Fiber Laser Pumped Femtosecond Optical Parametric Generator

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The first femtosecond fiber-laser pumped optical parametric system is demonstrated. Periodically poled lithium niobate crystals allows to use pump energies below 1 μJ with 24 % total conversion efficiency. 300 femtosecond pulses were generated tunable in the 1 - 3 μm range with output energies up to ~ 200 nJ.

We report here the first fiber-laser pumped optical parametric generator (OPG), which offers a compact, robust and cost-effective source of broadly tunable femtosecond pulses.

The efficient generation of 300 fs pulses tunable over the 1 - 3 μm range has been demonstrated with an ultimately simple single-pass OPG configuration and with pump pulses below 1 μJ by using periodically poled lithium niobate (PPLN) crystals. Bulk PPLN is a new nonlinear material for efficient frequency conversion employing quasi-phase matching (QPM) instead of birefringent phase matching [1]. The general advantage of using QPM is the possibility to implement phase matching at any wavelength within the crystal transparency range while utilizing any component of the nonlinear susceptibility tensor. For $LiNbO_3$ the key advantage is the use of the large nonlinear coefficient d_{33}(=27 pm/V), which offers a dramatic improvement in the pumping threshold. Estimates show that efficient parametric fluorescence can be achieved with peak intensities of only ~ 10 GW/cm^2.

For easy comparison with current Ti:sapphire pumped OPG systems we choose an experimental demonstration of a 780 nm pumped PPLN OPG configuration.

The pump source was a frequency doubled Er-doped fiber chirped pulse amplification (CPA) system [2]. 200 fs duration pulses from a mode-locked fiber oscillator were stretched with a diffraction-grating stretcher and amplified in a laser-diode-MOPA-pumped two-stage fiber system. Pump powers were 200 mW and 450 mW for the first and second stages respectively. Repetition rates of the amplified pulses were selectable at different subharmonic frequencies of the mode-locked oscillator repetition rate. Amplified pulses at 1.55 μm were recompressed to ~ 600 fs with a diffraction grating compressor and then frequency-doubled with a 400 μm long and 18.75 μm period PPLN crystal. Up to 1.4 μJ of second-harmonic (SH) at 777 nm were obtained with ~ 500 fs pulse durations. Microjoule SH energies were obtainable when operating the system at 1 to 10 kHz repetition rate. These SH pump pulses were then separated from the fundamental to prevent seeding and focused into a single-pass parametric generator PPLN crystal.

Several PPLN samples with QPM grating periods ranging from 19 to 20 μm and crystal lengths from 1 to 5 mm were used in the experiment. Crystal thickness for all samples was 0.5 mm. All interacting waves are of extraordinary polarization. Additionally, this geometry provides noncritical phasematching, which prevents spatial beam walk-off. Tuning of the signal and idler wavelengths was accomplished by heating the samples. Calculated (solid curves) and measured tuning curves for a 19 μm QPM-period sample are shown in Fig. 1. Changing the temperature from 60° to 375° C tunes the signal wavelength from ~ 1.4 μm down to ~ 1 μm and the idler wavelength from ~ 1.65 μm up to ~ 3 μm. Recently, similar tuning range at a fixed temperature has been demonstrated with a multigrating PPLN crystal [3].

The dependence of the pump-to-signal conversion efficiency vs pump energy in a 3 mm long sample, measured with a pyroelectric detector, is shown in Fig. 2. The signal wavelength for this measurement was 1.2 μm. Substantial conversion is already observable at 200 nJ pump input, and reaches saturation at ~ 17 % for 700 nJ pump. This constitutes more than an order of magnitude improvement over the best previously reported OPG threshold results [4]. The idler power was measured to be about one third of that of the signal, consistent with photon conservation. This gives the maximum total conversion of ~ 24 %. At the highest pump energies pump depletion of 40 % have been measured. The discrepancy from the total conversion efficiency might be attributed to the sum-frequency generation and the two-photon absorption at the high peak intensities. Signal energies observed with the maximum pump of 1.4 μJ were 200 nJ.

An autocorrelation trace of the signal pulse, shown in Fig. 3, reveals a wing-free profile corresponding to a 300 fs deconvolved pulse duration. Idler pulses were not measured at this point but their duration is expected to be similar to that of the signal.

In conclusion, we have demonstrated the first all-diode pumped widely tunable OPG system. Practical advantages come from the compactness of the fiber-based pump source and the fact that a single-pass OPG system is substantially more simple than synchronously pumped OPO systems. It is a promising alternative to bulk solid-state laser based systems.

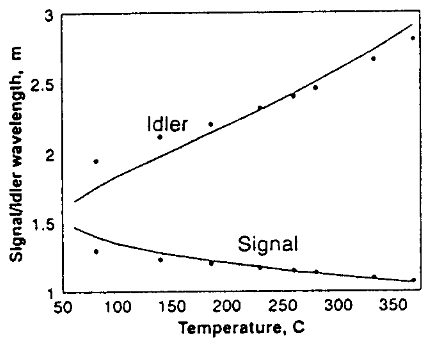

Fig. 1

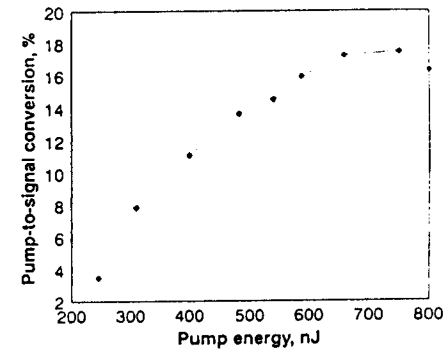

Fig. 2

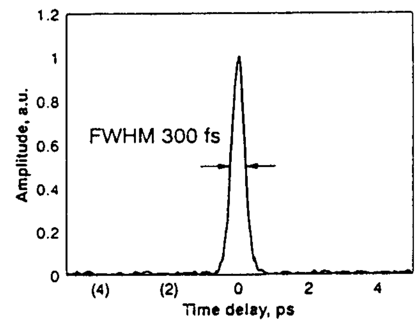

Fig. 3

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