Novanta

WHITEPAPER

INTELLIGENT LIGHT ENGINE PLATFORMS

The Role in Next-Gen Life Sciences Applications

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Abstract

Fluorescence based techniques are widely used throughout life science devices, in applications such as DNA Sequencing, Super Resolution Microscopy and Flow Cytometry. As the applications that make use of these tools rapidly evolve, the need for higher throughput, better data quality, and greater versatility, these tools and the components within must also evolve.

At the heart of any fluorescence system lies the excitation module—responsible for delivering precisely controlled excitation radiation to the sample and driving the fluorescence process.

This white paper introduces Novanta's FUSIONultra Configurable Light Engine Platform and highlights its benefits within these domains. The FUSIONultra platform is based on Novanta's ULTRALOQTM optomechanical technology enabling high power multi-line light engines that focus on stability, versatility and data quality.

Together, these innovations empower researchers and instrument developers with unprecedented control, performance, and flexibility in fluorescence imaging workflows.

Introduction

Modern life sciences applications employ a diverse array of imaging and detection techniques, each with distinct yet frequently overlapping illumination requirements. High-throughput workflows in proteomics, multi-omics, and DNA sequencing demand multi-wavelength illumination sources capable of delivering high peak optical power while maintaining precise control at low power levels. Data quality in these devices is also driven by the illumination radiation beam quality within the sample, requiring uniform illumination over the largest possible sample area. Furthermore, these performance attributes must remain consistent and stable over extended operational periods and under varying environmental conditions to ensure reproducibility and reliability in demanding research and diagnostic settings.

Advanced imaging techniques, including super-resolution microscopy (STED, PALM, STORM), require multi-line, ultra-stable excitation sources capable of operating across a dynamic power range spanning up to three orders of magnitude. These applications also demand precise modulation with fast, controlled rise times to ensure accurate temporal resolution. Similarly, flow cytometry—while typically operating at lower power levels—requires multi-wavelength, high-quality beams combined with ultra-fast modulation and rapid rise times to support high-throughput analysis.

Despite the diversity of these applications, several common requirements emerge configurability, flexibility, and stability. FUSIONultra has been designed to address these challenges by providing a highly adaptable platform that can be optimized and tuned to meet specific application and research needs. The platform integrates a broad range of technologies and capabilities, enabling the creation of custom light engine configurations tailored to exact performance specifications.

Within this white paper we will explore how this configurable light engine platform can add value to a variety of fluorescence-based imaging applications by providing example data sets and demonstrating how they are applicable to these applications.

High Optical Power: Driving Faster Acquisition

Improving data throughput in advanced imaging systems requires increasing data capture density, which can be achieved either by raising the sampling rate or by increasing the amount of data per sample. In High Throughput DNA sequencing for example - which typically uses Time Delay Integration (TDI) microscopy techniques - this translates into strategies of increasing the scan speed and acquisition rate, packing more data into a single camera frame or by expanding the field of view.

To ensure the data quality remains constant when applying these throughput scaling techniques the excitation laser power must scale in such a way that, for shorter camera exposures the signal level is still sufficient and for wider field of views the intensity per area in the sample is maintained.

To support these requirements, Novanta offers an extensive portfolio of laser technologies, including DPSS and direct diode solutions, all of which can be seamlessly integrated into the FUSIONultra Configurable Light Engine platform. Figures 1 and 2 illustrate the available wavelength coverage and corresponding power ranges for both technologies, enabling system designers to select configurations optimized for their specific application needs.

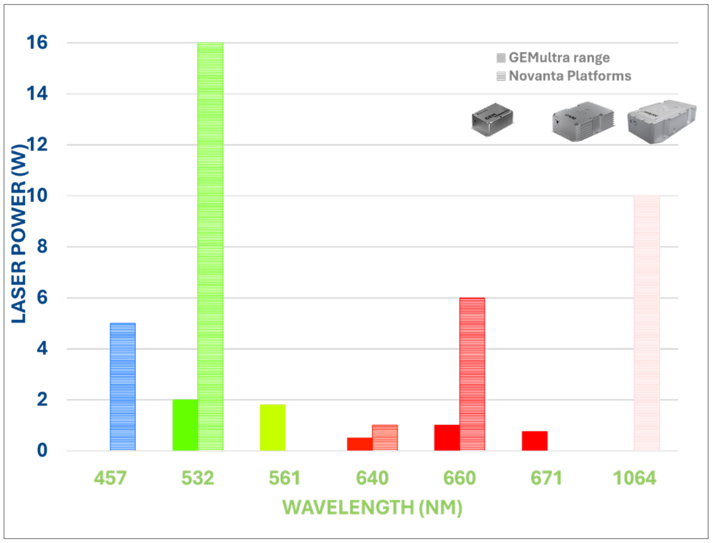


Figure 1: Demonstrating DPSS lasers, wavelength and power selection capabilities from Novanta Platforms

