

# Improved Nonlinear Optical Devices

Researchers at Stanford are advancing a new class of nonlinear optical devices that operate with significantly lower energy requirements than previous platforms. Commercial applications include various photonic applications; sensors; telecom (fast modulators); analytical instruments, and spectrometers. Specifically, the researchers have developed devices that combine quasi-phase-matching with nanophotonic waveguides to achieve efficient nonlinear interactions of femtosecond pulses over length scales an **order of magnitude larger than the current state of the art**. The crucial breakthrough is the change in dispersion due to sub-wavelength confinement; light propagates with a different velocity in nanophotonic waveguides, and the waveguide geometry can be chosen to achieve simultaneous group-velocity matching between multiple interacting waves and reduced higher-order dispersion. Using these methods, the researchers have developed and experimentally demonstrated several devices that achieve efficient spectral broadening and harmonic generation with **the lowest energy requirements demonstrated to date**.

## Stage of Development

Recent demonstrations include second-harmonic generation using  $\sim 50x$  less pulse energy than the previous state of the art, and multi-octave supercontinuum generation with  $\sim 500x$  less pulse energy than previous demonstrations in ion-exchanged waveguides with quadratic nonlinearities.

## Applications

- Near- and mid-infrared light generation
- Ultra-short pulse compression
- Supercontinuum generation
- Frequency comb stabilization
- Upconversion detection
- Quantum frequency conversion

- All-optical signal processing
- Coherent Ising machines
- Generation of nonclassical states of light such as Fock states, heralded photons, squeezed states and cat states

## Advantages

- Combines two key techniques: (i) quasi-phase-matching and (ii) dispersion engineering in nanophotonic devices
- Resulting interactions allow many typically used nonlinear interactions to be scaled to radically lower pulse energies
- Enables new class of nonlinear devices that operate with significantly lower energy requirements than previous platforms

## Publications

- Marc Jankowski, Carsten Langrock, Boris Desiatov, Alireza Marandi, Cheng Wang, Mian Zhang, Christopher R. Phillips, Marko Lončar, and M. M. Fejer, "**Ultrabroadband nonlinear optics in nanophotonic periodically poled lithium niobate waveguides**," *Optica* 7, 40-46 (2020)  
<https://doi.org/10.1364/OPTICA.7.000040>

## Patents

- Published Application: [20220252958](#)
- Issued: [11,469,567 \(USA\)](#)

## Innovators

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