WHITEPAPER

CONTROL DPSS LASER POWER OUTPUT

The Advantage of Extra-Cavity Power Tuning - Maintaining Critical Specifications

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The advantage of extra-cavity power tuning - maintaining critical specifications

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Abstract

This paper describes different methods to control the output power of a DPSS lasers, starting from basic current control towards power control whilst maintaining all other optical parameters. This is enabled by Novanta's proprietary ULTRALOQ™ technology combined with an onboard, extra-cavity variable optical attenuator. The focus of this paper lies on the noise profile, power stability, spectral behavior and beam profile under varying temperatures and output power levels. It is shown that the bandwidth of the GEMultra is stable over the complete power range ranging from 100mW up to 2W.

Introduction

The first diode-pumped solid-state (DPSS) laser was shown by Keyes and Quist in 1964 [ref]. They pumped a CaF2:U3+ crystal with a bank of GaAs laser diodes at 840nm in a liquid helium dewar. Whilst the choice of the active medium – a Uranium doped crystal – sounds strange today, the general laser scheme – usage of GaAs as pump-diodes – is still state-of-the-art.

A basic method to control the output power of a DPSS laser is to control the pump power, hence the current feeding the pump diodes. Such a scheme is called *current control*, it only would lead to a stable output in case all environmental conditions are stable. In reality, already minor temperature changes of the laser crystal, the pump diodes or any other component of the laser lead to varying output powers. However, it is not only the output power itself that changes in such a case but also other parameters such as the exact emitted wavelength, the spectral bandwidth and the beam diameter.

Despite these obvious limitations, current control is still a very common method to control the output power, just because it does not require any internal power monitoring component and power feedback loop. Under stable environmental conditions and stabilized pump diode temperatures, it is possible to realize DPSS lasers with just current control at RMS noise levels of 0.2%.

A more sophisticated and state-of-the-art way to achieve stable output is called power control. It was realized for the first time by Novanta in the finesse laser series back in 2005 with our proprietary PowerLoQ technology. Here a small fraction of the output beam is picked-off and steered towards an internal photodiode constantly monitoring the laser output. A control-loop feeds back the signal to the pump diode driver adjusting the pump currents accordingly at a bandwidth above 1 MHz.

Power control ensures that at the specified power value of the laser parameters such as power stability, noise, beam diameter, spectral behavior are within the specifications even at changing environmental conditions. At other power levels (typically lower power levels) this is no longer true, the specifications are not met and typically worse (with respect to noise and power stability for example).

[ref]: https://doi.org/10.1063/1.1753958

ULTRALOQ and Variable Optical Attenuator

Here Novanta's GEMultra comes into play. While ULTRALoQ combines an innovative material system designed to enhance the stability and durability of laser systems, an onboard variable optical attenuator (VOA) enables up to OD2 attenuation. The VOA is an integrated, extra-cavity optical element not replacing standard power control but extending it. The DPSS laser operates all the time at the same (high) power level. After the pick-off for the power control loop the VOA then attenuates the power to the requested value. This approach has plenty of advantages such as exceptional noise and power stability at all power levels without any disadvantage. One might raise the point that the lifetime of the laser is shortened if it always runs at full power. While this argument is true for many DPSS lasers in the market for Novanta's DPSS lasers this is not true since even at the full specified power the pump diodes are only driven with about 70% of their specified current.

Coming back to the advantages of ULTRALOQ™ and the VOA. Both play hand in hand resulting in exceptional noise and power stability since the laser constantly runs at its optimized settings while at the same time being immune to environmental changes. Fig. 1 shows the laser power at 100% power level (corresponding to 1750mW) over 50 hours while the laser temperature varies from 18 to 38°C. Throughout the white paper changing the laser temperature means that the chiller temperature is changed, so the base plate the laser is mounted to is changing its temperature.