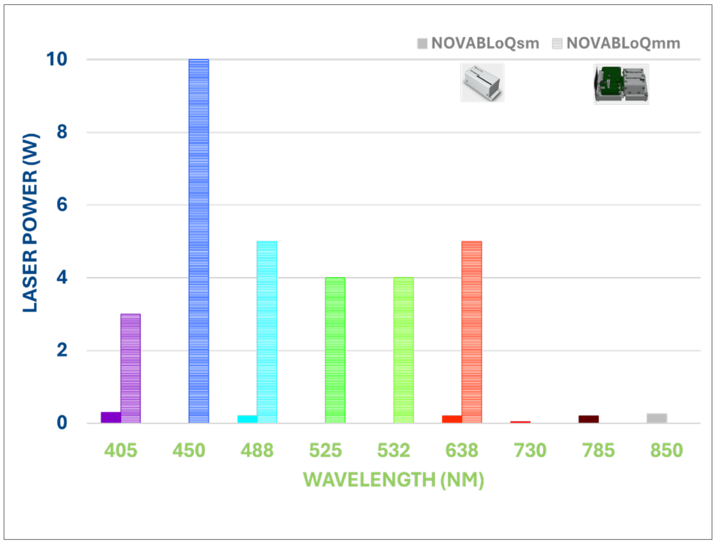


Figure 2: Demonstrating Single Mode and Multimode Novanta diode laser modules, wavelength and power selection capabilities

From this selection multiple variations can be obtained, for example a compact fiber-coupled 4-color light engine focused on super resolution microscopy can be quickly generated. This variant has a mixture of single mode laser diodes, multimode laser diodes and DPSS light sources with wavelengths of 405 nm, 488 nm, 561 nm and 638 nm and powers of 250 mW, 1000 mW, 1000 mW and 1000 mW all coupled into a single 50 μm core fiber, all individually addressable with modulation and power control.

Figure 3: FUSIONultra 4 Color variant

Fast rise and fall time: Unlocking speed for high performance imaging

Fast laser modulation with short rise and fall times is critical for minimizing cycle times and increasing overall system throughput. Any delay while lasers reach target power and stabilize represents dead time that reduces operational efficiency. Rapid switching between wavelengths and intensity levels enables high-speed acquisition for techniques such as flow cytometry, DNA sequencing, and super-resolution microscopy, all of which depend on precise triggering and synchronization between multiple components, including motion control systems, lasers, and cameras. By accelerating these transitions and minimizing dead time, systems can maximize the proportion of time spent acquiring data, thereby improving both data quality and throughput.

The platform approach taken by FUSIONultra enables ultrafast rise times regardless off the laser source type. The four-colour variant is able to achieve sub-microsecond rise and fall times for all laser wavelengths. Figures 4 and 5 illustrate this capability for the different technologies integrated within the four-colour variant, Figure 4 demonstrates the fast modulation performance of diode-based sources, while Figure 5 highlights the same capability in high-power DPSS lasers.

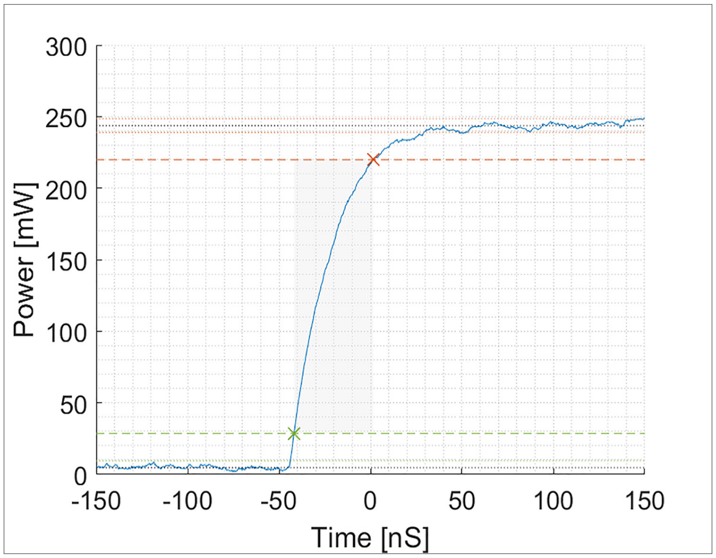


Figure 4a: Rise time demonstration measuring <50ns rise time for the 250mW 405 nm direct diode line within the 4-color light engine.

