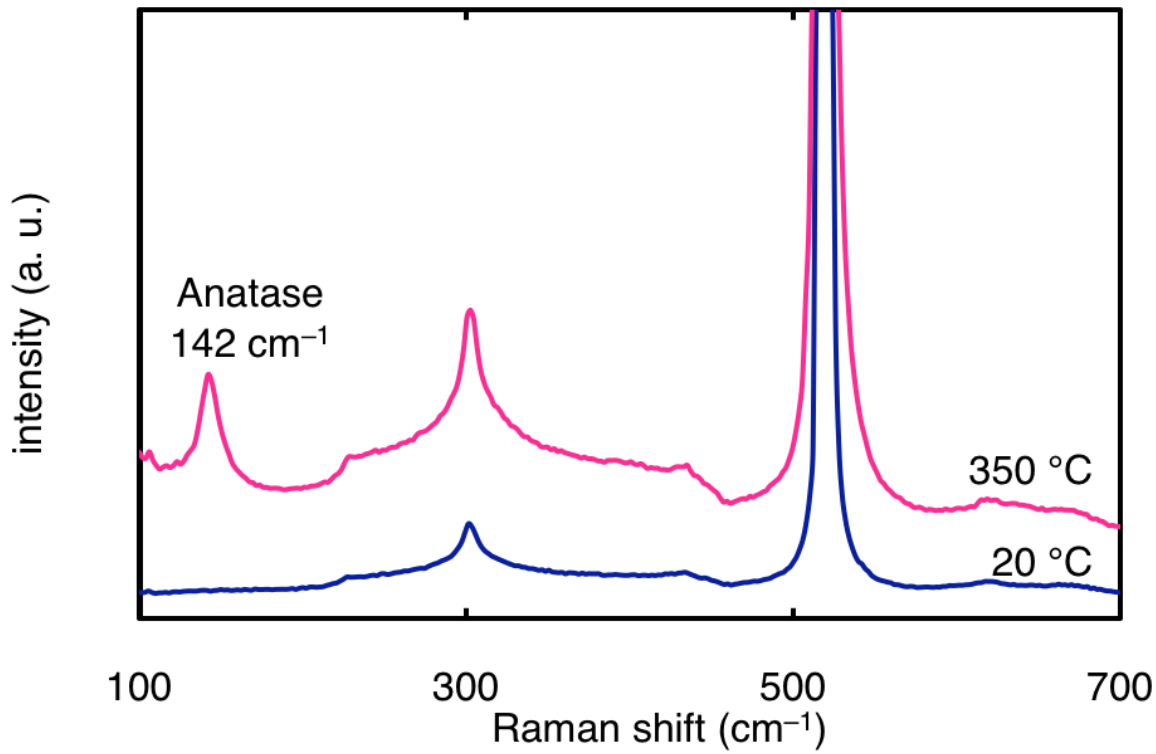
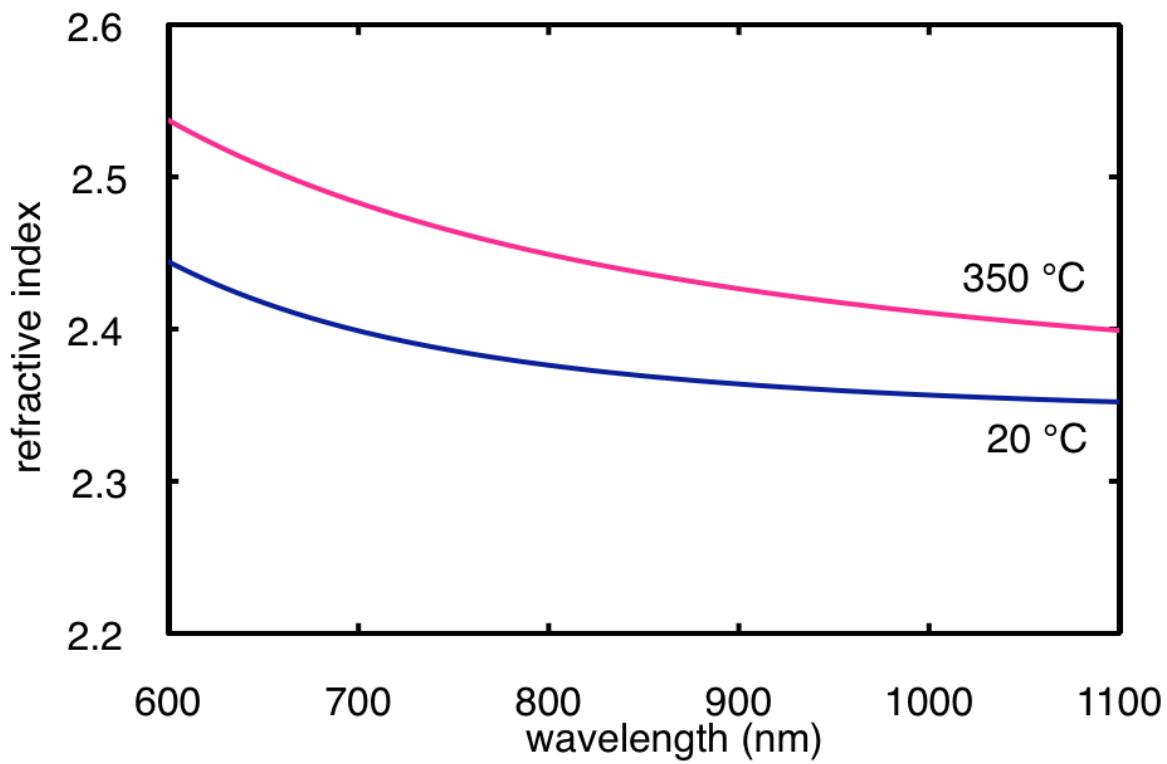


