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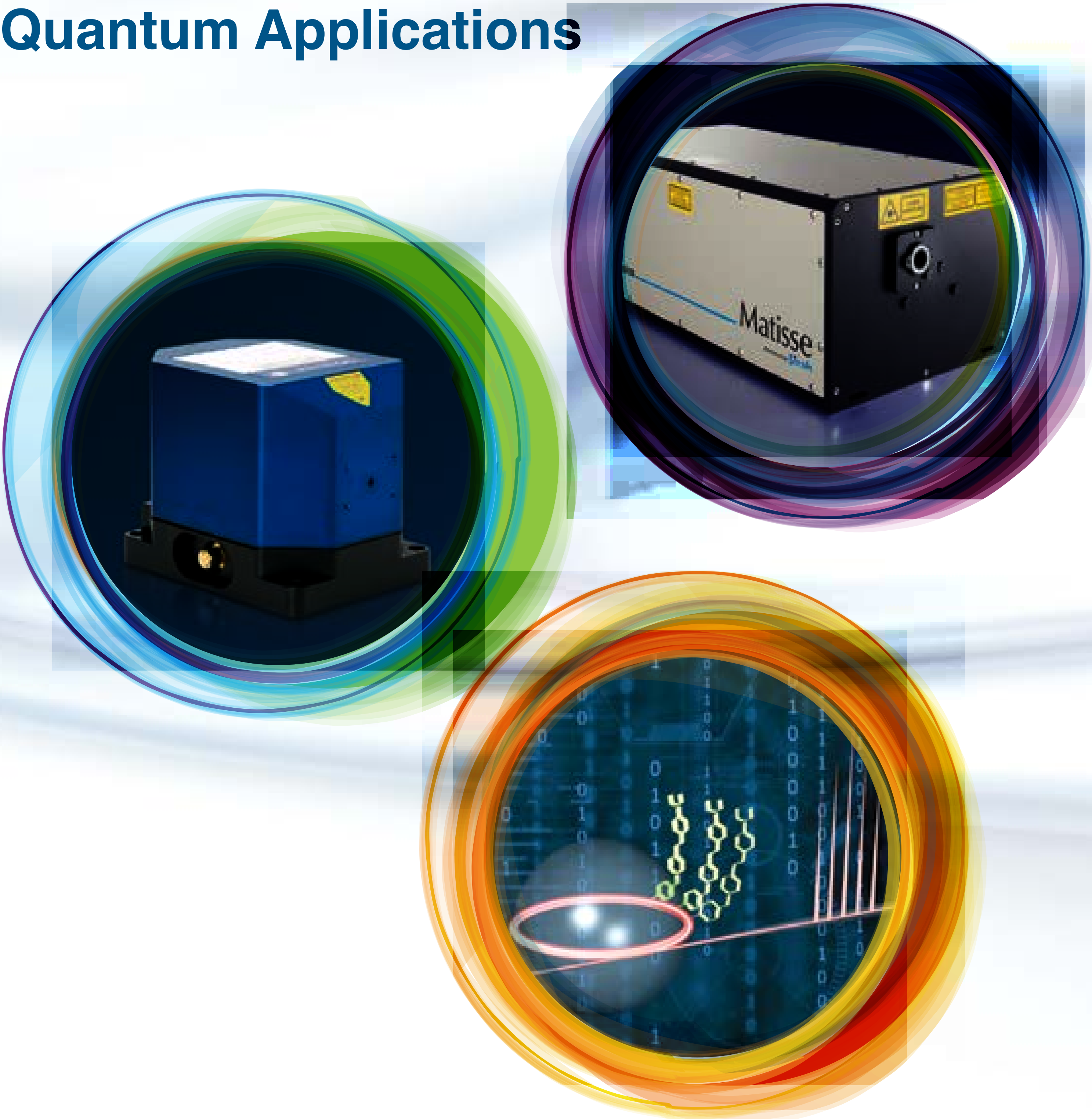
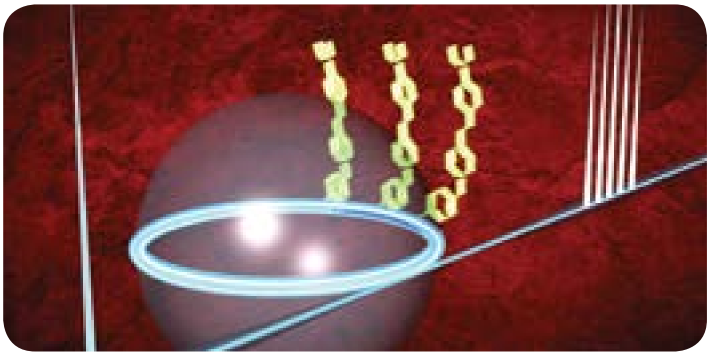
Spectra-Physics®

代理商: 森泉光电

CW Tunable Lasers for Quantum Applications



Widest Portfolio for Quantum Applications



On the Cover

Quantum entanglement is a physical phenomenon in which photon pairs are generated such that the quantum state of each photon cannot be described independently of the state of the other. It has many applications in quantum information theory including quantum cryptography. Ultrahigh quality factor (UHQ) microcavities have been emerging as a promising integrated platform for a wide range of applications from theoretical quantum physics to applied science. Pumped with a CW laser, multiple entangled photon pairs can be generated via optical parametric oscillation.

A research team led by post-doctoral researcher Xiaoqin Shen in the Armani Group at USC has invented a new method to create photon pairs in the form of frequency combs with 1000x reduction in power consumption compared to traditional methods utilizing ultrafast lasers. A monolayer of organic molecules on the surface of conventional UHQ microcavities allows these devices to effectively generate frequency combs. The surface layer interacts with the pump light, reducing the threshold of the optical parametric process.

