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Volume 60, number 4 OPTICS COMMUNICATIONS 15 November 1986

A HIGH POWER SYNCHRONOUSLY PUMPED DYE LASER OPERATING IN THE BLUE AND GREEN SPECTRAL REGION

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Received 23 July 1986

We describe a pulsed dye laser synchronously pumped by the third harmonic of an actively modelocked and actively Q-switched Nd:YAG laser. This laser produces tunable pulses of around 80 ps duration in the region 410–550 nm. The high peak power (1.5 MW at 420 nm) and excellent beam characteristics of its output indicate that this range may be extended efficiently by nonlinear frequency generation techniques.

1. Introduction

Several techniques are currently used for the generation of high power tunable optical pulses in the picosecond regime. Of these techniques the pulsed synchronously pumped dye laser [1, 2] and short cavity dye laser [3] produce the highest peak powers combined with wide tunability. Considerations of design simplicity, good spatial coherence and temporal profile have led us to favour the former approach. Recently we reported the design of a pulsed synchronously pumped dye laser operating in the red spectral region pumped by the second harmonic of an actively modelocked and actively Q-switched Nd:YAG laser [4]. Here we describe the further development of the system pumped by the third harmonic of YAG and operating in the blue green region where there are few other high power picosecond sources [5, 6]. Our design has retained all of the important operating features such as diffraction-limited performance, bandwidth limited performance , efficiency and amplitude stability discussed in ref. [4]. With stilbene 420 as the dye medium we have obtained approximately 160 μJ in a single pulse at 420 nm. Coumarin 540 dye was found to be less efficient producing approximately 85 μJ but had a wide tuning range of 525 nm to 575 nm. Pulse durations obtained were typically around 80 ps.

2. Laser design and performance

In ref. [4] we discussed two synchronously pumped dye oscillator configurations; one was longitudinally pumped and tuned by a grazing incidence grating while the other was transversely pumped and tuned by a Littrow grating with prism beam expander. Despite their quite different designs the lasers performed very similarly in terms of efficiency, tunability and bandwidth. However, this was found to be true when we investigated pumping blue dyes with the third harmonic of YAG. The longitudinally pumped oscillator was found to have a very high pump threshold an extremely poor efficiency compared to the transversely pumped design. This result was most probably due to strong excited state absorption (ESA), a feature observed at high pump powers by Cassard et al. [7]. The effect was also noted for third harmonic pumping by Cox et al. [6] in their short cavity dye laser while Azuma et al. [5] refer to the difficulty they had in reaching threshold in their synchronously pumped blue dye laser when pumped longitudinally. Accordingly we have adopted a transversely pumped oscillator for this work.

The Nd:YAG pump laser was a JK Laser System 2000 AML consisting of an actively modelocked and actively Q-switched oscillator (TEM_{00} mode) with partially reflecting optics to obtain outputs at both

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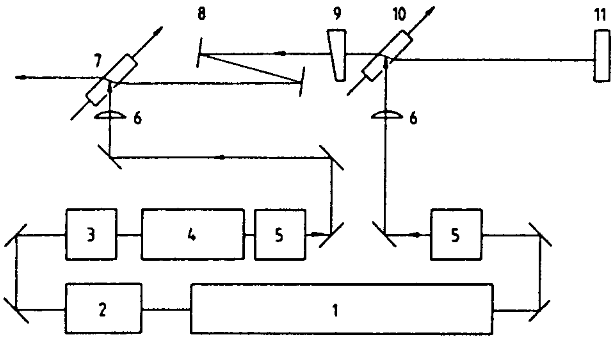

Fig. 1. Schematic layout of the laser system. 1, AML oscillator; 2, single pulse switchout; 3, 2× telescope; 4, Nd:YAG amplifier; 5, frequency tripler; 6, cylindrical lens; 7, flowing dye amplifier cell; 8, adjustable optical delay; 9, dye oscillator output coupler; 10, flowing dye oscillator cell; 11, holographic diffraction grating.

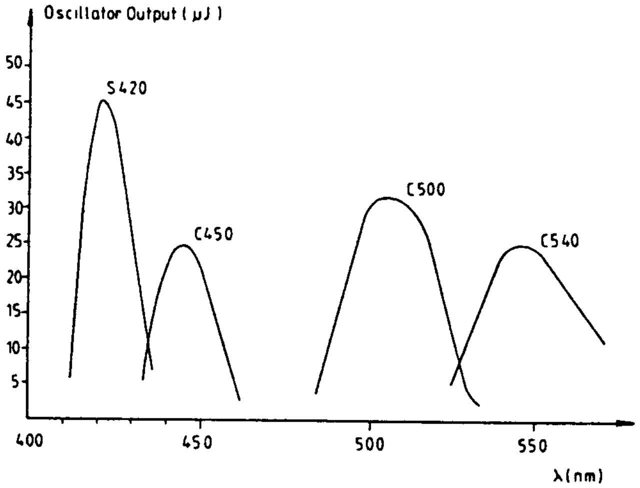

Fig. 2. Dye oscillator output for various dyes.

