Advanced Optical Technology Ltd

Technical Note (6)

ACE Laser Harmonic Performance

As noted elsewhere, short pulse duration, high peak power and high beam quality are unique features of all the ACE laser models. These characteristics allow high efficiency power conversion from the fundamental wavelength (1064nm) to harmonic wavelengths by the suitable choice of non-linear crystals.

Second Harmonic Output

Although optimisation can be made for a specific repetition rate, most users request performance that gives good 532nm (green) output across the operating range of their laser. AOT have investigated a number of configurations to best achieve this and adopted the most appropriate. The widest spread in 1064nm pump beam parameters arises with the MOPA lasers operating to 100kHz. However, even in this case we have found that, with a proper choice of doubling arrangement, we can achieve excellent 532nm results. Figure (1) shows that 500mW green output can be achieved over most of the operating range of the standard MOPA by a single fixed arrangement.

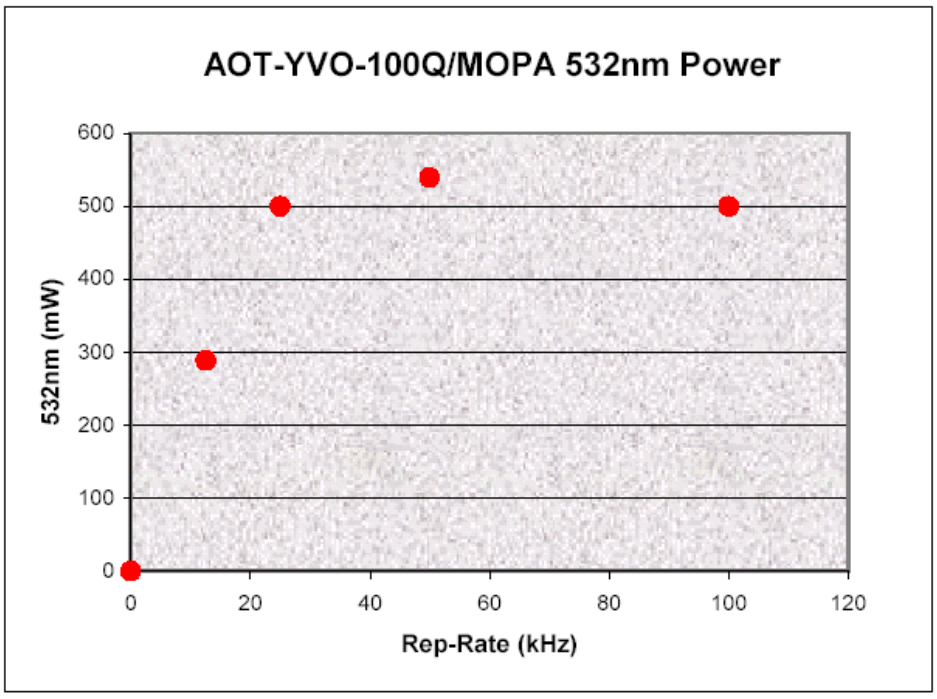

Figure (1

An exception to the above generalisation occasionally occurs when an SP laser model is selected, as this often occurs when the user also has a particular need for the shortest pulse duration i.e. is more interested in the 532nm power being optimised for the lower part of the repetition rate range. Again, this can be achieved. As an example, Figure (2) shows a comparison of performance for the AOT-VO-50QSP/MOPA (1064nm spec of 600mW @ 20kHz and 800mW @ 50kHz) using a doubler configuration that gives good performance across the rep-rate range (red data points) and one optimised for the shortest pulse, low rep-rate range (blue data points).

