# Advanced Optical Technology Ltd

**Technical Note (15)**

## High Power Laser Models

Over the past ~ 12 months (2006/7) AOT undertook a programme of work directed at further improving it's range of short pulse lasers. The main objective was to develop an increased power capability (W/$ for customers) without sacrificing product efficiency, reliability or beam quality. The programme was successful and resulted in both a new high power oscillator and a new high power MOPA. These two new models (designated AOT-YVO-xxxQ and AOT-YVO-xxxQ/MOPA, respectively) were launched in April 2007.

### AOT-YVO-xxxQ Oscillator

The high power oscillator is based on the same proven technology as all the previous AOT short pulse laser models. However, changes have been made to the design of the new model to allow higher power performance eg without increasing deleterious effects due to heat generation.

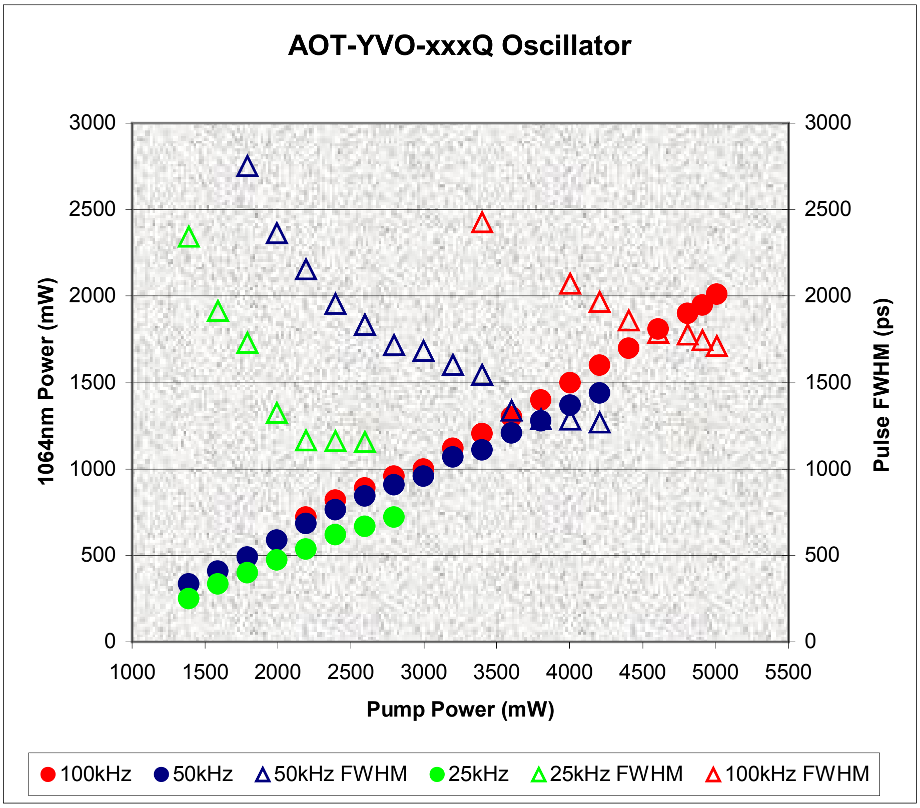


*Fig (1): Power and pulse length of the new oscillator recorded in project trials*


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It can be seen from Fig (1) that the new oscillator design has operated to 2W output, and this at a 40% optical efficiency (ie ratio of 1064nm power to diode pump power).

The laser performance was not at the expense of beam quality, a fact confirmed by examining the efficiency of conversion to the 532nm and 355nm harmonic wavelengths in suitable non-linear crystals. In the case of 2ω conversion with KTP, the oscillator produced a max of ~ 900mW/100kHz, 800mW/50kHz and 400mW/25kHz. Since the shortest pulses were ~ 1.25ns FWHM, this corresponds to a 532nm peak power of > 10kW @ 25kHz.

