UPM Series

Ultrashort Pulse Measurement System

Newport's **UPM Series Ultrashort Laser Pulse Measurement Device** is able to completely characterize the pulse, yet maintains experimental simplicity as opposed to the traditional autocorrelator. It also yields the most complete measurement technique of ultrashort laser pulses ever. The Newport UPM device operates alignment-free, requires only a few simple optical elements, and features an operating range that includes that of most ultrafast Ti:Sapphire and solid-state lasers and amplifiers.

Unlike other pulse-measurement devices, Newport's UPM is very easy to use. It comes pre-aligned, and aligning your beam into it is easy. Simply set the switch for the UPM to measure the beam spatial profile, connect the camera output to a video monitor or frame-grabber, send a fraction of your beam into it, and walk your beam to the center of the camera. Then switch to the temporal mode and the UPM is already generating Frequency-Resolved Optical Gating (FROG) traces of pulses!

The UPM Series yields the pulse intensity and phase vs. time, spectrum and spectral phase with great accuracy and reliability, making no assumptions about the pulse. The UPM device will not become misaligned for the simple reason that there are no alignment knobs to turn! And it's very tolerant to small displacements of the input beam.

In addition, the UPM Series also simultaneously measures spatio-temporal distortions, such as spatial chirp and pulse-front tilt, which occur in most ultrashort pulses but are almost never measured. The UPM Series is the most accurate diagnostic tool ever developed for these distortions and the only commercially available device capable of measuring them. In addition, it also yields the beam spatial profile and the pulse absolute wavelength; and with one of the available FROG pulse-retrieval software packages, it does all this in real time.

Frequency-Resolved Optical Gating

Since its introduction about a decade ago, Frequency-Resolved Optical Gating (FROG) has evolved into a powerful technique for measuring and characterizing ultrashort laser pulses. FROG is any autocorrelation-type measurement in which the autocorrelator signal beam is spectrally resolved, or in other words, FROG techniques add a spectrometer to an autocorrelator (Fig. 3).

Instead of measuring the autocorrelator signal energy vs. delay, which yields an autocorrelation, FROG involves measuring the signal spectrum vs. delay, which is a spectrogram. A graphical depiction of a spectrogram is shown in Fig. 1, where a piece of a linearly chirped Gaussian pulse is being gated out by a rectangular gate function.

Applications

- Ultrashort laser pulse measurement
- Measuring shaped pulses
- Measurements Include
  - Pulse intensity and phase vs. time
  - Pulse spectrum and spectral phase vs. wavelength
  - Beam spatial profile
  - Spatial chirp
  - Pulse-front tilt
  - Autocorrelation
- No assumptions
- No alignment
- Easy to use
- High sensitivity
- Real-time operation

For more details about the FROG technology, please visit www.newport.com and search for 'UPM'.

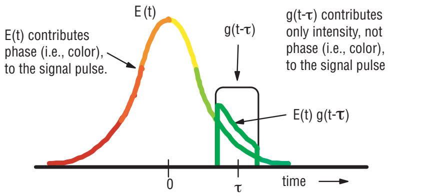


Figure 1—Graphical depiction of the spectrogram. A gate function gates out a piece of the waveform (here a linearly chirped Gaussian pulse), and the spectrum of that piece is measured or computed. The gate is then scanned through the waveform and the process repeated for all values of the gate position (i.e., delay).

The spectrogram is a highly intuitive display of a waveform. Some examples of spectrograms are shown in Fig. 2, where you can see that the spectrogram intuitively displays the pulse instantaneous frequency vs. time. Pulse intensity vs. time is also evident in the spectrogram. Importantly, knowledge of the spectrogram of E(t) is sufficient to essentially completely determine E(t) (except for a few unimportant ambiguities, such as the absolute phase, which are typically of little interest in optics problems).

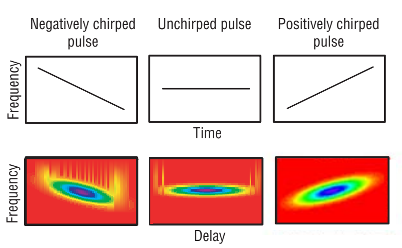


Figure 2—Spectrograms (bottom row) for linearly chirped Gaussian pulses. The spectrogram reflects the pulse frequency vs. time. It also yields the pulse intensity vs. time.

How is this better than autocorrelation, which also involves gating the pulse with itself (but without any spectral resolution)?