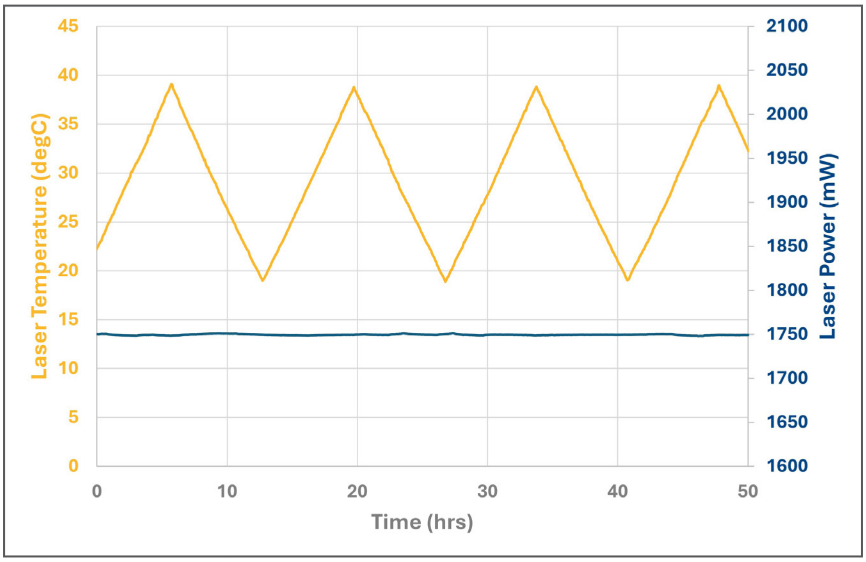

Fig. 1: Power (blue) over a 50-hour window while changing the laser temperature (yellow).

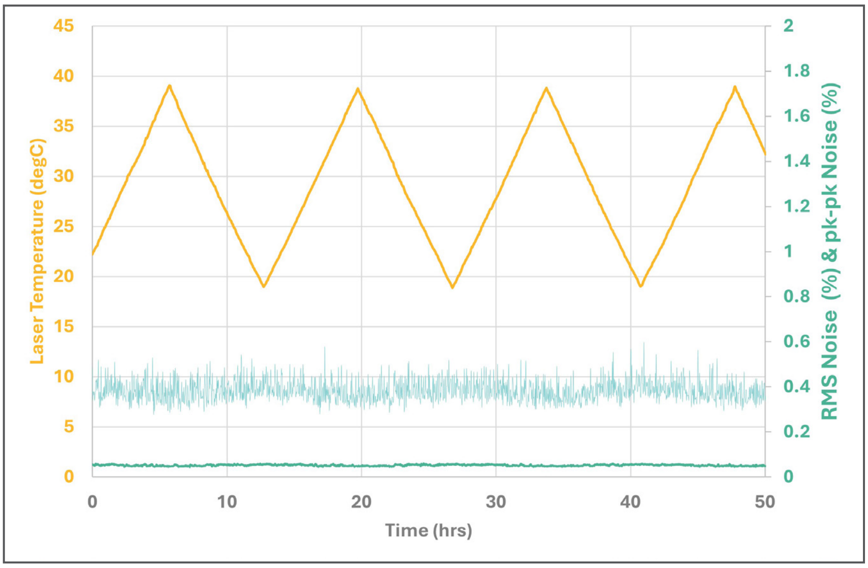

Fig. 2: RMS (blue-green) and peak-to-peak (light blue) noise over a 50 hours window while changing the laser head temperature (yellow).

Fig. 2 shows the same data focusing on RMS and peak-to-peak noise. For both graphs the laser power was set to 1750mW. While the temperature varies linearly back and forth from 18° to 38° within a period of 14 hours, the laser output only changes by +/-10mW over the 20°C temperature range. Both RMS and peak-to-peak noise remain within the specified range of <0.1% and <1%, respectively, also showing only a very minor reaction to the temperature profile. While this behavior can be mainly attributed to the ULTRALOQ™ technology the fact the noise stays within the specifications also for smaller power levels is a direct result of using the VOA instead of changing the pump power.

