# NEAR-IR GRENOUILLES

## THE WORLD'S MOST POWERFUL AND EASIEST TO USE ULTRASHORT-LASER-PULSE MEASUREMENT DEVICE

As a **FROG** device, GRENOUILLE yields the pulse intensity and phase vs. time and spectrum and spectral phase with great accuracy and reliability, requiring no assumptions about the pulse. It measures the actual pulse, not the coherent artifact.

In addition, GRENOUILLE also measures the **beam spatial profile**.

What's more, it also simultaneously yields the otherwise-difficult-to-measure spatio-temporal distortions, **spatial chirp** and **pulse-front tilt**, which occur in most ultrashort pulses but are almost never measured. GRENOUILLE is the only commercially available device to measure these distortions and the most accurate diagnostic for pulse-front tilt ever developed.

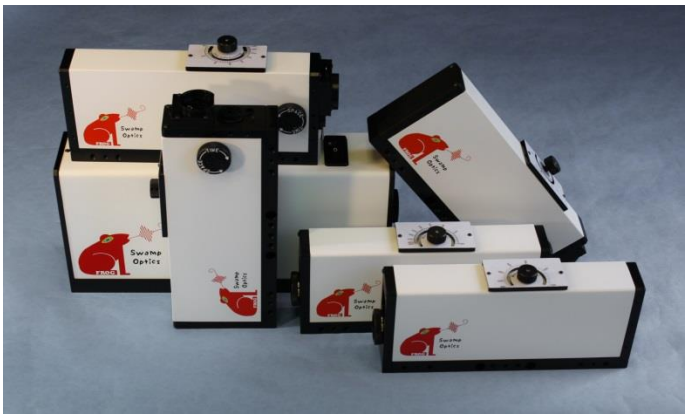
It yields the approximate pulse **absolute wavelength**, too.

Remarkably, GRENOUILLE **needs no alignment—ever!** Even placing it in the beam is amazingly easy.

GRENOUILLE tells you more about your pulse with less effort than ever imagined!

And weighing as little as 1 kg, it's light and compact, with a footprint smaller than a foot!

Note: currently, the Model 8-4-USB is only available as a kit.



## FROG/GRENOUILLE AT A GLANCE

- **The pulse intensity and phase vs. time**
- **The pulse spectrum and spectral phase vs. wavelength**
- **Measurements are of the actual pulse, not the coherent artifact**
- **The beam spatial profile**
- **The approximate spatial chirp**
- **The pulse-front tilt**
- **The autocorrelation**
- **No assumptions**
- **No alignment**
- **High sensitivity**
- **Real-time intensity and phase retrieval**
- **Minimal weight and size**
- **Laptop-friendly**

Swamp Optics FROG

A single GRENOUILLE can measure pulses from a wide variety of sources, from the lowest-energy oscillator to the highest-intensity amplifier.

Voted one of the 100 most important inventions of the year (across all fields) by R&D Magazine, and one of the top 25 optics inventions of the year by Photonics Spectra, GRENOUILLE represents a huge leap forward in ultrashort-pulse-measurement technology.

