Novanta

WHITEPAPER

LEVERAGING A NOVEL OPTOMECHANICAL SYSTEM AND EXTRA-CAVITY POWER TUNING TO UPHOLD CRITICAL SPECIFICATIONS

LEVERAGING A NOVEL OPTOMECHANICAL SYSTEM AND EXTRA-CAVITY POWER TUNING TO UPHOLD CRITICAL SPECIFICATIONS

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Abstract

This paper describes different methods to control the output power of a DPSS laser, 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. This work focuses on the characterization of the noise profile, power stability, spectral behavior and beam profile under varying temperatures and output power levels. It is shown that the performance of the GEMultra is stable over the complete power range ranging from 100mW up to 2W.

Introduction

A basic method to control the output power of a DPSS laser is to control the pump power by adjusting the current feed to the pump diode(s). Such a scheme is referred to as current control; however, it would only result in a stable output in case all environmental conditions are stable. Already minor temperature changes to the laser crystal, pump diodes, or any other component of the laser leads to varying output powers. However, it is not only the output power 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, 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 feasible to realize DPSS lasers with power stability better than 0.2% rms through current control alone.

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 20Hz.

Power control ensures that at nominal output power, the critical laser parameters such as power stability, noise, beam diameter and spectral behavior are within specification even at changing environmental conditions. However, laser specifications are not guaranteed at output powers other than the nominal value, as performance typically degrades—especially at lower operating power levels.

Ref1: https://pubs.aip.org/aip/apl/article-abstract/4/3/50/46709/INJECTION-LUMINESCENT-PUMPING-OF-CaF2-U3-WITH-GaAs?redirectedFrom=fulltext

ULTRALOQ™ and Variable Optical Attenuator

This is where Novanta's GEMultra platform comes into play. It integrates ULTRALOQ™ technology—an advanced material system engineered to enhance the stability and durability of laser systems—with an onboard variable optical attenuator (VOA), which provides up to OD2 attenuation as a standard (higher attenuations are possible). The VOA is an integrated, extra-cavity optical element not replacing standard power control but extending it. In this configuration, the DPSS laser maintains a fixed pump diode current, and the VOA dynamically attenuates the output to match the power setpoint defined by the control loop. This approach has plenty of advantages such as exceptional noise and power stability at all power levels while the inherent characteristics of all Novanta lasers, including exceptional wall plug efficiency and derated pump diodes, guarantee no adverse effects on thermal management or operational lifetime.

The implementation of ULTRALOQ™ and VOA technologies results 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 set at 1,750mW over 50 hours while the laser temperature varies from 18degC to 38degC. 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.

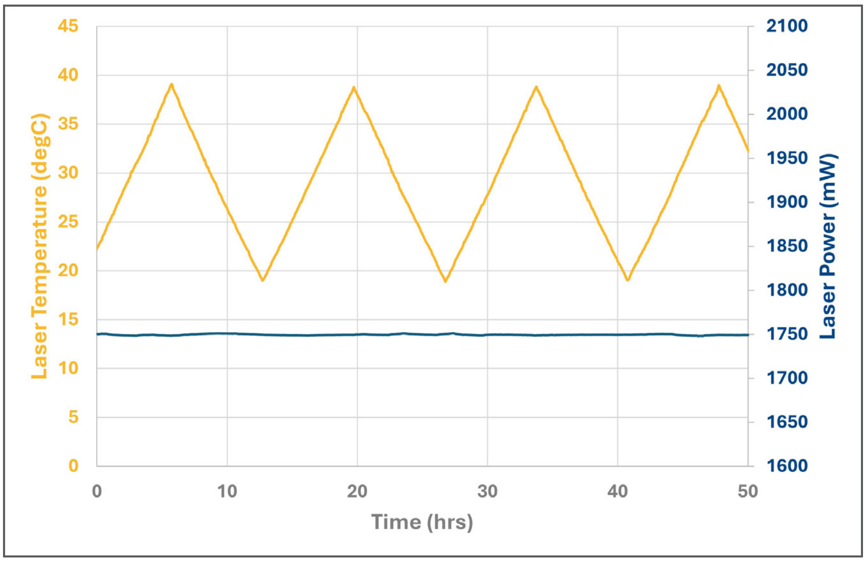


Fig. 1: Power (blue) over a 50-hour window while changing the laser temperature (yellow).