Reference: Xiaoqin Shen et al. Low-threshold parametric oscillation in organically modified microcavities, Science Advances (2018). DOI: 10.1126/sciadv.aao4507

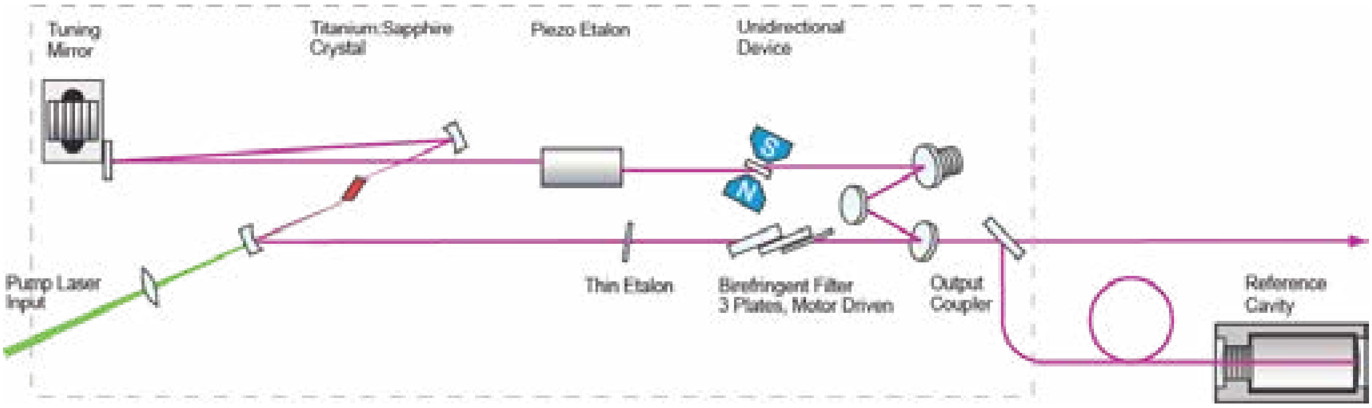
Matisse® CW Tunable Ring Lasers

The Spectra-Physics® Matisse series is a family of state-of-the-art single frequency ultra-stable, narrow linewidth tunable ring lasers. The Matisse system has the industry's highest output power, the narrowest external linewidth, the broadest tuning range.

Out of Plane Ring Resonator

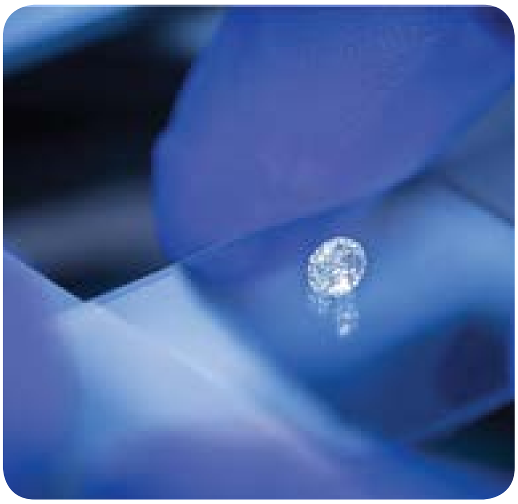
The Out of Plane cavity design is a stable and more reliable configuration delivering years of worry free operation.

All CW ring lasers support uni-directional propagation of light within the laser cavity. Most ring lasers utilize a thin intracavity waveplate which is easily damaged, resulting in lower output power and performance. The Matisse lasers are configured with an Out of Plane cavity design eliminating the need for this thin waveplate.



Matisse optical layout with reference cavity. The Matisse features an Out of Plane ring resonator design and two etalons for maximum mode stability.

Featured Application



Quantum computers, tap-proof data transfer or highly sensitive sensors – quantum mechanical properties, such as superposition and entanglement, are fundamental to many of tomorrow's technological systems. In the interdisciplinary core area of quantum information and technology, scientists at Ulm University investigate quantum physical phenomena in theory and by experimentation. The overall goal is to gain complete control over quantum systems. It is also about quantum physical effects in condensed matter, in nanostructures and in biological systems.

Novel sensors for use in cells are an important goal in research at Ulm University. To achieve this, scientists focus on the manipulation of individual atoms in diamonds. Prof. Fedor Jelezko, one of the world's leading experts in controlling the smallest particles in solids - as demonstrated by the prestigious awards he has won - is involved in these research groups.

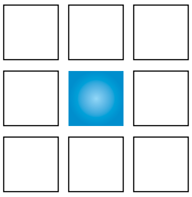
Matisse Features

Narrowest Linewidth

The Matisse is available with three levels of frequency stabilization: Passive stabilization with phase lock loop, active stabilization with reference cell, and active stabilization with Pound-Drever-Hall locking for ultra-narrow linewidths to <30 KHz (100 ms integration time).

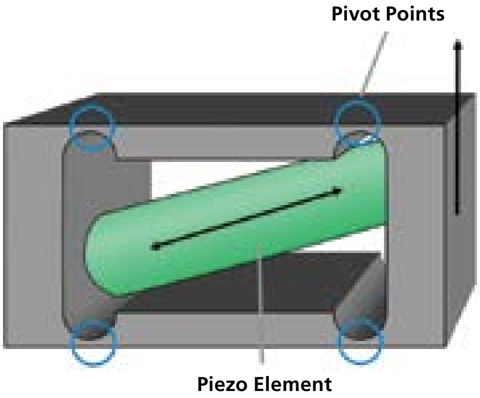
Mode-Hop-Free Tuning

Superior mechanical stability, specially designed optical mounts, unique tuning methods, and the preferred Out of Plane cavity design of the Matisse C all contribute to the exceptional mode-hop-free scanning range of >50 GHz. In order to take this to the next level, we have developed “Scan Stitching” for wide mode-hop-free tuning over the full wavelength range (up to 300 nm).



Flexure Optical Mounts for Optimal Power Flatness

Even the smallest tilts in linear travel when wavelength tuning by changing the cavity length of a ring laser will result in decreased output power. All optics meant to travel linearly in the Matisse are mounted on flexure optical mounts. These mounts enlarge the scan range and guides linear translation, therefore providing power flatness to within 5% across 50 GHz of mode-hop-free tuning.



Parallelogram Piezo Device: Accurate parallel motion in a single direction integrated lever transmission motion of up to 200 µm.

Pumped by Millennia® eV™ DPSS Laser

The Millennia eV platform is based on Spectra-Physics’ It’s in the Box™ design, where the laser optical cavity, diode and control electronics are all integrated in a single, compact package, eliminating the need for an external power supply.

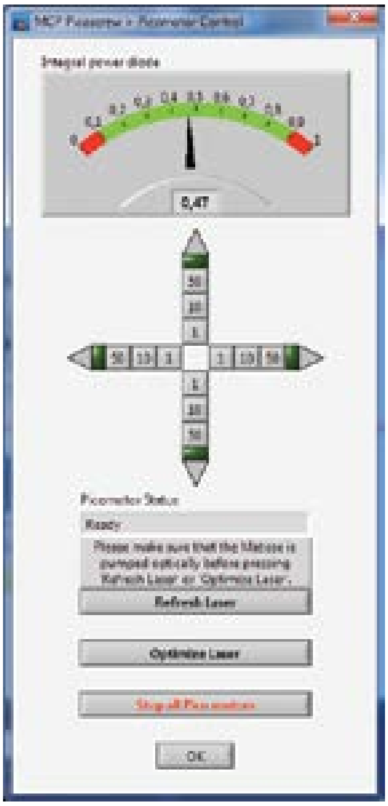
With its industry leading scalability from 5 W to 25 W average power and high reliability, Millennia eV is the next generation laser of choice for demanding scientific applications such as the pumping of CW Ti:Sapphire lasers.

