White Paper

SureLock™ Single Frequency Stabilized Lasers: Taking Your Lab into the Field

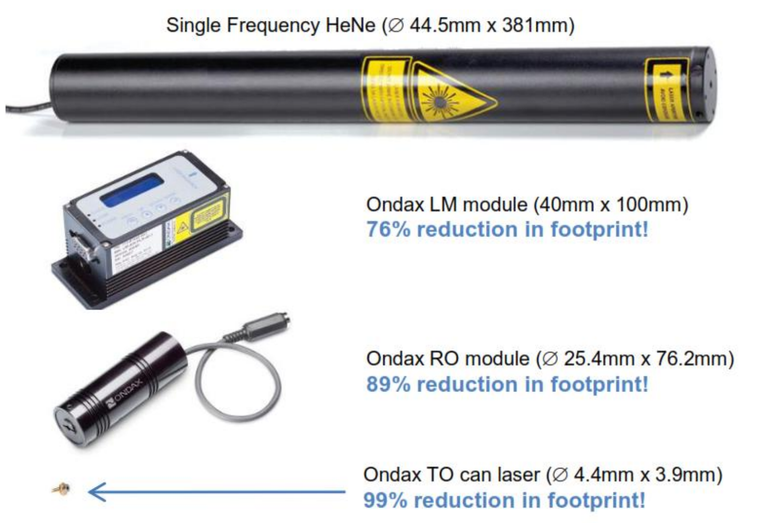
Precision optical instrumentation systems – from spectroscopy and holography to bio-instrumentation – depend on ultra-stable, high-quality laser sources for their performance. Unfortunately, they have historically been confined (anchored) to the research or clinical laboratory due to their bulk, power requirements and sensitivity to environmental conditions. The emergence of a new class of ultracompact, wavelength-stabilized single frequency lasers is now enabling the “untethering” of these systems from the lab, creating an explosion of new applications and configurations for field-deployed optical instrumentation solutions.

Based on commercially available visible and near-infrared semiconductor laser diodes, this new class of lasers incorporates **Volume Holographic Gratings** (VHGs) as a precise, wavelength-selective element that both narrows the spectrum and passively “locks” the wavelength over an extended temperature range. This simplified architecture greatly reduces the opto-mechanical complexity and thermal stabilization requirements for the laser source, enabling the transformation of these inherently inexpensive, low-power-consumption devices into ultra-high-quality single frequency laser sources.

Ondax **SureLock™** lasers are fueling a paradigm shift in both how and where optical metrology can be used in the most demanding applications. With VHG-stabilized single frequency lasers in packages as small as a TO can, they deliver exceptional performance over wide operating temperatures with minimal power consumption.

The SureLock™ System

SureLock™ lasers use PowerLocker® VHGs with a highly customized spectral profile to reflect a narrow portion of the laser emission spectrum back into the laser. Consequently, a single stable frequency is selected from a laser that might otherwise operate with multiple longitudinal modes. Since the grating can be designed around any portion of the laser gain curve and optimized for each diode, very precise wavelength control of the output to within 0.1nm of the desired wavelength can be achieved.



Comparison of three Ondax single frequency laser package options relative to an equivalent single frequency HeNe laser (images shown to scale).

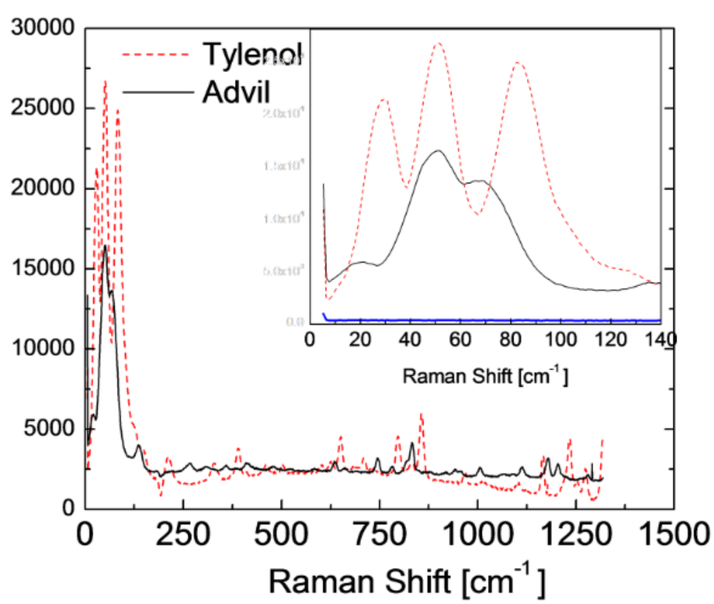
The profile of the VHG has a spectrum narrowing effect that reduces the natural laser linewidth to typically less than 50 MHz and increases the spectral brightness. In uncontrolled environments, VHG-stabilized lasers are able to provide passive wavelength stabilization over a wide operating temperature range of up to 60▪C, in many cases eliminating the need for active temperature control and significantly reducing the size, cost and power consumption of the system. All these benefits can be realized in a TO can or equivalent compact form factor, making the laser small, portable and lightweight to enable hand-held versions of larger complex systems.