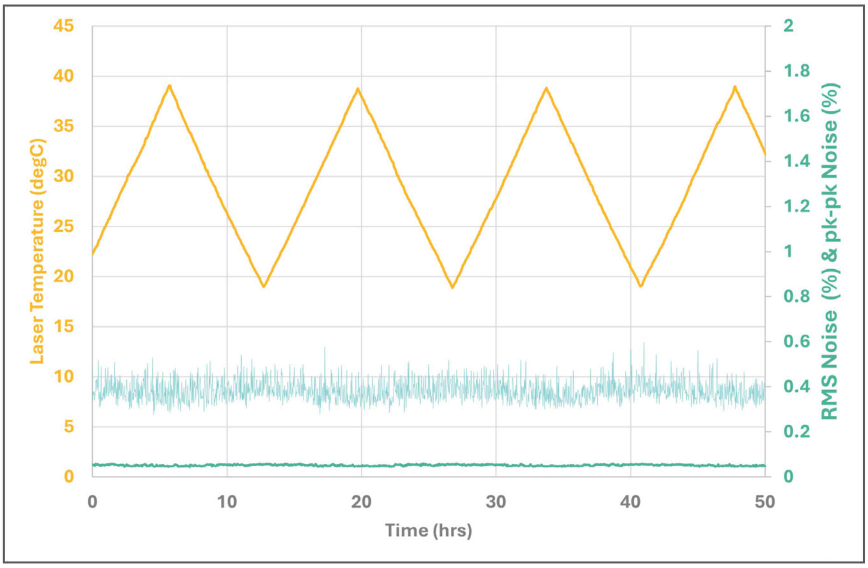


Fig. 2: RMS (blue-green) and peak-to-peak (light blue) noise over a 50 hour window while changing the laser head temperature (yellow).

Fig. 2 shows the same data focusing on RMS and peak-to-peak noise. While the temperature varies linearly back and forth from 18degC to 38°degC within a period of 14 hours, the laser output only changes by less than +/-2mW over the 20degC 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 aggressive temperature profile. While this performance can largely be attributed to ULTRALOQ™ technology, the fact that noise remains within specifications even at lower power levels is a direct result of implementing the VOA for power adjustment, rather than varying the pump power.

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 smd16 power supply.

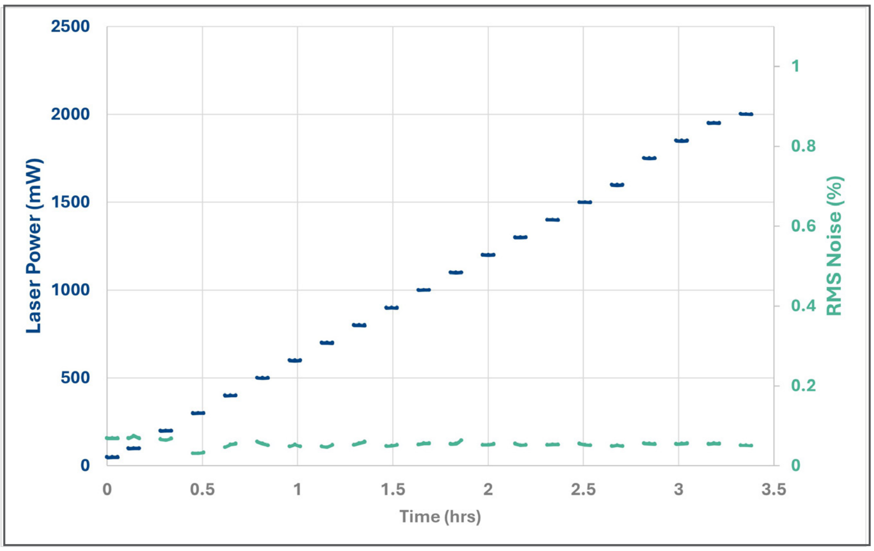


Fig. 3: RMS noise (blue-green) while output power (blue) is ramped up to full power.

Beside the noise over time also the Relative Intensity Noise (RIN) profile is important for some applications, since it provides information about the frequency distribution of the intensity fluctuations. This is shown in Fig. 4, for power levels of 150mW and 1500mW. The direct overlay (within test equipment limitations) of the RIN features clearly demonstrates the effect of the VOA: at both power levels, the intra-cavity performance of the laser remains unchanged. The output power is attenuated only post laser cavity output —still within the laser housing—ensuring consistent noise characteristics across different power settings.