Consider an SHG autocorrelator, where the signal field is $E_{sig}(t,\tau) = E(t)E(t-\tau)$. Spectrally resolving yields the Fourier Transform of the signal field with respect to time. The squared magnitude is the quantity that is actually measured, so the FROG signal trace is given by

$$I_{FROG}(\omega,\tau) = \left| \int_{-\infty}^{\infty} E(t)\, E(t-\tau) e^{-i\omega t}\, dt \right|^2$$

Note that the FROG trace is a spectrogram in which the pulse gates itself. So making a FROG trace yields is a very intuitive measure of the pulse. But, we are still left with the problem of retrieving the pulse intensity and phase from its spectrogram.

This inversion problem is well known. It is called the *two-dimensional phase-retrieval problem*. This yields an essentially unique solution and is a solved problem. Indeed, it is solved in a particularly robust manner, with many other advantageous features, such as insensitivity to noise and feedback regarding the validity of the data.

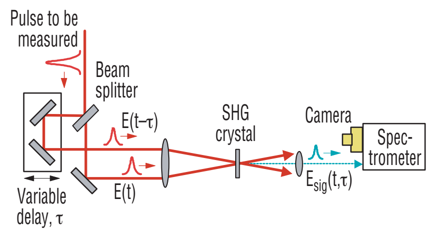


Figure 3—SHG FROG, the most common and most sensitive version of FROG.

There are many different beam geometries for FROG. Essentially any spectrally resolved autocorrelation works, and other geometries do also. The most common and most sensitive FROG beam geometry is Second-Harmonic-Generation (SHG) FROG. (Newport's UPM Series is a type of SHG FROG.) The SHG FROG beam geometry is shown in Fig. 5. SHG FROG traces are shown in Fig. 4, which shows that SHG FROG has symmetrical traces and hence has an ambiguity in the direction of time. And Fig. 5 shows an SHG FROG measurement of one of the shortest pulses ever created.

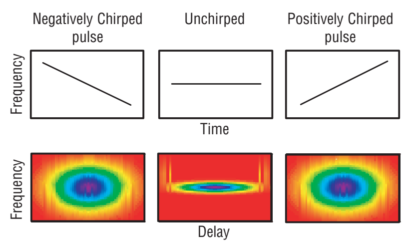


Figure4— SHG FROG traces for linearly chirped pulses. Note that the traces are necessarily symmetrical, so the direction of time is not determined. This and a few "trivial" ambiguities are the only known undetermined parameters in SHG FROG.

FROG is extremely accurate. Any known systematic error in the measurement can be modeled in the algorithm. Also, unlike autocorrelation techniques, FROG completely determines the pulse with essentially infinite temporal resolution. It does this by using the time domain to obtain long-time resolution and the frequency domain for short-time resolution.

Another useful and important feature that's unique to FROG is the presence of feedback regarding the validity of the measurement data. For more information regarding this, please contact Newport.

In practice, FROG has been shown to work very well in the IR, visible, and UV. It has been used to measure pulses from a few fs to many ps in length and from fJ to mJ in energy. It can also measure simple near-transform-limited pulses to extremely complex pulses with time-bandwidth products in excess of 1000. FROG has proven to be a very general technique that works. If an autocorrelator can be constructed to measure a given pulse, then making a FROG is straightforward since measuring the spectrum of it is usually easy.

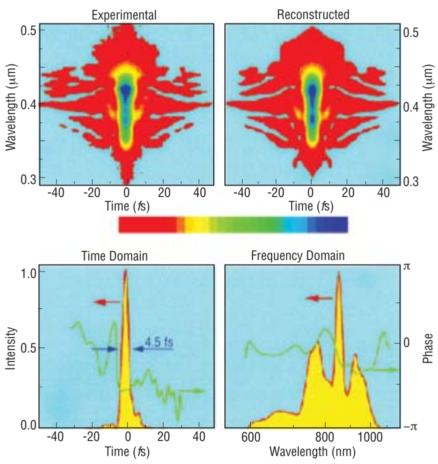


Figure5— One of the shortest events ever measured, a 4.5 fs pulse, measured using SHG FROG. Baltuska, Pshenichnikov, and Weirsma, J. Quant. Electron., 35, 459 (1999).

