Advanced Optical Technology Ltd

Technical Note (4)

New Sub-Nanosecond Laser Sources

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Today, there are many uses for lasers producing high intensity short pulses. Applications include; ranging, LIDAR, micro-materials processing, and UV spectroscopy in chemistry and biochemistry. For these markets and many others diode pumped solid-state lasers (DPSSLs) have become the preferred customer solution. They have many advantages including; the capability of good TEMoo beam quality from a compact package, high rep-rate, and the option of IR, visible or UV output via efficient harmonic generation.

DPSSLs predominantly use A-O (acousto-optic) Q-switching to generate the pulses, since this technique is efficient at the required high rep-rates - typically ~ 1 - 100kHz. As with all lasers, output characteristics (pulse length, peak power, and average power) mainly depend on the active laser material, pump power and resonator design. Since A-O Q-switching is an active technique, subject to electronic control, it also allows the user to synchronise the pulses in the many applications where this is required. However, a major restriction of the technique is that it is fundamentally limited in speed by the acoustic wave velocity across the aperture of the switching device. As a result, A-O Q-switched lasers typically produce pulses of ~ 5-50ns duration. Shorter pulses, in the 1ns range have been reported[2], but limited to 1-2 microjoule energy.

In some key applications energetic short pulses (~ 1ns or less) can bring significant advantages. For example in ranging, 3D imaging, high-speed/strobe photography and in scientific ‘excite and probe’ type experiments they allow increased temporal or spatial resolution. In the case of precision micro-machining there is practical evidence[3][4] that they allow results of superior quality due to the much reduced heat diffusion into the bulk material. This is not surprising, since it is found experimentally that the time for the laser power (coupled to the electrons) to transfer heat to the lattice of the material is typically in the ~ 10-1000ps range[5][6]. However, with these pulse durations and longer, there are plasma effects that can also affect the processing and need elucidation[7]. Interaction studies in this sub-nanosecond pulse length regime represent a very active R&D area, not least because the results raise the possibility that such pulses might achieve many of the processing benefits now being seen with sub-picosend irradiation produced with much more esoteric sources.

The attraction of sub-nanosecond pulses for these applications and others has led to considerable interest in the development of microlasers in the last few years. These are lasers with very short (few millimetre long) resonators and have resulted from the development of techniques to epitaxially grow or bond small passive Q-switch elements to laser microchips which allows monolithic laser design. The approach has provided ultra-compact DPSSL sources producing pulses of duration ~ 1ns or less. However, these lasers have some significant deficiencies. Most important from the users point of view are that (i) the pulses cannot be externally well synchronised and (ii) the operator only has a limited control over the laser output characteristics. For example, it is reported that typically pulses down to ~ 700ps duration at a few kHz with timing jitter of the order +/- 100ns are achieved with 3W diode pumping[8].

For applications requiring both short pulses and good time synchronisation these microlasers are of little benefit - a deficiency inherent to the passive Q-switch technique. To overcome this problem, AOT has developed and recently introduced a range of compact DPSSLs based on E-O (electro-optic) Q-switching technology. The E-O switching technique is very well established for low rep-rate (~ 0-100Hz) lasers where it provides nanosecond speed, high extinction, and allows users the opportunity for excellent pulse synchronisation. In the last 1-2yrs, using new proprietary designs, AOT has implemented the technology in a highly miniature and efficient form for use at high rep-rates. With this development, our ACE lasers produce IR TEMoo pulses of duration in the 1-2ns range (depending on rep-rate) to 50uJ energy, operate to 20kHz, and are externally synchronisable to less than 500ps.

