National Aeronautics and Space Administration

Octave tunable on-chip optical parametric oscillator for infrared laser spectroscopy

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Program: FY22 R&TD Innovative Spontaneous Concepts

Objectives:

To evaluate the applicability of widely tunable on-chip optical parametric oscillator (OPO) technology to future space-borne tunable laser spectroneter (TLS) instruments.

Background:

High precision Tunable Laser Spectrometers (TLS) are essential in-situ instruments for planetary missions, such as the Mars Curiosity Rover and the DAVINCI+ mission to Venus. Targeting a large range of molecules and stable isotope ratios is important for the identification of a large number of planetary geophysical processes, including environmental habitability and biology. However, TLS use distributed feedback lasers (DFB) with a limited tuning range, restricting the number of target compounds that can be addressed. Alternatively, optical parametric oscillators (OPOs) are sources of coherent radiation that can be tuned over a large wavelength range, and thus combine the advantages of single-frequency DFB lasers with the broad spectral coverage of FTIRs/combs. Table-top OPO spectroscopic setups exist, but no on-chip configuration has been demonstrated to date. A highly promising on-chip platform is thin-film lithium niobate on an insulating substrate (LNOI), which yields exceptional quadratic nonlinearities and can be quasi-phase matched through periodic poling. Using this platform, we have recently demonstrated an on-chip doubly-resonant OPO producing tunable radiation from 1.53 µm to 3.25 µm, which has the potential to greatly enhance the capability of the TLS in a small form factor.

Approach and Results:

- Characterized the power and spectral characteristics of our on-chip OPOs to evaluate their applicability to future space-borne TLS instruments (Figures 1 – 4).
- Proposed an improved design that inherits the current wide tunability and output power of our OPOs, while addressing necessary requirements for future planetary science instruments (Fig. 5).

