TSUNAMI

The First Choice

In Ti:Sapphire

Lasers.

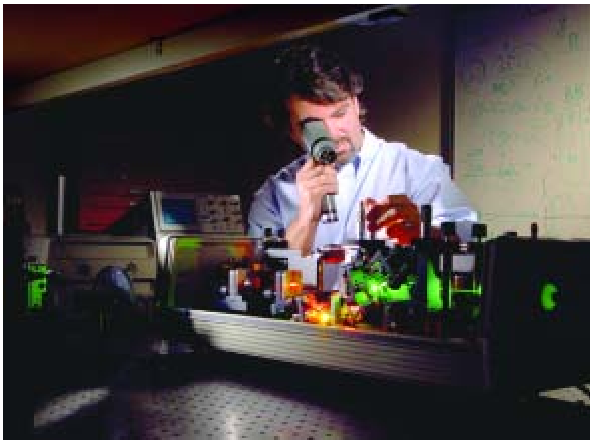
Spectra-Physics®

The Solid State Laser Company™

Tsunami:
The Gold Standard In Ultrafast Lasers

Ever since its introduction as the first commercial mode-locked Ti:sapphire laser in 1991, Tsunami® has remained the first choice of scientists in applications ranging from molecular dynamics to multiphoton imaging. The reasons for Tsunami's success are simple: it combines state-of-the-art performance with operational simplicity and reliability, allowing researchers to confidently focus on their experiments rather than the laser. At the same time, the amazing flexibility of the Tsunami, together with a broad selection of accessories, means a perfectly optimized laser for a wide range of applications. In fact, no other ultrafast laser offers this combination of performance, reliability, flexibility and ease-of-use.

Tsunami's superior performance and reliability are a direct result of Spectra-Physics' 40 years of experience designing and building lasers for the most demanding scientific applications. Just as important as our technology, Spectra-Physics is a vertically integrated laser company, manufacturing every component of the Tsunami ourselves, except the Ti:sapphire crystal and the acousto-optic mode-locker. Even the optics mounts have been specially designed and fabricated to deliver performance and stability that can't be achieved with conventional commercial mounts.



Tsunami is now the preferred ultrafast laser source in a wide range of research applications, because of its combination of high performance and rugged reliability.

At Spectra-Physics we realize that our commitment doesn't end with delivery of your laser system. That's why if you ever need assistance with your Tsunami laser, our worldwide service and support organization is only a phone call away. You're guaranteed a fast response, whether it's a simple question about integrating Tsunami into your application, optimizing it's performance, obtaining replacement parts, or scheduling a service visit.

