



PhD THESIS DEFENSE: Versatile nonlinear frequency conversion sources in the near- and mid-infrared

SUKEERT

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Tunable laser sources in different spectral regions are of interest for a variety of applications including spectroscopy, trace gas sensing, medical diagnostics, LIDAR and material processing. Existing lasers have limited tunability and many spectral regions continue to remain inaccessible to lasers due to lack of suitable gain media. Nonlinear frequency conversion is a viable approach to cover such difficult spectral regions in the visible, near and mid-infrared (mid-IR).

Optical parametric oscillators (OPO) can provide wide wavelength tunability with high output powers in good beam quality across continuous-wave (cw), nanosecond and ultrafast picosecond and femtosecond time-scales. With the development of quasi-phase-matched (QPM) nonlinear materials in fan-out grating structure, wide wavelength tuning is possible at

a fixed temperature, enabling the development of rapidly tunable devices for practical applications. Difference-frequency-generation (DFG) is also an attractive approach for generating high powers in the mid-IR in a single-pass scheme.

In this thesis, we have developed second-order nonlinear frequency conversion sources based on nanosecond and cw OPOs and cw DFG. Widely tunable green-pumped OPOs have been developed by using fan-out grating structure for the first time in different nonlinear materials, and a high-power cw source in the mid-IR has been developed by exploiting DFG. The sources developed in this thesis cover a wavelength range spanning 677-2479 nm. One of the OPOs developed in this work has also been deployed in an industrial environment in a device characterization setup.

In green-pumped OPOs, we demonstrate a widely tunable cw OPO based on PPKTP in a fan-out grating structure. The OPO is continuously tunable across 742-922 nm in the signal, and 1258-1884 nm in the idler. Resonant wave output coupling has been deployed to extract useful signal power and reduce the thermal load, and the OPO can deliver up to 1.65 W of total output power. The use of output coupling results in superior performance of the OPO over pure singly-resonant oscillator (SRO) configuration

We also develop the first green-pumped OPO based on MgO:cPPLT. Continuous wavelength tuning across 689-1025 nm in the signal and 1106-2336 nm in the idler at room temperature has been achieved in the nanosecond OPO by using a fan-out grating structure. The OPO can provide up to 131 mW of average output power at 25 kHz repetition rate, and the idler passive power stability is 3.9% rms over 30 minutes

. A cw OPO based on MgO:PPLN in a fan-out grating design is then described. The OPO is continuously tunable across 813-1032 nm in the signal and 1098-1539 nm in the idler. A short crystal length and signal output coupling are used to minimise thermal effects, and the OPO can generate up to 710 mW of total output power with signal and idler passive power stabilities better than 2.8% rms and 1.8% rms, respectively over 1 hour and signal $M^2 < 1$.

. As a part of an industrial internship, a cw green-pumped MgO:PPLN OPO is developed at Radiantis. The OPO is used as the input light source of a device characterization setup to test sensors for the aerospace sector. Compared to the existing light source, using the OPO results in orders-of magnitude-higher response of the InGaAs sensor, leading to a more precise and accurate characterization, and lower measurement error, thus improving the device evaluation process

s. Finally, we demonstrate a high-power cw source at 2.26 μ m using the DFG process. The source can deliver up to 3.84 W of output power at 2262 nm, with a power stability better than 0.6% rms over 1 hour, in a Gaussian mode profile with $M^2 < 1$

Thesis Director: Prof Dr. Majid Ebrahim-Zadeh

Thesis Co-Director: Dr. Chaitanya Kumar Suddapalli



Hosted by: Majid Ebrahim-Zadeh