STEVENS INSTITUTE OF TECHNOLOGY 1870

Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy
School/Department: Charles V. Schaefer, Jr. School of Engineering and Science / Physics
Date: 10:00 AM, Thursday, April 27th/2023
Time/Location: McLean, Room 104
Title: Quantum Sensing Applications with Integrated Lithium Niobate Photonic Circuits

Chairperson: Prof. Yu-Ping Huang, Department of Physics, School of Engineering & Sciences

Committee Members: Prof. Knut Stamnes, Department of Physics, School of Engineering & Sciences
Prof. Yong Meng Sua, Department of Physics, School of Engineering & Sciences
Dr. Yongxiang Hu, NASA Langley Research Center

ABSTRACT

The measurement of atmospheric gases through spectroscopic techniques and concentration dynamics tracking plays a crucial role in various fields, including environmental monitoring, atmospheric composition analysis, carbon cycle research, and satellite-based gas remote sensing. They are integral in assessing and identifying technological countermeasures against global warming. However, conventional bulk-optics devices present trade-offs among instrument size, throughput, and spectral resolution, which limit their end-performance for space-borne or airborne applications. To address this issue, thin-film Lithium Niobate (LN) photonic integrated circuits (PICs) have emerged as a promising technology for next-generation optical instrumentation in remote sensing.

In this study, we present two novel spectroscopic systems that employ lithium niobate nanophotonic chips for measuring the absorption spectrum of atmospheric carbon dioxide and oxygen. Our systems reduce power consumption significantly compared to current satellite payload devices, with power consumption dropping from 200 Watts to 25 milliwatts. Also, our chips outperform current satellite bulk-optical devices by improving the spectral resolution for detecting atmospheric carbon dioxide from 76 picometers to 6 picometers at around 1570 nm, and for detecting atmospheric oxygen A-band from 42 picometers to 10 picometers at around 770 nm. Benefiting from the single-photon counting technique, our remote gas sensor exhibits a detection sensitivity of 1.2 parts per million for measuring carbon dioxide molecules in the Earth's atmosphere. By providing improved spectral resolution and reducing the system's SWaP requirements, lithium niobate nanophotonic chips offer a more cost-effective and practical solution for remote sensing applications.

Furthermore, we explore the potential application of the nonlinear optical effect on our chips for observing single-photon level photon interference, which has the potential to enhance the sensitivity and detection limits of photonic sensors.