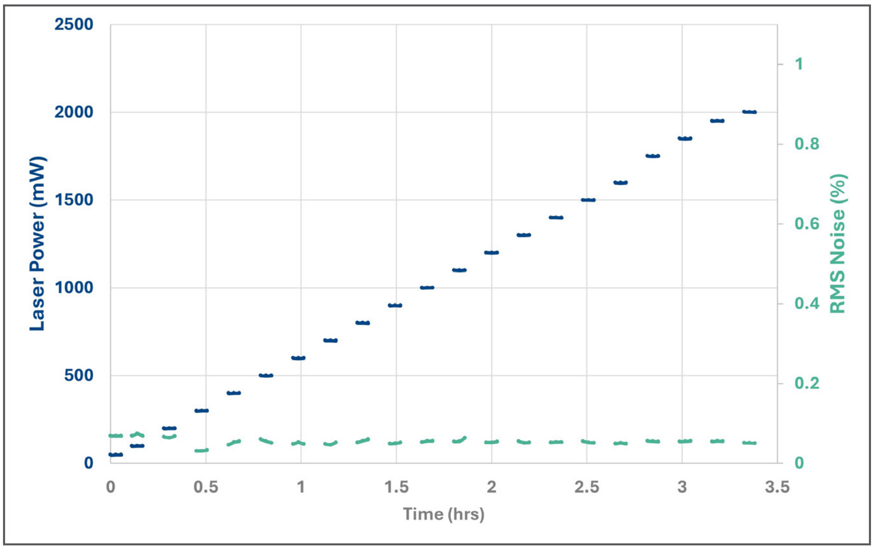

Fig. 3: RMS noise (blue-green) while output power (blue) is ramped up to full power.
The RMS nos

Fig. 3 shows the RMS noise when the laser output is increased from 50mW up to 100mW and then further in 100mW steps up to 2000mW. The RMS noise stays for all powers below the specified RMS noise value of 0.1%. This is enabled by the VOA together with the conventional power control loop both controlled by the new smart power supply smd24.

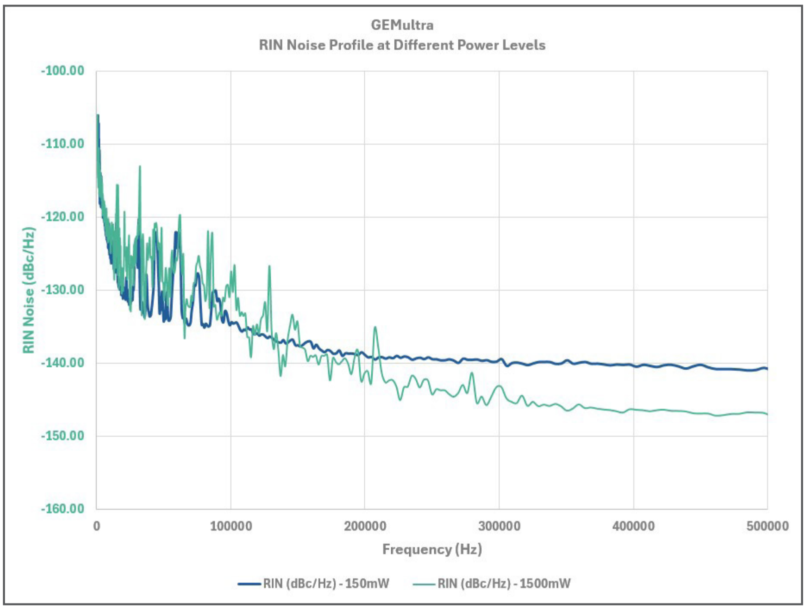

Fig. 4: RIN profile at 10/20% and 100% output power.

Fig.4 shows the Residual Intensity Noise (RIN) profile both at 10/20% and 100%. The fact the features – indicating the power spectral density of the intensity fluctuations - are overlaying directly shows the effect of the VOA; for both power levels the intra-cavity performance of the laser is identical, only after the laser output but still inside the laser the output power is attenuated to the requested power level.

While in the previous time-domain graphs (Fig. 1 to 3) one parameter was always changed (either power or temperature), Fig. 5 shows the power of the GEMultra at constant temperature for two set power levels over a very long period of time. While the very long measurement window shows the advantages of the ULTRALOQ™ technology, the two zoom-ins clearly show the advantage of the VOA. Not only is the power itself reduced by a factor of 5/10 but also the noise on the laser output itself is reduced by the same factor.

