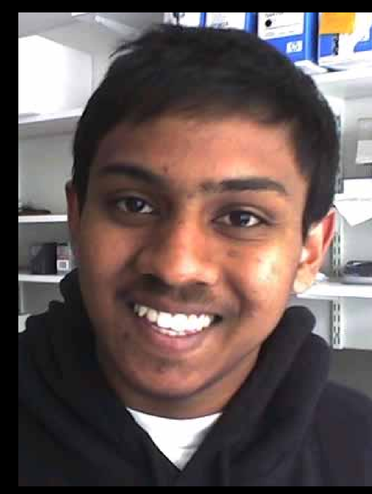
TiO_2 for All-Optical Logic

C. Evans[1], J. Bradley[1], R. Senaratne[1], K. Phillips[1], F. Parsy[2], P. Deotare[1], J. Choy[1], M. Loncar[1], M. Pollnau[3], E. Marti[1,4] and E. Mazur[1]

1 Harvard University, USA 2 INP Grenoble, France 3 University of Twente, Netherlands 4 BUAP, Mexico


Chris Evans


Ruwan Senaratne


Kasey Phillips

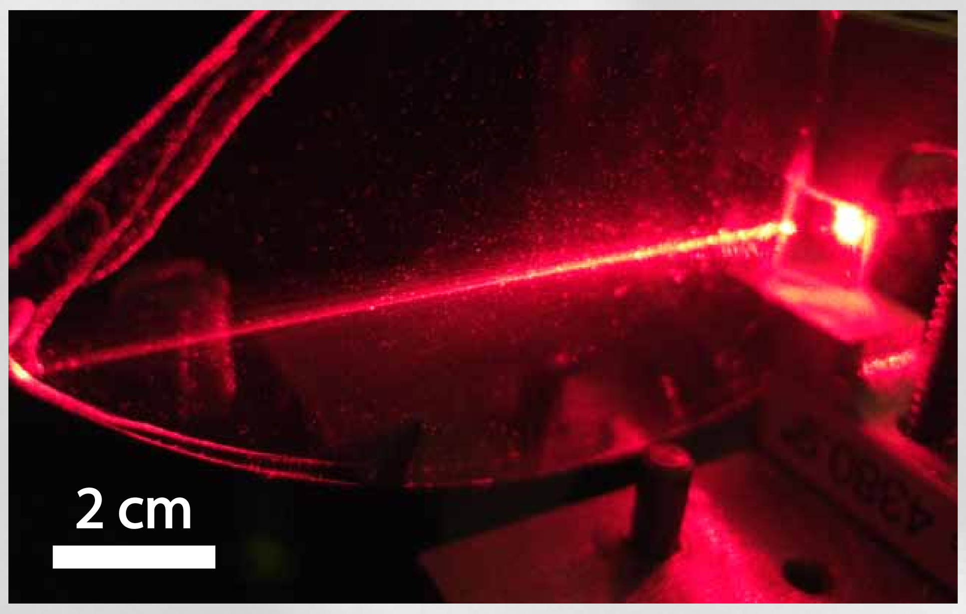

Eric Mazur

Motivation

In the Mazur Group, we seek to meet the future challenges of society by progressing technology to femtosecond timescales and nano-scale dimensions. Using our expertise in nonlinear optics and ultrafast lasers, we are investigating titanium dioxide (TiO_2) as a novel material platform for on-chip nonlinear optics. TiO_2's femtosecond time response can easily support ultrahigh bitrates. It is compatible with the entire telecommunication spectrum, from 800 to 1700 nm. Our current goal is to demonstrate an ultrafast all-optical logic device using TiO_2.

Our Vision

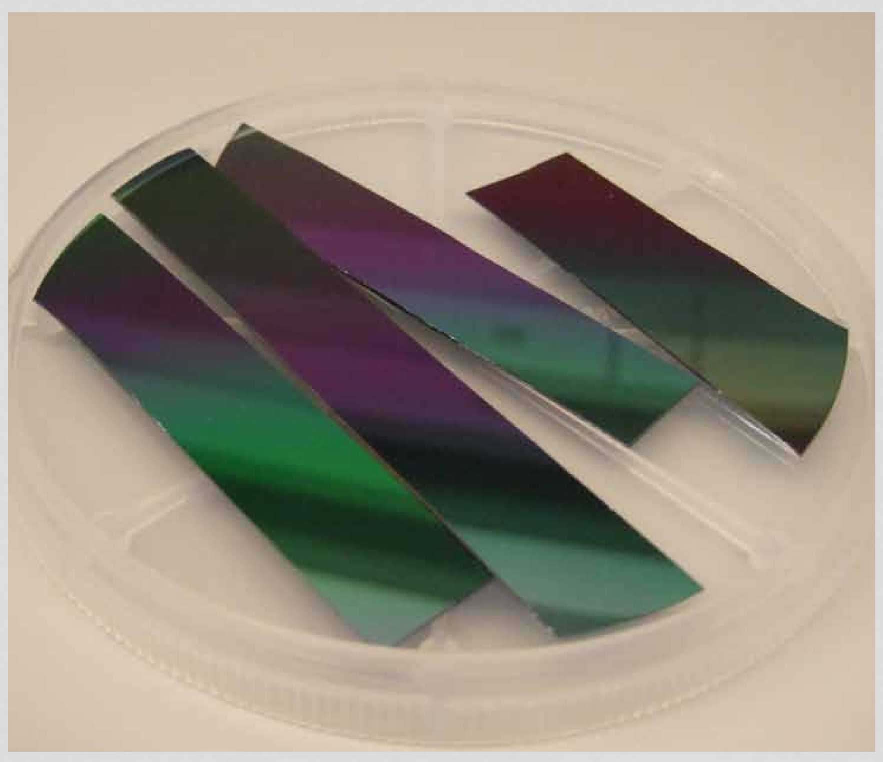
Our approach anticipates the shift to shorter pulsed optical signals as we push our telecommunication systems to higher bandwidths. Using femtosecond pulsed lasers, we are designing and testing devices today to meet and exceed the specifications of tomorrow's telecom needs.