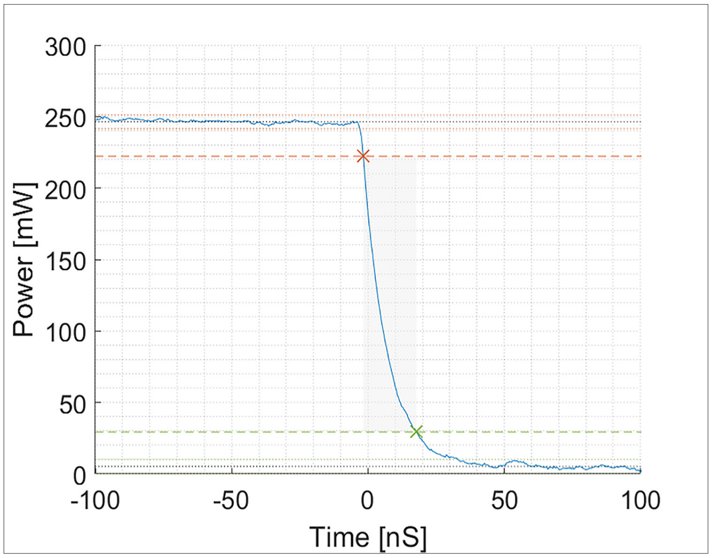


Figure 4b: Fall time demonstration measuring <20ns for the 250mW 405nm direct diode line within the 4-color light engine

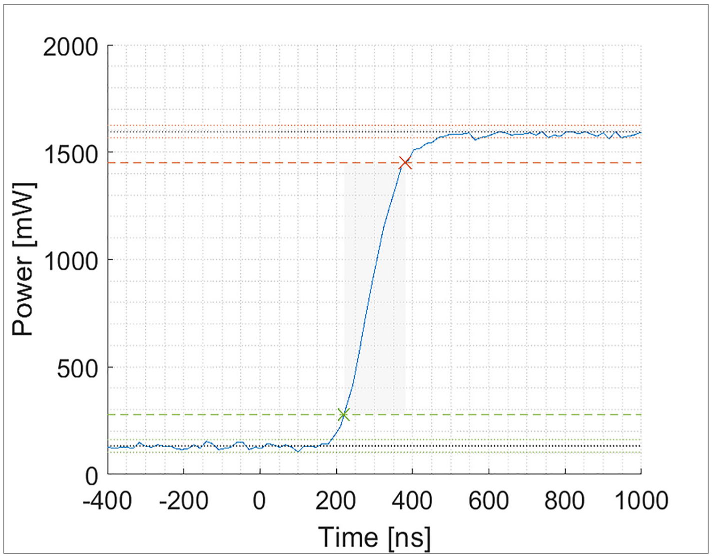


Figure 5a: Rise time demonstration measuring <200ns rise time for the 1W 561nm DPSS laser line within the 4-color light engine

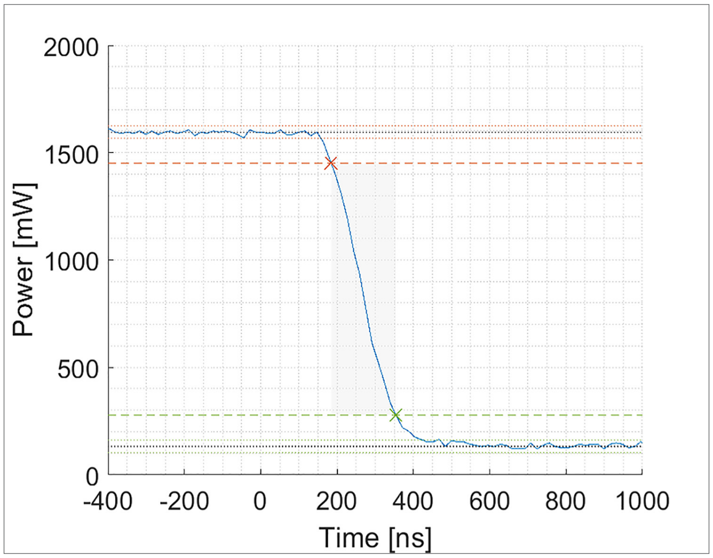


Figure5b: Fall time demonstration measuring <200ns for the 1W 561nm DPSS laser line within the 4-color light engine

High Dynamic Range and Rapid Power Transitions: Enabling Speed and Flexibility

A wide dynamic range combined with rapid transitions between power levels is essential for instruments that handle diverse sample types and complex imaging protocols. Dynamic range ensures precise control over excitation intensity for varying fluorophore brightness, while fast switching minimizes delays during multi-step processes. Together, these capabilities enable instruments to adapt quickly and maintain efficiency across demanding applications such as flow cytometry, sequencing, and advanced microscopy.

The **FUSION**ultra platform integrates Novanta technologies that enable fast transitions between powers and high dynamic range on diode modules and DPSS lasers alike. The latter include the GEMultra and GEMultra+ laser range, featuring an integrated Variable Optical Attenuator for consistent performance across the entire dynamic range. Here we present how the **FUSION**ultra can precisely control power levels from 2mW to 1000mW of output per laser line, with fast transition time while maintaining performance characteristics over a broad range of power levels. Figure 6 demonstrates typical performance characteristics of the **GEMultra+**, a 1W 561 nm line within the **FUSION**ultra light engine being tuned over a wide range of powers - in this case from 1000 mW to 150 mW. The noise characteristics over this range remain low, stable and independent of the laser set power.

