Frequency doubling of a diode-bar-pumped Nd:YAG laser at 946nm using non-critically phase-matched lithium triborate at high temperature

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ABSTRACT

A diode-bar-pumped Q-switched Nd:YAG laser at 946nm was frequency-doubled in a lithium triborate crystal maintained at a high temperature (~316°C) to allow non-critical phase-matching, resulting in 300mW of blue output at 473nm for 2.5W of fundamental power.

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Efficient, high-average power, solid-state sources of coherent visible light are sought after for numerous applications in important areas such as display technology, medicine and chemistry. One promising approach for the generation of light in the blue spectral region is via second harmonic generation of Nd:YAG lasers operating on the quasi-three-level transition at 946nm [1],[2]. However, progress in scaling to high average powers has been hindered both by the unfavourable spectroscopic properties of this transition, and by the lack of a suitable nonlinear crystal.

In this paper we describe an efficient linearly-polarised diode-end-pumped 946nm Nd:YAG laser with multiwatt average output power, and efficient extra-cavity frequency doubling in non-critically phase-matched lithium triborate (LBO) to produce blue light at 473nm. To achieve efficient linearly-polarised operation of Nd:YAG at 946nm at multiwatt power levels is significantly more challenging than on the much higher gain 1.064μm line. The main problems arise from the need to focus the diode pump beam to a relatively small beam size due to the very low gain cross-section and quasi-three-level nature of the 946nm line.

This places extra demands on the beam quality of the pump source and on the resonator design, which must cope with strong thermal effects resulting from the intense pump beam. The resonator design used in our preliminary experiments (shown in fig.1) employs a simple folded cavity arrangement with a 7mm long 1% Nd-doped YAG rod mounted in a water-cooled heat-sink maintained at 13°C. Both end faces of the Nd:YAG rod were pumped with fibre-coupled, beam-shaped diode-bars focussed to a relatively small beam radius of 150μm. The maximum combined pump power was limited to 17W incident on the laser rod, due to non-optimum coupling optics. This resulted in very strong thermal lensing and thermally-induced birefringence. The resonator design was carefully chosen to minimise the effects of strong thermal lensing, and particularly the highly aberrated nature of the lens, by requiring that it was stable over a wide range of thermal lens powers. The resonator also incorporated a quarter-wave plate to reduce the depolarisation loss due to stress-induced birefringence [3] from 7% to <0.3%, allowing efficient linearly polarised operation with cw output powers up to 3.5W in a beam with beam quality factors of M_y^2=1.2 and M_x^2=2.2. Q-switched operation was achieved using a TeO_2 acousto-optic modulator which when operated at a repetition rate of 5kHz, resulted in pulses of duration ~100ns and an average output power of ~2.5W.

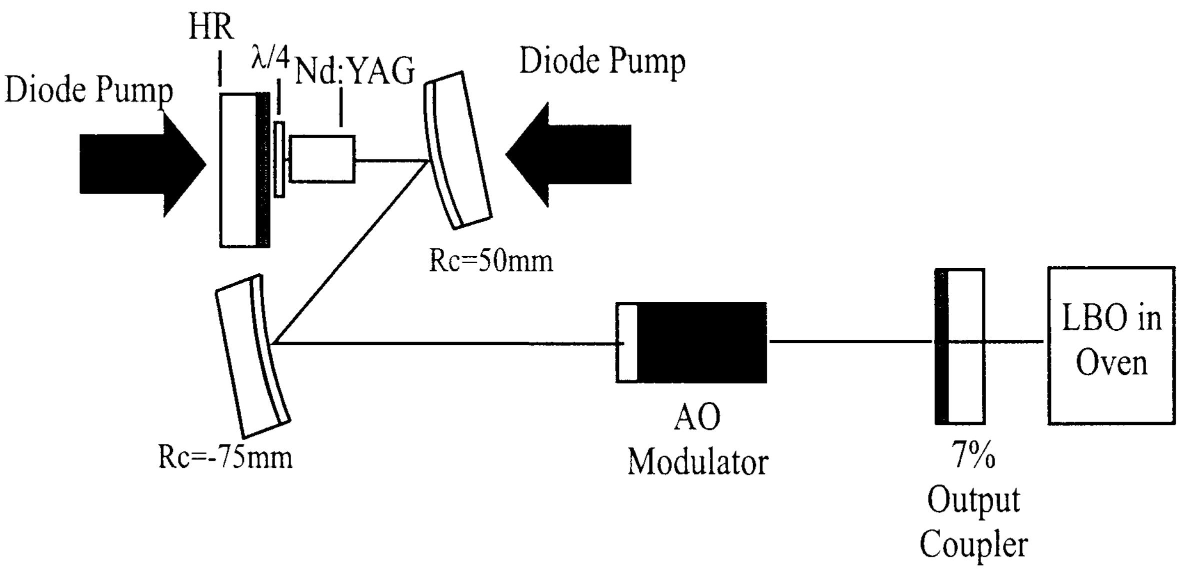

Fig.1. 946nm Nd:YAG Laser with LBO Frequency Doubler

For frequency doubling of the Q-switched 946nm output to the blue we have used a 15mm long LBO crystal cut for type I non-critical phase-matching. LBO is often the preferred choice of nonlinear crystal for frequency doubling of 1.06μm Nd lasers at multiwatt average powers due to its low loss and high damage threshold . In this case the temperature required for non-critical phase-matching is typically in the region of 150°C. LBO can also be used to generate the second harmonic of 946nm, but a much higher temperature (~316°C) is required for phase matching. By operating the LBO at this high temperature we have generated ~300mW of average power at 473nm for 2.5W of average fundamental power. Predictions based on the measured second harmonic conversion efficiency for the laser when operating in the cw regime, suggest that much higher second harmonic conversion efficiencies for the Q-switched output should be achievable. We believe that this reduction in efficiency is due to increased thermal loading under Q-switched operation, due to upconversion processes [4], which result in a degradation in beam quality and hence a larger focussed fundamental beam size in the LBO. Thus, with further optimisation of the resonator design, including the use of a Nd:YAG rod with lower Nd concentration to reduce upconversion, we believe that it should be possible to achieve average powers at 473nm in excess of 1W.

References

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