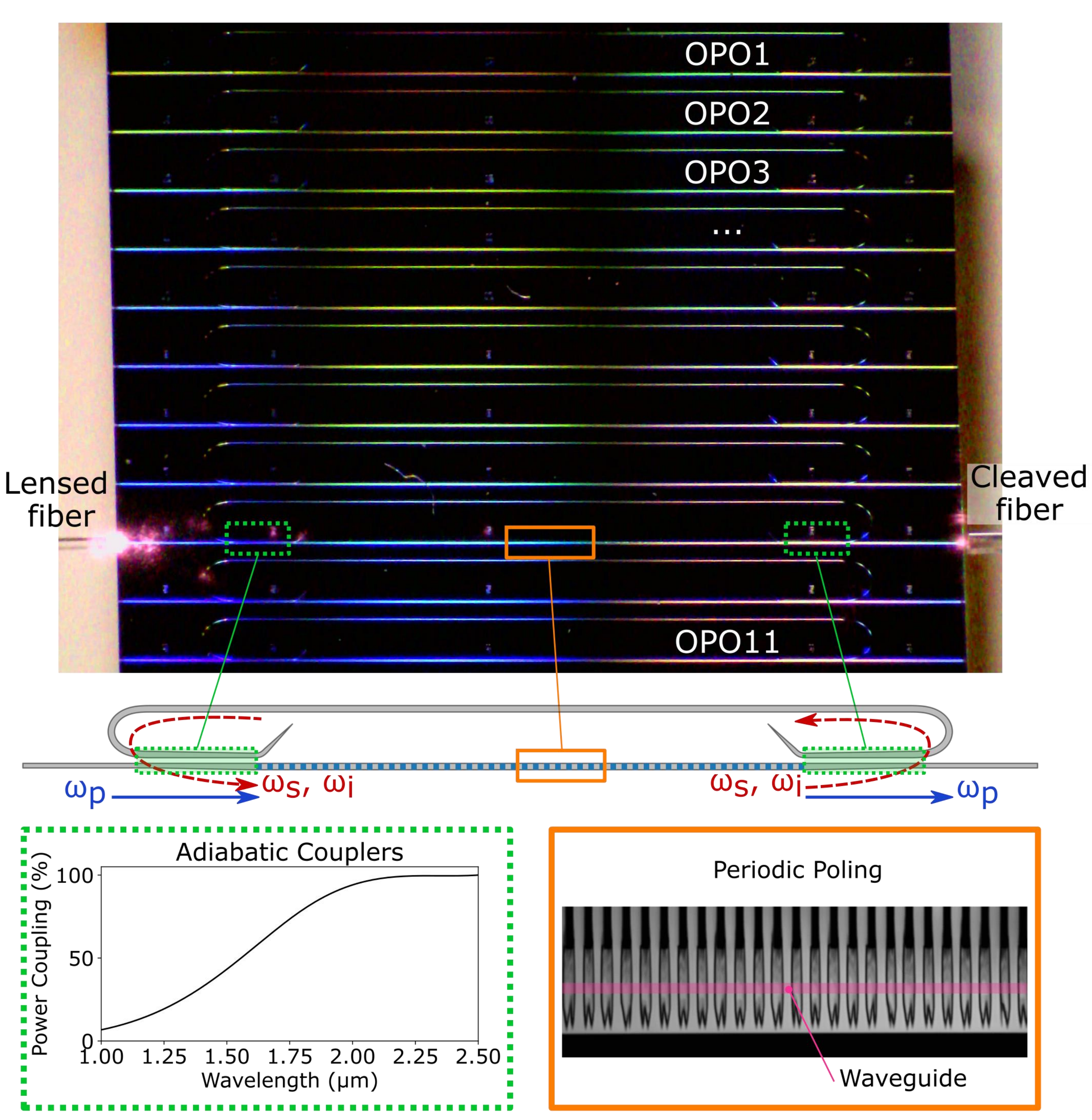

Figure 1. On-chip optical parametric oscillators.
(a) Image of chip under test showing 11 devices.
(b) Schematic of single parametric oscillator.
(c) Simulated response of input/output couplers.
(d) Second harmonic microscope image of parametric gain section.

