Rapidly tunable fiber laser pumped continuous-wave optical parametric oscillator

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Abstract: We report on an ytterbium fiber-laser-pumped continuous-wave singly resonant optical parametric oscillator which is rapidly, all-electronically tunable from 3160 nm to 3500 nm. The output power of the mid-infrared idler wave is 1.1 W.

OCIS Codes: (140.3510) Lasers, fiber; (190.4970) Parametric oscillators and amplifiers

Continuous-wave (CW) singly resonant optical parametric oscillators (SROs) pumped by high-power fiber lasers are efficient and widely tunable light sources in the mid-infrared wavelength range [1]. In this contribution we report on extremely fast, all-electronically controlled wavelength tuning of an ytterbium fiber laser pumped CW SRO. The idler wavelength is tunable from 3160 to 3500 nm in 330 µs, which is the fastest CW SRO tuning demonstrated so far.

The SRO pump laser is based on a 30-m long ytterbium-doped double-clad large mode area (LMA) fiber provided by IPHT Jena, Germany. The fiber is pumped through the D-shaped inner cladding of the ytterbium fiber by a 25 W fiber-coupled 980 nm diode laser. The laser resonator is set up as a unidirectional ring cavity that incorporates an acousto-optic tunable filter (AOTF) to achieve all-electronic wavelength tuning of the fiber laser from 1057 nm to 1100 nm. The fiber laser provides up to 6.6 W in a linearly polarized beam for pumping the SRO.

The SRO is based on a 40 mm long periodically poled lithium niobate (PPLN) crystal, with a single grating period of $\Lambda = 29.75$ µm. The crystal is placed in a four-mirror bow-tie ring cavity, which is resonant only for the signal wave.

Figure 1 shows the signal and idler wavelengths of the SRO as a function of the fiber laser wavelength, which is tuned stepwise by all-electronically tuning the AOTF via the RF driver frequency, while keeping the PPLN crystal temperature constant at 181°C. When tuning the fiber laser wavelength from 1057 nm to 1100 nm, the signal wavelength tunes only in the small range of 1583 nm to 1597 nm, whereas the mid-infrared idler wave tunes over 437 nm (11.7 THz) from 3132 nm to 3569 nm. This agrees well with the theoretical tuning curves (lines) calculated from the Sellmeier formula [2]. The spectral bandwidth of the idler wave corresponds to the bandwidth of the fiber laser of 30 to 100 GHz.

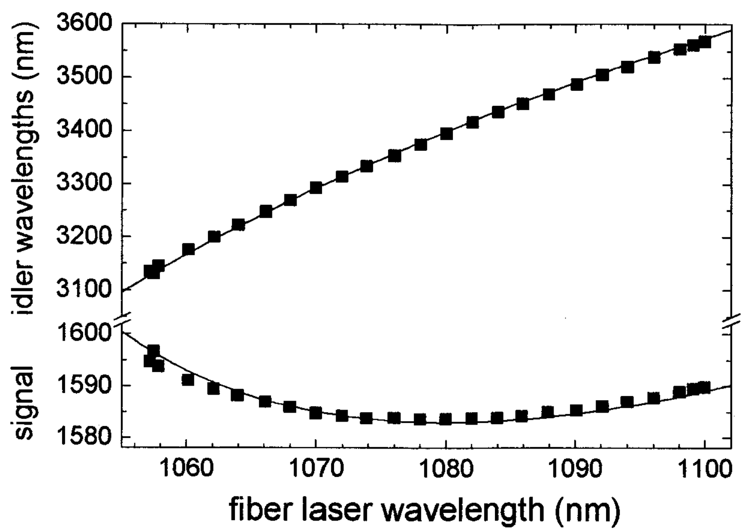

Fig. 1. Signal and idler wavelength of fiber-laser-pumped SRO as a function of the all-electronically tuned fiber laser wavelength, for a fixed grating period of 29.75 μm and a temperature of 181°C of the PPLN crystal. The measured wavelengths (dots) are in good agreement with theory (lines) [2].

Figure 2 shows the idler output power (part A) as a function of the idler wavelength, which was tuned stepwise via the fiber laser wavelength. The corresponding fiber laser power is shown in part B. The maximum idler power of 1.13 W in a single beam at 3335 nm is achieved at a fiber laser power of 6.6 W at 1074 nm. The variation of the idler power is mainly caused by the variation of the fiber laser power when tuning the laser wavelength over more than 40 nm.