Applications for Wavelength Stabilized Lasers

Historical applications of wavelength stabilized lasers have been in the areas of metrology, holographic or interferometric systems, spectroscopy, or bioinstrumentation. In these cases, a single frequency output is required to achieve high contrast interference fringes or strong signal-to-noise ratios.

Intevac Photonics' ReporteR™ hand-held Raman systems use wavelength stabilized lasers for rapid identification of unknown narcotics in the field.

Raman spectroscopy is a key application that is benefiting from the new-found portability of VHG-stabilized single frequency stabilized lasers. Applications for Raman systems range from explosives and drug detection by law enforcement, to chemical compound analysis and process control in the pharmaceutical industry, to characterization and classification of nanostructures. Since the detected Raman signal shifts with any change in wavelength of the excitation source, a very stable wavelength is required for calibration to known standards. Any multi-line behavior creates spurious peaks in the detected signal that make it more difficult to match with known library fingerprint signals. Narrowing the laser line spectrum improves resolution in the signal as spectral signature components can often be close enough to overlap when convolved with a broader band source.



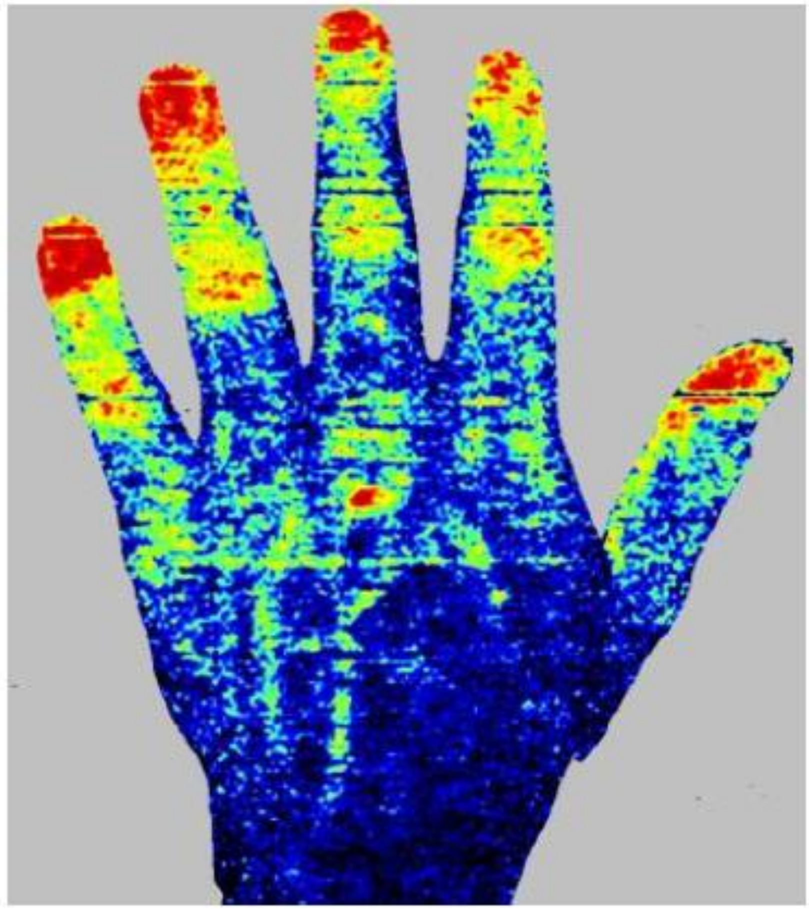
Ultra-low frequency Raman measurements of Tylenol and Advil showing sharp, structures below 100cm^{-1}.