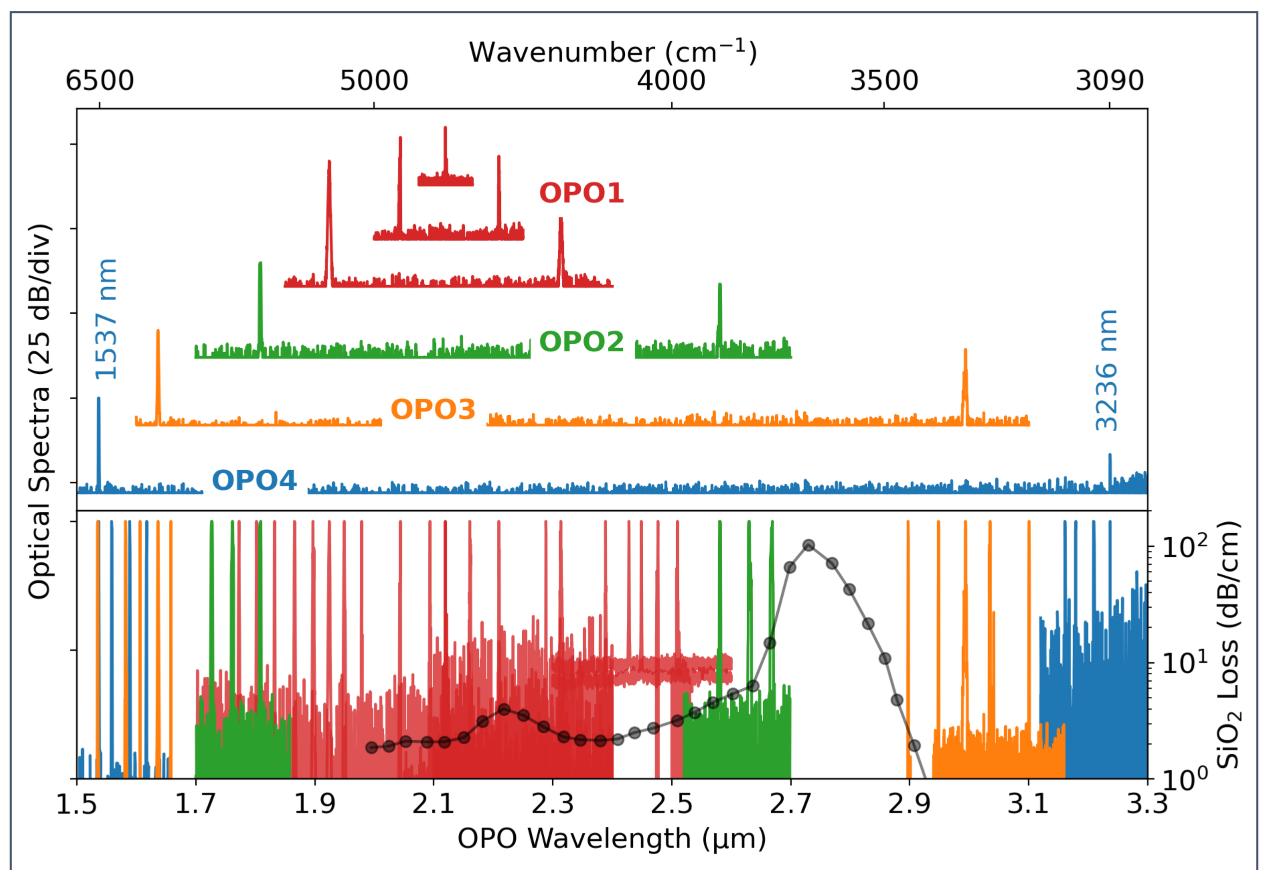

Figure 2. Tuning Coverage using four different devices on the same chip. Black curve in bottom panel represents absorption of silica undercladding.

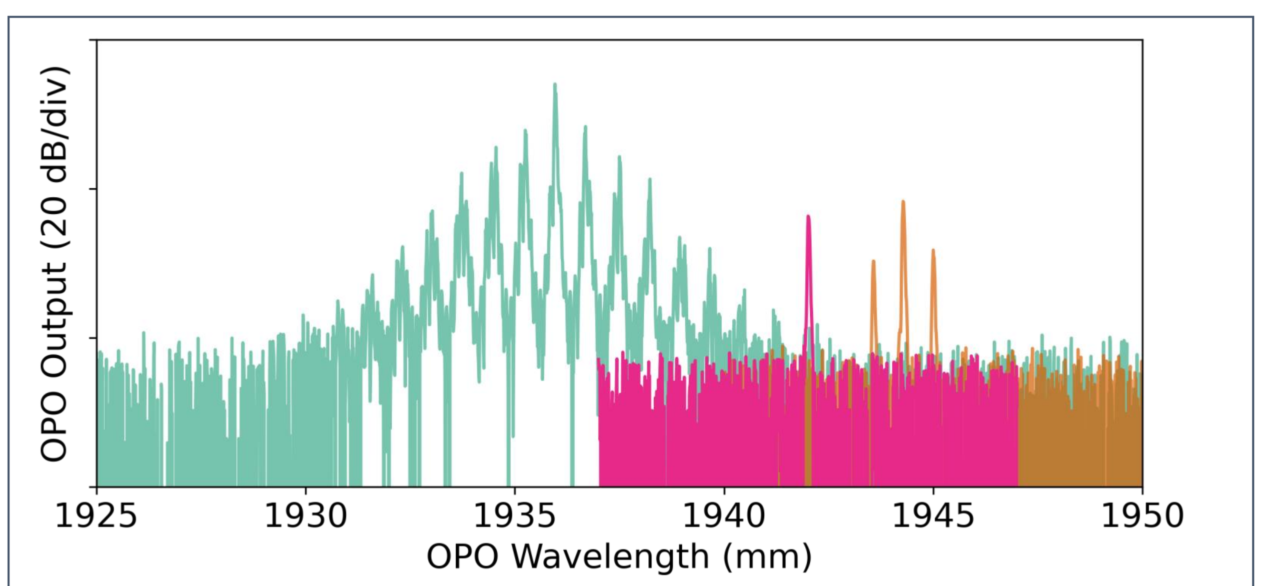

Figure 3. Mode structure at different output power (10 GHz resolution bandwidth). While single mode operation is possible, the spectrum is usually multimode.