Tsunami Advantages

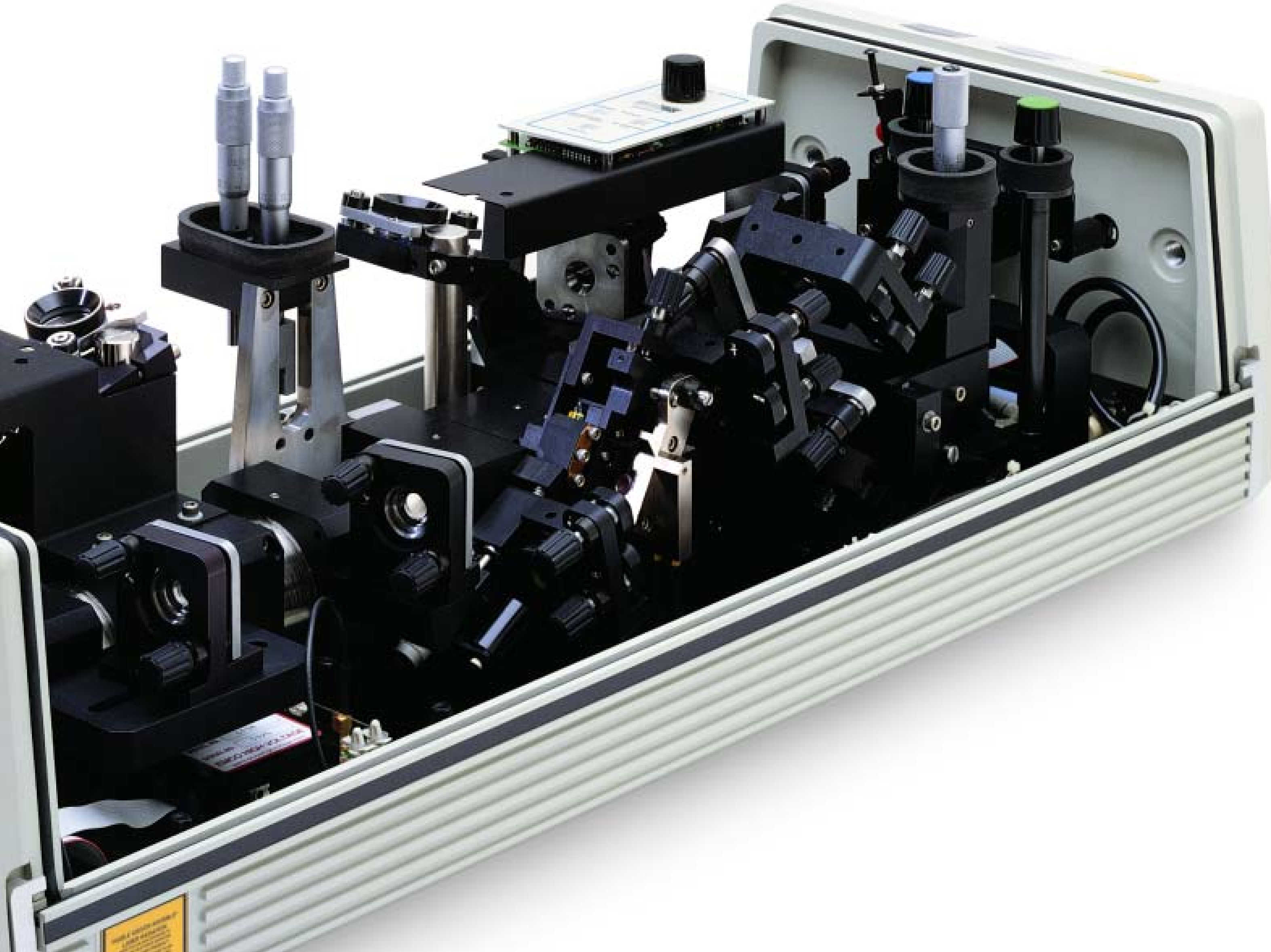
- *Ease of use. Tsunami is a compact, rugged laser designed to provide reliable, hands-free operation.*
- *Rock solid mode-locking. Regenerative mode-locking is self starting and self-sustaining and can be continuously operated for days without dropouts.*
- *Pulsewidth flexibility. Tsunami is optimized for both femtosecond and picosecond operation. It takes only minutes to switch between the two operating regimes.*
- *Widest Tuning Range. Thanks to regenerative mode-locking, Tsunami delivers the widest tuning range of any mode-locked Ti:sapphire laser. And with the latest broadband optics, a single set of optics covers the entire Ti:sapphire wavelength range.*
- *Optimized to your application. A full range of accessories, such as harmonic generators, pulse pickers and an OPO allows the laser output to be modified to meet the precise needs of your application.*

Tsunami: Superior Design Delivers Superior Benefits

The reliability, flexibility and superior performance of Tsunami are a direct result of its unique design features. Most important is the use of regenerative mode-locking based on an acousto-optic modulator. The mode-locking is self-starting and self-sustaining. As a result, Tsunami can be used to continuously acquire data for hours, or even days, with no risk of losing mode-locked output. Also, because regenerative mode-locking does not depend on the laser power level, Tsunami can deliver mode-locked output across the entire Ti:sapphire gain region (690 to 1080 nm)—the widest tuning range of any mode-locked Ti:sapphire laser. This tuning is remarkably simple requiring the adjustment of only two knobs.