Matisse Stability

Electronic Laser Self Alignment (ELSA)

The Beam Steering Mirror on the input of the Matisse is mounted on a Picomotor™ actuated mirror mount. The Picomotor actuator is the best technology on the market enabling "set and forget" alignment. To account for long term pump beam-walk, the output power of the Matisse is monitored and provides feedback for self-alignment.

Matisse input beam-steering mirror.



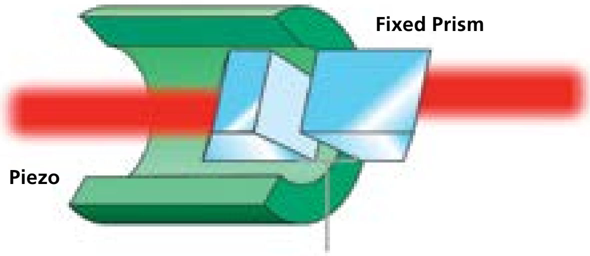
Ready

Please make sure that the Matisse is pumped optically before pressing 'Refresh Laser' or 'Optimize Laser'.

ELSA control GUI.

Two Etalons

The unique cavity design of the Matisse incorporates two etalons. The second etalon provides increased long term mode stability. This "thick etalon" uses air gap technology for maximum locking stability



Thick etalon air-gap design.

Variable Low Frequency Locking

CW single frequency ring lasers utilize a Phase Lock Loop (PLL) in order to stabilize the laser cavity to a single longitudinal mode. The Matisse incorporates a unique PLL technique that delivers low dither frequencies (down to 500 Hz) to minimize laser noise and allows easy adjustability of the frequency (500 Hz – 3 kHz) via software.

Counter Drift Option

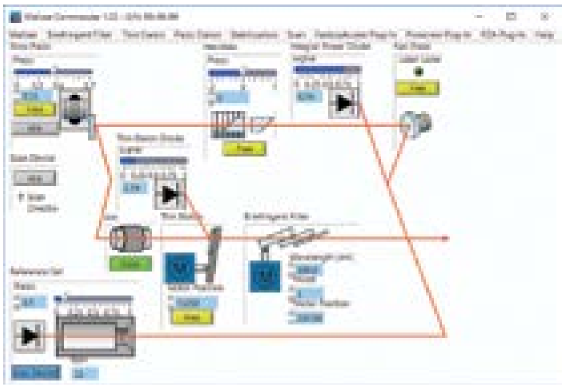
The Matisse can counteract the wavelength drift which is specific to any tunable CW single mode laser.

To further counteract drift for a Matisse without reference cavity, a good wavemeter can be used as reference. Or for a Matisse laser with reference cavity an optional strain gauge can be installed on the scanning piezo. It is also possible to use the Matisse reference cavity as a transfer cavity or to stabilize it to an atomic resonance or a frequency comb.

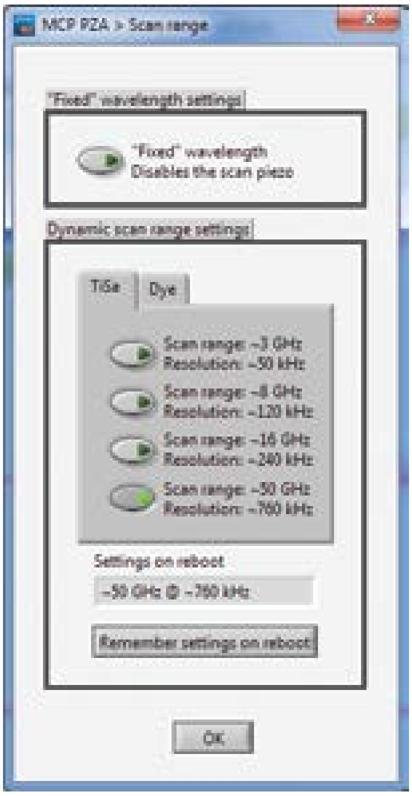
Matisse Software Control

Fully Automated Software Control

The Matisse is controlled with an intuitive GUI allowing fully automated and easy operation. Functionality, such as wavelength selection, piezo scanning, and frequency locking are easily visualized with a pictorial schematic of the Matisse laser cavity. Other GUI windows display automated monitoring of beam alignment and laser performance.



Screenshot of the Matisse Commander software.



MCP PZA > Scan range

"Fixed" wavelength settings

"Fixed" wavelength
Disables the scan piezo

Dynamic scan range settings

Scan range: ~3 GHz
Resolution: ~50 kHz

Scan range: ~8 GHz
Resolution: ~120 kHz

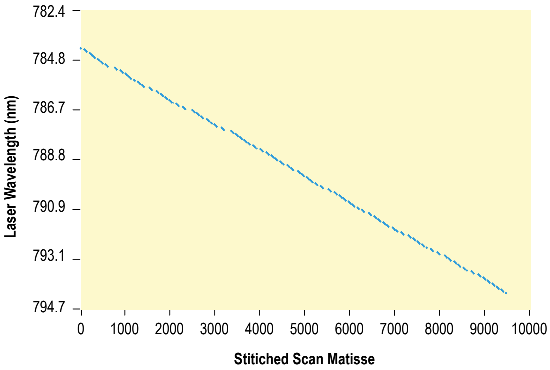
Scan range: ~16 GHz
Resolution: ~240 kHz

Scan range: ~50 GHz
Resolution: ~760 kHz

Settings on reboot: ~50 GHz @ ~760 kHz

Automated Scan Stitching

The Matisse can perform indefinitely long scans by stitching the 50 GHz scans together. An implemented software routine automatically optimizes the position of all the optical elements involved in wavelength selection, allowing to scan the laser in 50 GHz steps without the need to manually reset or realign any components.



Dynamic Scan Range

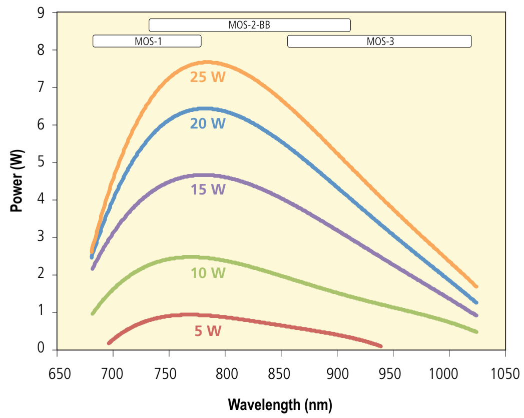
The Dynamic Scan Range function allows easy adjustment of the wavelength tuning resolution. This is achieved via a built in switchable piezo amplifier with easy software control. Tuning resolutions down to 50 kHz can be selected when fine wavelength adjustments are needed.

