Nanophotonic Devices

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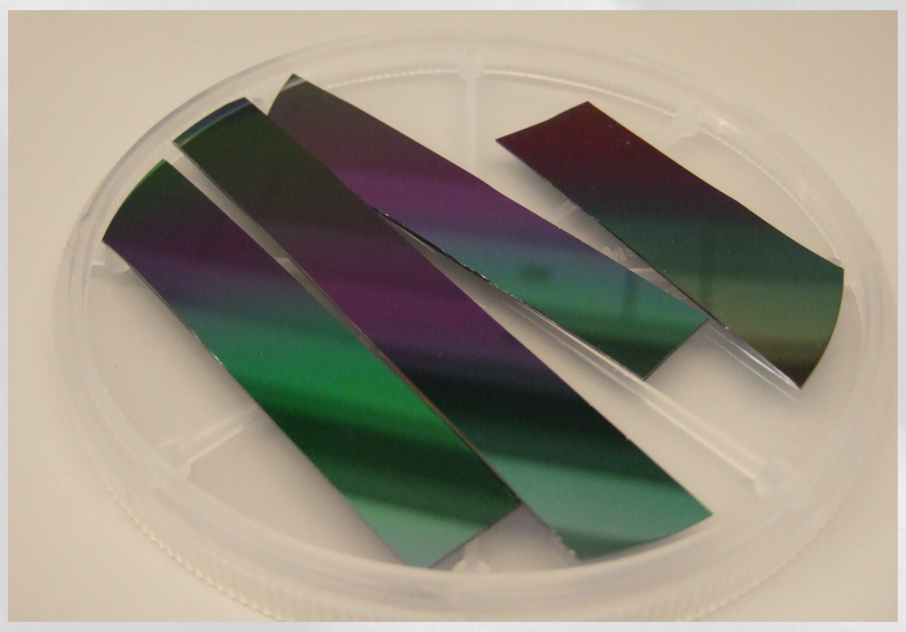
Research Goals

Light traveling in a nonlinear optical material experiences an intensity dependent index of refraction. This varies the effective optical path length. In an interferometer, this effect can produce intensity dependent fringes which can be exploited to perform ultrafast all–optical switching.

We have identified TiO_2 as a promising yet unexplored material platform for on–chip nonlinear optics. Its high refractive index of 2.4 and large nonlinearity, which is over 50 times that found in silica, can strongly enhance nonlinear interactions. Our goal is to realize nanophotonic devices for all-optical modulation, logic and wavelength conversion.