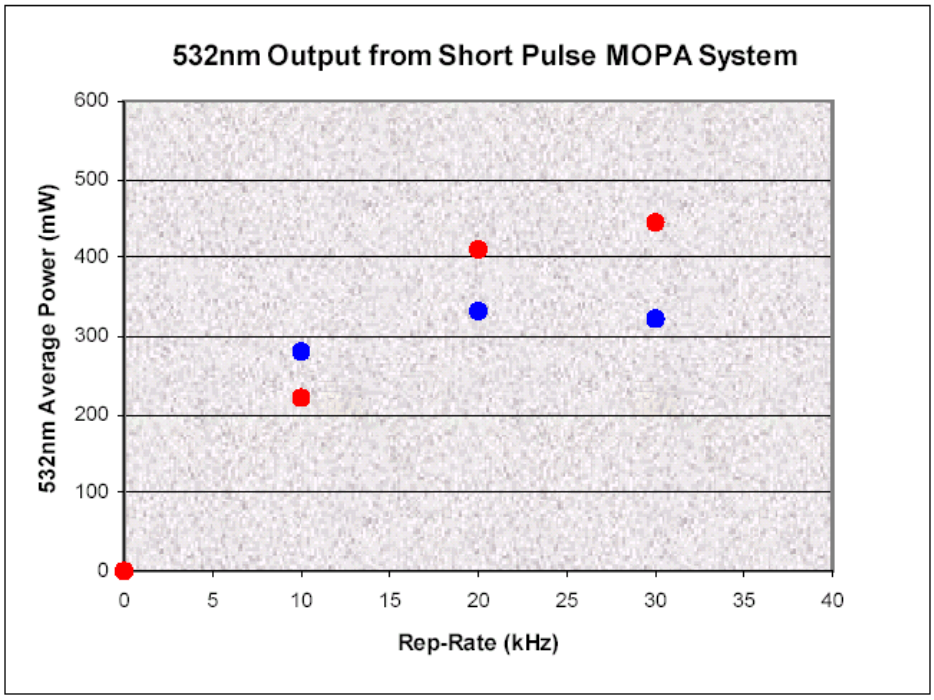

Figure (2)

The figure shows that ~ 25% more power can be achieved at ~ 10kHz (or lower) by the proper choice of the doubling arrangement.

Also of interest for many applications is the effect of frequency doubling on pulse duration. The non-linear nature of the effect causes some pulse shortening relative to the 1064nm pump pulses and Figure (3) shows the example of this for the Short Pulse (SP) model lasers. At repetition rates around 10kHz or lower, the pulses at 532nm are down to ~ 600ps FWHM duration.

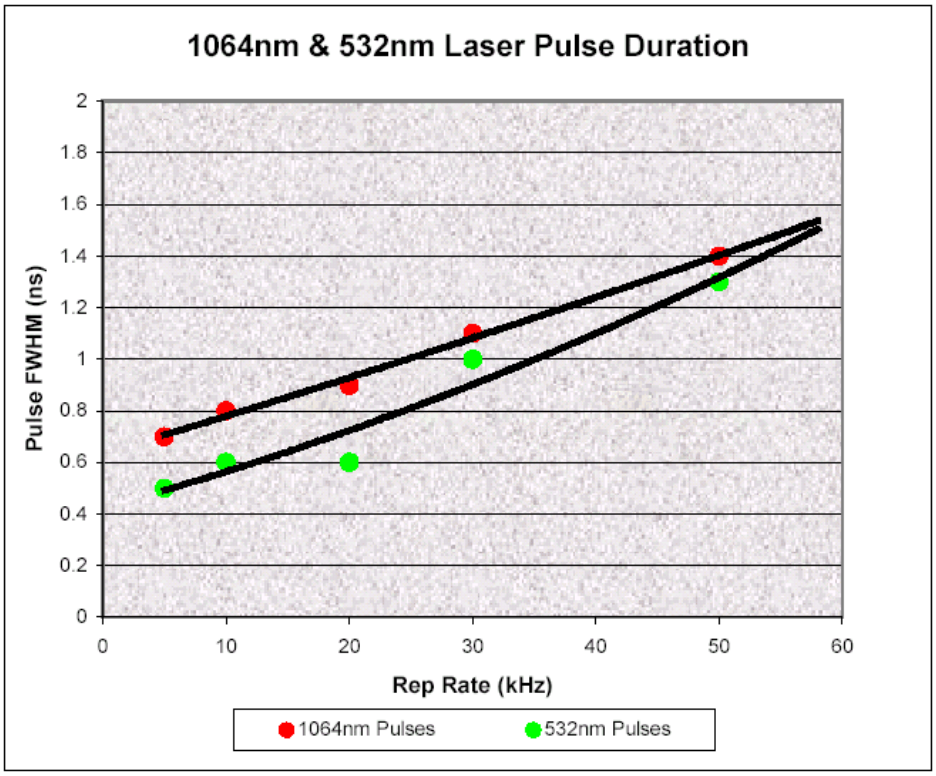

Figure (3)