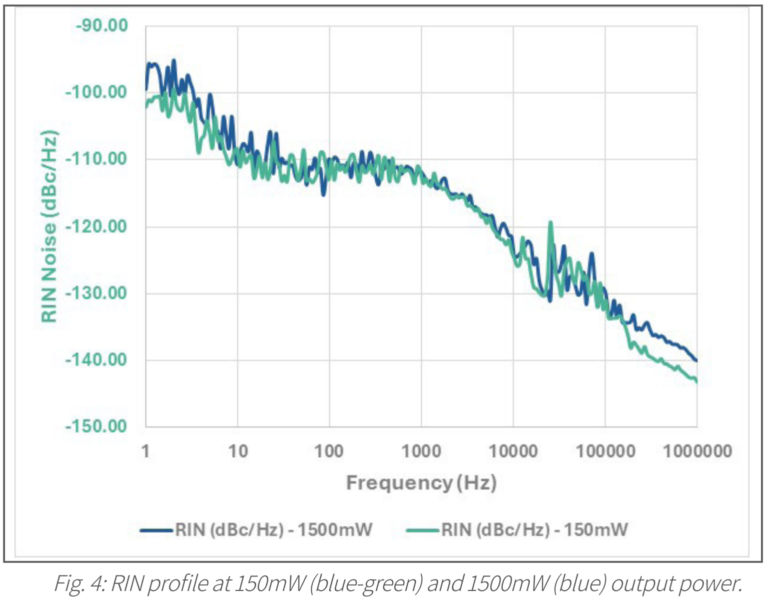


Fig. 4: RIN profile at 150mW (blue-green) and 1500mW (blue) output power.

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 with the power set to 150mW and 1500mW over 50 hours. The graph is on the first look somehow counter intuitive, since the lower power data is a perfect straight line at that scale while the higher power line shows some tiny variations. For a laser with a normal power control loop this is unexpected, since noise and power stability are always worse at lower power levels. For a laser with extra-cavity power tuning this is the expected behavior since the residual instabilities at full power get dimmed by the same factor as the total power is reduced.

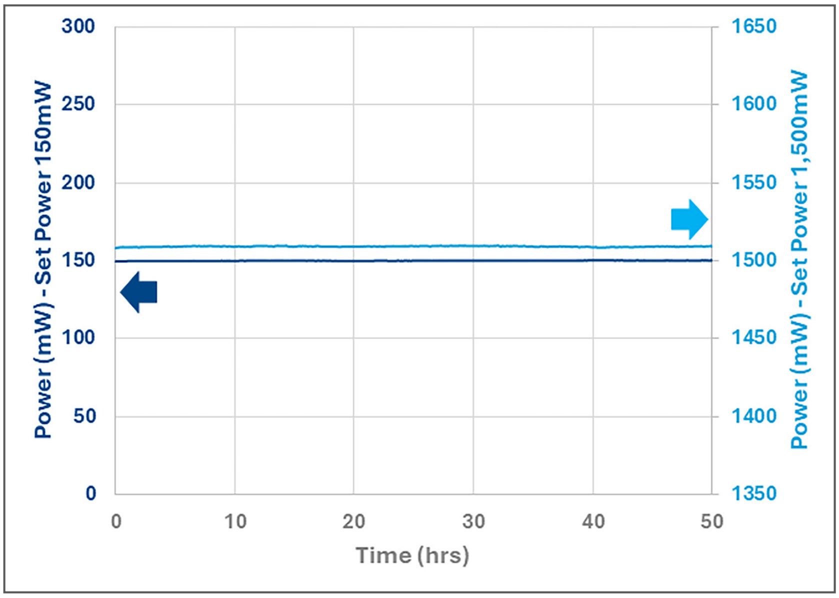
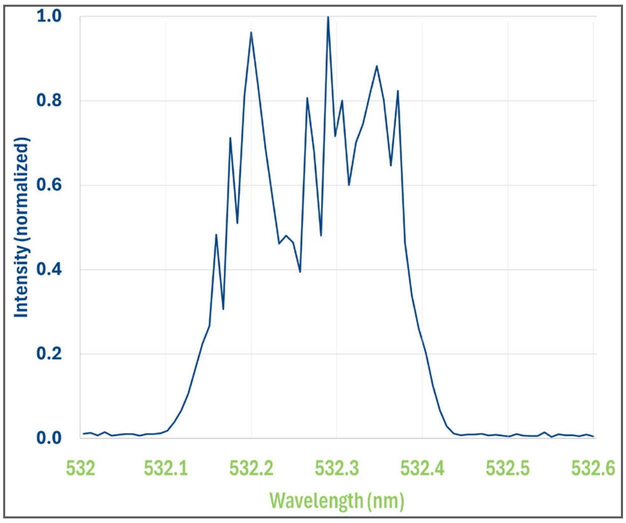


Fig. 5: Power at 150mW (dark blue, left axis) and at 1500mW (blue, right axis) over a 50-hour window at constant temperature.