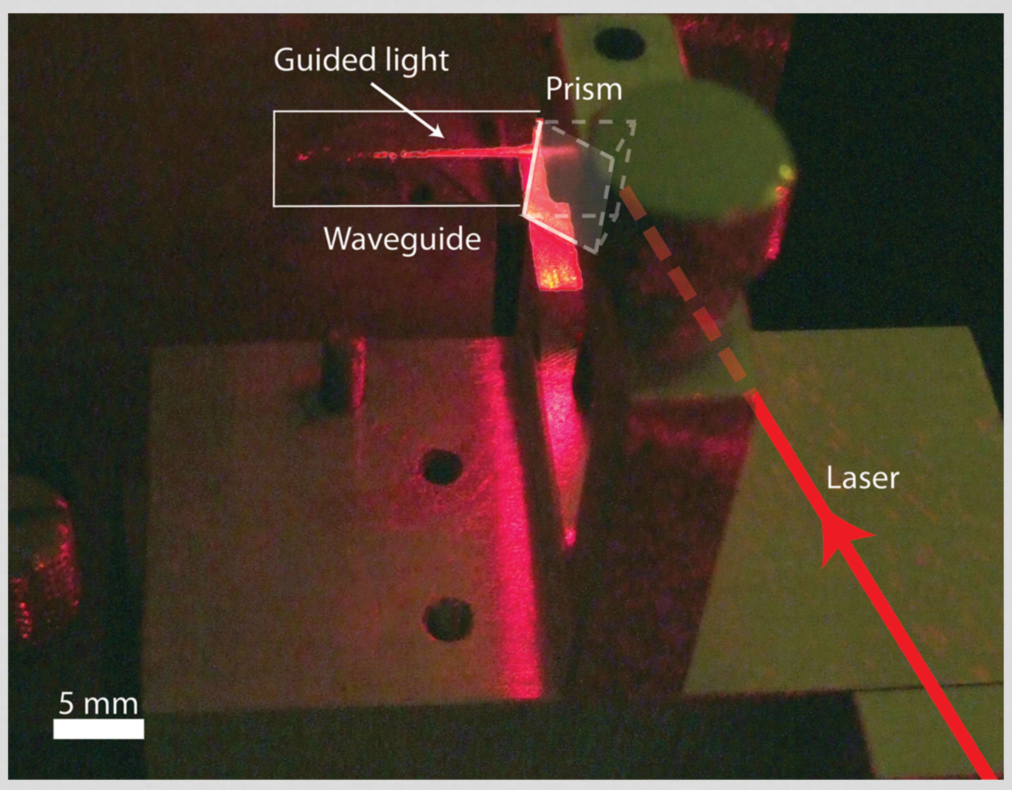
TiO_2 Thin Films

The first step to realizing advanced nonlinear optical devices is to deposit and evaluate thin films of TiO_2 to optimize their linear and nonlinear optical properties. The properties depend on the phase, which can be amorphous, anatase or rutile. We are exploring different deposition techniques using the CNS facilities including sputtering, electron beam evaporation, atomic layer deposition and the sol-gel method to develop an optimal platform for nonlinear optics.



Material Characterization

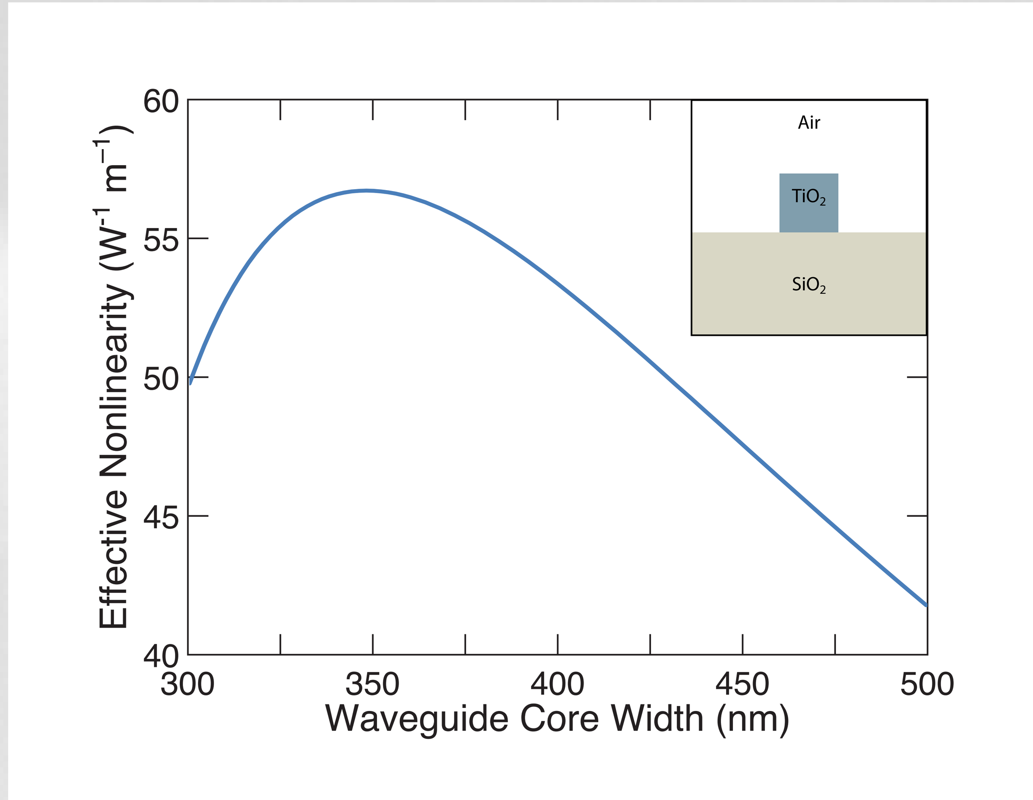
We rely on a suite of metrological techniques to fully characterize our thin films. Ellipsometry provides detailed information about the refractive index and material dispersion, whereas with prism coupling we directly measure planar waveguiding losses (left). Using TEM and Raman spectroscopy, we determine the crystallinity of our films. Lastly, the z-scan technique is capable of measuring both the nonlinear index and multi-photon absorption using femtosecond laser pulses. We have deposited both amorphous and anatase films with losses approaching 1 dB/cm at 826 nm.