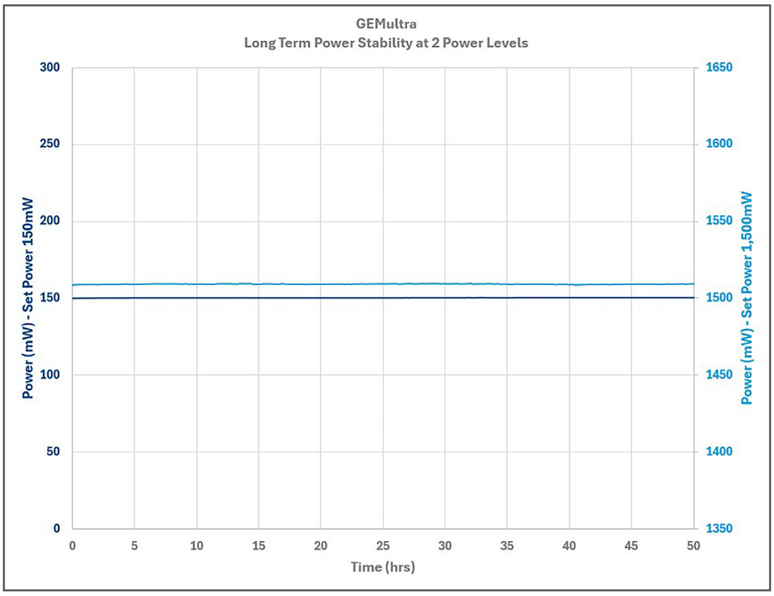

Fig. 5: Power at 150mW (dark-blue, left axis) and at 1500mW (blue, right axis) over a 50-hour window at constant temperature.

Spectral Performance

FFig.6 a) and b) show two typical spectra of two different lasers. From laser to laser the structure of the spectrum does change, also over time the spectra do slightly change but with almost no effect on the wavelength centroid. This is due to the multimode nature of the GEMultra.

Beside the bandwidth of the spectrum itself the stability of the spectrum over time is the other crucial parameter for Raman applications. Any jump or movement of the spectrum would be mis-interpretated and attributed to the sample leading to wrong or inconsistent results. The wavelength centroid is used as metric for the evaluation of stability of the spectrum. This is done in an analog way as it is done in Fig. 1 and 2 (power/noise over temperature) and Fig. 3 (noise over power).