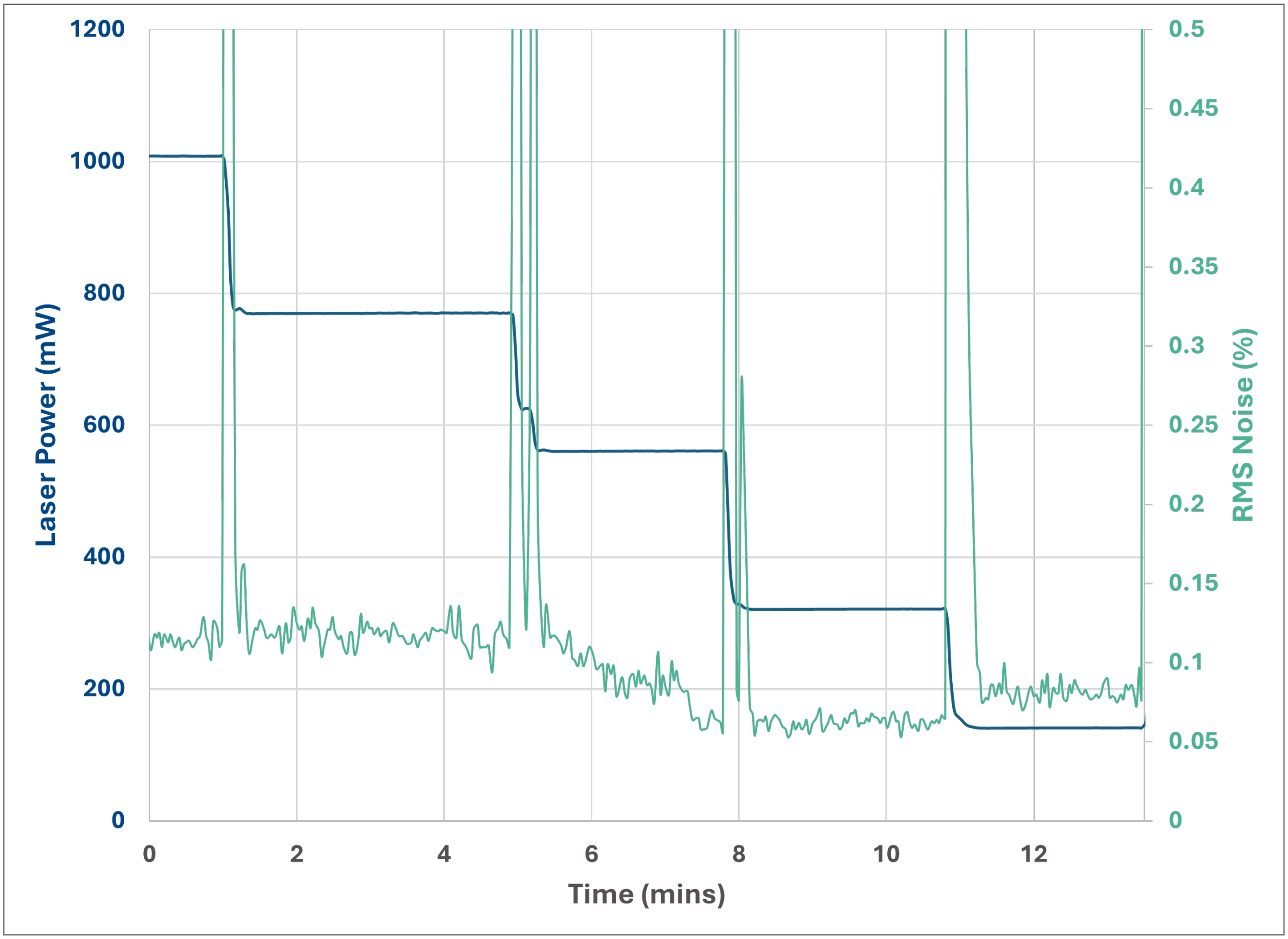


Figure 6: RMS noise and Laser Power plotted as a function of time for the GEMultra+ 561 nm DPSS laser.

While this level of performance is exceptional for a DPSS laser and highly valuable across a broad range of applications, it can also be extended to very low power levels. Figure 7 illustrates the behavior of the same laser when commanded to very low power levels. Figure 7 illustrates the behavior of the same laser when commanded to transition from 100 mW to 120 mW and then down to 2 mW. The results demonstrate that the laser remains ultra-stable across all power settings. For clarity, Figure 8 provides a zoomed view of the 2 mW region. Although detector noise becomes more pronounced at this scale, it is evident that laser noise remains minimal and independent of the set power level.