Since regenerative mode-locking functions equally well over a wide range of peak output powers, Tsunami also can be operated over a broader range of pulsewidths than any other Ti:sapphire laser. This flexibility allows the output to be optimized for short pulse duration (< 35 fsec) or high spectral resolution, with pulsewidths as long as 100 psec and a spectral bandwidth of only 4 GHz.

Another key feature of Tsunami is its physical stability. The cavity elements are all mounted on a rigid Invar tube. This results in a very stable cavity, whose length is virtually immune to thermal drifts, in marked contrast to lasers assembled in a kit-like fashion on aluminum breadboards. This cavity stability has several significant benefits. First, it means that the laser is a hands-free tool that remains perfectly optimized with no requirement for ongoing tweaking and adjustment. Also, the combination of regenerative mode-locking and superior cavity stability allows the laser to be synchronized to other lasers and external equipment with a specified precision of better than 1 picosecond, using the optional Lok-to-Clock feature (see page 6).



The Ultimate In Pulsewidth Flexibility

Many ultrafast applications require the shortest possible pulsewidth and the highest possible peak power. However, applications such as spectral imaging require the laser output to be optimized for narrower spectral bandwidth. Tsunami is ideal for all these applications because it is designed to operate in both the femtosecond and picosecond regimes. In addition, Tsunami delivers optimized mode-locked pulses throughout the entire Ti:sapphire tuning range (690 to 1080 nm) in both operating regimes.

Thanks to the latest broadband optics, tuning from 700 to 1,000 nm can be accomplished without ever removing the laser cover.

Tsunami can be switched between the femtosecond and picosecond operating regimes by simple adjustment of only three optical elements. The entire procedure, including optimization, can be completed in minutes. This flexibility is particularly useful in large research groups or shared laser facilities, where the same laser may be used for several very different experiments in the same week.

In both picosecond and femtosecond configurations, the pulse duration can be minimized to the transform limit by adjustment of a single external knob that controls GVD (group velocity dispersion) compensation. The pulse duration can be as short as <35 fs in the femtosecond regime and as long as 100 ps in the picosecond configuration.

**Millennia:
The Ultimate Pump Laser**

In 1995, Millennia® was the first all-solid-state laser to provide high power CW visible output and immediately became the first choice for pumping Ti:sapphire lasers. While many of the first generation Millennia lasers have been operated for years without ever requiring a single service call, the latest Millennia lasers takes this reliability to an even higher level. Orders of magnitude more rugged and reliable than a lightbulb, Millennia is the best turnkey source of pump light available today. The sealed cavity design never needs adjustment, and produces the ideal combination of excellent spatial mode (TEM_{00}), beam pointing and ultra-low-noise output. With a choice of either 5 or 10 watts at 532 nm, this compact laser is ideal for the crowded environment typical of research labs, providing the smallest available footprint size, and with no requirement for elaborate mounting or cooling interfaces.

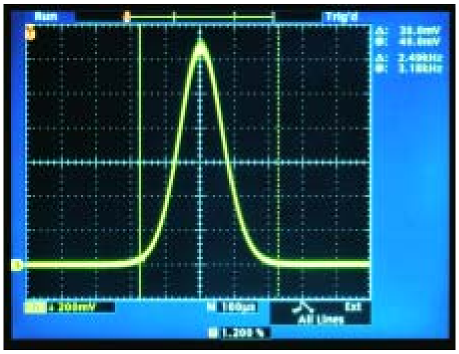
With its proven reliability, superior performance, and small footprint, Millennia is the ideal pump source for your Tsunami.

