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Femtosecond and picosecond fiber-feedback OPOs

T. Südmeyer, J. Aus der Au, R. Paschotta, and U. Keller
Ultrafast Laser Physics, Institute of Quantum Electronics
Swiss Federal Institute of Technology, ETH Hönggerberg – HPT, CH-8093 Zürich, Switzerland

P. G. R. Smith, D. J. Richardson, G. W. Ross, and D. C. Hanna
Optoelectronics Research Centre, University of Southampton
Southampton SO17 1BJ, United Kingdom

Abstract: We demonstrate a novel type of synchronously pumped high-gain optical parametric oscillator with feedback through a single-mode fiber. We present two fiber-feedback OPO systems, generating multi-watt average signal powers tunable around 1.5 μm in 10-ps and 800-fs pulses.

1. Introduction

Synchronously pumped optical parametric oscillators (OPOs) are attractive sources of broadly wavelength-tunable ultrashort pulses as required for many applications, i.e. RGB display systems. We present a novel type of synchronously pumped OPO, which is based on feedback through a single-mode fiber in combination with a very high parametric gain and strong output coupling. This concept leads to compact, stable and powerful systems in the femtosecond and picosecond regime. We present a picosecond fiber-feedback OPO generating up to 4.4 W of average signal power in ≈ 10-ps pulses tunable from 1485-1582 nm. We also demonstrate a femtosecond fiber-feedback OPO that generates up to 2.7 W average signal power tunable from 1429-1473 nm in 700-900 fs pulses. In contrast to many other OPOs in this pulse duration regime, this system is very insensitive against drifts of the OPO cavity length and does not require active stabilization of the cavity length. Because of the high parametric gain, fiber-feedback OPOs are unusually insensitive against intracavity losses. Even at low repetition rates, the setup is very compact since most of the resonator feedback path consists of the fiber.

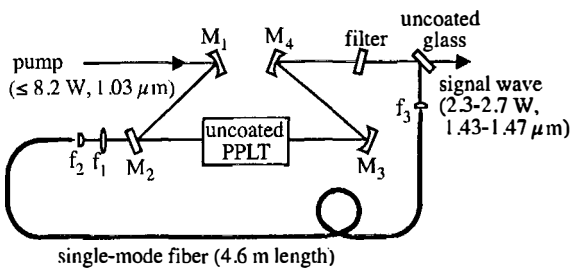

Fig. 1: Setup of the femtosecond fiber-feedback OPO ring cavity. M_1 – M_4 = mirrors, f_1 – f_3: lenses, PPLT = crystal of periodically poled $LiTaO_3$.

2. Femtosecond fiber-feedback OPO

The femtosecond fiber-feedback OPO (Fig. 1) is based on a 22 mm long uncoated periodically poled $LiTaO_3$ (PPLT) crystal, pumped with up to 8.2 W at 1030 nm from a passively mode-locked thin disk Yb:YAG laser [1] (600 fs pulse duration, 35 MHz repetition rate). The crystal is operated at ≈ 150 °C to avoid photorefractive damage

and has different grating periods (28.3 μm – 29 μm). After the crystal, 82 % of the signal wave are coupled out, and part of the rest is launched into a 4.6 m long standard telecom fiber and fed back into the crystal.

We obtain up to 2.7 W of average signal power in the range 1429-1473 nm for a pump power of 8.2 W incident on the crystal (Fig. 1). We would expect to obtain even higher signal output powers in the order of 4 W by reducing the losses of several non-optimized optical components (uncoated PPLT, non-ideal output coupler). The pulse duration (FWHM) is typically around 700-900 fs with a spectral width of 3-4 nm (FWHM).

The adjustment of the cavity length is very uncritical: it can be varied over 0.5 mm (corresponding to more than one pulse width) with the output power reduced only by 6 % (Fig. 3). No active cavity length stabilization is required. The performance of the system is unusually insensitive to intracavity losses: the output power is reduced by only 6 % when a 10-dB attenuator is inserted into the cavity. The operation is stable over hours.

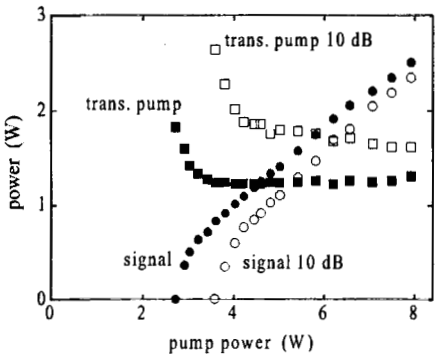

Fig. 2: Signal power (filled circles) and transmitted pump (filled rectangles) versus pump power for a signal wave of 1429 nm (grating period 28.3 μm). Open circles and rectangles: same with a 10-dB attenuator in the feedback loop.

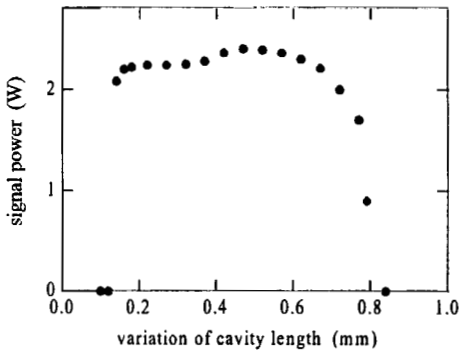

Fig. 3: Variation of signal output power with cavity length.

3. Picosecond fiber-feedback OPO

Very recently, we constructed a similar OPO as described above, but using a 19 mm long multi-grating periodically poled $LiNbO_3$ (PPLN) crystal, pumped with up to 17 W of average power at 1064 nm in 16-ps pulses (59 MHz repetition rate) from a passively mode-locked Nd:YAG laser (modified version of [2] with 2 laser heads). Feedback is provided through a 2 m long large mode area holey fiber [3]. In first experiments, we obtain up to 4.4 W of average signal power at 1485-1582 nm. The pulse durations (FWHM) are around 10 ps. The average idler power is up to 1.9 W. The operation is stable over hours.

4. Summary

We demonstrated a novel concept for synchronously pumped OPOs, which is based on feedback through a single-mode fiber in combination with high parametric gain, leading to multi-watt average signal powers both in the femtosecond and picosecond regime. The devices are unusually insensitive to intracavity losses and have a very compact setup. Even in the femtosecond domain, the cavity length adjustment is uncritical.

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2. G. J. Spühler, T. Südmeyer, R. Paschotta, M. Moser, K. J. Weingarten, U. Keller, "Passively mode-locked high-power Nd:YAG lasers with multiple laser heads," *Appl. Phys. B* **71**, 19 (2000).
3. N. G. R. Broderick, H. L. Offerhaus, D. J. Richardson, R. A. Sammut, "Power scaling in passively mode-locked large-mode area fiber lasers," *IEEE Photonics Technol. Lett.* **10**, 1718 (1998).