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# FREQUENTLY ASKED QUESTIONS

## About Swamp Optics

**What is Swamp Optics?**
Atlanta-based Swamp Optics develops, markets, and supports ultrashort-laser-pulse measurement devices. Swamp Optics' products are used by researchers, scientists, and engineers involved in variety of endeavors for which ultrafast lasers play an important role, including materials science, electronics, and biomedical research. Swamp Optics was founded in 2001 by Rick Trebino, a leading scientist in the field of ultrafast optics and a specialist in ultrashort-laser-pulse measurement.

**What is Swamp Optics' unique value proposition?**
Swamp Optics' products incorporate frequency-resolved-optical-gating (FROG) technology, a proven method for accurately determining critical pulse information (in particular, the intensity and phase vs. time and frequency). Co-invented by Swamp Optics' founder, FROG is the subject of five patents. It is rigorous, general, and accurate, and it is a widely used technique with many applications. The company's FROG-based products are the only devices available to fully characterize an ultrashort laser pulse, yielding the pulse's time-dependent (or, equivalently, frequency-dependent) intensity and phase, plus spatio-temporal distortions (spatial chirp and pulse-front tilt), absolute wavelength, and the beam spatial profile.

**What are Swamp Optics' offerings?**
Swamp Optics' flagship product is GRENOUILLE (pronounced gra-NEW-ee), a highly compact FROG device combining full-information pulse measurement with experimental simplicity; GRENOUILLE operates alignment-free, uses only a few simple optical elements, and requires no more than about ten minutes to set up. It features an operating range that includes that of most ultrafast Ti:Sapphire and solid-state lasers and amplifiers. Multiple GRENOUILLE products are available, including the Model 8-20, for pulses as short as 20 femtoseconds (fs), and the Model 8-50, for pulses as short as 50 fs.

**What are typical applications for Swamp Optics products?**
Ultrashort laser pulses—pulses with durations of about 10 picoseconds or less—have many applications in biology, chemistry, physics, and electrical engineering. They commonly serve to explore kinetics in proteins and as ultrafast probes in electronic circuits, leading to the development and testing of highly advanced biomedical products, electronic circuitry, and semiconductors.

To produce the desired final ultrashort pulse shape, laser pulses are routinely dispersed, stretched, and eventually compressed to their shortest possible width. The process typically introduces significant phase distortions and spatio-temporal distortions—like spatial chirp and pulse-front tilt—and other flaws that can seriously impair research data. Until recently, these distortions were difficult, if not impossible, to measure.

With the introduction of FROG and GRENOUILLE devices, comprehensive characterization of ultrashort laser pulses is both feasible and accurate. A FROG or GRENOUILLE can operate alone, yielding the beam spatial profile and a FROG-generated pulse spectrogram (a plot of signal intensity vs. frequency and time, and which contains all of the information about the laser pulse) on a video monitor, or with a frame-grabber and FROG software, yielding the precise pulse intensity and phase vs. time and the pulse spatio-temporal characteristics.

**How are Swamp Optics products distributed?**
Newport Corporation (www.newport.com) is the worldwide distributor for Swamp Optics products. Swamp Optics' GRENOUILLEs are sold by Newport as UPM (Ultrafast Pulse Measurement) devices.

## About Swamp Optics Products

**What has been the conventional method for measuring or characterizing laser pulses?**
Autocorrelation was the first technique used to measure the intensity vs. time of an ultrashort laser pulse. Invented in the 1960s, autocorrelation uses a laser pulse to measure itself, splitting the pulse into two, variably delaying one with respect to the other, and spatially overlapping them in some instantaneously responding nonlinear optical medium. Since their introduction, autocorrelators have had severe limitations: at best, they yield a poor measure of a laser pulse's width, and, worse, they say nothing at all about the pulse's phase or spatio-temporal distortions. Moreover, autocorrelators are complex, difficult to set up, and no algorithm exists for retrieving the pulse intensity or any other information from an autocorrelation.