State of The Art Performance

	Average Power	Pulsewidth	Pulse Energy	Tuning Range**	Nominal Rep Rate
With 10 W Pump*					
Femtosecond Configuration	1.5 W @ 800 nm	<100 fs	~15 nJ	700-1000 nm	80 MHz
Picosecond Configuration	1.5 W @ 800 nm	< 2 ps–100 ps	~15 nJ	700-1000 nm	
With 5 W Pump*					
Femtosecond Configuration	> 0.7W @ 800 nm	< 100 fs	~8 nJ	710-980 nm	80 MHz
Picosecond Configuration	> 0.7W @ 800 nm	< 2 ps–100 ps	~8 nJ	710-980 nm	

** All specifications refer to pumping with a 532 nm Millennia laser.*
*** Tuning range with single broadband optics set, 690–1080 available with extra optics option.*

The story of Tsunami is not just about reliability, flexibility and ease of use. Tsunami also provides state-of-the-art performance to meet the needs of even the most demanding femtosecond and picosecond applications, such as pump/probe spectroscopy, time-correlated single photon counting and multiphoton microscopy.



Autocorrelation trace of typical femtosecond Tsunami pulse.

Figure A. Tsunami femtosecond cavity layout.

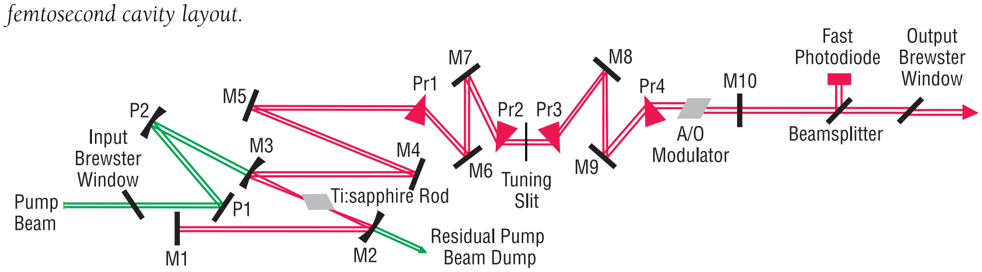
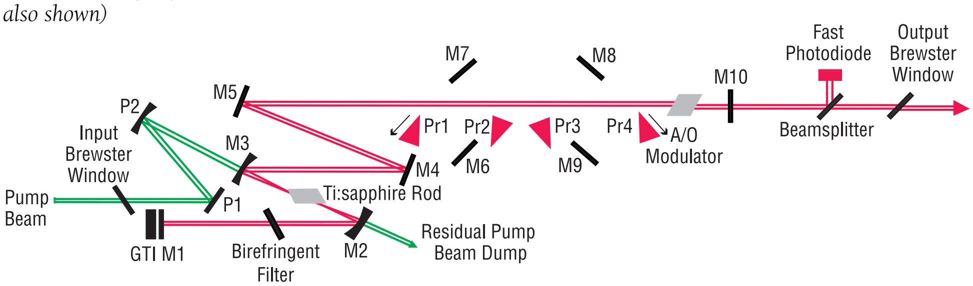


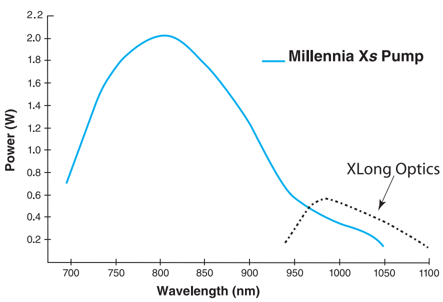
Figure B. Tsunami picosecond cavity layout (femtosecond optics also shown)