While the conventional strategy for all-optical processing uses materials only compatible with 1.5 microns, our devices, designed for 800 nm operation, can easily be scaled to longer wavelengths.

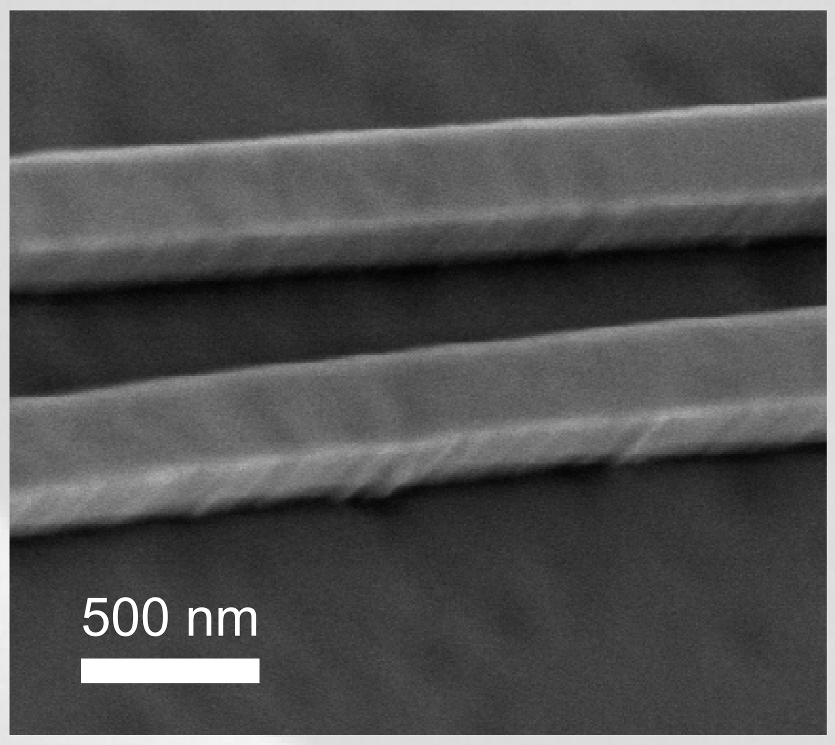
Material Features

TiO_2 is an attractive material for nonlinear optics. It has a large nonlinear index of refraction (30 times silica) combined with low nonlinear absorption. These ultrafast nonlinearities have characteristic response times of several femtoseconds, enabling bandwidths great than 100 THz.

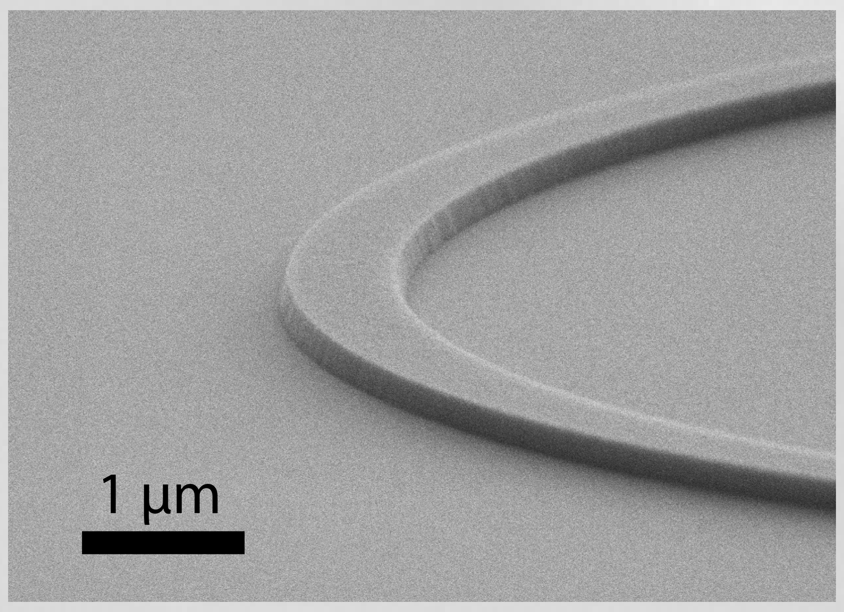


It is transparent throughout the visible and the NIR. Its high refractive index of >2.4 will enable compact and efficient devices. Additionally, its non-toxicity, natural abundance and compatibility with conventional clean-room fabrication techniques can expedite its adoption into future commercial use.