Third Harmonic Output

Third harmonic laser power is obtained by combining the power of generated 532nm pulses with the residual power of the 1064nm pulses after the doubler in a 'mixing' crystal. Again, this is a non-linear process favouring short intense TEMoo pulses such as those generated by the ACE laser models. Good performance requires the pulses to overlap well in the mixing crystal, be of appropriate polarisation, and be of suitable 532nm/1064nm power ratio.

This is a higher non-linear process than doubling and, as a result, tends to be more sensitive to laser peak power and beam intensity ie favours higher power lasers. We have studied arrangements to optimise performance for the main ACE laser models and found, by suitable crystal choice and selection, that; (i) with oscillators we can achieve up to ~ 20% conversion of the 1064nm power to the third harmonic at 355nm and (ii) with MOPA models up to ~ 40% conversion.

Figure (4) shows the example of results for the AOT-YVO-50Q oscillator where it can be seen that best 355nm power occurs at ~ 20kHz and that the 355nm/1064nm efficiency rises monotonically with decreasing repetition rate. The results for the AOT-YVO-100Q/MOPA are shown in Figure (5). In this case, it can be seen that the selected third harmonic arrangement provides a conversion efficiency that depends primarily on 1064nm pulse energy and is insensitive to laser repetition rate.

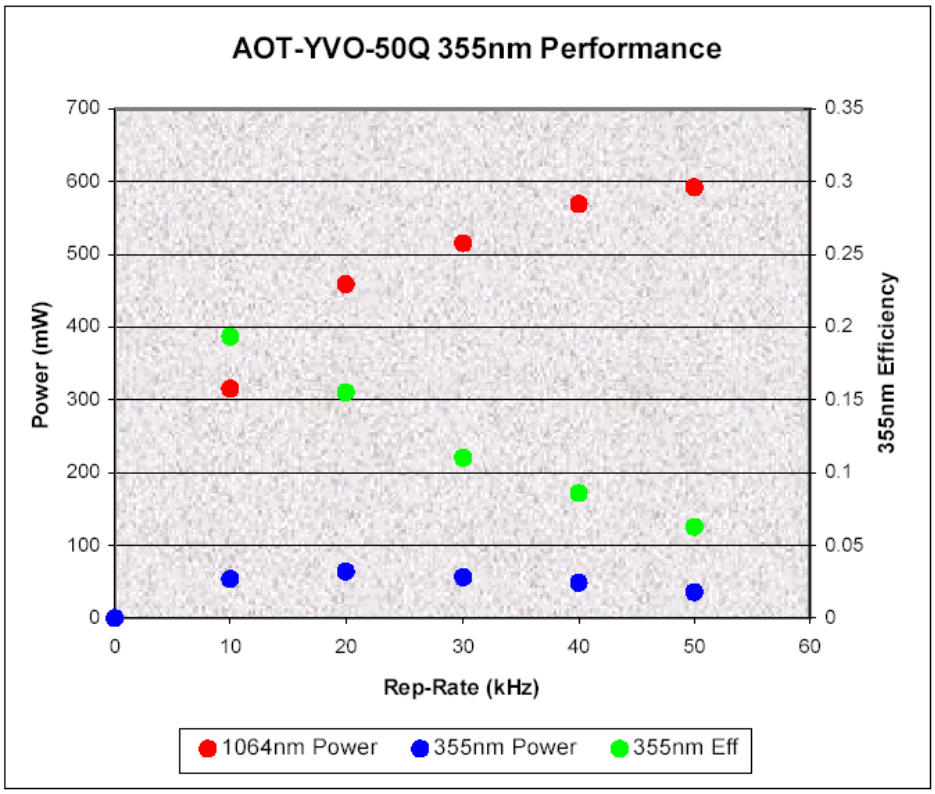

Figure (4)