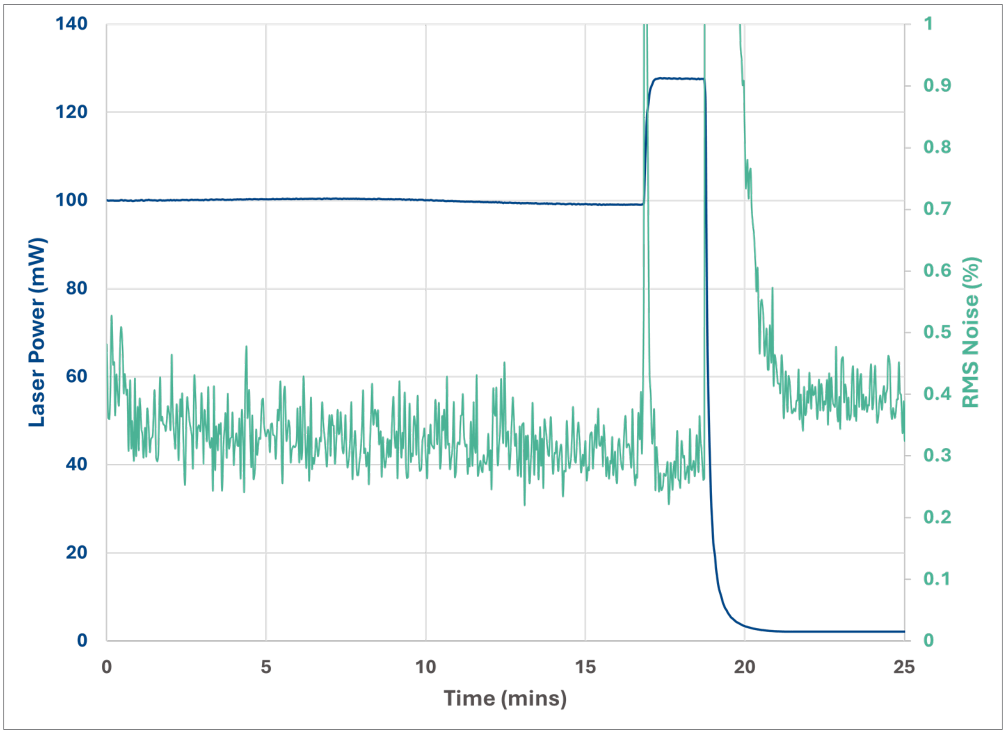


Figure 7 RMS noise and Laser Power plotted as a function of time for the GEMultra+ 561 nm DPSS laser, focusing on the lower power region.

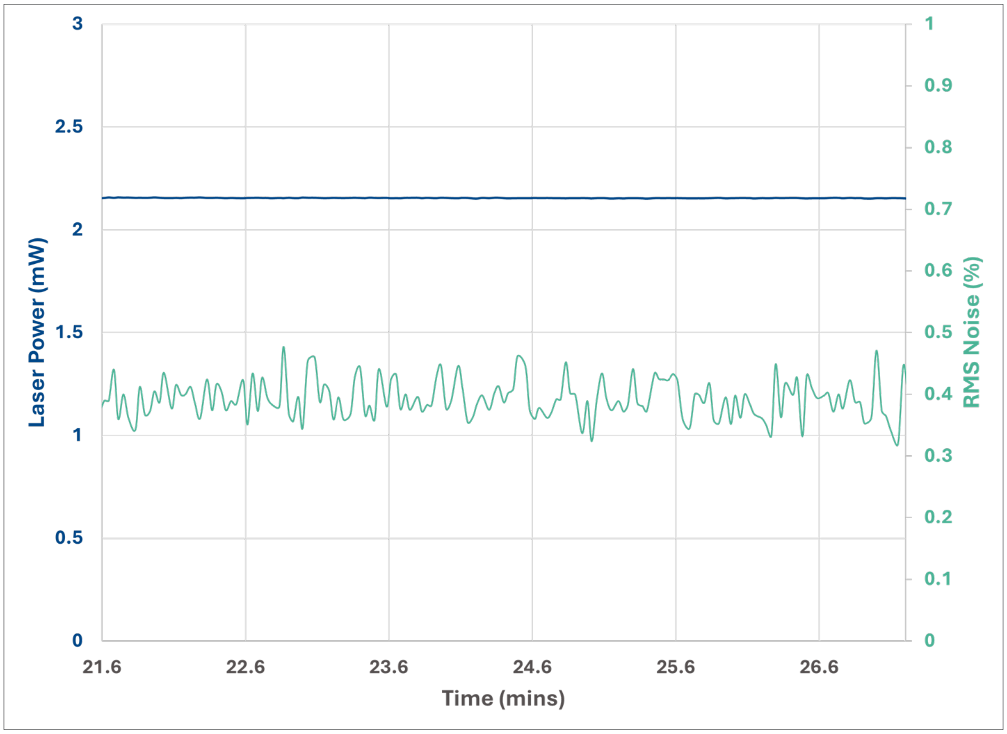


Figure 8: RMS noise and power plotted as a function of time for the GEMultra+ 561 nm DPSS laser. Focusing on the 2 mW power region.

