National Aeronautics and Space Administration

Periodic Poling of Thin-Film Lithium Niobate Waveguides

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Program: R&TD Innovative Spontaneous Concepts

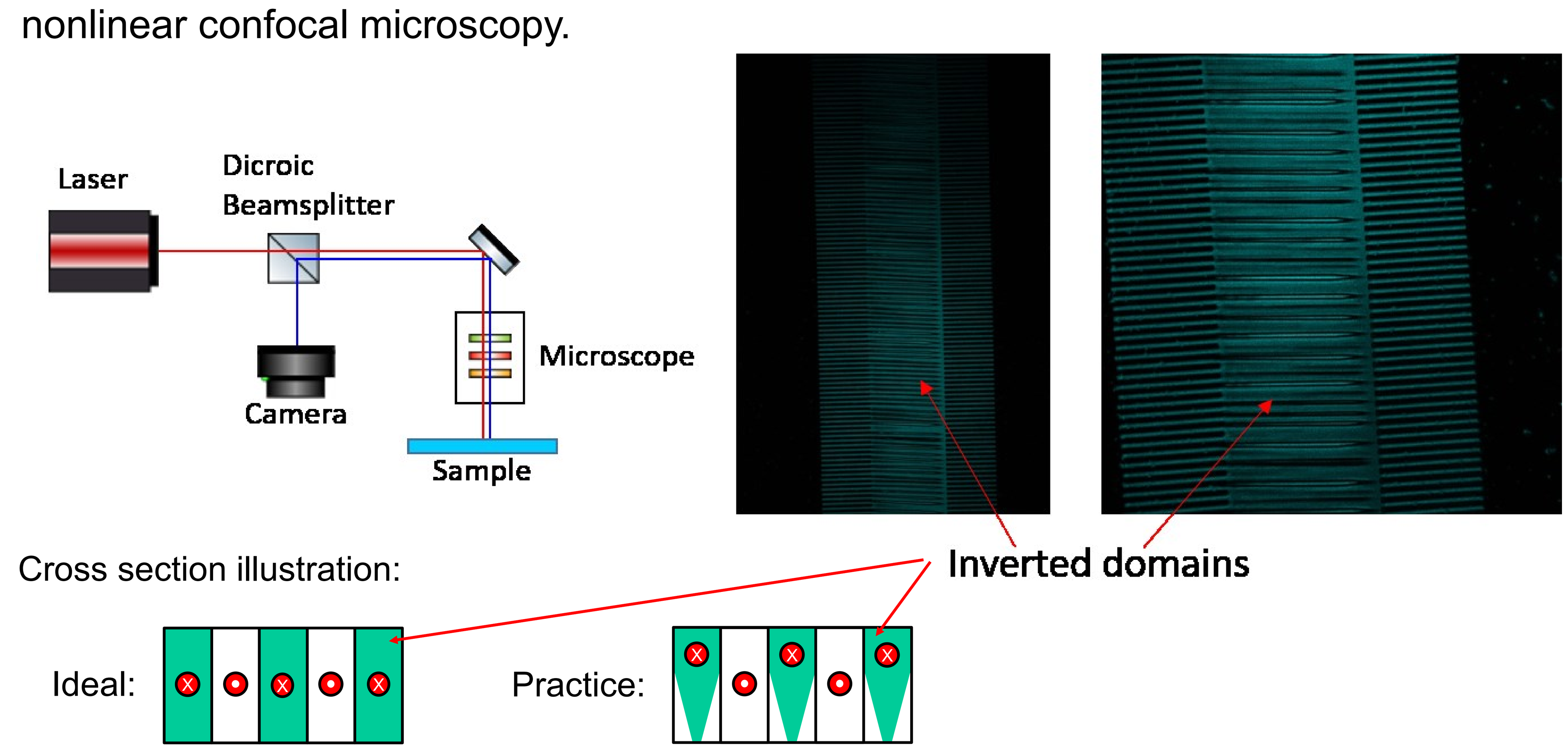
Project Objective:

Lithium niobate on insulator (LNoI) is one of the most promising platforms for the integration of novel photonic systems in the next decades. One of its differentiating features is its strong second order nonlinear effect that enables applications like tunable optical sources in spectral regions not accessible by lasers gain media, optical parametric amplifiers and oscillators, sources of entangled photons for quantum applications, etc. Harnessing this nonlinearity requires the use of phase-matching techniques between the interacting signals at different wavelengths. One of these techniques is known as quasi-phase matching and consists of periodically reversing the ferroelectric domains on the material.