Matisse Tuning Curves

Tune over 300 nm with one optics set

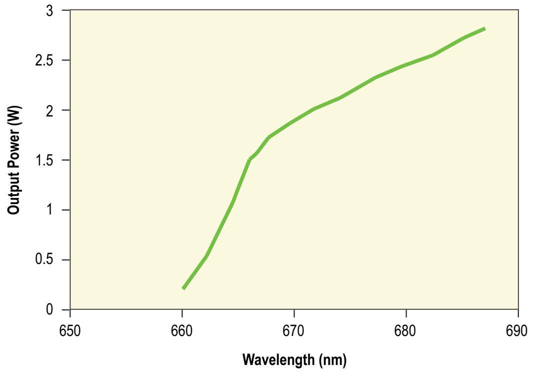
Broadband optics provides over 300 nm automated continuous tuning with no need to change optics. Other wavelength options are available for higher power at specific wavelength ranges between 670 nm and 1038 nm.

Matisse tuning Curves with Millennia eV Pump[1]



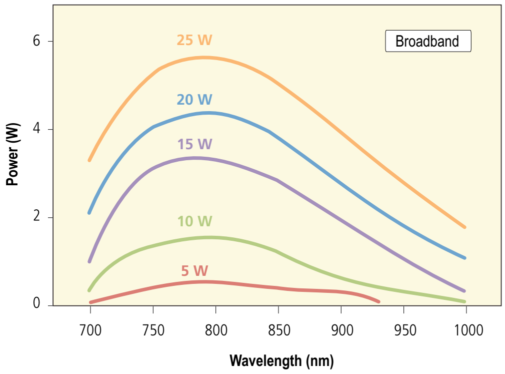
1. Typically measured performance; not a guaranteed or warranted specification.

Matisse tuning curve with MOS-1-BB and MOS-1-EXT mirrors. Pumped with a Millennia eV 15W laser[1]



1. Typically measured performance; not a guaranteed or warranted specification.

Matisse tuning curve with a single broadband mirror set. Pumped with various pump powers[1]



1. Typically measured performance; not a guaranteed or warranted specification.

Matisse Models

Matisse CR

Passively Stabilized

- Phase Lock Loop
- Linewidth <2 MHz (100 ms), <1.4 MHz (100 µs)

Matisse CS

Actively Stabilized

- Reference Cell
- Linewidth <50 kHz (100 ms), <35 KHz (100 µs)

Matisse CX

Pound-Drever-Hall Stabilized

- Linewidth <30 kHz (100 ms), <20 KHz (100 µs)

Matisse 2

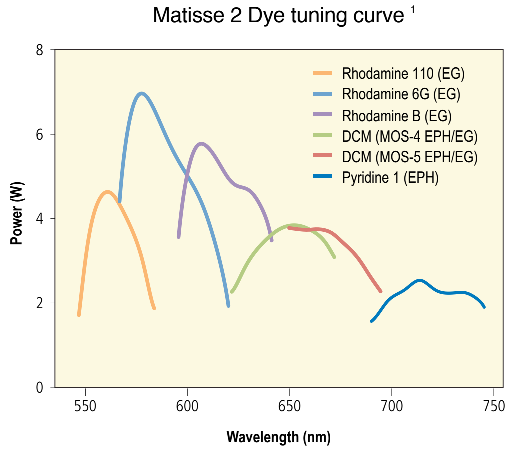
- Ultimate Flexibility
- Ti:Sapphire and Dye Options

The Matisse 2 is a flexible open architecture platform and is available with Ti:Sapphire or Dye gain medium for wavelength options across the visible range. The Matisse 2 can be easily converted between Ti:Sapphire and Dye and optics readily changed.

Matisse CS with Millennia eV pump laser

Matisse C Compact Form

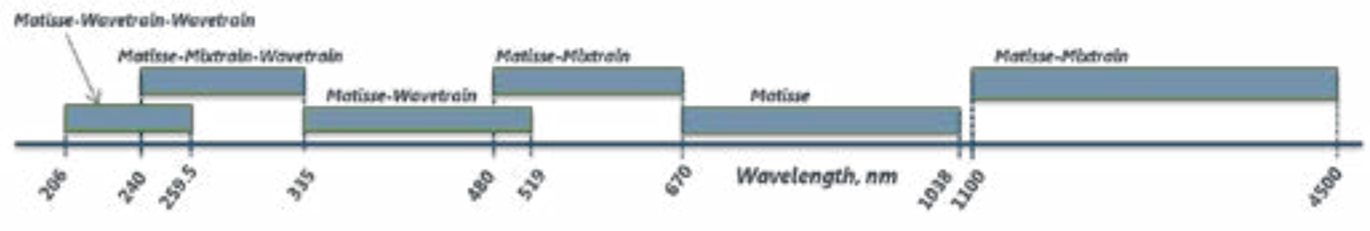
The Matisse C is a closed box and fully automated system. For the CS version, the reference cavity is housed beneath the Millennia eV pump laser for a compact layout.

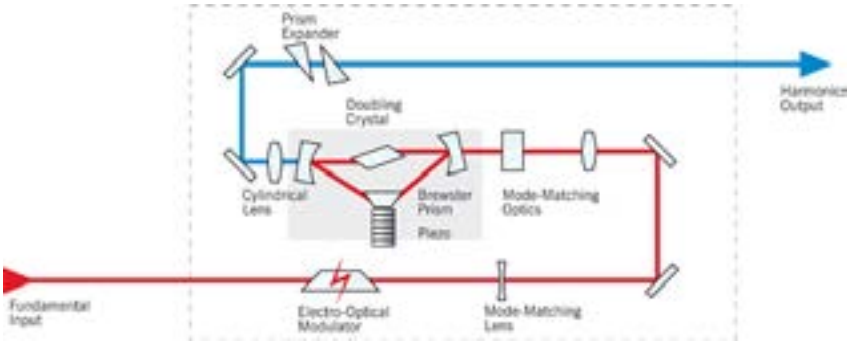


1. Typically measured performance; not a guaranteed or warranted specification.

Wavelength Extension – An automated all solid state solution

With various configurations of the Matisse, WaveTrain® doubler, and MixTrain™ frequency mixer, Spectra-Physics offers an all solid state solution for wavelengths ranging from 206 nm to 4.5 µm.