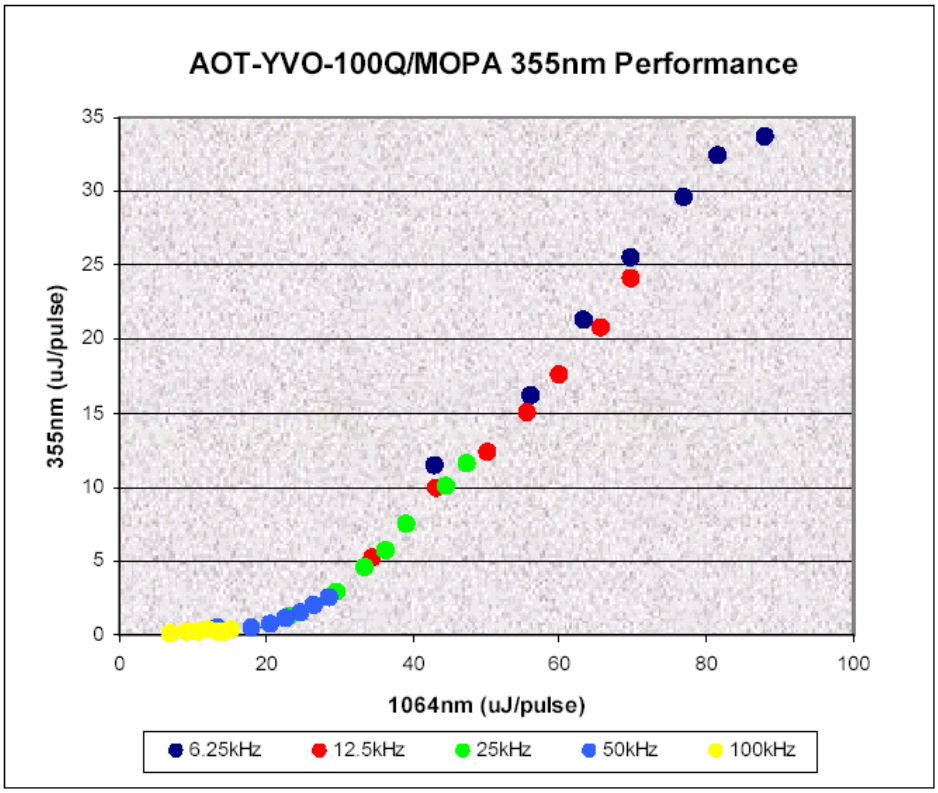

Figure (5)

Fourth Harmonic Output

Fourth harmonic laser power is obtained by a further stage of frequency doubling after maximising the conversion of IR power to 532nm. Although the doubling process is similar, the conversion from 532nm to 266nm (deep into the UV) requires different crystal types. Again, this tandem process is highly non-linear favouring short intense TEMoo pulses such as those generated by the ACE laser models.

As with third harmonic generation, the process efficiency is sensitive to laser peak power and beam intensity i.e. favours higher power lasers. We have studied arrangements to optimise performance for the main ACE laser models and found, by suitable crystal choice and selection, that we can achieve good performance. For example, Figure (6) presents results for the AOT-YVO-50Q/MOPA where it can be seen that conversion from 532nm power is up to ~ 40% for an optimised arrangement,