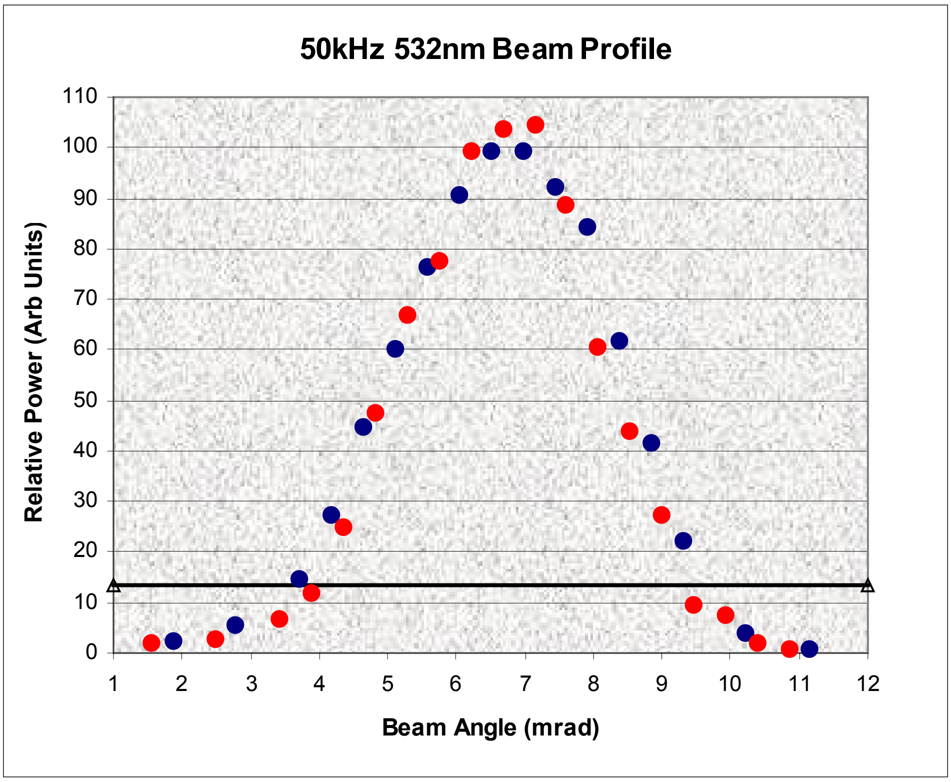


*Fig (2): 532nm Beam Profile at 580mW (red data) and 700mW (blue data)*

The oscillator beam power distributions were taken from measurement of the transmission of a pinhole scanned across the beam in the far-field. An example of the 532nm beam profile at 50kHz is shown in Fig (2). The beam divergence full angle (1/e^2 intensity diameter) of ~ 6mrad was predicted well by our in-house resonator model.

## AOT-YVO-xxxQ/MOPA

*Power*

The MOPA uses the proven AOT format of a compact and reliable double-pass amplifier to boost power, which does not compromise performance in the areas of efficiency and beam quality. With an optimised set-up, the new design allowed a maximum overall optical power efficiency for the MOPA of 45%, with 3.5W 1064nm laser output at high rep-rates. These results, shown in Fig (3), have again been well modelled.

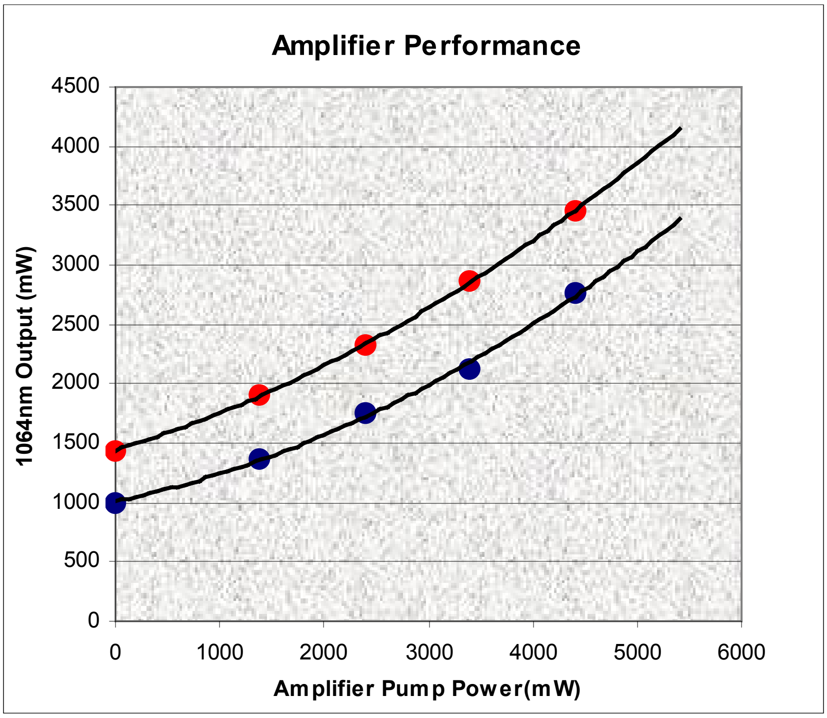


*Fig (3): 1064nm MOPA Power at 100kHz (Red) and 50kHz (Blue)*

*Energy*

Of interest for a number of users is the maximum pulse energy capability of any new laser. In the zero to a few kHz regime (where the inter-pulse period is long compared with the $Nd:YVO_4$ gain storage time) pulse energy is high and near independent of rep-rate. However, in this regime, there are some potentially adverse effects that need to be dealt with via careful design. The adverse effects include gain depletion via up-conversion, parasitic oscillations and ASE, as well as decreased beam quality due to increased thermal load. The design of the new laser models deal with these issues well. As an example, Fig (4) shows the gain of the MOPA amplifier measured at 21uJ/pulse and 42uJ/pulse 1064nm input from the oscillator, respectively. It can be seen that the maximum amplifier gain was in the x3 to x4 range, allowing the MOPA output energy to reach > 100uJ/pulse. The linearity of the gain with pump power (to the maximum) indicates that the amplifier was heavily saturated (as required for good/high efficiency of extraction), and that non-linear losses had not become significant.