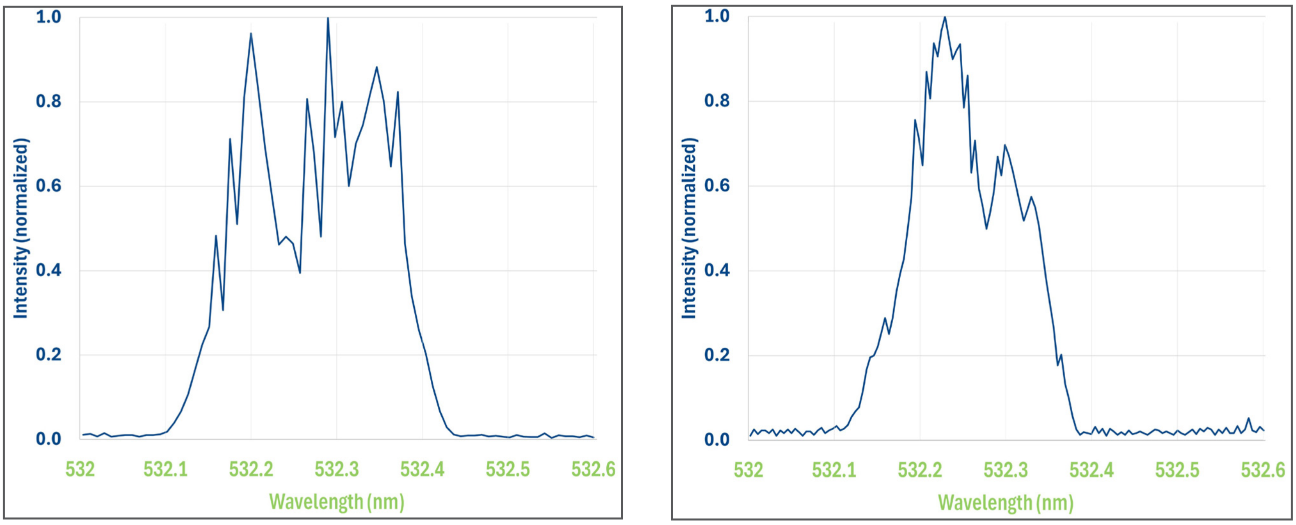

Fig. 6: Typical (normalized) spectra of two GEMultra.

Fig. 7 shows the spectral performance over an 8-hour window when the temperature is cycled between 31 and 35°C. In contrast to Fig. 1 (power over temperature) it is obvious that the temperature changes do influence the spectrum, the wavelength centroid varies at the frequency of the temperature change by +/-3.5 pm corresponding to +/-3.7 GHz.

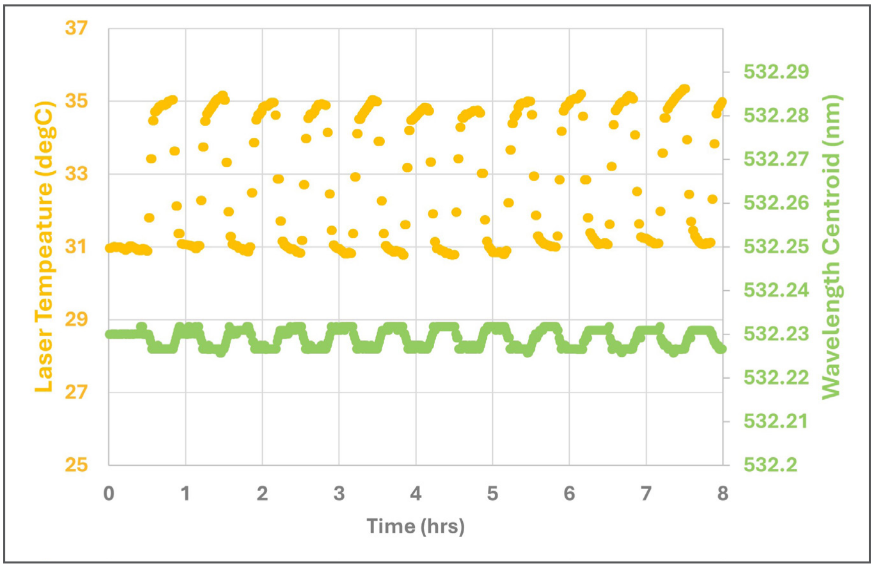

Fig. 7: Stability of the wavelength centroid (green) over an 8-hour window while changing the laser temperature (yellow).

Analog to Fig. 3 (noise over power) Fig. 8 shows the spectral stability over power, more precise the wavelength centroid over an 18-minute time window while the power is ramped up from 10mW to 50mW and then in 50mW steps up to 1500mW. The impact of the power ramp-up on the wavelength centroid is only +/-2.2 pm corresponding to +/-2.3 GHz. This feature is unique in the market and enables the laser to be used in ways that were previously not possible.