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## NEAR-IR GRENOUILLE MODELS AND SPECIFICATIONS

| GRENOUILLE model | 8-4-USB (kit) | 8-9-USB | 8-20-USB | 8-50-USB |
|---|---|---|---|---|
| Center-wavelength range | 700 – 1100 nm | | | |
| Pulse-length range @ 800 nm | ~4 – ~80 fs | ~10 – ~100 fs | ~20 – ~200 fs | ~50 – ~500 fs |
| Pulse-length range @ 1050 nm | | ~8 – ~80 fs | ~15 – ~80 fs | ~30 – ~100 fs |
| Delay increment | 0.42 fs/pixel | 0.95 fs/pixel | 0.85 fs/pixel | 1.15 fs/pixel |
| Temporal range[2] | 250 fs | 336 fs | 480 fs | 1.9 ps |
| Spectral resolution @ 800 nm | 4 nm | 2 nm | 1.5 nm | 0.7 nm |
| Spectral resolution @1050 nm | NA | 2.2 nm | 5 nm | 2 nm |
| Spectral range @ 800 nm[2] | 600 nm | 300 nm | 160 nm | 50 nm |
| Spectral range @1050 nm[2] | | 400 nm | 400 nm | 125 nm |
| Pulse complexity | Time-bandwidth product < ~10 | | | |
| Intensity accuracy | 2% | | | |
| Phase accuracy | 0.01 rad (intensity-weighted phase error) | | | |
| Single-shot operation? | Optional[1] | | Yes; both free-running mode & triggered single-shot mode are now standard. | |
| Sensitivity (single-shot) | 0.5 mJ | 0.1 mJ | 1 μJ | |
| Sensitivity (at $10^3$ pps) | 3 mW (3 μJ) | 500 μW (500 nJ) | 100 μW (100 nJ) | |
| Sensitivity (at $10^8$ pps) | 300 mW (3 nJ) | 50 mW (500 pJ) | 10 mW (100 pJ) | |
| Spatial profile accuracy | < 0.2 % (Camera has true 8 bits and 480 x 640 pixels) | | | |
| Spatial chirp accuracy (dx/dλ) | 1 μm/nm | | | |
| Pulse-front tilt accuracy (dt/dx) | 0.05 fs/mm | | | |
| Required input polarization | Any (just rotate GRENOUILLE!) | | | |
| Required input-beam diameter | 2 – 4 mm (collimated) | | | |
| Input-beam lateral-displacement tolerance | > 1 mm | | | |
| Number of alignment knobs | Zero | | | |
| Time to set up | ~ 10 minutes | | | |
| Dimensions (L x W x H) w/camera | 45 cm x 18 cm x 15 cm | 33 cm x 7.5 cm x 16.5 cm | 33 cm x 7.5 cm x 16.5 cm | 33 cm x 4.5 cm x 11.5 cm |
| Weight | 7 kg | 3 kg | 3 kg | 1.2 kg |

1. The Model 8-9-USB can be modified to allow single-shot measurement using a thinner crystal, but this reduces its sensitivity.
2. Temporal and spectral ranges are the full-scale ranges, not the pulse FWHM (which is typically a factor of ~3 smaller).

## ADDITIONAL NOTES

- Spatial chirp is easily revealed by tilt in the otherwise symmetrical measured trace.
- Pulse-front tilt is easily revealed by a displacement of the trace along the delay axis.
- Absolute wavelength is indicated to a few nm by the crystal-angle dial.
- FROG & GRENOUILLE have a (removable) ambiguity in the direction of time. (In contrast, other methods have infinitely many ambiguities.)
- Triggered single-shot operation is now standard on all models, except for the Models 8-4-USB and 8-9-USB, when using an angle-dithered crystal.
- Comparison of the retrieved and measured traces confirms the measurement.
- Input-beam mode quality should be good; GRENOUILLE's spatial-profile measurement helps to ensure this.
- Just connect to your computer's USB port; no power supply needed.
- The Model 8-50-USB has one camera, which is switchable between temporal and spatial profiles. All other Ti:Sapphire FROG and GRENOUILLE models use two cameras for simultaneous display of spatial and temporal profiles.
- Models 8-20-USB, 8-50-USB are GRENOUILLE designs. Models 8-4-USB and 8-9-USB are FROGs with a built-in spectrometer for spectral resolution.

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# IR GRENOUILLEs

## THE WORLD'S MOST POWERFUL AND EASIEST TO USE ULTRASHORT- LASER-PULSE MEASUREMENT DEVICE NOW MEASURES IR PULSES!

Swamp Optics' IR GRENOUILLEs measure pulses with wavelengths from 900 to 1100 nm and 1220 to 1620 nm.

As **FROG** devices, GRENOUILLEs yield the pulse intensity and phase vs. time and the spectrum and spectral phase with great accuracy and reliability, making no assumptions about the pulse or its shape.