*Note: Whilst pulse energy drops at increasing rep-rate, average power increases as energy stored in the gain medium has less and less time to decay between pulses. As a result, maximum power extraction occurs at high rep-rate.*

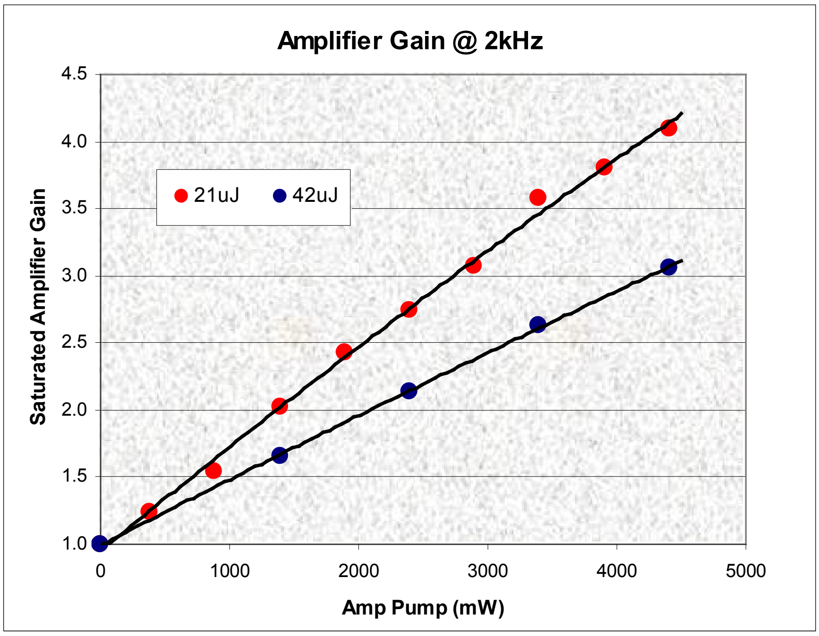


*Fig (4): Gain of MOPA amplifier with 21uJ (red data) and 42uJ (blue data) pulse input at 2kHz*

As noted in the discussion of the performance of the new oscillator, harmonic conversion allows a useful assessment of laser beam quality/brightness. In the case of the MOPA, 532nm power was measured in a number of experiments with different length KTP doubling crystals. Fig (5) shows that, at all rep-rates up to the maximum of 100kHz, power conversion of 50% was achieved. This was a good indicator of the excellent beam quality of the MOPA at high power.

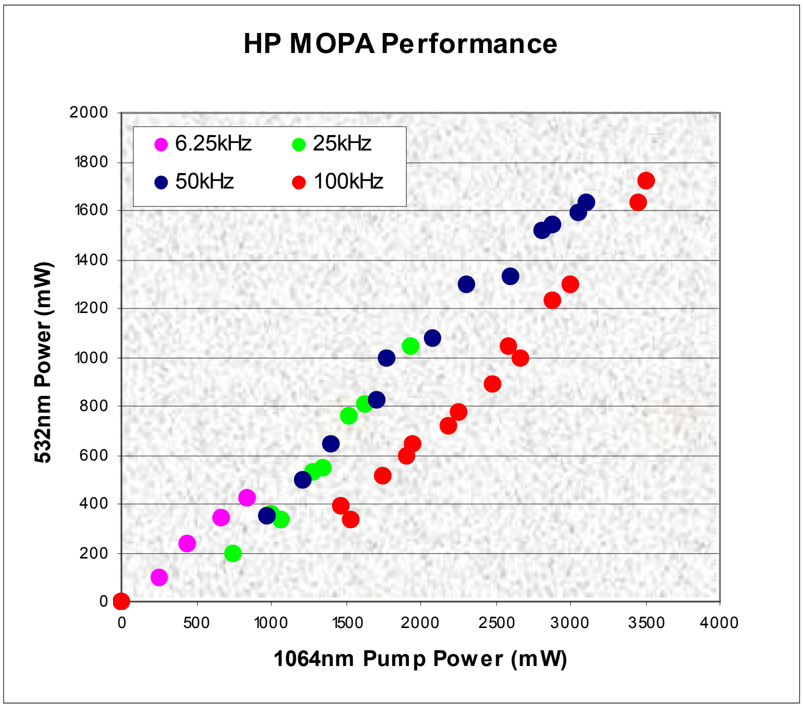


*Fig (5): 532nm Power Achieved by New MOPA Laser*

A number of further experiments were undertaken using LBO crystals to convert the 1064nm MOPA power to the third harmonic in the UV at 355nm. The arrangement used a standard AOT harmonic module.