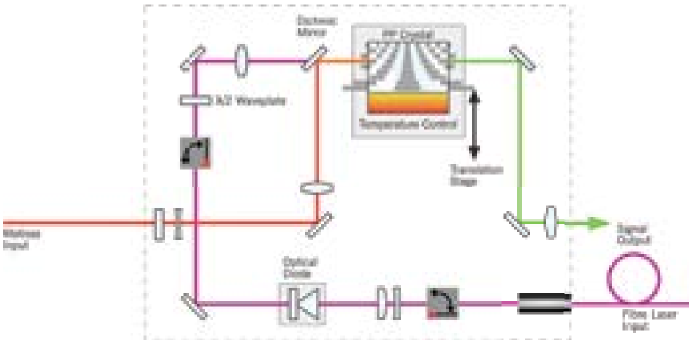




WaveTrain 2 optical schematic

WaveTrain 2 is an advanced stand-alone device that provides simple frequency doubling of single frequency CW laser beams. With greater efficiency than traditional intra-cavity or extra-cavity methods, this product can be used to generate the second harmonic of the output of the Matisse.

The MixTrain utilizes quasi-phase matching in periodically poled crystals for sum- or difference frequency mixing of two cw-lasers. The system uses a motor controlled translation stage for changing the period of the crystal and a temperature stabilized oven capable of heating up to 180°C. All optics for beam shaping, polarization control, beam combination, and beam separation are included. An optical diode isolates the fiber laser input from back reflections from the setup.



MixTrain 2 optical schematic

WaveTrain 2

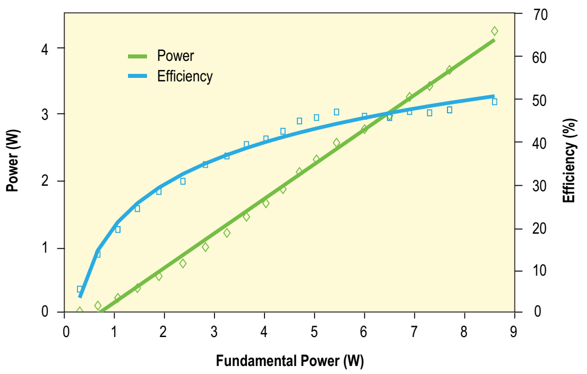
Resonant Ring Frequency Doubler

- Most efficient CW SHG available today
- Highest output powers available
- Fast response piezo control
- Piezo mounted prism in triangular configuration leads to excellent beam pointing stability
- Auto-locking loop in stabilization circuit
- 205 nm to 800 nm output

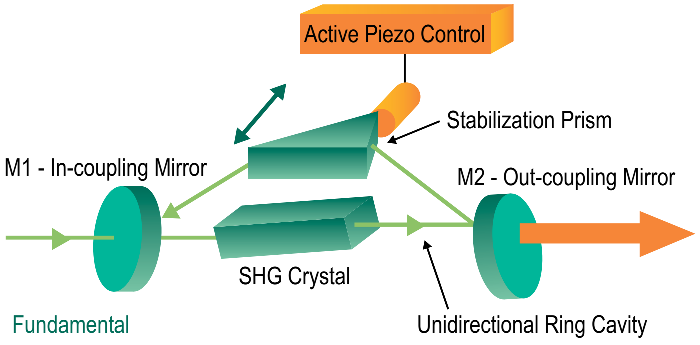
Patented DeltaConcept® Cavity Design

The WaveTrain 2 utilizes a ring cavity to achieve harmonic efficiencies greater than 35%. Unlike conventional bow-tie cavities, WaveTrain 2 is based on a patented triangle-shaped cavity configuration called the DeltaConcept®, which allows the cavity length to be adjusted with no effect whatsoever on output beam position, direction or beam astigmatism.

WaveTrain 2 Efficiency Performance[1,2]



1. Typically measured performance; not a guaranteed or warranted specification.
2. Taken with LBO crystal at 754 nm.



DeltaConcept ring resonator

The DeltaConcept design requires two cavity mirrors (as opposed to four in a bowtie resonator) which minimizes losses for maximum output power.

WaveTrain 2 Stability

Hermetically Sealed Resonant Ring Cavity for Crystal Longevity

The WaveTrain 2 resonant ring cavity is housed in a massive metal block and hermetically sealed with an O-ring and metal cover plate. Hygroscopic material inside of the housing protects against humidity. The doubling crystal is temperature stabilized and nitrogen purging is available.

Adjustment Knobs External to Sealed Cavity

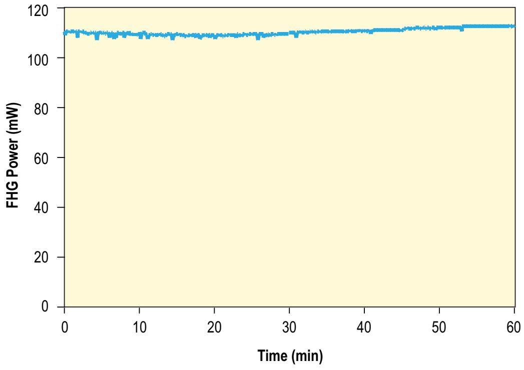
There is no need to remove the lid of the hermetically sealed cavity during adjustment. This prevents cavity misalignment that can occur with lid closure.

Isolation Legs

The WaveTrain 2 is mounted onto 3-point ceramic ball isolation legs to decouple the system from laboratory vibrational noise.

Pound-Drever-Hall Lock

The WaveTrain 2 comes standard with the Pound-Drever-Hall locking schematic for the most stable frequency lock.



One hour power measurement of the output of a WaveTrain 2 pumped by a WaveTrain 2.

Auto Locking Frequency Loop

Output stability is further enhanced by the use of a lightweight piezo-activated prism to optimize the cavity length, making the WaveTrain 2 especially resistant to vibrations and acoustic noise. This inherent beam stability enables the control hardware to automatically lock the cavity for maximum doubling efficiency during both fixed frequency and scanned operation.

Fourth Harmonic Generation

The low noise output of the WaveTrain 2 enables stable fourth harmonic generation by pumping a second WaveTrain 2.

MixTrain

Sum and Difference Frequency Mixer

Complete System

The MixTrain includes beam shaping optics, polarization control, beam combination, and beam separation optics. An optical diodes isolates the fiber laser input from back reflections.

Automated Wavelength Setting

A motor controlled translation stage and temperature stabilized oven are easily software controlled. Manual adjustmnets are not required for tuning.

Wide Scan Ranges

Multiple crystals can be mounted simultaneously for tuning across 100+ nm. Scan ranges without the change of crystal temperature are >20 GHz for visible and >60 GHz for IR tuning.