Ohsaka et. al., *J. Raman Spectrosc.* **7**, 1978.

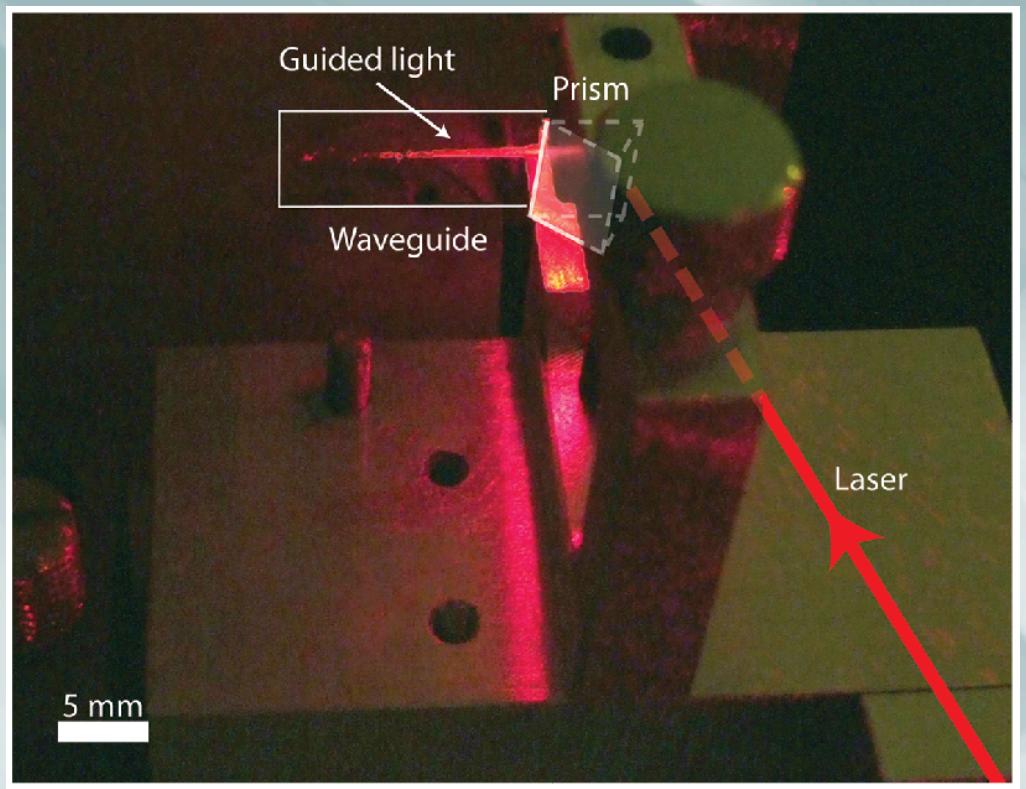
Results

Dispersion



Results

Propagation Loss



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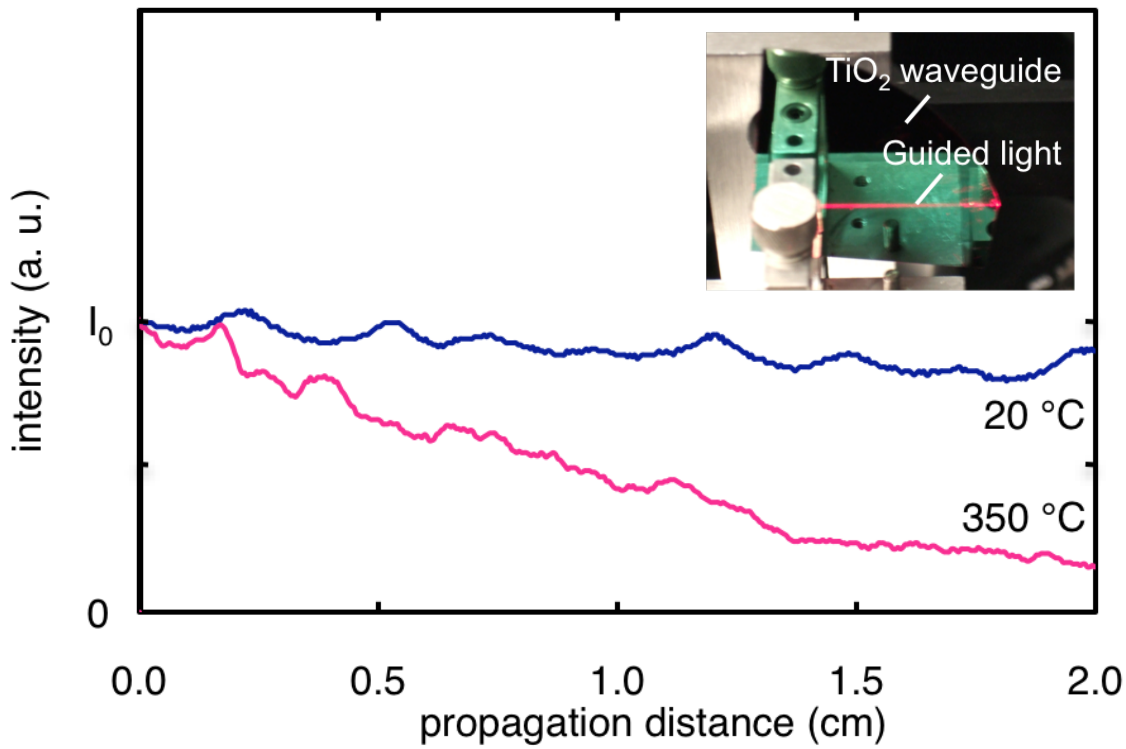

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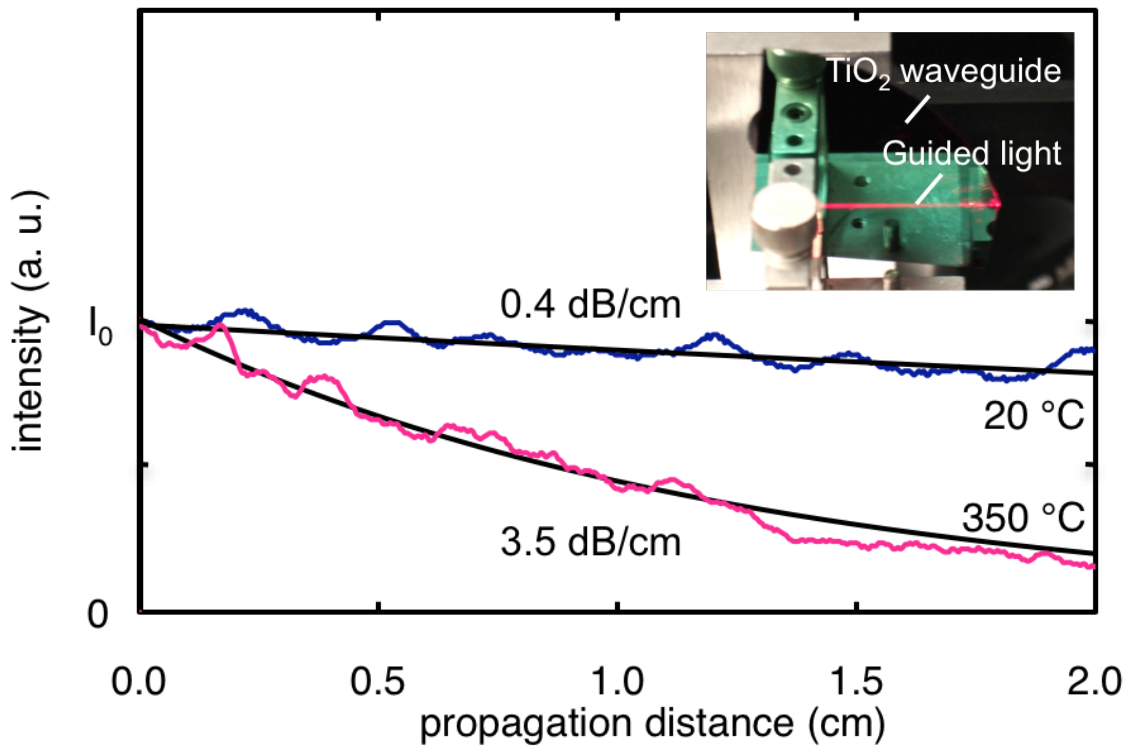

Results

TiO_2 Film Properties

Property	Amorphous Films	Anatase Polycrystalline Films
Temperature (°C)	20	350
Deposition rate (nm/hr)	100	16
*Refractive index	2.35	2.43
*Loss (dB/cm)	0.4	3.5

* At λ = 826 nm

Conclusion

We have developed a method for depositing amorphous and anatase TiO_2 thin films with low losses.

These high-index thin films will be used for nanophotonics applications over a wide wavelength range.

Acknowledgements

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