The superior performance of the GEMultra+ platform, enabled by the integrated Variable Optical Attenuator becomes evident when compared to typical DPSS laser behavior. Figure 9 illustrates how noise typically varies across a range of power levels, while Figure 10 provides a direct view of the relationship between RMS noise and laser output power. As shown in both figures, laser noise is strongly dependent on power, with optimal noise performance confined to a narrow operating window. Outside this range, noise typically increases by more than an order of magnitude, significantly impacting system stability and data quality.

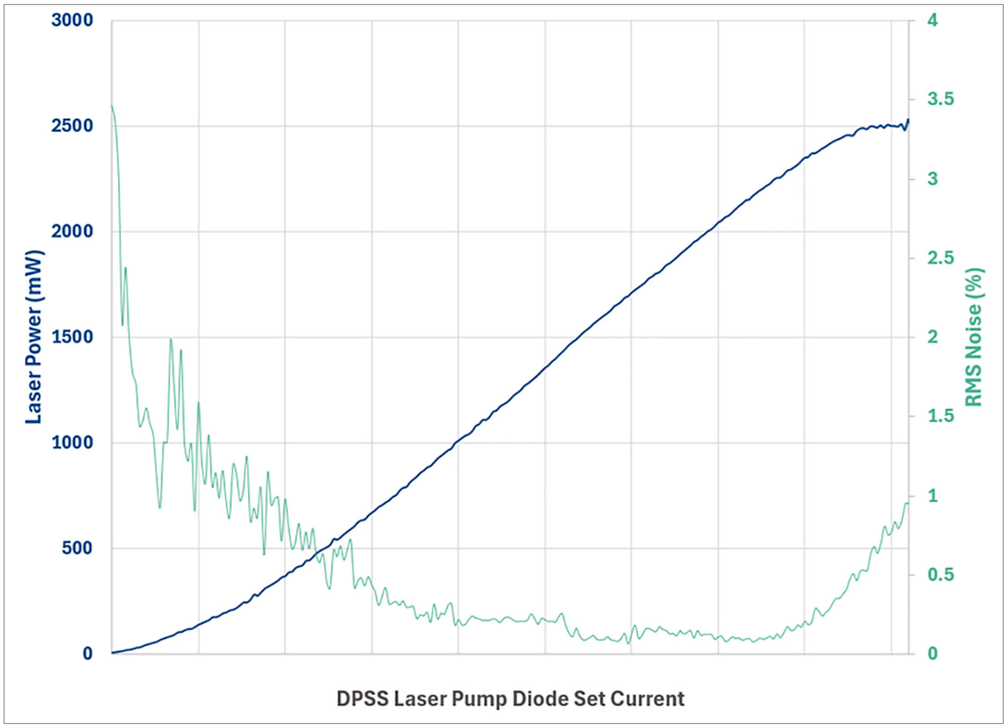


Figure 9 Laser Power and RMS Noise evolution with changing Pump Diode Current settings for a typical DPSS laser