**What makes FROG and GRENOUILLE better than other measurement methods?**
Unlike autocorrelation, GRENOUILLE measures the complete pulse intensity and phase vs. time (and the spectrum and spectral phase) and does not require any assumptions about the pulse shape. In addition, GRENOUILLE has many additional advantages. It combines this full-information pulse measurement with much-needed experimental simplicity. It has few elements and so is inexpensive and compact. It also operates single-shot. And it is more sensitive than autocorrelators. In addition, several feedback mechanisms on the measurement accuracy that are already present in the FROG technique work with GRENOUILLE, allowing confirmation of—and confidence in—the measurement. And it measures the beam spatial profile. Even better, it measures the most common spatio-temporal pulse distortions, spatial chirp and pulse-front tilt. But best of all, GRENOUILLE is extremely simple to set up and align: it involves no beam-splitting, no beam-recombining, and no scanning of the delay, and so has zero sensitive alignment degrees of freedom.

**How reliable are FROG and GRENOUILLE?**
FROG is universally considered the most reliable ultrashort-pulse-measurement technique. The shortest pulse ever generated at the time of this writing (4.0 fs) was measured using FROG. Indeed, autocorrelation measurements (interferometric or otherwise) are no longer acceptable for determining a pulse length. GRENOUILLE is a simplified version of FROG and has similar performance, although it can't currently be used for pulses shorter than ~15 fs. Swamp Optics will soon offer a FROG device for measuring pulses as short as 10 fs.

**Do FROG and GRENOUILLE require any assumptions about the pulse shape?**
Absolutely not. FROG and GRENOUILLE yield the pulse intensity and phase vs. time (and vs. frequency) even for complex pulses.

**How compact is GRENOUILLE?**
So compact, you can carry it in your hip pouch. The GRENOUILLE Model 8-50, for example, measures 33 cm x 4.4 cm x 11.5 cm and weighs just 1.2 kg.

**Can measuring only the autocorrelation and spectrum (the so-called TIVI and PICASO methods) determine a pulse intensity and phase?**
Occasionally this works; usually it doesn't. It's unpredictable and akin to relying on a thermometer whose temperature reading might or might not be right.

**I have an autocorrelator and spectrometer; must I buy a FROG or GRENOUILLE?**
No. Just place the spectrometer behind the autocorrelator, and measure the spectrally resolved autocorrelation, and you have a FROG. You can then just buy the FROG software from Mesa Photonics, Femtosoft, or Spiricon. Swamp Optics is happy to provide free advice to anyone in this situation.

**Is there an ambiguity in the direction of time in GRENOUILLE?**
Yes, this is the case in all SHG-based pulse-measurement devices. Unlike autocorrelation, which has infinitely many ambiguities, the direction-of-time ambiguity is essentially the only one in GRENOUILLE. If you'd like to remove it, just place an etalon in the beam before the GRENOUILLE [this is our POLKADOT (Procedure for Objectively Learning the Kalibration And Direction Of Time] option, which will be available soon. You can check out our paper on the subject: Zeek, E., A. P. Shreenath, M. Kimmel, and R. Trebino (2002). "Simultaneous automatic calibration and direction-of-time removal in frequency-resolved optical gating," *Applied Physics B (Lasers and Optics) B74(Suppl.)*, p.S265-71.

**I understand that optics, crystals, and cameras aren't so broadband that one GRENOUILLE will work for all wavelengths, but will there be GRENOUILLEs for other wavelength ranges?**
Yes. In fact, GRENOUILLEs for visible and the 1- to 2-micron wavelength range are on the way.

**I need to measure supercontinuum, and it's a very complex pulse. Autocorrelator company reps just laughed when I asked about this. Can a Swamp Optics device measure it?**
Yes. Continuum is the most complex ultrafast light ever generated, and only Swamp Optics' FROG devices can measure it.

**Why is GRENOUILLE so much less expensive than an autocorrelator? Am I really getting more for less?**
GRENOUILLE is a very recent invention that takes advantage of two new and clever pulse-measurement ideas: a thick crystal as a spectrometer and the Fresnel biprism for beam-splitting and recombining. Swamp Optics has the exclusive rights to the relevant patent, so you are indeed getting more—for less.

**Can I use a FROG or GRENOUILLE device without buying anything else?**
Yes. The FROG trace is a spectrogram of the pulse, a measure often preferred to the intensity and phase (especially in acoustics). Its horizontal width is a measure of the pulse width; its vertical width is a measure of its spectral width; and its area is a measure of the time-bandwidth product. You can, for example, align your laser in real time for the shortest pulse length by minimizing the horizontal width.