ends of the resonator, a single pulse selector and single stage Nd:YAG amplifier (see fig. 1). Trains of smooth bandwidth-limited 100 ps pulses separated by 8 ns in a 50 ns (fwhm) envelope were generated by the laser. Output energies used in this work were typically 2.5 mJ at the single pulse selector end and 4.5 mJ at the other end. The more energetic pulse train was frequency doubled in a CD*A crystal and the third harmonic produced by mixing in KD*P. Typical conversion efficiency to the third harmonic was 23%. The train, used to synchronously pump the dye oscillator, was vertically polarised and contained typically 20 pulses with energies greater than 10% of the peak pulse energy. The other train passed through a Pockels cell single pulse selector, beam expansion telescope and a single pass Nd:YAG amplifier to increase the single pulse energy to 8 mJ. The third harmonic of this pulse was generated by the two KD*P crystals with typical efficiency of 30% and was used to pump the dye amplifier stage.

The dye oscillator design was similar to the transversely pumped oscillator described in detail in ref. [4]. A near grazing incidence grating provided wavelength tuning and bandwidth control. The dye cell, of 28 mm length, was placed close to the output coupler (a wedged, fused silica flat) and a 1 m lens placed at the grating end of the cavity provided the desired stable resonator configuration [4]. In this design the optical length of the dye oscillator was matched to that of the pump laser by translating the output coupler. With this arrangement the dye oscillator containing stilbene 3 produced a train of approximately 9 pulses with total energy 45 μJ when pumped by approximately 1 mJ at 355 nm. The beam quality was close to diffraction limited.

Fig. 2 illustrates the tuning behaviour of four dyes dissolved in methanol, stilbene 420 (3×10^{-3} M), coumarin 450 (2.2×10^{-3} M) coumarin 500 (4.4×10^{-3} M), and coumarin 540 (9.9×10^{-3} M). The gap in tunability between C450 and C500 could probably be covered by coumarin 480 but this was not available during characterisation.

The train of dye pulses from the oscillator passed to the amplifier dye cell via three mirrors. The mirrors used were not optimised for this wavelength range and so introduced a loss of 50% typically. To obtain optimum amplification the oscillator output and pump were chosen to have parallel polarisations and their arrival times in the amplifier cell were carefully optimised as discussed in refs. [2] and [4]. The performance achieved with stilbene 420 and coumarin 540 is shown in fig. 3 for which the pump pulse energy deposite in the dye amplifier cell was approximately 750 μJ.

Stilbene 420 tuned from 412 nm to 436 nm (10% points) and peaked at around 425 nm producing 160 μJ in a single pulse. Coumarin 540 tuned form 525 nm to 575 nm with a single pulse energy of 86 μJ at 544 nm.

3. Conclusions

We have described the performance of a pulsed synchronously pumped dye laser operating in the

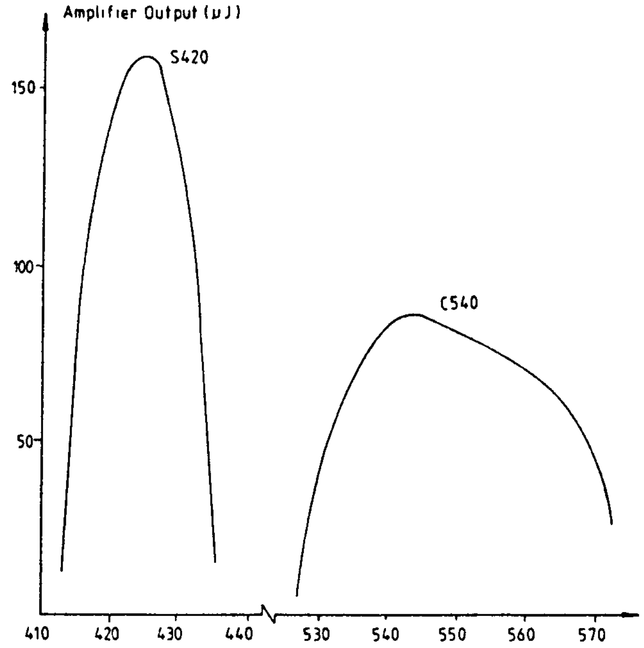

Fig. 3. Amplifier output for stilbene 3 and coumarin 540.

blue/green spectral region. We have confirmed that the use of transverse pumping of blue dyes by the third harmonic of Nd:YAG leads to much more efficient operation compared to longitudinal pumping. From a relatively simple system we have generated single pulses with wide tunability and high power, up to 2 MW power at 425 nm. Results obtained from the same system when used with red dyes suggest that the output will be capable of efficient conversion to the UV by Raman shifting and nonlinear harmonic generation.

Acknowledgements

The development of a tunable short pulse laser by JK Lasers was financed in part by the Department of Industry. DJP acknowledges support from the SERC and Culham Laboratory in the form of a CASE studentship.

We gratefully acknowledge useful discussions with C.L.M. Ireland and the technical assistance of P. Miles.

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