Fraunhofer IPM

Waveguide-based frequency upconversion modules

Compact and efficient frequency conversion

Close-up view of an MIR-to-NIR sum-frequency upconversion module.

Silicon-based CMOS detectors clearly outperform their mid-infrared (MIR) counterparts in terms of noise, simplicity and measurement speed. Therefore, efficient conversion of MIR light to the visible spectral range can enhance the measurement performance in many applications, or even make them possible in the first place. Waveguide-based frequency conversion modules can provide the link from MIR measurement applications to silicon detectors.

Making the invisible visible: efficient frequency conversion

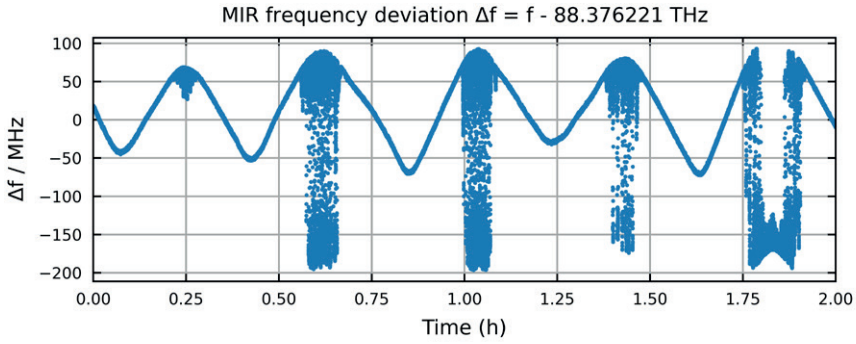
Nonlinear-optical frequency conversion is a widely used tool in optical applications. On the one hand, frequency conversion provides light in spectral ranges where direct laser emission cannot be realized. On the other hand, it can transfer a signal from a more difficult to detect region into the visible to near infrared region, where silicon-based detectors offer the highest flexibility and accuracy of detection. Especially upconversion of wavelengths in the mid infrared to the visible or near infrared wavelengths are a common application.

Waveguide-based frequency converters can be an advantage in different respects. Firstly, waveguides provide the means to achieve high conversion efficiency. Due to the optical confinement of the waveguides, that keeps the light focused along the entire length of the crystal, the nonlinear light-matter interaction can be enhanced. On top of that, engineering of the modal dispersion can be used to generate a broader acceptance bandwidth in terms of wavelength.

The higher efficiency per Watt of pump light compared to bulk converters as well as simpler and more robust optical setups compared to resonator-based upconverters makes waveguide-based frequency converters a promising alternative.

Frequency upconversion

Based on periodically poled lithium niobate waveguides, we provide upconversion from the mid infrared to the visible or near infrared wavelength range. This is realized by sum frequency or difference frequency generation. The interaction of two light waves (pump and MIR signal) generates a third wave equal to either the sum or difference of the incident wave frequencies, depending on the chosen phase-matching conditions.



*Frequency measurement of a free running 3.392 µm HeNe laser using the "Upconversion wavemeter" (see **Project New-VIEUW**). The instantaneous frequency is given as the difference against 88.376221 THz.*

Using for example difference frequency generation of 780 nm pump with a 3.4 µm signal generates an upconverted signal at around 1 µm, which is easily detectable with a silicon-based detector.

Project NeW-VIEUW[1)]

Wavelength range extender in the mid-IR for wavemeters

In the NeW-VIEUW project, funded as part of the Eurostars program, the three partners Covesion Ltd. (UK), Fraunhofer IPM (D) and HighFinesse GmbH (D) have developed a demonstrator that converts mid-IR light into the NIR range, enabling measurements with the most accurate wavelength meters using silicon-based CMOS detectors. By measuring the wavelength of the pump laser for the PPLN waveguide crystal as well as the converted light, the original mid-IR wavelength can be calculated with high speed (up to 500 Hz) and accuracy (< 10 MHz).

This is shown in a frequency measurement of a free running 3.392 µm HeNe laser using the "Upconversion wavemeter" (See figure at the top). This measurement reveals a detailed view on the actual frequency that cannot be achieved by using a standard mid-IR wavemeter.

1) Next generation WaVelength Meters for the mid-Infrared Enabled by Upconversion in Waveguides

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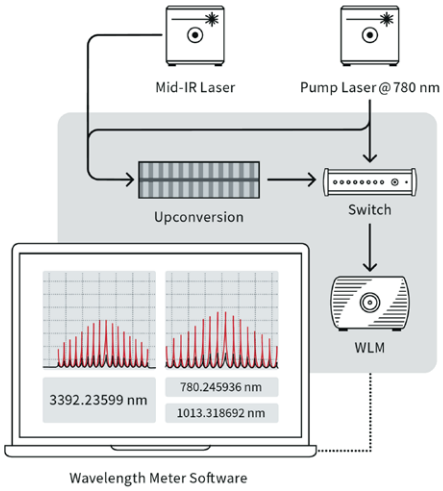
Fiber coupled module

With a fiber coupled module, the system is easy to use and flexible to switch between different light sources and application. At Fraunhofer IPM we are able to develop a custom and ready-to-use frequency conversion module for applications in the near to mid infrared wavelength range. The module includes input and output power monitoring and temperature control of the waveguide for temperature dependent wavelength tuning.



Schematic view of a waveguide-based upconverter module, integrated in an "upconversion wavemeter" setup. This setup was developed in the Project NeW-VIEUW (see left). Through difference frequency generation, the mid-IR light is converted into the near infrared, where the wavelength is measured with a near infrared wavemeter.

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