**Another company's pulse-measurement device requires the entire beam to operate. Is this true for FROG and GRENOUILLE?**
No. FROG and GRENOUILLE are much more sensitive than other intensity-and-phase methods. GRENOUILLE, for example, requires only about 10 milliwatts of average power from a Ti:Sapphire oscillator and about 100 microwatts from a regen.

**Okay, so FROG yields the intensity and phase vs. time. How about the spectrum, spectral phase, and group delay?**
Simply Fourier transforming the time-domain electric field (fully determined by the intensity and phase vs. time) yields their frequency-domain equivalents, the spectrum and spectral phase. The derivative of the spectral phase is the group delay. The FROG software gives all of these quantities, except the group delay, which is easily calculated from the spectral phase.

**Are there software tools for analyzing the pulse spectrogram output by GRENOUILLE?**
Yes. A substantial amount of useful quantitative information can be retrieved from a GRENOUILLE trace and analyzed using third-party FROG software. These programs compute and display the pulse intensity vs. time, the phase vs. time, the spectrum, the spectral phase, the spatial profile, the spatial chirp, and pulse-front-tilt. (Of course, the autocorrelation is also available, which is trivially derived from the intensity, although, of course, there's no need to compute it once the intensity is known.) Two FROG software packages are available: Mesa Photonics' VideoFROG and Femtosoft's FROG Code (which operates with the Spiricon frame-grabber).

**Which pulse-analysis option is better for me, Mesa Photonics' VideoFROG or Spiricon/Femtosoft?**
Mesa Photonics' VideoFROG is specifically designed to operate with GRENOUILLE. It performs the retrieval of the pulse intensity and phase vs. time and frequency as rapidly as 20 pulses per second (depending on the computer) from the GRENOUILE trace. It will also automatically compute the pulse spatio-temporal distortions from the measured trace. It also contains spatial-profile software, allowing you to see the beam spatial profile with just a flip of a switch. It's one integrated program that matches GRENOUILLE's capabilities.

Spiricon's spatial profile frame-grabber and software comprise one of the world's leading laser beam spatial-profile packages, offering tremendous power and a very user-friendly interface. When measuring the pulse's FROG trace, it allows the trace to be saved as a FROG trace for input into Femtosoft's FROG code for pulse retrieval. Femtosoft's FROG code is the gold standard of pulse-retrieval code and is extremely versatile and complete, yielding numerous additional measures of the pulse that can be retrieved from the intensity and phase. And it determines the pulse spatio-temporal distortions form the GRENOUILLE trace. It also can also be used with other FROG beam geometries that might be required for measuring pulses at unusual wavelengths or very low energies.

**Why do I need the FROG software to determine the pulse intensity and phase when there is no such software to buy with an autocorrelator?**
There is no software for an autocorrelator because it's impossible to determine the intensity or phase from an autocorrelation trace. The autocorrelation doesn't contain enough information to determine these quantities. The FROG trace, on the other hand, does. Of course, as we said above, you can use FROG or GRENOUILLE without the software, and you'd still have a lot more information than there is in an autocorrelation.

**I've heard that the FROG software is complicated. Is this true?**
Yes, the code is complex, but using it isn't. Both the Spiricon/Femtosoft and Mesa Photonics FROG software packages provide the full intensity and phase vs. time and frequency, as well as beam property displays with many

 

options for analysis. And they're very user-friendly. More information, including links to the respective FROG software companies, is available on the Swamp Optics Web site.

**Will I need an all-day intensive training session to use FROG or GRENOUILLE?**
No. Setup is straightforward and takes less than 10 minutes on average.

**Will I need a specialist to come and set up the FROG or GRENOUILLE?**
No. A simple setup procedure and clear instructions make this an easy, do-it-yourself job, even if you have little or no experience with lasers. Without question, GRENOUILLE will be the simplest-to-use device on your optical table, with the possible exception of the screwdriver.

**What does the word "GRENOUILLE" stand for?**
GRENOUILLE stands for "GRating Eliminated No-nonsense Observation of Ultrafast Incident Laser Light E-fields." It's the French word for "frog." We've chosen it to honor the great French and French-speaking scientists who have contributed to the field of ultrashort laser pulse measurement, including Jean-Claude Froehly, J. A. Giordmaine, and Jean-Claude Diels.

**Will GRENOUILLE match my lab's color scheme?**
Yes! GRENOUILLE comes in several beautiful colors: classic black, blood red, bright yellow, sky blue, and emerald green.

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