Variable Repetition Rate, High Power, Picosecond Optical Parametric Oscillator Synchronously Pumped by a Fibre-Amplified Gain-Switched Laser Diode

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ABSTRACT

We demonstrate a picosecond singly resonant optical parametric oscillator (OPO), which is synchronously pumped by a source consisting of a gain-switched laser diode and a chain of Yb-doped fibre amplifiers. The OPO produces up to 7.3W at 1.54μm (signal) and 3.1W at 3.4μm (idler) from 24W of average pump power. Pulse durations are typically ~17ps. M^2-values of 1.1 × 1.2 (signal) and 1.6 × 3.2 (idler) are measured at high output power. Signal and idler tunability is demonstrated from 1.4μm to 1.7μm and 2.9μm to 4.4μm, respectively, by accessing different gratings of the MgO-doped periodically poled $LiNbO_3$ (MgO:PPLN) crystal. The repetition rate is user-controllable between ~100MHz and ~1GHz, without adjusting the OPO cavity length.

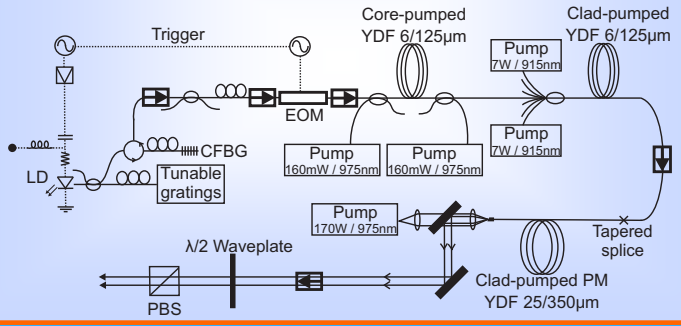
INTRODUCTION

Synchronously pumped OPOs are of great interest as sources of broadly tunable ultrashort pulses. Typically, such systems are pumped by mode-locked bulk solid-state lasers with fixed repetition rates in the ~100MHz range. However, the emergence of new ps and fs pulse sources has led to various demonstrations of OPOs with repetition rates up to 39GHz [1] and combined signal and idler output average output powers up to ~27W [2]. More compact pump systems have also been developed based on amplified mode-locked laser diodes [3], fibre lasers [4] and passively mode-locked miniature bulk lasers [1, 5]. Here, we describe, for the first time, the use of an amplified gain-switched laser diode to pump an OPO, resulting in a compact, rugged, tunable, picosecond source, with potential for scaling to high average powers and repetition rates.

Possible applications include areas as diverse as telecommunications [1] and non-invasive nonlinear microscopy [6].

PUMP SOURCE [7]

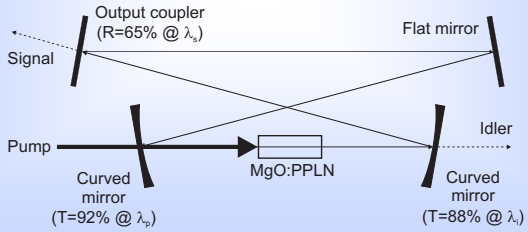
- MOPA configuration:
  (1) gain-switched laser diode
  (2) Yb-doped fibre amplifiers
- centre wavelength: 1.06μm
- pulse width: ~21ps
- average power: up to 100W
- beam quality: M^2 = 1.02
- variable repetition rate
  (here: 114.8MHz, 459.2MHz, 918.4MHz)
- linear polarisation



OPTICAL PARAMETRIC OSCILLATOR

Nonlinear crystal:
- periodically poled congruent $LiNbO_3$
- 5% MgO-doping
- 40mm × 10mm × 0.5mm
- 11 poling periods: 26.5μm to 31.5μm
- temperature: T=150°C
- anti-reflection coated end-faces