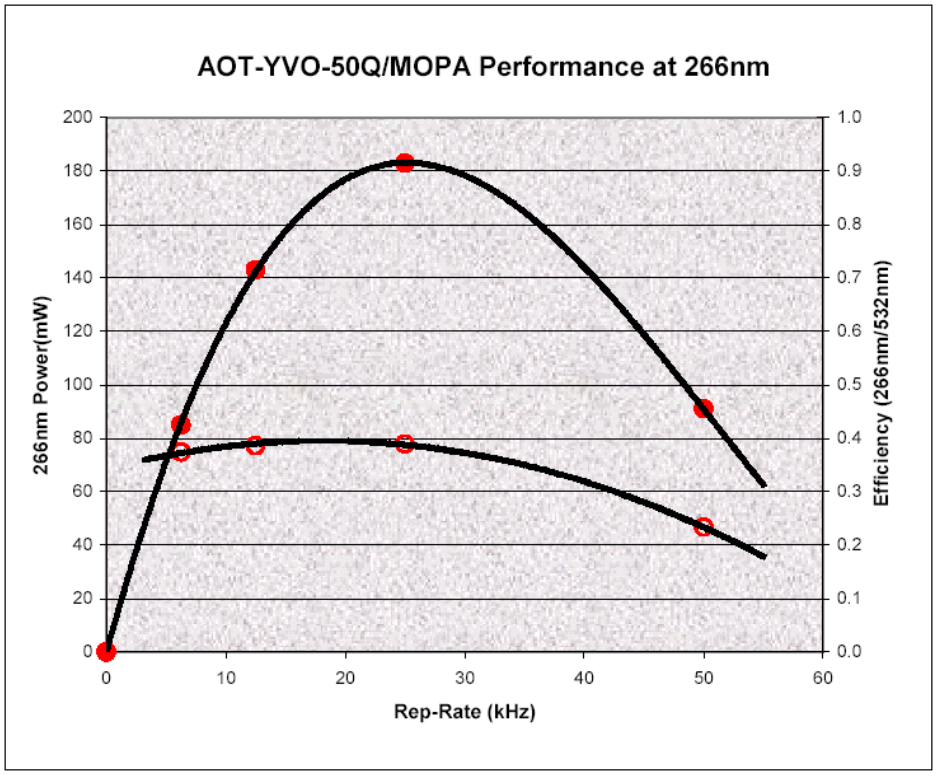

Figure (6)

and the maximum output power reaches ~ 180mW at ~ 25kHz. Figure (7) shows how 266nm average laser power at this repetition rate scales with the input pump power at 532nm.

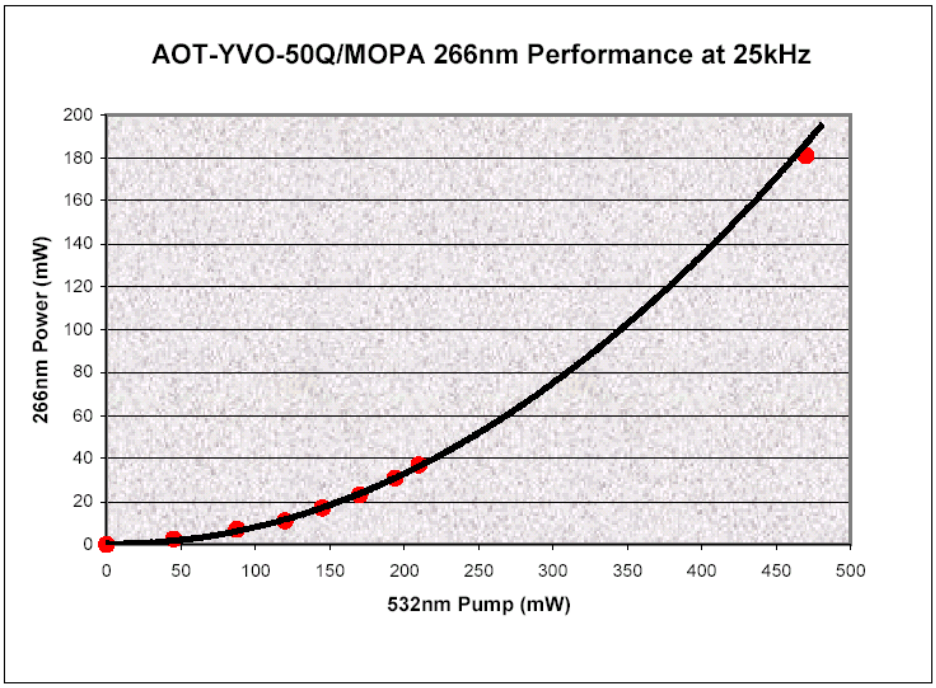

Figure (7)

Finally, as noted above for 532nm power generation, both the further harmonic generation stages (mixing to produce 355nm, and doubling to produce 266nm) lead to further reduction in the pulse duration. For the case of the SP laser models, where the 1064nm pulses are down to ~ 700ps duration and the 532nm pulses are down to ~ 600ps, we have measured the UV pulses as having duration down to ~ 500ps.