A typical set of data recorded at 50kHz is shown in Fig (6). In this case, both the initial 1064nm and converted 355nm powers are plotted against the MOPA total diode ~ 808nm pump power. It can be seen that the MOPA supplied over 1W of UV power at this rep-rate. Measurement showed that the UV conversion efficiency (ratio of 355nm to 1064nm power) was > 20% across the full test range, and > 30% at all rep-rates to 70kHz with a maximum of ~ 38% around 50kHz.

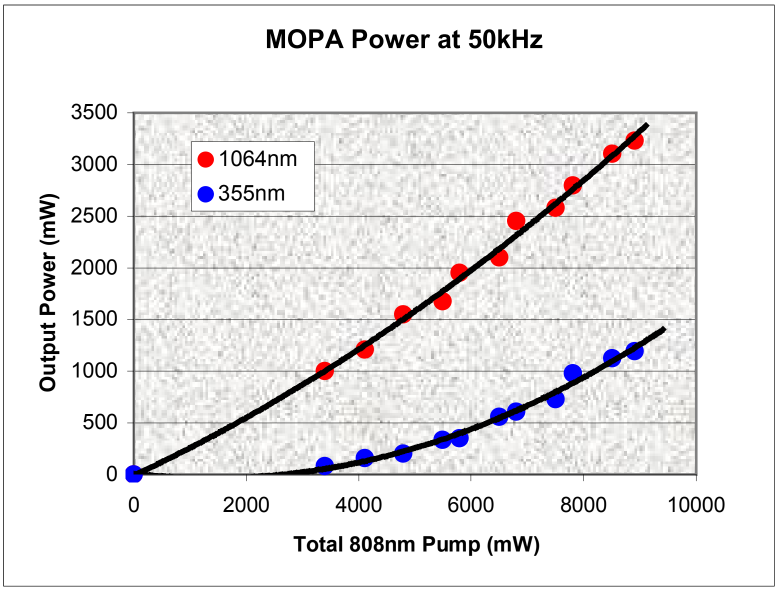


*Fig (6) IR and UV Performance of MOPA at 50kHz*

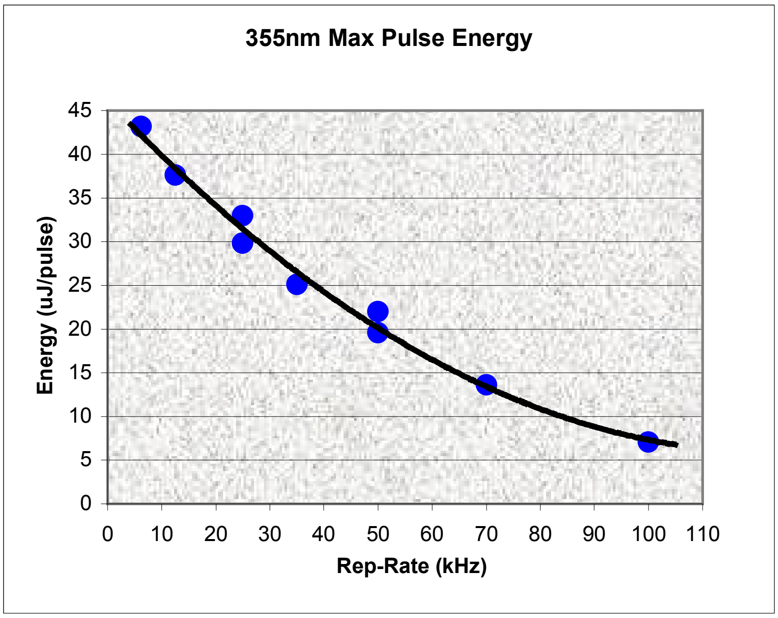


*Fig (7): MOPA Maximum UV Pulse Energy*

As with 532nm performance, many UV applications require a certain pulse energy to become viable. For this reason, Fig (7) plots out the maximum 355nm pulse energy available from the new MOPA as a function of rep-rate.

**Summary**

This note has briefly reported on the performance of a new oscillator and a new MOPA recently developed into laser products by AOT. Specifications for the two new models can be found on the company Website.

The development project uncovered a number of subtle aspect of design, which were found to allow a modest degree of trade-off between some laser parameters eg pulse length, pulse energy, rep-rate, average power, etc. AOT would be pleased to discuss these trade-offs with interested customers following their review of the new product specifications.