Field Exchange Optics

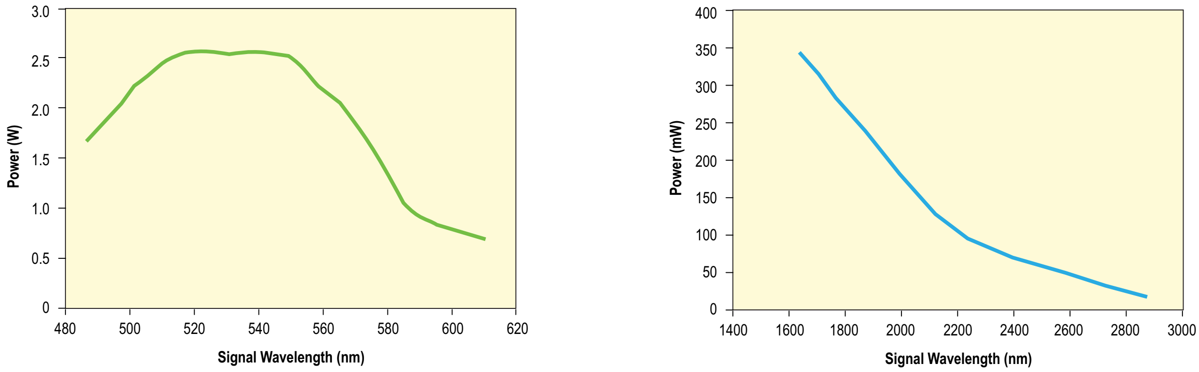
Crystals and optics are easily field exchangeable, providing flexibility for conversion between sum frequency mixing and difference frequency mixing.

Wavelengths

The Mixtrain output tuning curve is dependent on input wavelengths and power. The output of a ti:sapphire laser is mixed with a single mode fiber laser at 1064 nm, 1550 nm, or 1950 nm. Sum frequency mixing provides visible wavelengths and difference frequency mixing provides near to mid-IR wavelengths.

- Sum Frequency Mixing ~480 to 670 nm
- Difference Frequency Mixing ~1.1 to 4.5 µm.

Typical tuning curves when mixing 4.5 W Matisse output and 1550 nm single mode fiber laser output with 10 W.



New Focus™ Tunable Diode Lasers

The New Focus tunable external cavity diode lasers lead the market with high performance, true continuous mode-hop-free tuning over wide wavelength ranges.

Narrowest Linewidths

- <200 kHz (measured over 50 milliseconds)
- <2.5 kHz (measured over 5 microseconds)

Broad Range of Wavelengths

- Widest wavelength offering in the Littman-Metcalf mode-hop-free cavity design

Superior Mechanical Design

- Magnetic damping provides further wavelength stability by essentially stiffening the cavity tuning arm.
- Integrated fiber coupling

Easy Operation

- Controllers automatically read and set critical laser parameters upon startup
- Controller or computer interface
- Easy to use GUIs provided

New Focus Tunable Lasers on the International Space Station

The New Focus Vortex™ Plus lasers and Tapered Amplifiers are employed in the JPL Cold Atoms Laboratory (CAL) science module now operating on the International Space Station (ISS), launched on May 21, 2018. The CAL science module will enable cold atom experiments in a microgravity environment with the intent to observe new quantum phenomena.

Velocity™ TLB-6700

Littman-Metcalf Wide and Finely Tunable Laser

True continuous mode-hop-free tuning and widest selection of wavelengths.

- <200 kHz linewidth (measured over 50 ms)
- <2.5 kHz linewidth (measured over 5 µs)

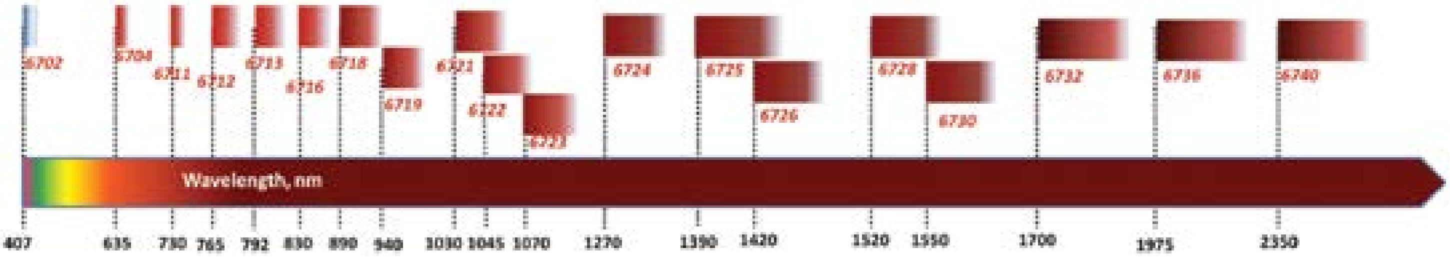
The Velocity TLB-6700 is our premier tunable diode laser system offering both wide and fine wavelength scanning. The laser cavity housing is shock proof and thermally insulated with active temperature control and incorporates our unique magnetic damping technology providing higher power, stability, and narrow linewidths.

Robust fiber coupling

The fiber coupled option includes an isolator and fixed fiber coupler mated to the laser cavity block. This ensures optimal fiber alignment without the need for readjustments.

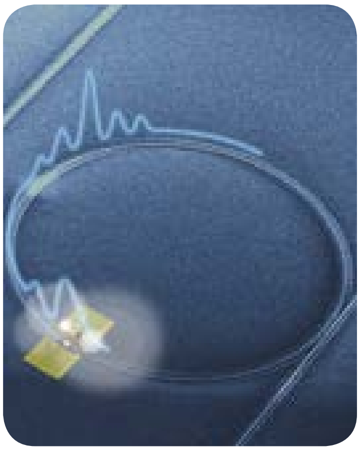
Widest Range of Wavelengths

The New Focus Velocity is available at wavelengths from the UV to the mid-IR.


Wavelength

See latest Velocity datasheet for current wavelength offerings.