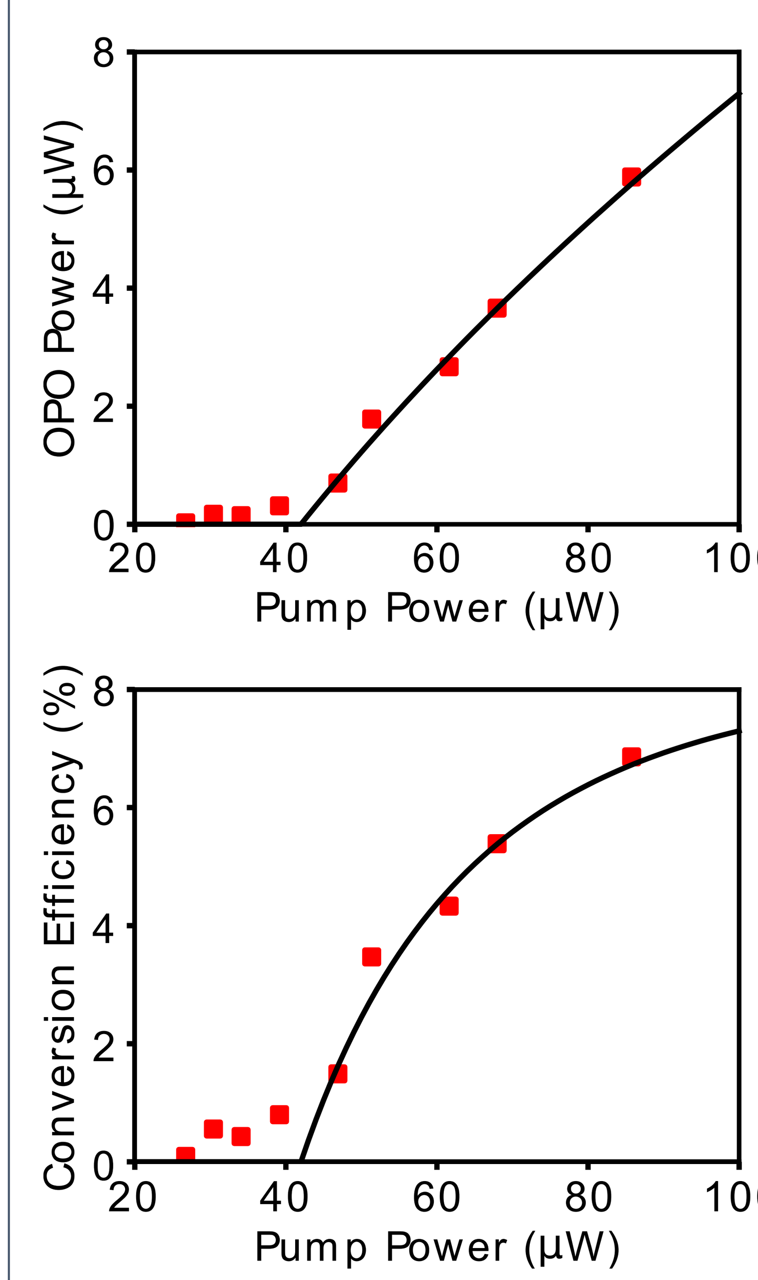

Figure 4. Pump power sweep measurement showing an on-chip threshold of 30 mW and output efficiencies approaching 8%.