Spectral Performance

The spectral performance of a laser is key for many applications, especially Raman spectroscopy. Since the GEMultra is a multimode laser, the spectrum is not in the MHz range but in the GHz range. This is still sufficient for almost all Raman applications, the 30 GHz bandwidth (see Fig. 6) of the GEMultra corresponds to only 1 wavenumber (or 0,028nm). This is much smaller than typical Raman shifts, the lower limit for lattice modes in solids is in the region of 10 wavenumbers.



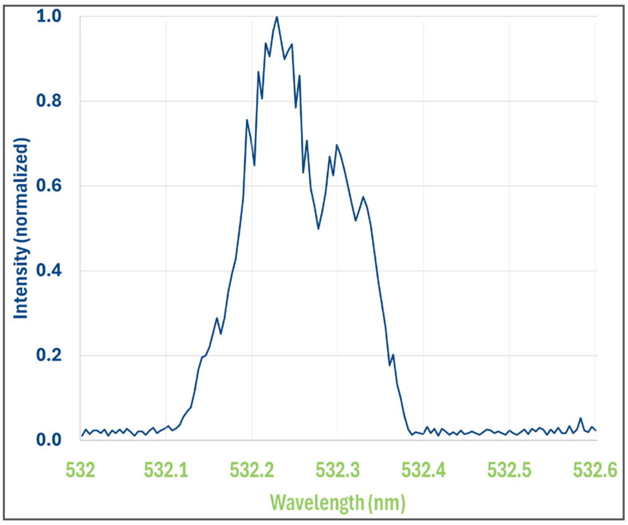


Fig. 6: Typical (normalized) spectra of two GEMultra.

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

Beside the bandwidth of the spectrum itself, the stability of the spectrum over time is the other crucial parameter for Raman applications. A significant jump or movement of the spectrum would be misinterpreted 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. 7 shows the spectral performance over an 8-hour window when the temperature is cycled between 31degC and 35degC. The spectrum dynamically responds to temperature variations, with the wavelength centroid shifting in sync with the temperature modulation by +/-3.5 pm (+/-3.7 GHz). This predictable and narrow spectral shift highlights the system's stability under thermal cycling.

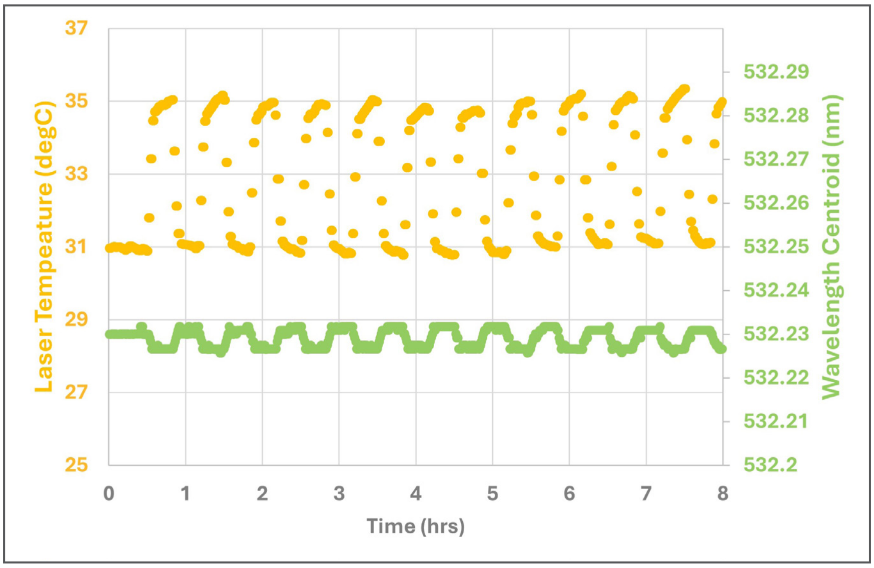


Fig. 7: Stability of the wavelength centroid (green) over an 8-hour window while changing the laser temperature (yellow).