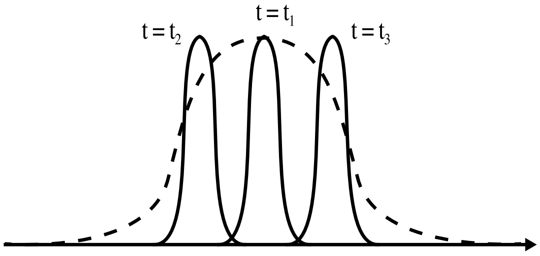
Featured Application


Courtesy of Chee Wei Wong and Abhinav Kumar Vinod, University of California at Los Angeles

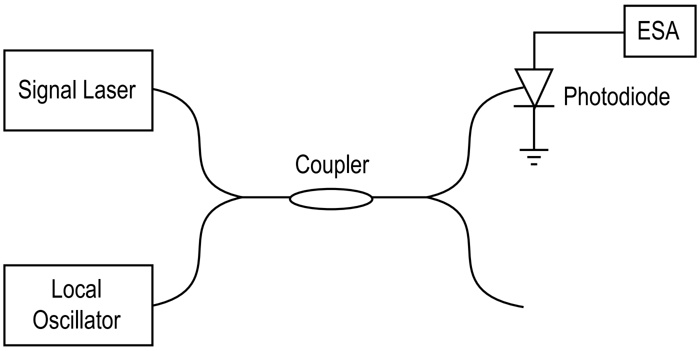
Optical frequency combs are cornerstones of modern day metrology, precision spectroscopy, astronomical observations and ultrafast optics. State of the art methods to generate frequency combs in chip scale devices are based on Kerr and Raman nonlinearities in ultrahigh Q monolithic microresonators. Chee Wei Wong's group at UCLA has demonstrated an electronic method to tune the dispersion of a silicon nitride microresonator used in comb formation, via a dual-layer ion gel gated graphene transistor fabricated on top of the cavity. This dispersion tuning is accomplished by coupling the gate-tunable optical conductivity of the graphene transistor to the intracavity field in the microresonator, while preserving cavity quality factors up to 106. With this method, charge-tunable primary comb lines from 2.3 terahertz to 7.2 terahertz, coherent Kerr frequency combs, controllable Cherenkov radiation and controllable soliton states, are all generated in a single microcavity.

Linewidth

Laser linewidth, the width of the laser optical field power spectrum, fundamentally describes the frequency noise behavior of a laser oscillator. Intrinsic linewidth determined by the gain medium in addition to technical fluctuations due to the environmental impact on the laser cavity and driving conditions contribute to a linewidth specification. Integration over the millisecond timescale ensures these influences are captured in the linewidth measurement.

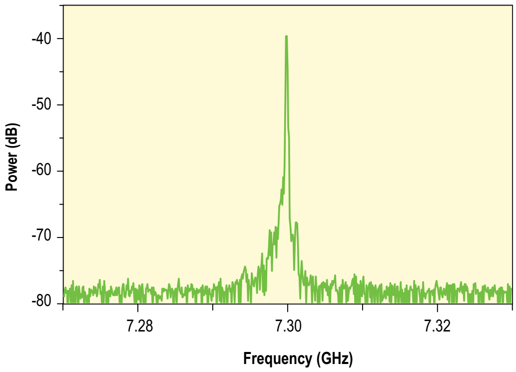


Instantaneous shots of the drifting Lorentzian spectrum (straight lines) varying with time and long term spectrum (dotted).



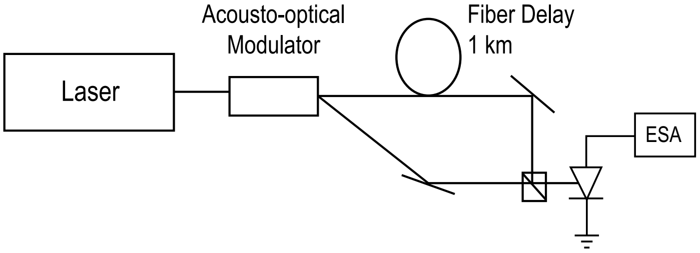
Heterodyne beat note schematic using two independent lasers

Heterodyne beat note of two Velocity TLB-6712 lasers, 50 ms integration. Deconvoluted linewidth <200kHz[1]

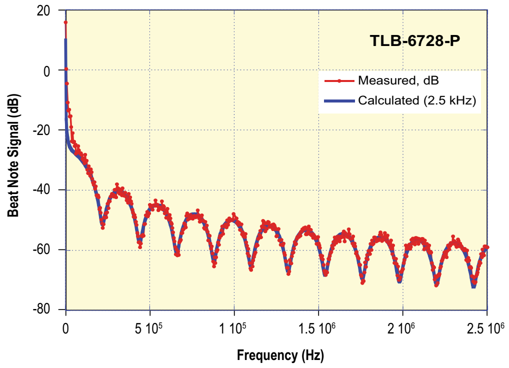


1. Typically measured performance; not a guaranteed or warranted specification.

Historically, linewidth is measured over an integration time of 50 msec or longer with the heterodyne beat note method utilizing two independent similar ECDLs. This method is less dependent on the measurement setup and provides a true snap shot of spectral broadening.



Delayed (4.6 μs) Self-Homodyne Linewidth Measurement[1]



1. Typically measured performance; not a guaranteed or warranted specification.

The delayed self-beat note method is another linewidth measurement technique. While this technique filters out spectral broadening, it provides an instantaneous snapshot of the Lorentzian spectrum. The New Focus Velocity laser measures 2.5 kHz over a delayed 4.6 μs measurement.

Vortex Plus TLB-6800

Littman-Metcalf Finely Tunable Laser

Fine piezo mode-hop-free tuning

The New Focus Vortex Plus offers the widest piezo mode-hop-free tuning and narrowest linewidth.

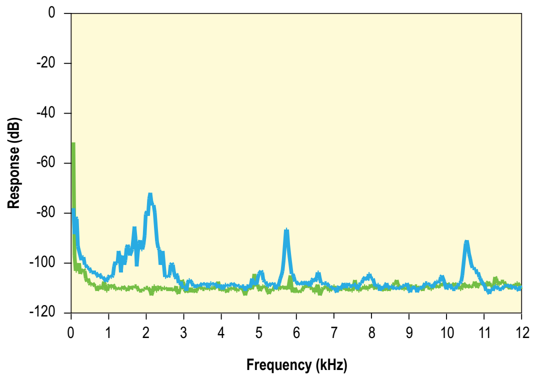
- >100 GHz mode-hop-free tuning
- <200 kHz linewidth (measured over 50 milliseconds)

Industrial Design

The Vortex Plus was designed for industrial applications and delivers high performance in a compact platform. The Star-flex actuator provides reproducible rotational motion. This mechanically stiff actuator was designed to withstand extreme shock and vibration such as would be experienced during a space launch.

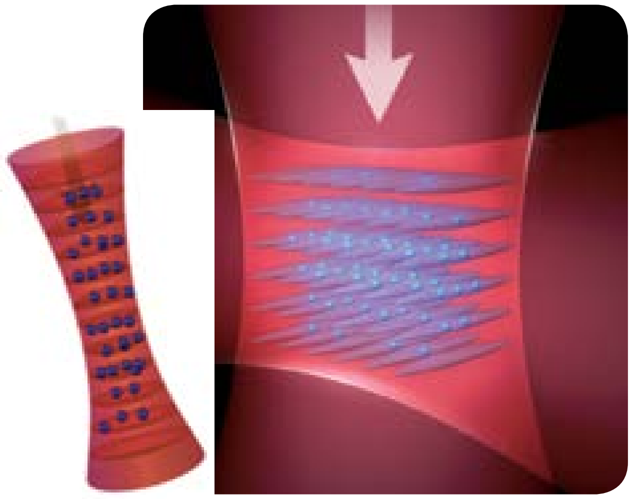
Star-Flex actuator design of the TLB-6800 Vortex Plus laser.

