Stable high repetition rate single frequency Q-switched Nd:YAG ring laser

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ABSTRACT

Reliable single-frequency operation of a diode-pumped, Q-switched, Nd:YAG ring laser at high repetition frequencies up to 25kHz has been achieved by active stabilisation of the prelase power. Average powers of 250mW have been obtained for a 1.2 watt diode pump.

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SUMMARY

A reliable single-frequency Q-switched laser with high pulse repetition frequency (PRF) and good pulse to pulse stability is desirable for many applications, including for example micro machining and coherent laser radar. Operation at high PRFs is also desirable in applications where a high average power is required.

One popular approach for obtaining single-frequency operation of Q-switched lasers is to use the technique of prelase Q-switching, where a low power cw single-frequency oscillation is established prior to opening the Q-switch[1, 2]. In practice this technique has been limited to low PRFs (typically $\leq$1kHz) since the prelase usually begins with strong spiking behaviour followed by relaxation oscillations. These take a time to decay to the steady cw prelase required for reliable single-frequency operation and high pulse to pulse stability. At high PRFs, when the Q-switched pulse builds up from prelase spikes, large fluctuations in pulse amplitude and excessive timing jitter occur, which become severe when the prelase time is too short for establishment of single-frequency operation[3].

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One way of extending reliable single-frequency Q-switched operation to high PRFs is to use a short cavity such as in microchip lasers[4]. Such lasers have limited power scalability.

An alternative approach is to use the technique of injection seeding. This technique suffers from the disadvantage that a second laser (the master oscillator) is required and must be mode matched to the slave oscillator, adding extra complexity and cost to the overall system.

In this paper we report a simple technique for extending reliable single-frequency prelase Q-switching to high PRFs up to 25kHz and which can be applied to any acousto-optically Q-switched laser.

The technique involves actively controlling the RF drive power supplied to the Q-switch, and hence its diffraction loss, so as to damp out spiking and relaxation oscillation. We have applied this technique to a Nd:YAG ring laser, pumped by a 1.2W high-brightness diode, in which a single acousto-optic modulator enforces unidirectional operation and is used to Q-switch the laser, as shown in Fig. 1.

To control the prelase power we have monitored the power in the diffracted beam (which passes over the prism), and using a simple PID (proportional-integral-differential) control unit to control the RF power and hence diffraction loss of the A-O Q-switch to hold the prelase power at an adjustable preset level. The spiking is then damped and as a result the establishment of a unidirectional and single-frequency prelase occurs sooner. The stable and reliable prelase results in much reduced pulse to pulse amplitude and timing fluctuations.

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At low repetition rates, around 1kHz, we obtained pulses of 13.5ns FWHM and more than 50μJ, while at 25kHz we obtained 250mW average power with 55ns pulses. At all PRFs the amplitude and pulse length fluctuations were $<2\%$, and the timing jitter was <2.5ns. For comparison, without the active stabilisation scheme single-frequency output was only possible up to 15kHz and then only with very careful alignment. Above this PRF the output became partly bidirectional with very large pulse amplitude fluctuations and timing jitter of ~ 90ns (ie much greater than the 35ns pulse lengths). At 5kHz the amplitude fluctuations were still 20% and the timing jitter 35ns.

This technique offers a simple and attractive alternative to injection-seeding for reliable single-frequency operational high PRF, with the capability of being scaled to much higher powers using diode-bar pumps.

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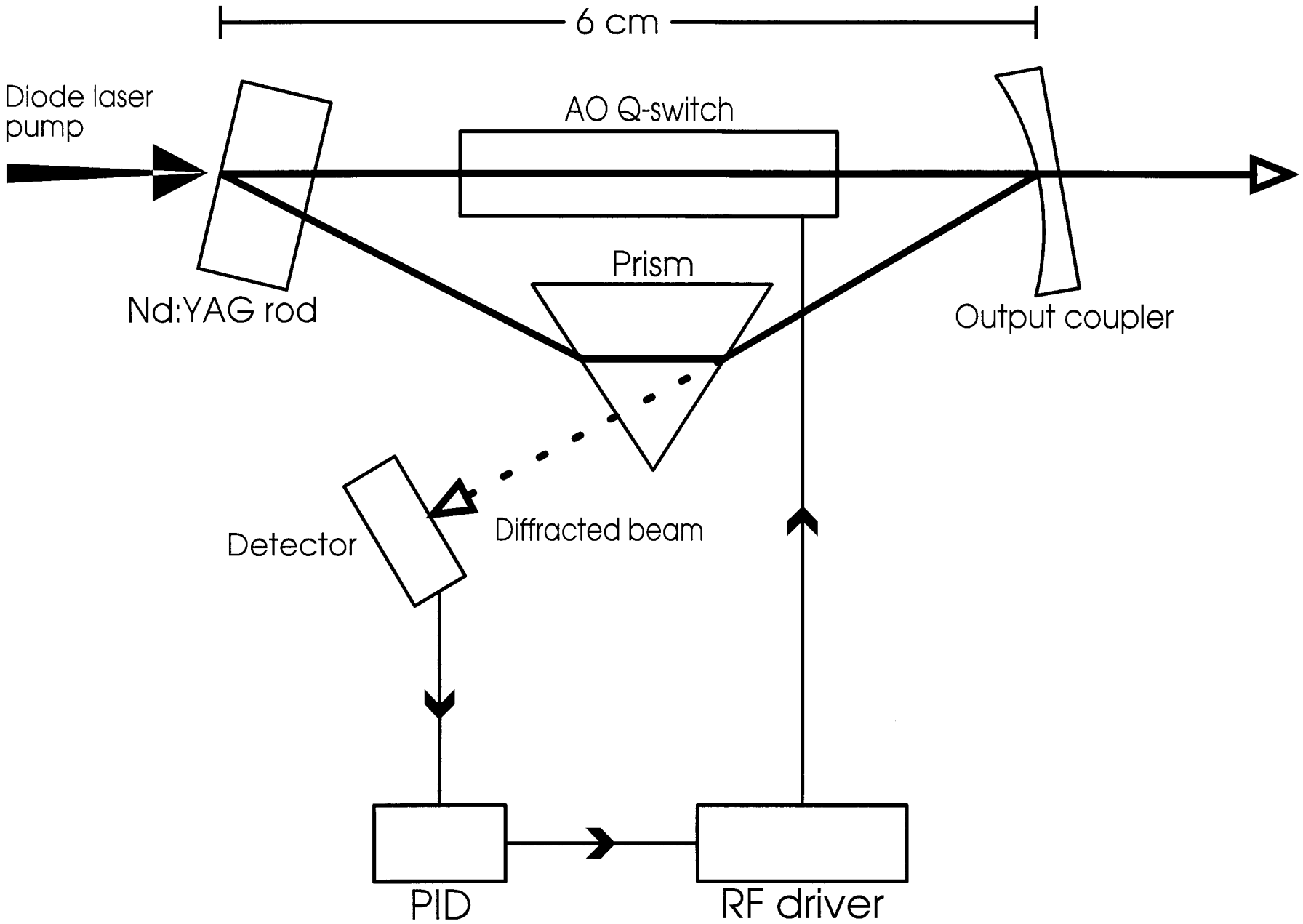
FIGURE CAPTIONS

Fig.1 Prelase power feedback control experimental setup. The diffracted beam passes over the prism to the detector.


6 cm
Diode laser pump
AO Q-switch
Nd:YAG rod
Prism
Output coupler
Detector
Diffracted beam
PID
RF driver