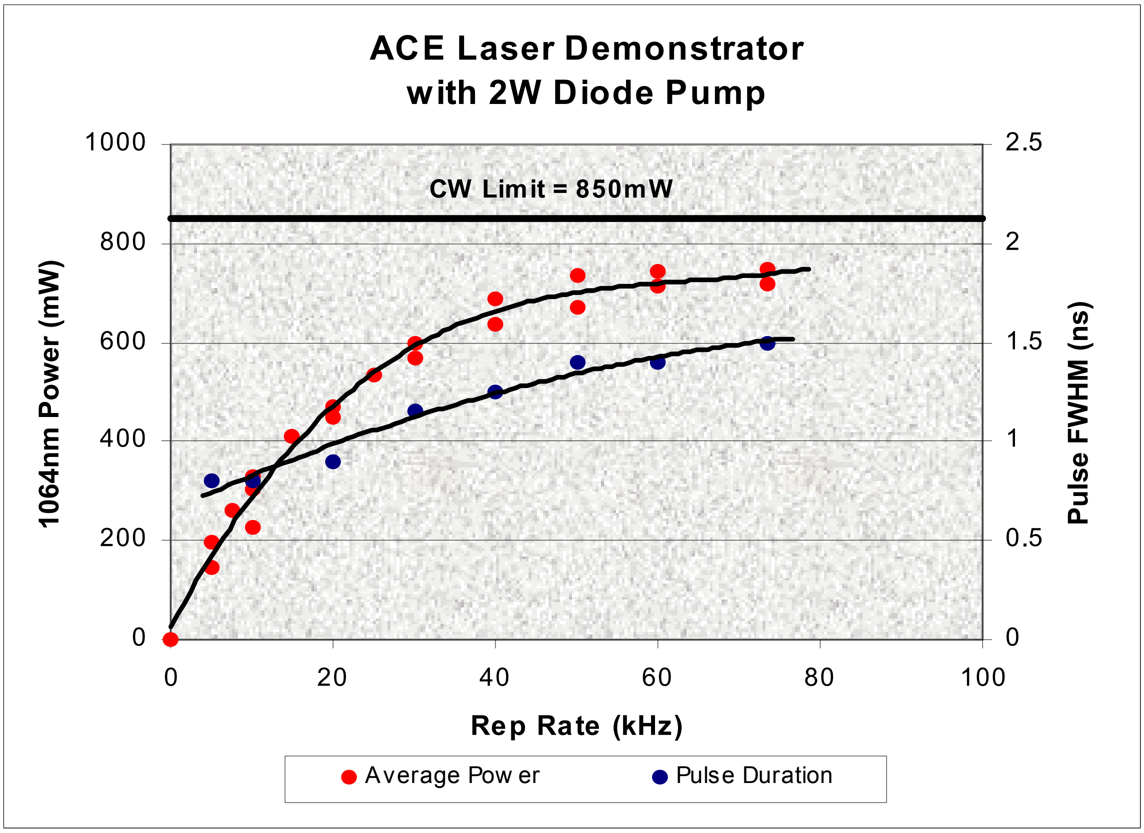

Figure (1)

However, this performance by no means represents the limitation of E-O switching technology. Via a current collaboration[9] involving our sister company, Leysop in the UK and a partner Raicol Crystals in Israel, AOT is extending the laser operating envelope further. Recently, we have demonstrated TEMoo laser performance to 75kHz with average power to 750mW, and the generation of pulses down to ~ 750ps in duration with timing jitter of +/-100ps. Figure (1) summaries this performance and also indicates the excellent efficiency that can be achieved by the technology.

The high extinction provided by E-O devices allows the design of lasers with very high gain and fast pulse dynamics. We have studied this as part of our development programme and find that Q-switched laser sources with even shorter pulse duration are feasible at the same high efficiency. Figure (2) shows the measured relationship between resonator length and pulse duration where, in all cases, the average laser TEMoo output power was in the 250-350mW range. Within the collaboration, AOT is working towards implementing lasers with resonators of < 10mm in length.

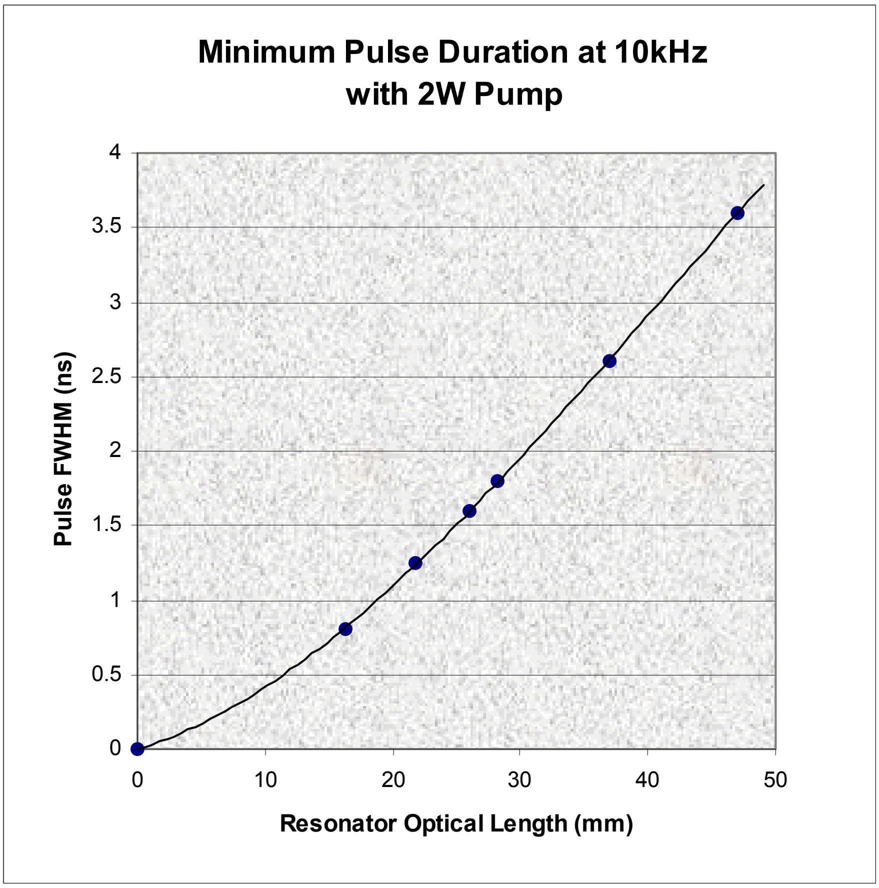

Figure (2)

When complete early in 2003, it is planned that the current laser development programme will deliver new pulsed DPSSL models operating up to ~ 100kHz rep-rate with less than 1ns pulse duration with less than 1ns pulse duration, greater than 1W average power, and provide a minimum pulse duration performance below 500ps with very low jitter. These attributes are anticipated to very significantly enhance the attractiveness of pulsed

DPSSLs to users currently seeking short pulse synchronisable sources for their industrial or research applications.

References

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(9) Project, 'Advanced Lasers Including New High Frequency E-O Modulator and Deflector Devices', Supported by the Britech Foundation Ltd.

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