Meeting Challenges



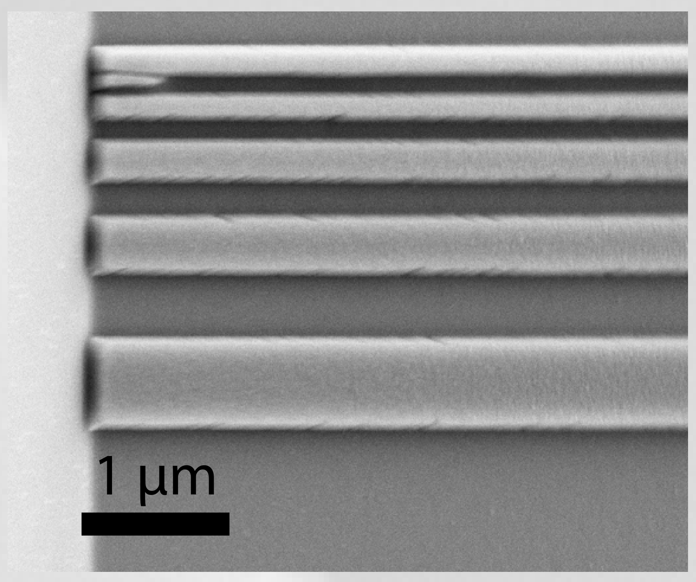
Pioneering such a novel material poses many technical challenges. We require high quality thin films of TiO_2 with low waveguiding losses and structuring capabilities of down to 100 nm. We developed a deposition process using reactive sputtering, achieving losses less than 1 dB/cm (see far left photograph), highly competitve with other photonic materials. Using electron-beam lithography and reactive ion etching, we have demonstrated 100 nm features.

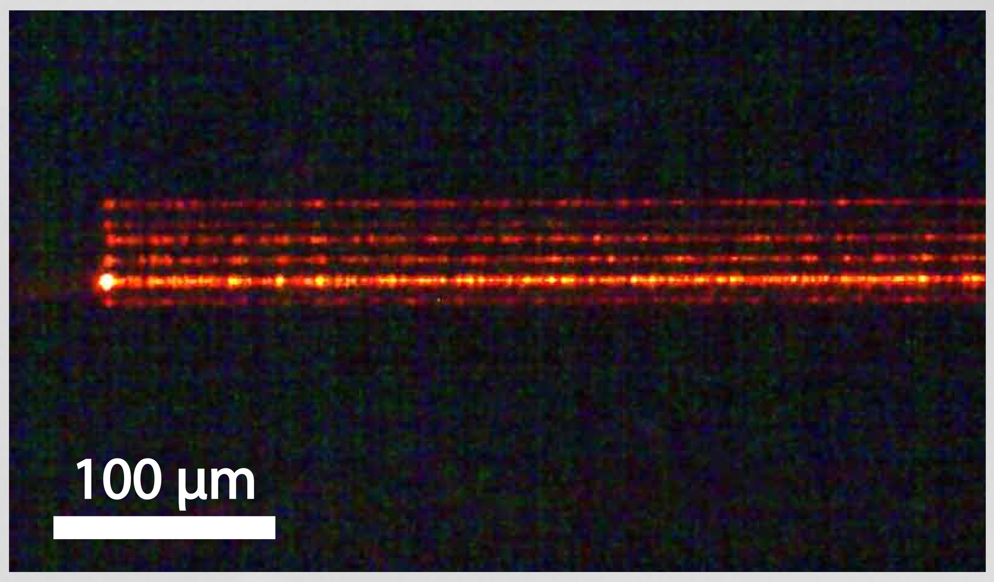


TiO_2's nonlinear properties are not well characterized near our target wavelength of 800 nm. A transition from a maximum nonlinearity to device debilitating absorption is expected here. We have built a system to pinpoint this transition and optimize operational wavelengths.

Recent Achievements

The low loss ridge waveguide shown below demonstrates our capabilities to prototype and test optical devices in TiO_2.





Future Impact

We can use our advanced capabilities with TiO_2 for many other applications. While wavelength converters and optical regenerators can provide high-speed interconnect solutions, nano-sized waveguides, resonators and supercontinuum generators can have applications in sensing, diagnostics and biology. Our promising initial results lead us to expect the maturation of the technology within the next 5 years and commercial products within 10 years.

Harvard University Center for Nanoscale Systems

Funding provided by NSF

http://mazur-www.harvard.edu

Contact: Christopher C. Evans (evans@fas.harvard.edu)

MAZUR GROUP