Simulation

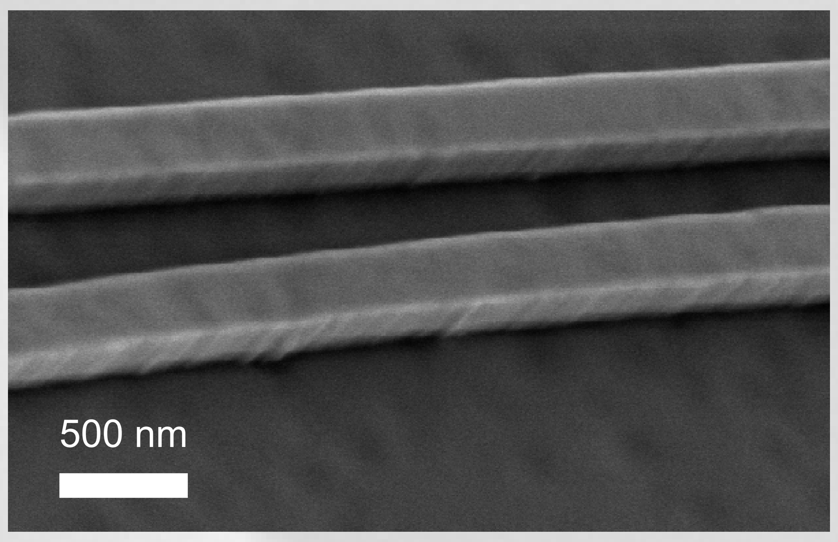
The working principle of an interferometer is based on phase accumulation, which depends on the optical path length. Here, the intensity dependent index results in additional phase.

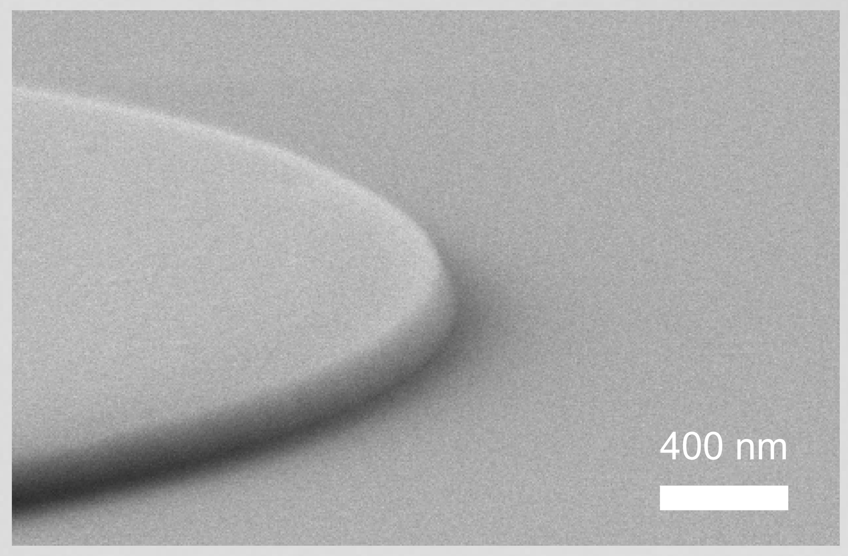
To optimize device performance, the effective nonlinearity, the nonlinear phase accumulated per unit distance and unit power, must be maximized. This parameter depends on the material properties and the dimensions of the waveguide core. Plotted here is the effective nonlinearity for a square TiO_2 waveguide for 800 nm light. As the core area is decreased, better confinement leads to a stronger effect. At smaller dimensions, a larger percentage of the light is guided outside the core and the effective nonlinearity decreases.



Nano–Structuring

Using electron-beam lithography combined with reactive ion etching, we have fabricated photonic structures, including channel waveguides (below left) and microdisk resonators (below right) with dimensions down to hundreds of nanometers.





Future Work

We will design, fabricate and test linear and nonlinear nanophotonic waveguide components. The basic toolset will consist of straight channel waveguides, bends, splitters and couplers fabricated using lithographic techniques. These components will be exploited to realize advanced nonlinear optical devices for wavelength conversion, soliton propagation, supercontinuum generation and all–optical switching.

NSEC Harvard, MIT, UCSB, MoS

National Science Foundation

Harvard University Center for Nanoscale Systems

Funding provided by NSF

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