The objective of this R&TD task was to develop a process for the reversal of ferroelectric polarization domains within a thin-film lithium niobate crystal.

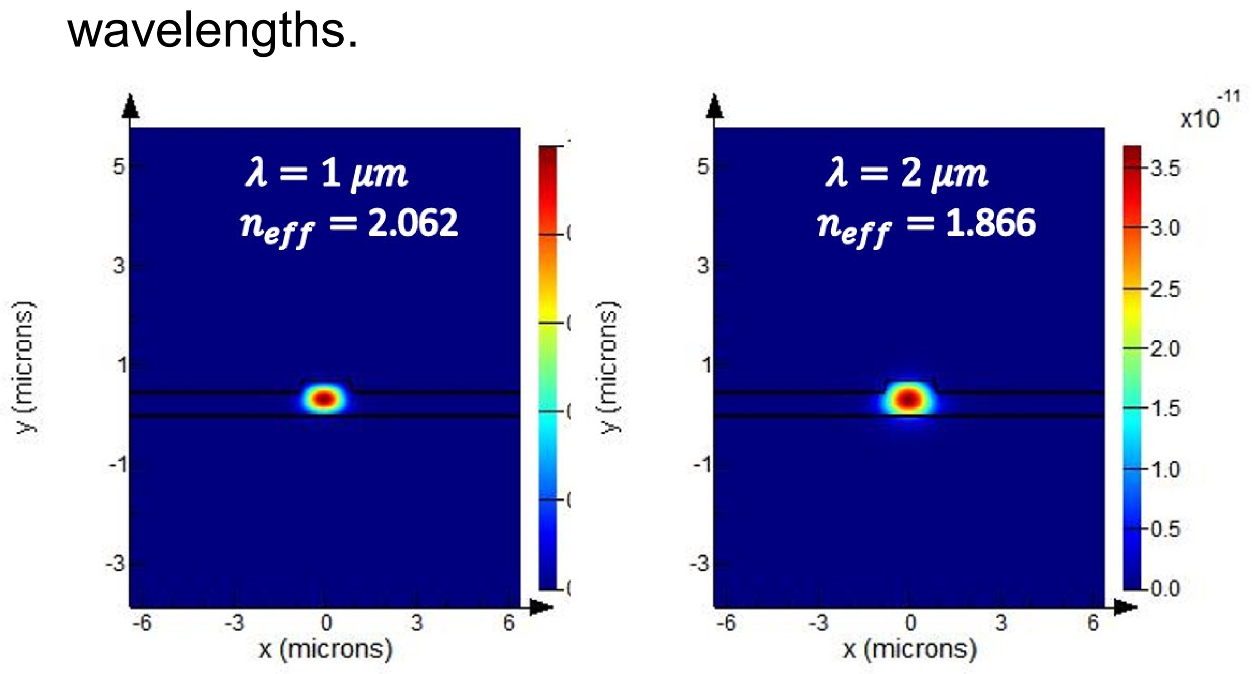
FY19 Results:

We were able to achieve periodic domain inversion as evidenced by laser scanning nonlinear confocal microscopy.



Modal Simulations:

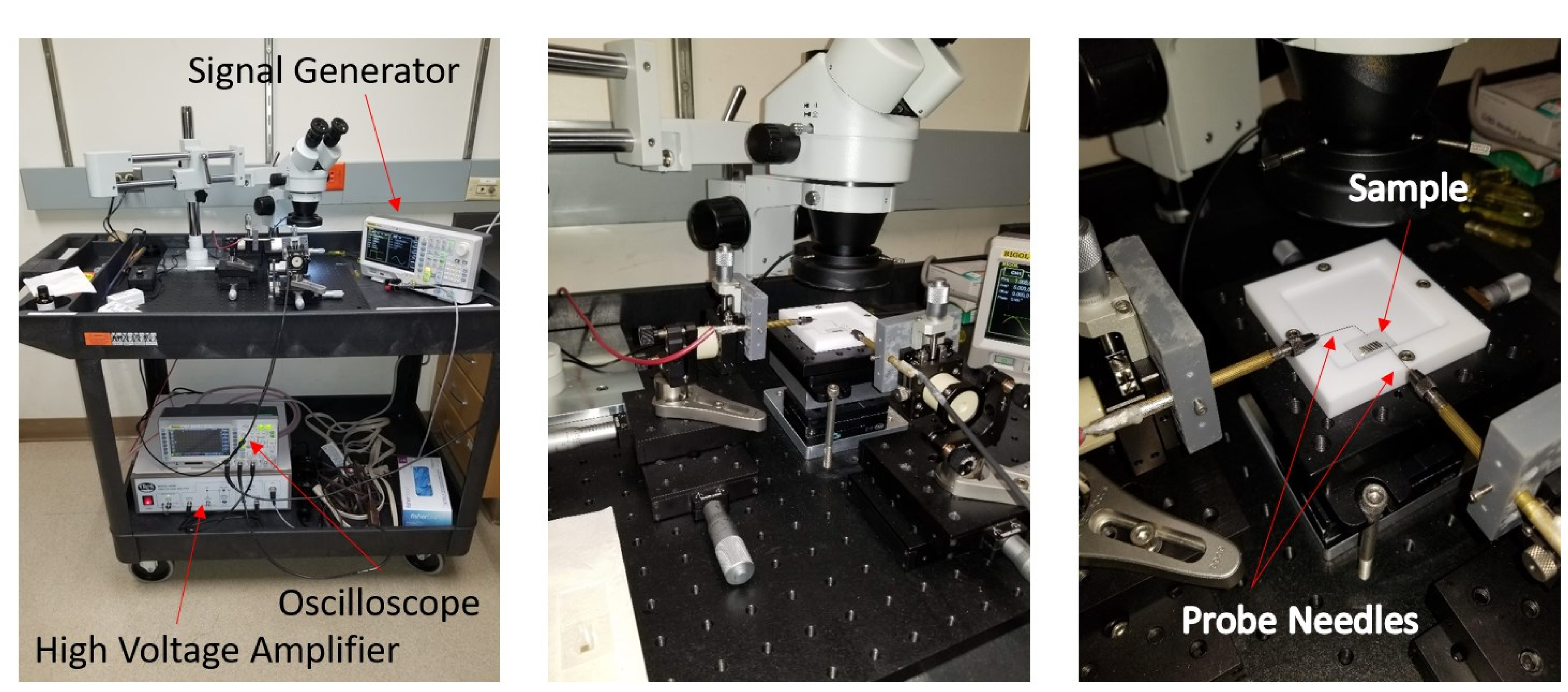
The poling period necessary for quasi-phase matching was determined based on modal simulations of the lithium-niobate waveguides at 1um and 2um wavelengths.

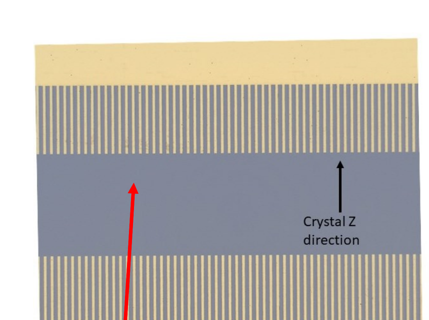


$$\Lambda = \frac{\lambda_{2\omega}}{n_{2\omega} - n_{\omega}}$$

Poling station:

The reversal of polarization domains requires the application of a large voltage (~1kV); we implemented a laboratory setup for that purpose.





The metallic electrodes were patterned with a liftoff process based on e-beam photolithography and e-beam evaporation.

Benefits to NASA and JPL (or significance of results):

Thanks to this R&TD effort, we are able to design and implement a quasi-phase matching method for integrated waveguides enabling high efficiency nonlinear photonic interactions. This is a necessary component for a large variety of devices, including optical parametric oscillators (OPOs). OPOs could play an important role in a new generation of optical frequency combs that could fork into a plethora of applications relevant to JPL's mission, including the calibration of spectrographs for astronomy, frequency and time transfer, ultra-precise optical clocks in space, simultaneous large range and high-resolution distance measurement, precision infrared spectroscopy, and optical computing of NP-hard problems.

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Poster No. RPC-185