Software Packages

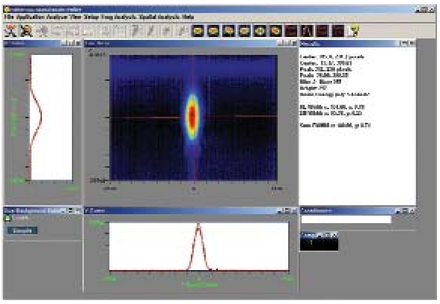
Mesa Photonics VideoFROG

VideoFROG, combined with Newport's UPM GRENOUILLE, is an oscilloscope for ultrashort laser pulses, providing the time domain and frequency domain intensity and phase in the blink of an eye. VideoFROG provides high-resolution retrievals in a real-time package. Its 30 Hz maximum pulse-retrieval rate is frame-grabber limited. VideoFROG also provides beam spatial-profiling and computes the spatio-temporal distortions, spatial chirp and pulse-front tilt, from the GRENOUILLE trace. VideoFROG is not just a real-time diagnostic, but it also allows convenient and sophisticated data acquisition for third-party plotting and analysis packages. AVI movie capture allows VideoFROG to be used for presentations and demonstrations. Additional features include 3-D plotting, resizable windows, plot zooming, background subtraction, averaging for added dynamic range, hard-copy output, full-time video monitoring, software triggering for low-rep-rate laser systems, adjustable video contrast and offset for maximum performance, and real-time data output to other programs.

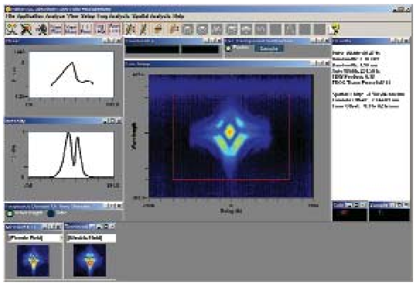
Femtosoft QuickFROG

QuickFROG operates seamlessly with Newport's UPM Devices. Calibrations for UPM devices are preconfigured, so setting up your software is as easy as picking a UPM model name from a list - once. Capable of 25 retrievals per second, QuickFROG applies the powerful Generalized Projections algorithm, along with the venerable "Basic" FROG algorithm, running hundreds of iterations per second to ensure rapid and reliable pulse convergence. QuickFROG also yields the beam spatial profile and the spatio-temporal distortions, spatial chirp and pulse-front tilt. Femtosoft algorithms are the gold standard of FROG retrieval, so you can be assured of the best possible convergence for your pulses.

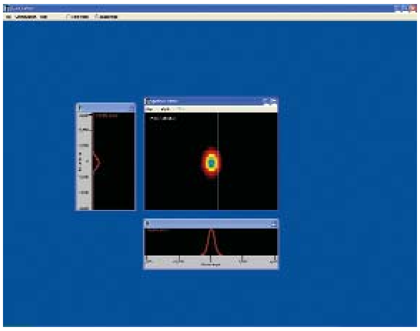
Mesa Photonics VideoFROG	Femtosoft QuickFROG
Windows 98, NT, 2000 and XP Pentium II, III or IV processor 128 MB RAM, 30 MB HD space Available PCI slot or FireWire port (depending on model selected)	Windows 2000 and XP Pentium III, 500 MHz (minimum) Pentium 4, 1GHz (preferred) 256 MB RAM, 30 MB HD space FireWire port



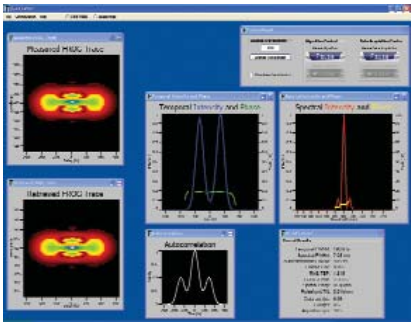
Mesa Photonics VideoFROG spatial profile measurement