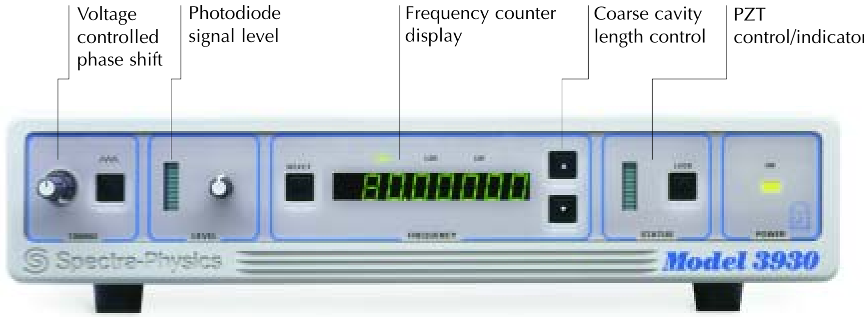
Advanced Performance For Your Research

Broadband™ Optics

A mode-locked Ti:sapphire laser requires cavity mirrors with very high reflectivity, low scatter, and a linear GVD function — a combination which is notoriously difficult to design and fabricate in a broadband format. Because we fabricate our own laser optics at Spectra-Physics, we had the experience and resources to successfully address this challenge and introduced Broadband Optics for Tsunami in 1998. These optics now allow complete tuning of Tsunami with a single mirror set, greatly simplifying the operation of the laser, and saving valuable time for your experiments.



The latest thin film coating technology from Spectra-Physics enables a single mirror set to cover the entire Ti:sapphire tuning range.



The Lok-to-Clock accessory allows Tsunami to be externally synchronized to better than ± 0.5 ps.

Lok-to-Clock®

Because Tsunami has a stable Invar cavity and uses predictable regenerative mode-locking, it is possible to reliably synchronize the laser pulses to other lasers and laboratory equipment using the optional Lok-to-Clock accessory. This system actively stabilizes the cavity length by automatic translation of the cavity high reflector and by fine adjustment of a pzt-mounted fold mirror. The control unit generates a synchronized reference signal which can be used to trigger other pieces of lab instrumentation in phase with the Tsunami output. The unit also has a high-speed input which can be used to slave the laser pulse to a reference pulse train from another laser (including a second Tsunami) or another oscillator, for example in pump-probe spectroscopy. In both modes of operation, the typical timing jitter is ± 0.5 ps or less.

The utility of Lok-to-Clock can be further enhanced by the optional 3931 variable delay generator. This accessory utilizes high speed digital electronics to provide a delay in the synchronization pulse that can be varied from less than 1 psec up to 12 nsec. The delay can be controlled through a software interface, enabling automated data acquisition.

Professor Enrico Gratton and Research Associate Nicholas Barry rely on the Lok-to-Clock feature to synchronize their Tsunami laser with data acquisition electronics.

Professor Enrico Gratton
University of Illinois, Urbana-Champaign

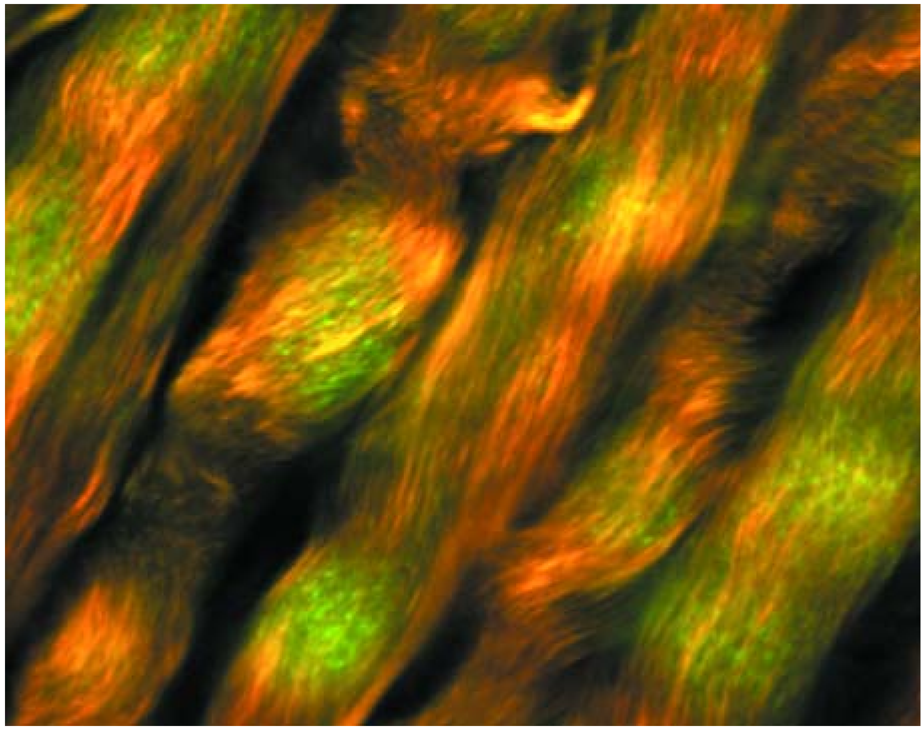
Professor Enrico Gratton and co-workers at the Department of Physics, University of Illinois, Urbana-Champaign utilize the Lok-to-Clock feature in their fluorescence studies on the dynamics of molecular systems of bio-physical interest. Gratton notes that, "We use Lok-to-Clock to synchronize the laser repetition rate with the acquisition electronics in our frequency-domain two-photon excitation microscope to obtain fluorescence lifetime images. In our experience, Lok-to-Clock is a stable, easy to use accessory of the Tsunami system. We interface it with the rest of the frequency-domain electronics by simply connecting the 10 MHz reference from the Lok-to-Clock module with the reference input of the frequency synthesizer used by the RF electronics."