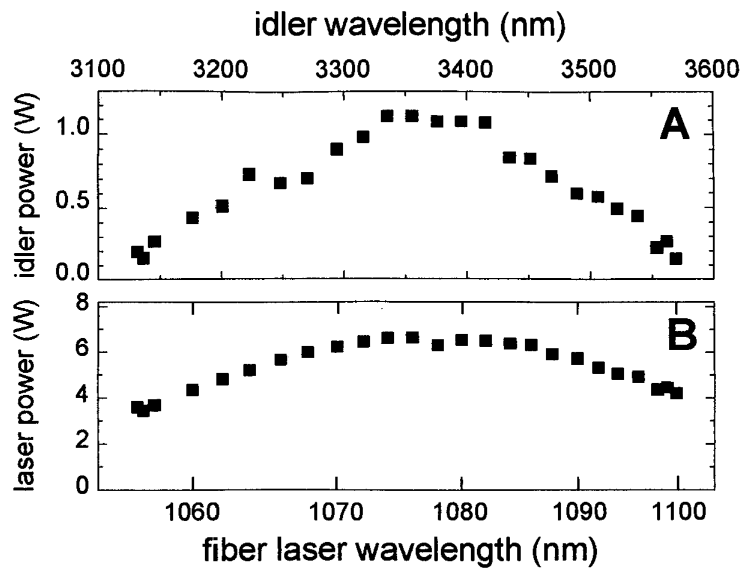

Fig. 2. Part A: Idler output power of the CW SRO as a function of the all-electronically tunable idler wavelength. Part B: Fiber laser power at the corresponding fiber laser wavelength. At 3335 nm a maximum idler power of 1.13 W is generated, for a fiber laser power of 6.6 W at 1074 nm.

Figure 3 shows the idler wavelength as a function of time, when tuning the fiber laser wavelength by applying a triangular function with a frequency of 1.5 kHz to the RF driver of the AOTF. By sampling with a monochromator (resolution 6 nm), it was verified that the idler wave covered the entire range from 3160 to 3500 nm in 330 μs. This corresponds to an idler frequency tuning rate of as much as 28 THz per ms.

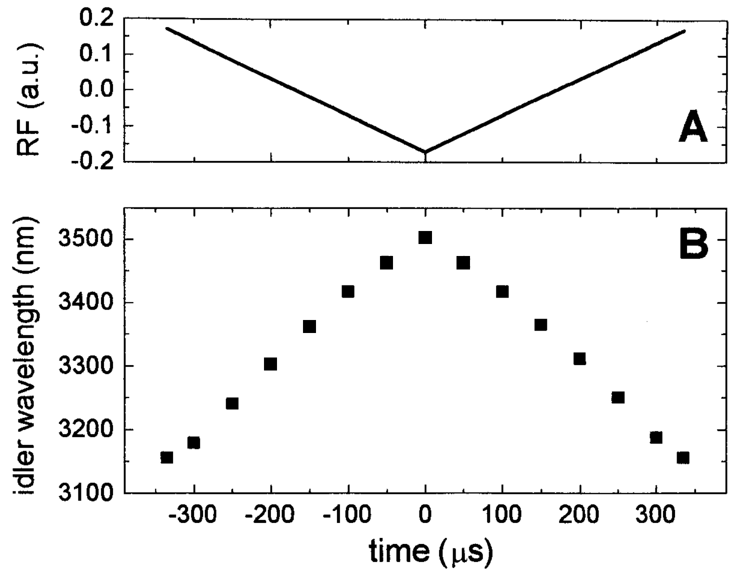

Fig. 3. RF signal applied to the AOTF driver for tuning the fiber laser (part A) and the induced SRO idler wavelength tuning (part B) as a function of time. Within the resolution of 6 nm of the monochromator used for sampling, the idler wave covers the entire range from 3160 nm to 3500 nm within 330 μs.

In conclusion, the all-electronically tunable ytterbium fiber-laser-pumped CW SRO enables an easy and fast coverage of a considerable portion of the so-called "fingerprint" spectral region of organic molecules, which can be exploited, e.g. for on-line monitoring of industrial, high pressure gas mixtures.

[1] P. Groß, M. E. Klein, T. Walde, K.-J. Boller, M. Auerbach, P. Weßels, C. Fallnich, Opt. Lett. **27**, 418 (2002)
[2] D. Jundt, Opt. Lett. **22**, 1553-1555 (1997)