Mesa Photonics VideoFROG temporal profile measurement



Femtosoft QuickFROG spatial profile measurement



Femtosoft QuickFROG temporal profile measurement

Specifications

	UPM-8-10	UPM-8-20	UPM-8-50	UPM-8-200 (1)	UPM-8-500 (1)	UPM-10-100 (1)	UPM-15-100
Wavelength Range (nm)			700 - 1100			900 - 1100	1320 - 1620
Pulse Length Range (fs)	10 - 100	18 - 180	50 - 500	150 fs - 2 ps	500 fs - 5 ps	100 fs - 1 ps	100 fs - 1 ps
Maximum Pulse Bandwidth (nm)	150	100	35	20	10	10	90
Spectral Resolution (nm)	2	4	2	0.2	0.1	0.1	1
Pulse Complexity	Time-Bandwidth Product < 10						
Intensity Accuracy	2%						
Phase Accuracy	0.01 rad (intensity-weighted phase error)						
Sensitivity (at 10^8 pps)	50 mW (500 pJ)	10 mW (100 pJ)					
Sensitivity (at 10^3 pps)	500 μW (500 nJ)	100 μW (100 nJ)					
Single-Shot Operation	No	Yes					
Sensitivity (single-shot)	N/A	1 μJ					
Spatial Profile Accuracy	<0.2%						
Spatial Chirp Accuracy (dx/dλ)	1 μm/nm						
Pulse-Front Tilt Accuracy (dt/dx)	0.05 fs/mm						
Required Input Polarization	Any (just rotate the UPM)						
Required Input Beam Diameter	2 - 4 mm						
Input Beam Lateral Displacement Tolerance	1 mm						
Set-Up Time	~ 10 minutes						
Dimensions [in. (cm)]	13 x 3.0 x 6.50 (33 x 7.5 x 16.5)		13 x 1.8 x 4.53 (33 x 4.5 x 11.5)	13 x 3.0 x 6.50 (33 x 7.5 x 16.5)		13 x 1.8 x 4.53 (33 x 4.5 x 11.5)	
Weight [lb (kg)]	6.6 (3)		2.6 (1.2)	6.6 (3)		2.2 (1)	

Ordering Information

Model	Description
UPM-8-10	Ultrashort Laser Pulse Measurement Device, 10 - 100 fs Range, 800 nm
UPM-8-20	Ultrashort Laser Pulse Measurement Device, 18 - 180 fs Range, 800 nm
UPM-8-50	Ultrashort Laser Pulse Measurement Device, 50 - 500 fs Range, 800 nm
UPM-8-200	Ultrashort Laser Pulse Measurement Device, 150 fs - 2 ps Range, 800 nm
UPM-8-500	Ultrashort Laser Pulse Measurement Device, 500 fs - 5 ps Range, 800 nm
UPM-10-100	Ultrashort Laser Pulse Measurement Device, 100 fs - 1ps Range, 1000 nm
UPM-15-100	Ultrashort Laser Pulse Measurement Device, 100 fs - 1ps Range, 1550 nm
UPM-SP-1-PCI	Mesa Photonics VideoFROG with PCI Frame Grabber
UPM-SP-1-FIRE	Mesa Photonics VideoFROG with FireWire Frame Grabber
UPM-SP-2	Femtosoft QuickFROG with FireWire Frame Grabber

NEW

Laser Beam Profiler

Post and base sold separately

- High dynamic range through automatic gain and shutter control
- 190 - 1100 nm, 1310 nm and 1550 nm spectral ranges available (with different cameras)
- 2D/3D intensity plots and X and Y profiles
- Real-time beam profile characteristics and statistical tables
- Color and size selection
- Video capture with playback for future analysis
- Trigger level and camera gain software controllable for pulsed lasers

Newport's **LBP Series Laser Beam Profiler** has evolved with the introduction of its *Automatic Gain and Shutter Control* to improve performance and ease of use. The LBP series laser beam profiler is a powerful software driven device with complete beam diagnostic measurement features, including a multi-measurement routine to increase signal integrity for higher accuracy results. For continuous or pulsed laser beams, it provides an extensive range of graphical presentations and analysis capabilities of laser beam parameters such as: beam width, shape, position, power and intensity profiles.

The CCD camera is equipped with a built-in filter wheel, enabling the use of up to four, 0.5 in. diameter attenuators. Three attenuators are included with the system: **LBP-NG4, LBP-NG9 and LBP-NG10**, while additional ones may be purchased separately. The camera can be post-mounted via a single 8/32-threaded hole, centered directly below the sensor surface. Other accessories include a 2.5X beam reducer, expanding capability to measure beams ≈11 mm in diameter.

Available in both PCI and USB2.0 formats, the board resides in your PC desktop computer. Using the LBP software, included on an accompanying CD, your PC becomes a powerful beam diagnostic tool. This user-friendly system presents graphical and numerical information for an intuitive interpretation of data in real-time.

Applications

- Laser beam optimization
- Gaussian fit analysis
- Quality control
- Beam alignment