The corresponding increase in spectral brightness is also extremely valuable as typical Raman signals are several orders of magnitude lower than the incident laser power. By combining the SureLock™ lasers with Ondax SureBlock™ ultra-narrow band notch filters, ultra-low frequency Raman measurements can be made to within 10 cm^{-1} of the laser line for both Stokes and anti-Stokes signals[1].

Finally, the size, cost and environmental performance advantages of VHG-stabilized lasers have led to the development of portable hand-held systems for rapid material and chemical screening. With recent regulatory requirements put in place to ensure purity of chemical components, this portable testing capability enables rapid, inexpensive analysis with minimal production delay.

Wavelength stabilized lasers are also used to boost performance in other bio-instrumentation applications such as HIV blood testing, DNA sequencing, blood flow imaging, and cell sorting. Laser Doppler perfusion imaging and monitoring systems in particular require a stable single frequency laser source to eliminate spurious signals caused by multi-line behavior when measuring the Doppler shift from in vivo blood flow. The compact nature of VHG-stabilized lasers has greatly reduced the form factor and enabled the portability of all these systems.

Outside the bio-instrumentation industry, wavelength stabilized lasers are beneficial to a variety of physical and environmental measurement applications. Automated robotic and navigation systems can rely upon wavelength stabilized lasers for precision orientation and placement of objects. Gesture recognition systems, which use a diffractive optical element to produce a structured light pattern for location and movement monitoring, require the source to have a stable wavelength over a broad range of environmental conditions. Any change in wavelength will cause the diffractive pattern to scale accordingly, resulting in a change of the apparent size/depth of the tracked object. VHG-stabilized lasers are particularly useful for these applications due to their compact, robust nature and their ability to maintain performance over a large operating temperature range with low power requirements.



Blood perfusion image of a hand taken with a Perimed PeriScan PIM 3 System. Areas of high blood flow are shown in red.

Performance Comparison of Alternative Technologies

While VHGs are one of the most robust and cost-effective ways of stabilizing a laser diode, there are other approaches with advantages and disadvantages depending on the application. The predecessor to the VHG-stabilized laser is the dispersive grating based external cavity laser (ECL). Instead of using a VHG to provide feedback for the laser, a diffraction grating is mounted in either Littrow or Littman configuration. This approach tends to be much bulkier and is often expensive and difficult to implement with high performance. The increased size also means these systems are particularly prone to vibrations, reducing their suitability for many field-based applications.

Distributed feedback (DFB) and distributed Bragg reflector (DBR) lasers, or vertical cavity surface emitting lasers (VCSELs) that incorporate a DBR, require the grating to be fabricated within the laser die itself. While this makes the laser compact, it can be difficult to passively achieve the desired wavelength with significant yield across a wafer due to manufacturing variations. The range of available wavelengths for these lasers is also currently limited to the red or near-IR, with red varieties being the most expensive and often having low output power.

The table below shows a comparative performance analysis of various visible wavelength stabilized lasers along with the typical output of a raw laser diode

Performance comparison of various visible wavelength stabilized lasers

Feature	Raw Laser Diode	SureLock™ Laser	Dispersive Grating ECL	DFB Laser	VCSEL
Precise wavelength		✓	✓		✓
Narrow spectrum		✓	✓	✓	✓
Passive wavelength stabilization		✓			
Several mW output power	✓	✓	✓	✓	
Size/portability	✓	✓		✓	✓
Low weight	✓	✓		✓	✓
Cost	$	$-$$	$$$-$$$$	$$-$$$$	$-$$

SureLock™ VHG wavelength stabilized lasers simultaneously provide a precise stable wavelength, narrow linewidth (long coherence length) and low power consumption, all in a compact package at low cost. Their development has been a driving force in the miniaturization of systems that were once confined to lab settings; allowing them to be taken into the field and enabling entirely new applications.

Ondax SureLock™ Wavelength Stabilized Laser Diodes and Modules

Ondax SureLock™ Wavelength Stabilized Lasers are currently available in a wide variety of wavelengths and packaging options, from TO can to fully computer-controllable integrated modules; enabling compact, robust, low-cost, and portable high-performance optical instrumentation applications. For more information on available options or to learn more about the various applications of VHG-stabilized lasers, please visit our website at www.ondax.com, email sales@ondax.com or call (626) 357-9600.

[1]*Moser C., Havermeyer F., "Compact Raman spectrometer system for low frequency spectroscopy," Proc. SPIE 7598, 75980S (2010)*