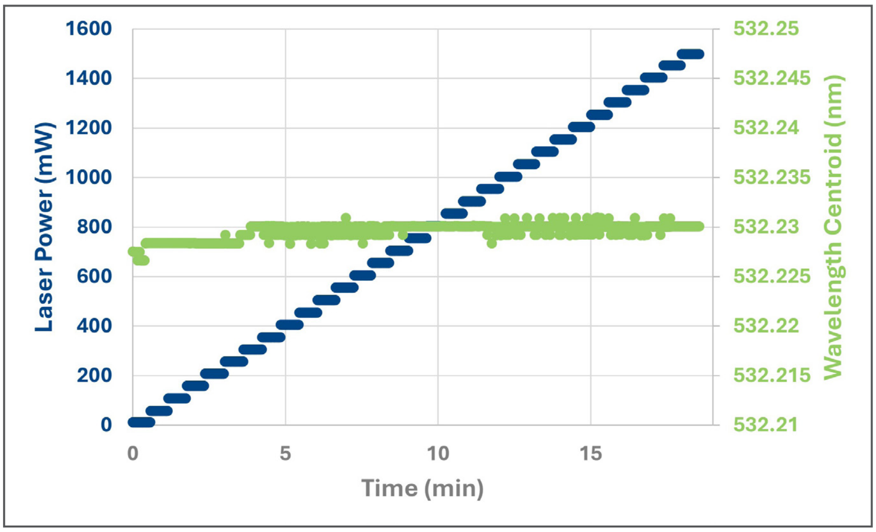

Fig. 8: Stability of the wavelength centroid (green) over an 18-minute window while ramping-up the laser power (blue).

Beam Properties

Finally, the focus is on the beam profile of the GEMultra. Fig. 9 shows the stability of the beam profile at different power levels starting at 100mW up to 1500mW. Indicators are the major and minor axis of the beam (1/e^2) together with the ratio of both values, hence the ellipticity. The ellipticity is well within the specified value of <1:1.2. Also the beam profiles itself confirm these observations for all 4 measured power levels.

Again, this proves that the VOA ensures a stable beam profile over the complete power range of the GEMultra.

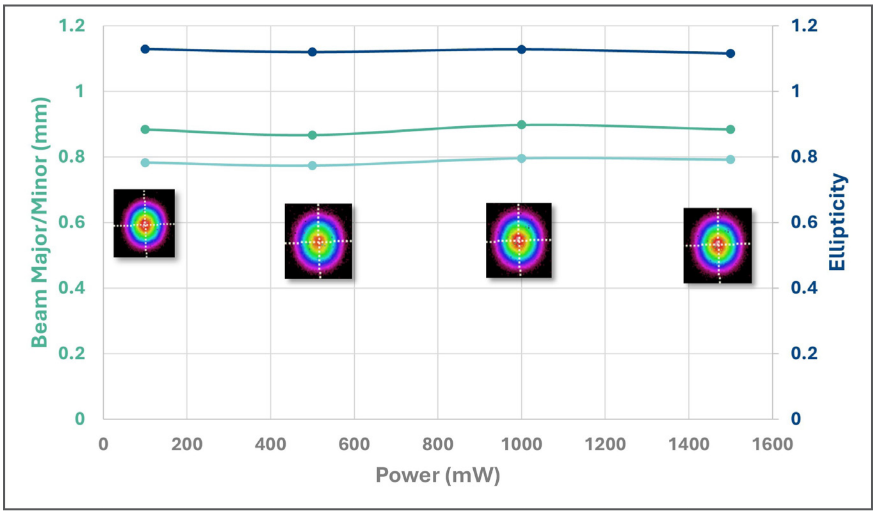

Fig. 9: Beam major (blue-green) and minor (light blue) axis together with ellipticity (blue) over various power levels. The four insets show the corresponding 2D intensity plots at 100mW, 500mW, 1000mW and 1500mW

Summary

This paper summarizes the values Novanta's proprietary VOA and ULTRALOQ™ technology brings to customers. While the ULTRALOQ™ technology ensures the specifications of the GEMultra do not change even under aggressive temperature changes, the VOA ensures that the specifications do not change when the output power is changed. This is not only proven on rather trivial specifications like power levels and noise but also on more sophisticated specifications like spectral behavior and beam profile. The VOA brings a unique feature to the market enabling customers to operate the laser at different power (OD2, so from 20mW to 2000mW) levels while having the guarantee the laser is always within its specifications.

Novanta Benefits

Novanta is uniquely positioned to solve even the most complex challenges for OEMs, system integrators, and end-use customers seeking to advance their manufacturing processes with high precision laser systems. With some of the most well-known brands in the industry and in-country application and service support, Novanta delivers reliable, precise, and durable components and sub-systems.

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