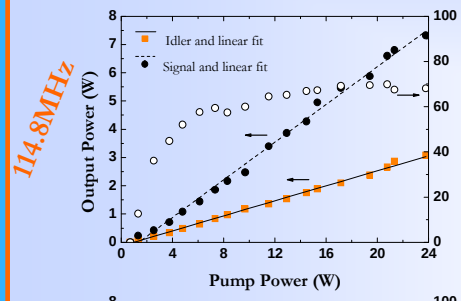
Resonator:
- ring cavity
- synchronously pumped
- singly resonant
- signal output coupler: R=65%
- mirror radius of curvature: 250mm
- spot sizes: w_p=50μm , w_s= 47 × 59μm



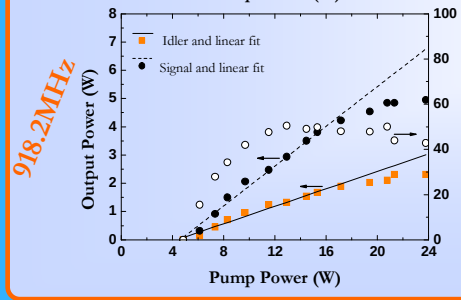
EXPERIMENTAL RESULTS

Output power performance with repetition rate:

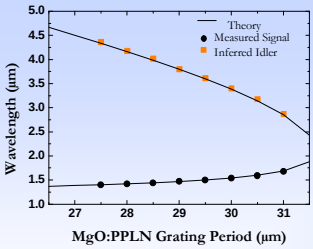
OPO operation can be obtained by having 1, 2, 4 or 8 pulses circulating in the cavity corresponding to repetition rates from 114.8MHz to 918.4MHz.



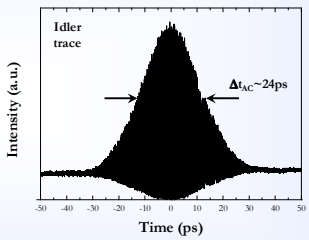
- signal average power: 7.3W at 1.54μm
- idler average power: 3.1W at 3.4μm
- pump depletion: ~70%



- signs of a power roll-over effect observed
- similar but stronger effect observed in standing-wave cavity
- high $(dn_e/dT)/K_C$ (20× higher than in YAG) causes strong sensitivity to any thermal input



Wavelength tuning performance:
- accessing 11 gratings with different poling periods in MgO:PPLN
- temperature: constant at 150°C
- signal: 1.4μm to 1.68μm
- idler: 2.87μm to 4.36μm



Pulse width measurements:
- interferometric autocorrelation using two-photon absorption signal in Si (signal) or extended InGaAs (idler) detector
- Gaussian pulse shape assumed
- FWHM duration: ~17ps (for both signal and idler)

Pump Power	Signal (1.54μm) M_x^2	Signal (1.54μm) M_y^2	Idler (3.4μm) M_x^2	Idler (3.4μm) M_y^2
11W	1.06	1.01	2.50	1.56
24W	1.20	1.09	3.18	1.58

Beam quality measurements:
- for signal: beam profiler
- for idler: knife-edge + 15%-85% power method

DISCUSSION

The observed power roll-over effects, with certain resonator configurations and operational parameters, appeared to be thermal in nature as oscillation recovered when the average pump power was reduced using a mechanical chopper.

Ring cavities were found to be superior in performance to standing-wave cavities and we suggest that this may be due to the lower thermal aberrations experienced by a signal pulse, which only passes once through the crystal per round-trip.

More surprisingly, we also observed signs of a roll-over effect in the ring cavity at the highest repetition rate, which we speculate may be related to the lower intensity and hence gain of the pump pulses in this regime.

OUTLOOK

We have demonstrated a highly compact and rugged source of tunable picosecond pulses with variable repetition rate based on an OPO pumped by a fibre-amplified gain-switched laser diode. Future work will investigate the surprising thermal effects observed in some configurations to provide a route towards exploiting the potential for scaling to high average powers (up to 100W) with this pump source.

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