Analog to Fig. 3 (noise over power) Fig. 8 shows spectral stability over power, more precisely 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.

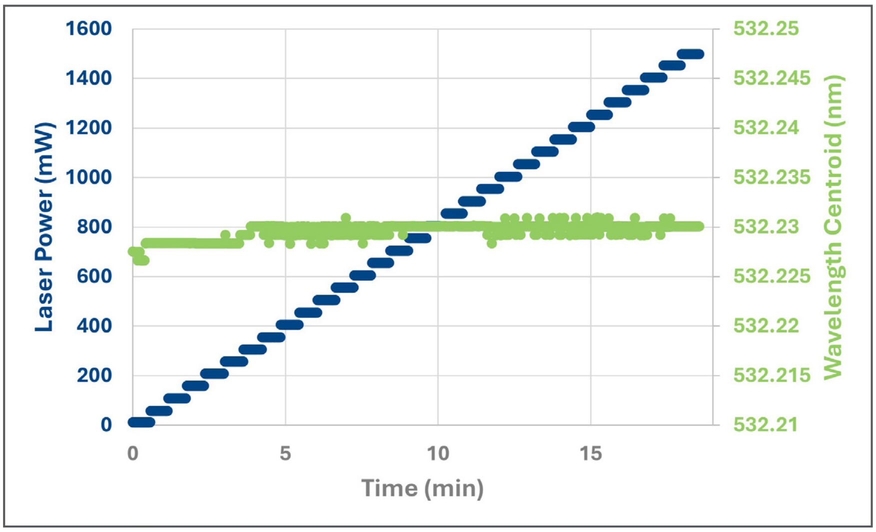


Fig. 8: Stability of the wavelength centroid (green) over an 18-minute window while ramping-up the laser power (blue).

Beam Properties

Finally, the focus is on the beam profile of 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 themselves confirm these observations for all 4 measured power levels.

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

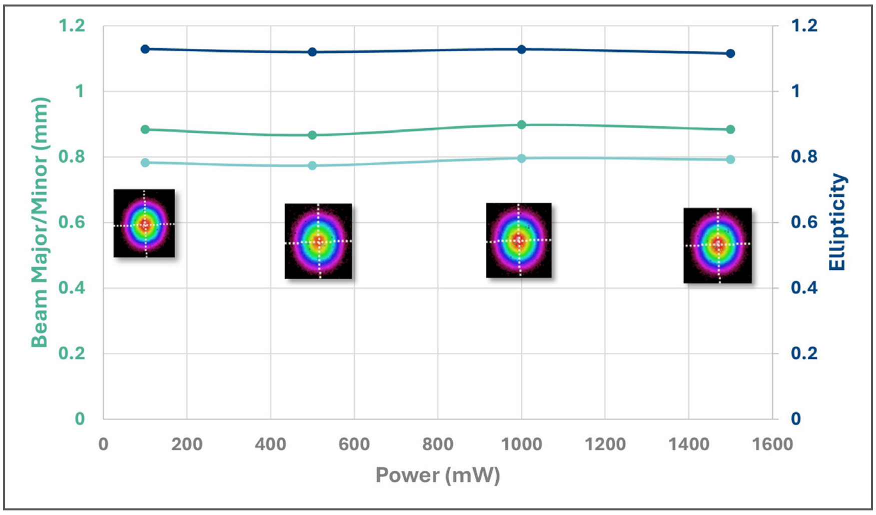


Fig. 9: Beam major (blue-green) and minor (light blue) axis together with ellipticity (blue) over various power levels. The four insets show the corresponding 2D intensity plots at 100mW, 500mW, 1000mW and 1500mW

Summary

This paper summarizes the values Novanta's proprietary VOA and ULTRALOQ™ technology brings to customers. While ULTRALOQ™ technology ensures that GEMultra's specifications remain stable even under aggressive temperature fluctuations, the VOA maintains those specifications when output power levels are adjusted. This has been validated not only for fundamental specifications such as power stability, but also for more advanced parameters including spectral behavior, noise profile and beam properties. The integrated VOA introduces a unique capability to the market, allowing customers to operate the laser across a wide power range with the assurance that the laser consistently remains within its specified performance parameters. This unique feature eliminates conventional design limitations in optical systems, introducing a new level of flexibility that supports a wide range of applications. The exceptional stability of the GEMultra across both power and temperature variations empowers photonics engineers to explore novel system architectures and performance enhancements.

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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