Significance/Benefits to JPL and NASA:

- This work offers a clear path towards a tunable source that can replace several laser diodes providing an immediate advantage in size, weight and power (SWaP) for tunable laser spectrometers for planetary missions.
- Our work (along with NTR 52511) could enable integrated frequency synthesis similar to that available at RF frequencies.

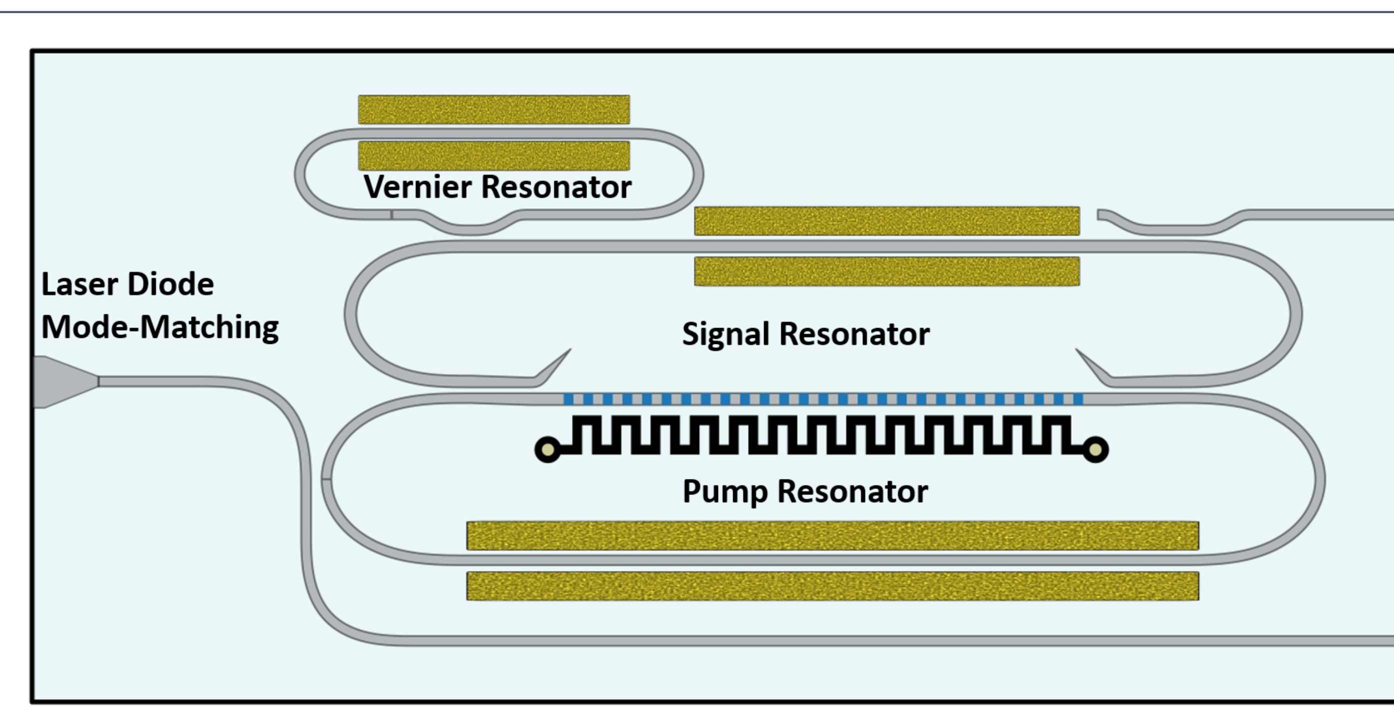

Figure 5. New conceived design that addresses coupling to laser diodes, lower threshold, mode filtering for single mode emission, and continuous tunability (NTR 52511).

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Publications:
Ledezma, Luis, et al. "Widely-tunable optical parametric oscillator in lithium niobate nanophotonics." arXiv preprint arXiv:2203.11482 (2022).

NTR 52511 "Widely Tunable Integrated Source of Coherent Radiation in the Mid-Infrared".

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