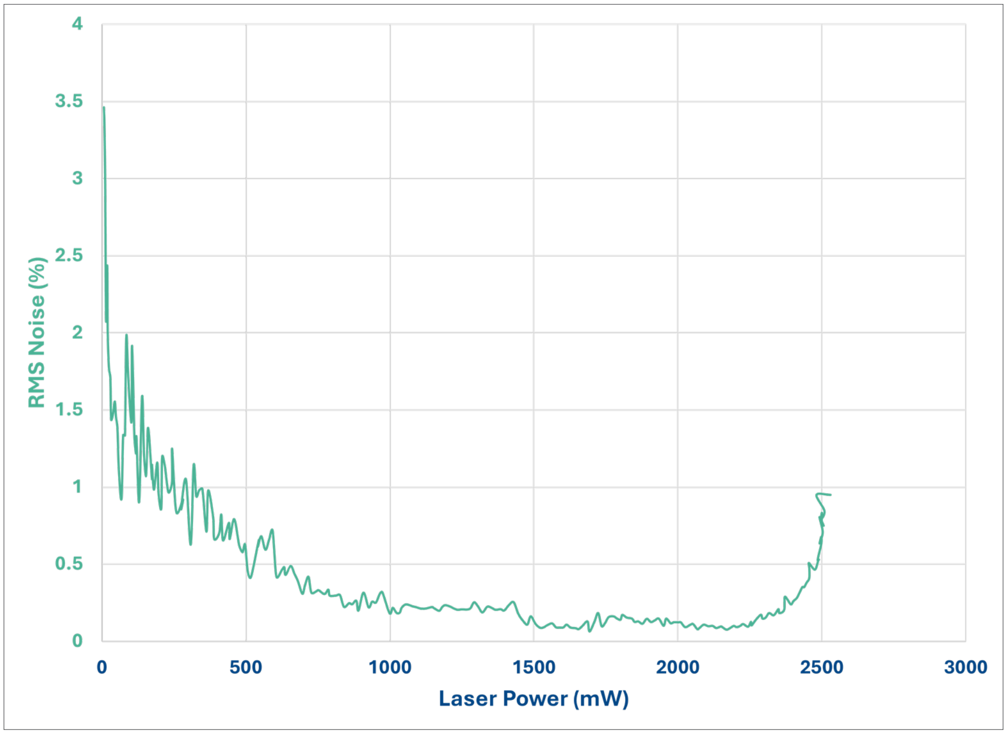


Figure 10: RMS Noise plotted as a function of Laser Power for a typical DPSS laser.

Reducing Variability and Improving Data Integrity with Advanced Beam Conditioning

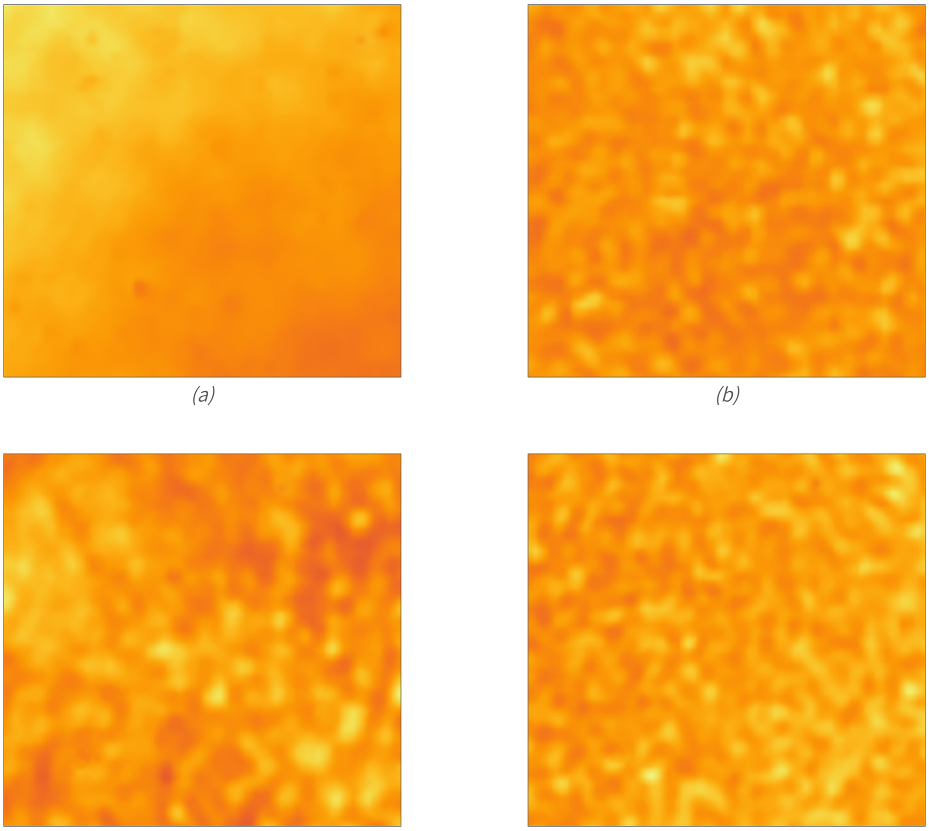
In high-precision life science applications, optical beam quality directly impacts data quality and workflow efficiency. Techniques such as despeckling and beam shaping play a pivotal role in minimizing variability, enhancing measurement accuracy, and supporting throughput optimization. Speckle artifacts and non-uniform beam profiles can introduce noise, degrade signal-to-noise ratios, and reduce the usable imaging area—leading to operational inefficiencies.

By implementing advanced beam conditioning strategies, OEMs and researchers can achieve consistent and environmentally insensitive illumination, safeguard data quality, and reduce the cost of poor quality. These improvements not only drive confidence in experimental results but also accelerate innovation across life science applications.

As innovation in life sciences aims to drive higher throughput and improved data quality, there is increasing demand to boost optical power while reducing fibre core size without compromising beam quality. However, as core diameter decreases, the number of supported transverse modes also drops, making effective despeckling significantly more challenging. In fact, finding a commercially available despeckling solution that performs reliably at core sizes below 100–150 µm is often difficult.

