Efficient harmonic generation with large mode-area fibre sources.

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Abstract

We report highly efficient second and third harmonic generation with large mode-area, erbium doped, nanosecond fibre sources. Different configurations have allowed up to 83% efficiency for SHG, 34% for THG, and pulse energies up to 180μJ.

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Recent advances in active fibre design such as large mode area fibers and cladding pump techniques have enabled the development of simple, widely wavelength tunable, nanosecond fibre based systems capable of giving out pulses of ~0.2 mJ energies, 100 kW pulse peak powers in a single transverse mode [1]. At these power and energy levels such sources become attractive as seed sources for nonlinear parametric devices, particularly those based on engineered materials such as periodically poled lithium niobate (PPLN) which can be designed to phase-match a broad range of nonlinear processes.

In this paper we present the results of a series of experiments using doped fibre sources in which we have, to the best of our knowledge, demonstrated the highest ever pulse energies from a Q-switched fibre laser (180μJ), the highest second harmonic conversion efficiency from a single pass in PPLN (83%), and the first generation of visible light by sum-frequency mixing in cascaded PPLN crystals.

The sources are based on large-mode area erbium-doped fibre of low NA step index profile, which had a core which is approximately ten times larger than the conventional fibres used in erbium doped fibre amplifiers, thus allowing for greater energy storage and increased nonlinear thresholds and tolerances. The fibres, of varying erbium concentrations [400-1400ppm], were all single transverse mode at the laser operating wavelength, which is very important for nonlinear optics applications.

Two source configurations were used, the first was based on a DFB diode-seeded amplifier cascade in which 1mW level square pulses of duration 1-10ns were amplified in large mode-area fibre amplifier to give peak powers in the range 0.1-100kW. The pulses from this source were too short for certain applications such as the pumping of a nanosecond optical parametric oscillators (OPOs) and to this end a large mode area Q-switch fiber source was constructed. This diode pumped laser gave us ~45-50ns pulses of

upto 180μJ energy at 200 Hz repetition frequencies for launched pump powers of only ~300 mW (see Fig.1).

We used the sources for generating second harmonic in PPLN samples (lengths 16-20mm, periods 18.05 to 18.7 μm) and for third harmonic generation by mixing the second harmonic and fundamental pulses in PPLN (length 20mm, period 6.5 μm). All of the PPLN samples were fabricated by electric field poling. A summary of the best results achieved to date are shown in table 1. The record PPLN harmonic conversion efficiencies can be attributed to the fact that the pulses from source 1 had close to square in temporal profile (see Fig.2). The >80μJ SHG pulse energies (external) achieved for the Q-switch laser pulses are adequate for the pumping of fibre laser pumped PPLN OPOs and we have indeed now gone on to successfully demonstrate the operation of such a device based on such a pump source concept.

We believe the results presented in this paper to be significant in that they directly demonstrate the great potential of the combination of high power fibre based sources and PPLN for the development of a wide range of practical, efficient, flexible and highly tunable sources. Adoption of cladding pump techniques and more radical fibre designs will undoubtedly extend the achievable performance limits achievable from such systems to the multi-Watt and mJ regimes.

Source	Pulse length	Pulse energy	SHG effic.	THG effic.
Fibre amplifier cascade	10ns	160μJ	83%	34%
Q-switch fibre laser	45ns	180μJ	62%	15%

Table 1. Summary of best SHG and THG conversion efficiencies (internal) for the two fibre based sources under optimal focussing conditions.

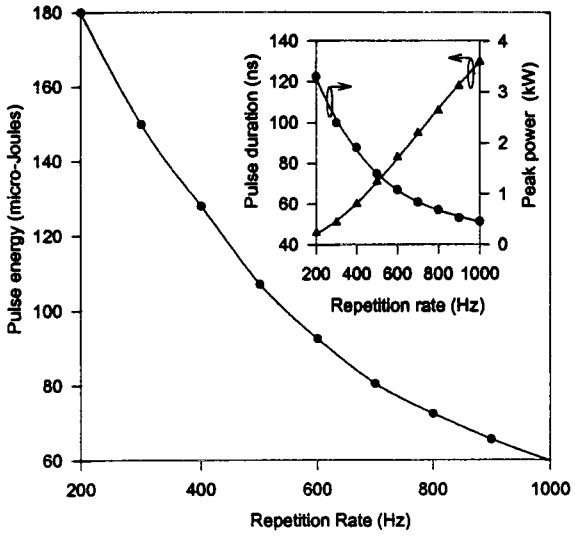

Figure1 Plot of Q-Switch laser performance, showing high powers and energies achievable from a simple diode pumped laser cavity.

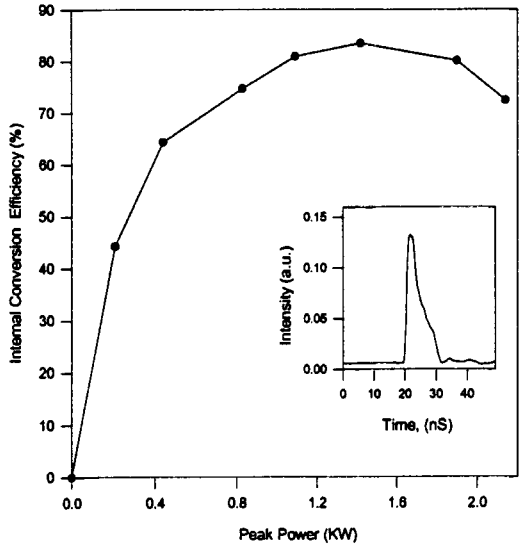

Figure 2. SHG conversion efficiencies for the diode seeded large amplifier system showing record 83% conversion efficiencies. The decrease in eficiencies at high powers is as result of back conversion of the SHG to wavelength around the fundamental.