Frequency response of the Vortex Plus in comparison to the original Vortex. The Vortex Plus has improved stability due to the Star-Flex design and magnetic damping.[1]



[1] Typically measured performance; not a guaranteed or warranted specification.

Featured Application



Strontium Optical Lattice - Courtesy of Prof. Jun Ye, UC Boulder, JILA, NIST

The strontium optical lattice clock at JILA works by referencing an ultra-stable clock laser to laser-cooled and trapped strontium atoms. Strontium is one of nature's highest-Q frequency references, with a quality factor of 1018. This clock takes advantage of the lower quantum projection noise of a many-body quantum system to achieve new records in clock precision, stability, and total systematic uncertainty. To prepare the atoms for precision spectroscopy, they are first laser-cooled using light from 461 nm blue diode lasers. Then, after a second red laser cooling stage, the atoms are loaded into an optical lattice, where they are trapped in standing waves of light. The clock laser is then used to perform coherent spectroscopy. The blue light is used again to measure the number of atoms in the ground and excited states via fluorescence. This allows us to measure the laser frequency against the atomic resonance

VAMP™ Tapered Amplifier TA-7600

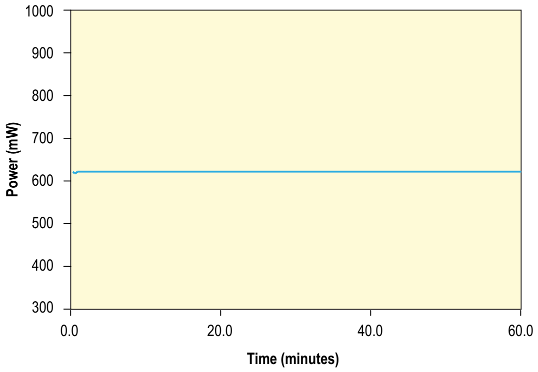
Power Amplification

- Fiber coupled input ensures fast, easy, and reliable alignment
- Active input power monitoring ensures that self-lasing will not damage the tapered amplifier chip
- Optical isolation of the amplifier output standard on all models

Easy Alignment

Every New Focus tapered amplifier includes an FC/APC input fiber connection which ensures reliable and trouble-free alignment – every time. Two onboard photodiodes are used to monitor the input and output powers. Active input power monitoring helps prevent damage to the tapered amplifier chip through self-lasing at low seed power. Active

Power measurement of a VAMP TA-7600 tapered amplifier[1]



1. Typically measured performance; not a guaranteed or warranted specification.

Stable Power Output

For additional power stability, a power lock loop monitors and levels the output power to provide quiet, low-drift output and withstand laboratory environment changes.

Featured Application

ColdQuanta's innovative BEC system is designed to streamline and simplify the production of ultracold atoms and BECs. At the heart of the system is the RuBECi® where rubidium atoms are cooled to temperatures of below 1 mK, trapped, and manipulated inside the vacuum cell. A New Focus Tapered Amplifier is used to provide ample power for laser cooling and manipulation of the atoms.

Venturi™ TLB-8800

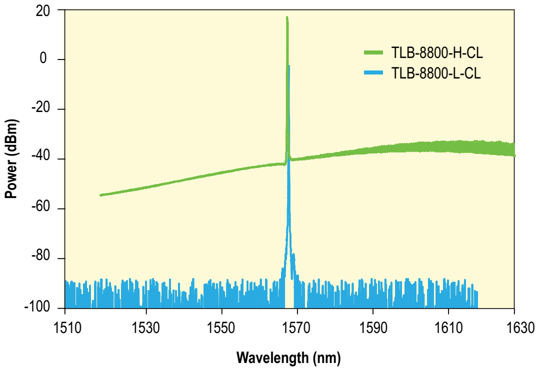
Swept and Step Wavelength Tunable Laser

- Up to 20,000 nm/s wavelength tuning
- Swept and step modes
- Programmable high frequency repetition rates
- Programmable coherence control

Fast and Programmable Wavelength Tuning

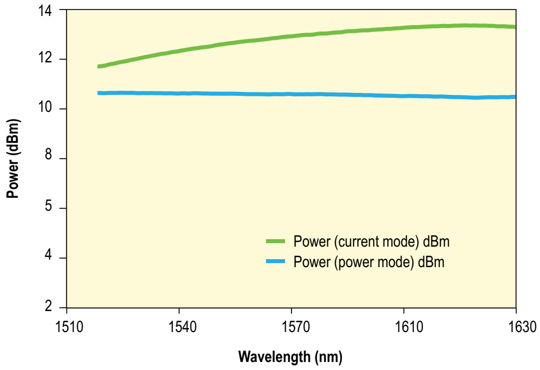
The Venturi TLB-8800 is the only swept wavelength laser with up 20,000 nm/second tuning speed and high frequency repetition rates enabling true real-time measurements. Tuning speeds, repetition rates, dwell times, and wavelength ranges are adjustable to accommodate your unique needs. In addition to wavelength sweeping, the Venturi is capable of step tuning in 0.01 nm increments. The front panel offers easy access to RS232 and USB interfacing with use of a user friendly GUI.

Carrier and ASE for the models TLB-8800-H-CL and TLB-8800-L-CL over the entire C+L tuning range [1]



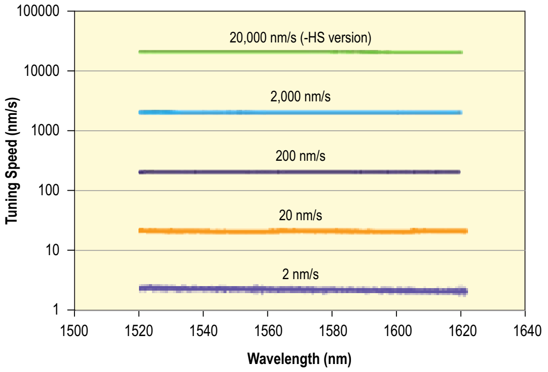
1. Typically measured performance; not a guaranteed or warranted specification.

Venturi TLB-8800 Swept-Wavelength Tunable Laser Performance[1]



1. Typically measured performance; not a guaranteed or warranted specification.

Tuning linearity for the model TLB-8800-H-CL[1]



1. Typically measured performance; not a guaranteed or warranted specification.

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