The **FUSION**ultra platform features a modular architecture that enables seamless integration of advanced beam conditioning technologies. In its four-color, 50 µm fibre-coupled configuration, the system incorporates an integrated despeckling solution that delivers exceptional uniformity, achieving a coefficient of variation (CV) of less than 10% across all wavelengths at an exposure time of 10 ms. Representative data is shown in Figure 11.

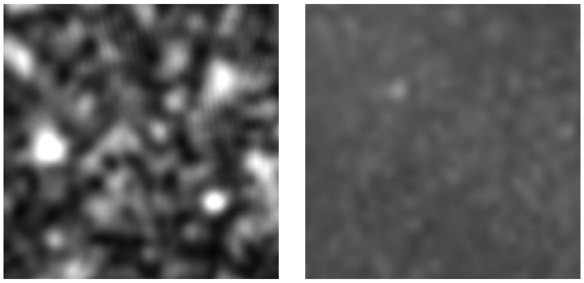
This capability ensures highly uniform illumination, eliminates random intensity fluctuations that degrade image clarity, and minimizes noise in fluorescence and scattering measurements. The result is improved quantitative accuracy, enhanced reproducibility, and greater confidence in experimental outcomes—critical factors for high-precision life science applications.



(a) *(b)* *(c)* *(d)*

Figure 11 Fiber tip reimaged to measure speckle patterns for (a) 405 nm diode (b) 488 nm diode (c) 561 nm DPSS and (d) 638 nm diode with the despeckle device enabled

Among the above wavelengths, the 561 nm laser typically exhibits the highest speckle contrast due to its superior coherence properties. As a result, the despeckling device has the most pronounced impact on this beam type. Figure 12 illustrates the effect of despeckling, comparing the beam with the despeckle function disabled (a) and enabled (b). Typical speckle contrast values without despeckling can exceed 90%, whereas with despeckling activated, values can be reduced to below 10%, delivering highly uniform illumination.



(a) (b)

Figure 12: Re-imaged 561nm illuminated 50 um fiber tip re-imaged with (a) despeckle turned off and (b) despeckle turned on

The implementation of ULTRALOQ™ technology ensures exceptionally stable and repeatable fibre coupling across a broad range of fibre types—including single-mode, polarization-maintaining, and multimode fibres—with support for various core geometries and diameters as small as 50 µm as illustrated in Figure 13. This flexibility is further demonstrated in the four-colour variant, which delivers optimized beam geometries tailored to the specific fibre configuration, enabling superior optical performance across diverse life science applications.

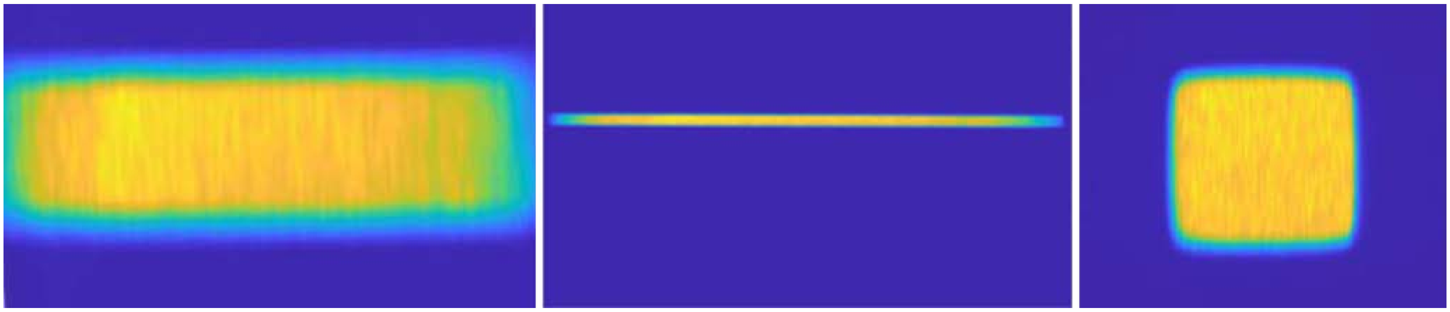


Figure 13: Examples of exotic fiber shapes (a) Octagonal (b) Rectangular

Summary

The **FUSION**ultra Configurable Light Engine platform redefines performance standards for life science applications by advancing key parameters across the board—optical power, stability, beam quality, and modularity. Increased available optical power enables higher throughput and reduces end-user operational cost. Enhanced stability improves instrument reliability and ensures consistent data quality, while superior beam quality drives accuracy in demanding imaging workflows.

Built on a modular architecture, **FUSION**ultra minimizes development costs and accelerates time-to-market for instrument manufacturers. This flexibility empowers OEMs and researchers to configure solutions tailored to their specific needs, enabling uncompromising precision and faster discovery in high-performance life science environments.

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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