

1 *Nonlinear optics for tailor-made light output, developed and built at Fraunhofer IPM: crossed beams of four continuous-wave optical parametric oscillators tuned to different wavelengths in the visible range.*

OPTICAL PARAMETRIC OSCILLATORS

CONTINUOUS-WAVE, SINGLE FREQUENCY

Continuous-wave, single-frequency lasers are powerful tools for a wide range of applications such as spectroscopy, gas analysis, holography, or interferometry. Depending on the task, wavelengths between ultraviolet and far-infrared are needed. The generation of the desired wavelengths depends on the availability of suitable laser materials. This leaves gaps in the spectrum where direct generation of laser light is difficult or even impossible, especially at power levels above 100 mW or in the visible (VIS) and in the mid-infrared (MIR) spectral ranges.

Nonlinear-optical frequency conversion opens a way to generate the desired wavelengths via second harmonic generators (SHG), sum and difference frequency generators (SFG, DFG), and optical parametric oscillators (OPOs). Especially periodically poled nonlinear-optical materials offer high flexibility and versatility since they allow utilization of the whole transparency range of

the respective material. Nonlinear-optical conversion in the continuous-wave regime, however, is much more challenging than in pulsed systems due to the smaller single-pass nonlinear gain which requires well-designed resonators and low-loss optical setups.

Our expertise

Fraunhofer IPM has specialized in frequency conversion of continuous-wave lasers. Based on more than ten years of experience in the field of nonlinear optics and materials, a technology platform has been developed for different converter modules, delivering light with narrow linewidth, excellent beam profile, and low amplitude noise. In-house solutions for optics, mechanics and electronics result in modules distinguished by mechanical robustness, reliable operation and high conversion efficiencies.

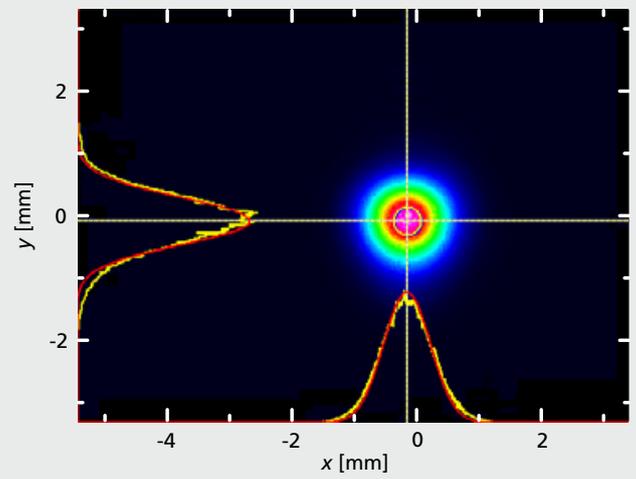
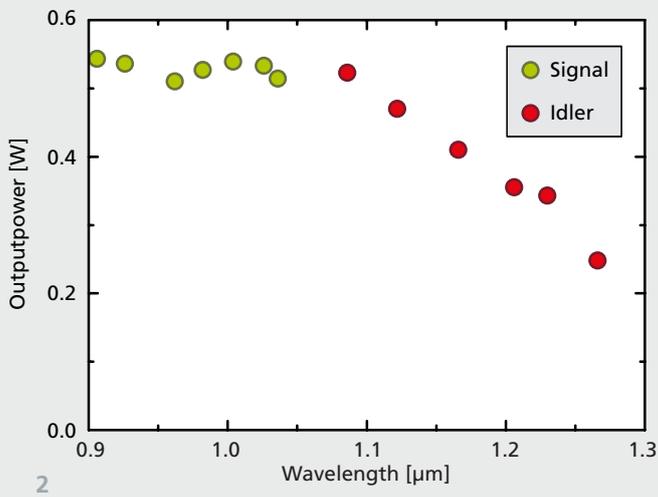
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Optical parametric oscillator

Continuous-wave OPOs are the first choice in nonlinear-optics when narrow linewidth, wavelength flexibility or wide tunability and high output powers are required, e.g. in atomic or molecular spectroscopy, quantum optics or trace gas analysis.

By selecting the proper crystal and phase-matching conditions and applying suitable tuning mechanisms and frequency stabilization methods, the emission can typically be set across several hundred nanometers in the mid-infrared with MHz precision. The coherence properties of the pump wave are preserved or even enhanced in the conversion process.

Features

Optomechanics

- Sealed and stable optic platform
- Customer-tailored wavelength range
- Alignment-free operation
- Integration of pump laser
- Lock to external reference

Electronics

- Low noise electronics
- Fully automated wavelength changes and wavelength locking

Control

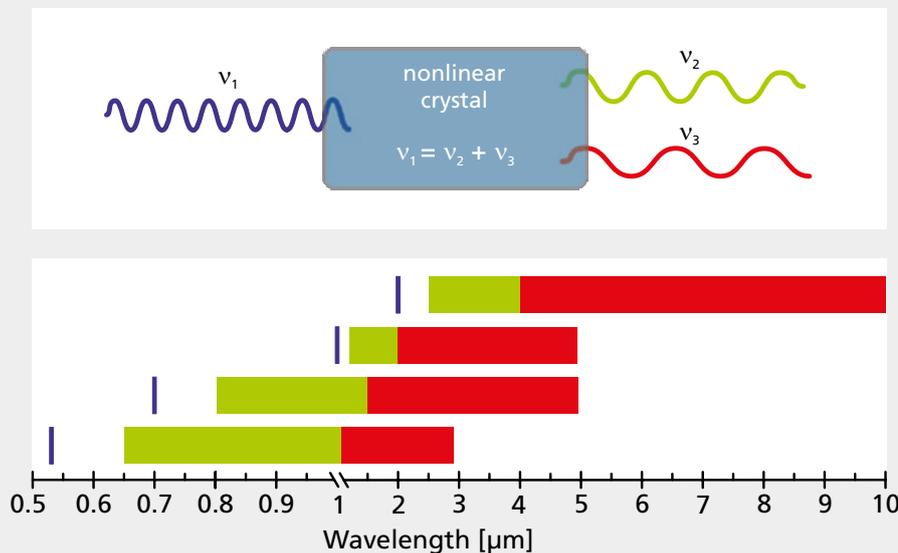
- User interface or libraries for customer programs
- System control via ethernet

2 Typical wavelength coverage and output power for an OPO pumped at a wavelength of 532 nm with a power of 1.5 W.

3 Typical output beam profile of the non-resonant wave.

4 Top: Schematic illustration of optical parametric generation – the underlying process for optical parametric oscillators: A pump wave generates signal and idler waves within a nonlinear-optical crystal. Bottom: Examples for OPO configurations and possible tuning ranges. Blue: pump waves, green: signal waves, and red: idler waves.

4



EXAMPLE SPECIFICATIONS

for a MIR OPO pumped at 1064 nm

- **Tuning range** 1.35-1.8 μm, 2.6-5.0 μm
- **Mode hop free tunability** > 10 GHz
- **Linewidth** < 1 MHz (based on linewidth of pump source)
- **Output power** up to several Watts
- **Power noise** < 1 %
- **Beam profile** TEM₀₀
- **M²** < 1.2
- **Linear polarization** > 1000:1

OUR PORTFOLIO

- Customized OPOs and frequency converters
- System design
- Solutions for special applications
- Product development