Multiphoton Imaging Made Simple

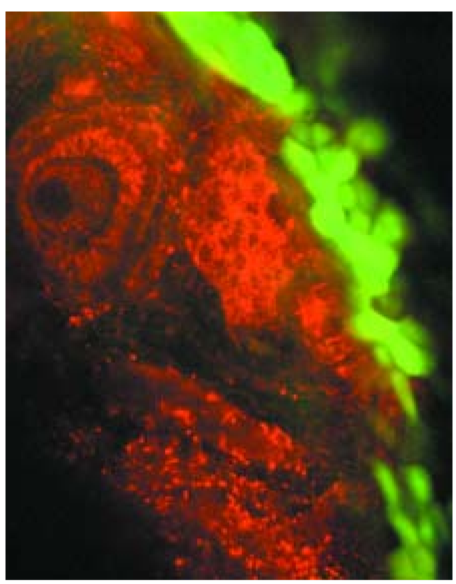
The simplicity and solid-state reliability of Tsunami provide turnkey access to ultrafast laser pulses. Thus, researchers who require ultrafast pulses no longer need to be experts in laser technology. This development has not only simplified "traditional" ultrafast applications such as pump/probe spectroscopy, but has enabled new applications that would not have been practical with traditional laser technology. Nowhere is this more evident than in multiphoton imaging, a technique first demonstrated in 1990 by Denk, Strickler and Webb.

In multiphoton microscopy, a laser beam is directed through an optical microscope and tightly focused into the sample. At the beam waist, the fluence is high enough to drive non-linear effects such as multiphoton absorption. In the case of two photon excitation, this allows a near-infrared wavelength to be used to excite blue fluorophores, for example. Because these non-linear effects only occur at the beam waist, this technique provides natural z axis discrimination without the need for any confocal aperture. By scanning the laser spot, a three dimensional image or slice can be rapidly acquired. Compared to confocal laser scanning microscopy, this technique can be less destructive to the sample, results in lower background, and can be used to study thick samples.

There are now many variants on this technique, including multifocal excitation, SHG (second harmonic generation) imaging of intrinsic proteins such as collagen or of membrane potential probes, THG (third harmonic generation) imaging of transparent membranes, and two-photon optical beam induced current (OBIC) imaging. The majority of these applications rely on Tsunami as the laser of choice.



Second harmonic (SHG) image of a tendon from mouse. Excitation 780 nm (SH-390 nm). Green and red pseudocolor are SH collected in epiand trans modes, respectively. (R.Williams, W. Zipfel, Cornell University.)



GFP transfected epithelial cells on a mouse ovary in an ovarian cancer model system. Green pseudo-color is eGFP, red pseudocolor tissue intrinsic fluorescence (400 to 500 nm). (R.Williams, K.C. Choi, A. Nikitin, and W. Zipfel, Cornell University.)

Tsunami and Multiphoton Imaging

Dr. Warren Zipfel of Cornell University is a leading researcher in the field of multiphoton microscopy. "We operate six Tsunami lasers within the Developmental Resource for Biophysical Imaging and Opto-Electronics (DRBIO). We are an NIH-funded instrumentation development resource, where researchers with a variety of backgrounds bring their imaging experiments. Tsunami has several features that make it an invaluable tool for this type of research environment. It offers a uniquely broad tuning range, it can be operated around the clock for days and weeks on end, and it is remarkably simple to operate. In fact, we typically only need to provide 10 minutes of training, before a new user is ready to take data."

A Family Of Ultrafast Accessories

Spectra-Physics offers a full range of Tsunami accessories and complementary ultrafast products, to customize the laser output, in terms of wavelength, pulse repetition rate, timing/synchronization and pulse energy.

Lok-to-Clock.

This unit allows Tsunami(s) to be synchronized with other pulsed light sources with a jitter of ±0.5 ps or better—see p.6 for details.

Pulse Selector/Frequency Doubler.

The model 3980 is a versatile accessory that is available as a pulse selector or frequency doubler. As a pulse selector, this unit allows the pulse repetition rate to be set anywhere between single shot and 8 MHz, which is useful for photon correlation/lifetime studies of long-lived excited states. As a frequency doubler, the 3980 provides simple output conversion to blue and near-UV wavelengths.

The 3980 provides access to short wavelengths and a variable repetition rate.

Synchronously Pumped OPO.

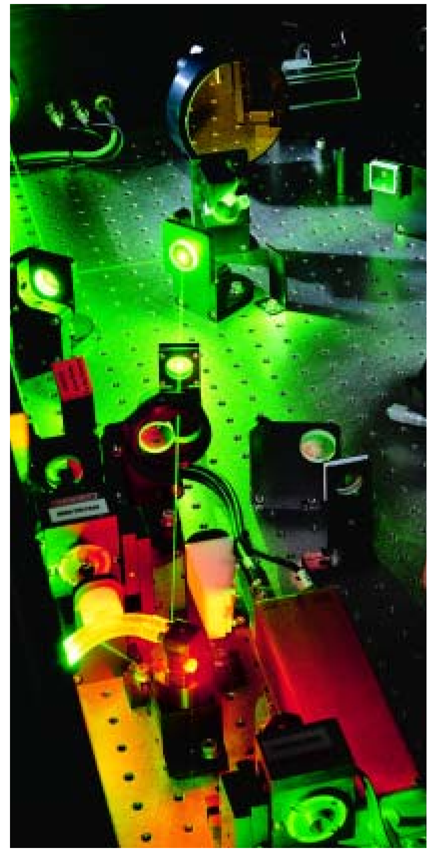
At the other end of the spectrum, the Opal optical parametric oscillator, provides tunable femtosecond output throughout the near-IR (1.1–2.6 µm). These wavelengths are particularly useful for studying atmospheric gases, semiconductors and fiber optic components.

GWU Flexible Harmonic Generator.

The GWU FHG is a compact accessory containing several non-linear crystals for harmonic generation. This unit provides simple access to second, third and fourth harmonic wavelengths, allowing direct excitation of highly excited states and blue/UV chromophores.

Regenerative Amplifiers.

In some applications a high pulse energy is more important than a high repetition rate. The performance of Tsunami can be extended to this domain by use of a regenerative amplifier. Spectra-Physics offers a choice of amplifiers— Spitfire and TSA. Spitfire delivers up to 2 mJ pulses at repetition rates up to 5 kHz. TSA provides pulse energies between 2 and 50 mJ at a 10 Hz rep rate. These high energy pulses are well-suited to studying photochemical and photophysical events with inherently low signal-to-noise.



Regenerative amplifiers such as the Spitfire deliver higher pulse energies at lower repetition rates.

OPA-800C.

The utility of the amplified pulses can be further extended by the OPA-800C. This optical parametric amplifier provides both femtosecond and picosecond pulses with microjoule energy that are tunable from 240 nm to 10 µm. These high energy tunable pulses are used in non-linear optical techniques.

Spectra-Physics

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