GRENOUILLEs measure the actual pulse, not the coherent artifact, which is all that is currently measured by most other methods.

Both devices also yield the **pulse-front tilt** and **spatial chirp**, and the Model 10-100-USB yields the **beam spatial profile**.

GRENOUILLE tells you more about your pulse with less effort than ever imagined!

Remarkably, GRENOUILLEs **need no alignment—ever!** Even placing one in the beam is amazingly easy.

Free-space coupling is standard (in all models), but the Models 15-40-USB and 15-100-USB also include (as standard) fiber coupling for simple integration with fiber-optic systems.

And weighing only about 1 kg, they're light and compact, with a footprint smaller than a foot!

### IR GRENOUILLEs AT A GLANCE

- **The pulse intensity and phase vs. time**
- **The pulse spectrum and spectral phase vs. wavelength**
- **The actual pulse, not the coherent artifact**
- **The beam spatial profile (1μm models)**
- **The spatial chirp**
- **The pulse-front tilt**
- **The autocorrelation**
- **No assumptions**
- **No alignment**
- **Very easy to use**
- **High sensitivity**
- **Real-time intensity and phase retrieval**
- **Minimal weight and size**

A single GRENOUILLE can measure pulses from a wide variety of sources, from the lowest-power oscillator to the highest-intensity amplifier.

Voted one of the year's 100 most technologically significant inventions in 2003 and one of the top 25 new optics products of 2004, GRENOUILLE represents a huge leap forward in ultrashort-pulse-measurement technology.

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# IR GRENOUILLE SPECIFICATIONS

| FROG/GRENOUILLE model | 10-100-USB | 10-300-USB | 15-40-USB | 15-100-USB |
|---|---|---|---|---|
| **Wavelength range** | 0.9 – 1.1 μm | 0.9 – 1.1 μm | 1.22 – 1.65 μm | 1.32 – 1.62 μm |
| **Pulse-length range** | ~0.1 – ~1 ps | ~0.3 – ~3 ps | ~40 – ~400 fs | ~0.1 – ~1 ps |
| **Delay increment (resolution)** | 1.145 fs/pixel | ~4 fs/pixel | 2.25 fs/pixel | 5.41 fs/pixel |
| **Temporal range[1]** | 1.9 ps | 9 ps | 1.9 ps | 3.8 ps |
| **Spectral resolution** | 0.4 nm | 0.4 nm | 3.0 nm | 1.0 nm |
| **Spectral range[1]** | 35 nm | 35 nm | 150 nm | 100 nm |
| **Pulse complexity** | Time-bandwidth product < 10 | | | |
| **Intensity accuracy** | 2% | | | |
| **Phase accuracy** | 0.01 rad (intensity-weighted phase error) | | | |
| **Single-shot operation?** | Yes (free-running mode and triggered single shot are standard) | | | |
| **Sensitivity (single-shot)** | 1 μJ | | | |
| **Sensitivity (at $10^3$ pps)** | 100 μW (100 nJ) | | | |
| **Sensitivity (at $10^8$ pps)** | 10 mW (100 pJ) | | | |
| **Sensitivity (at $10^{10}$ pps)** | 100 mW (10 pJ) | | | |
| **Spatial-profile accuracy** | < 0.2% (8 bits; 480 x 640 pixels) | | NA | |
| **Spatial-chirp accuracy (dx/dλ)** | 1 μm/nm | | | |
| **Pulse-front tilt accuracy (dt/dx)** | 0.05 fs/mm | | | |
| **Required input polarization** | Any (Just rotate GRENOUILLE!) | | | |
| **Fiber-coupling available?** | No | | Yes | |
| **Desired input-beam diameter** | 2 – 4 mm (collimated) | | 2 – 4 mm (if not fiber coupled) | |
| **Input-beam lateral-displacement tolerance** | 1 mm (if not fiber-coupled) | | | |
| **Number of alignment knobs** | Zero | | | |
| **Time to set up** | ~ 10 minutes | | | |
| **Dimensions (L x W x H)** | 33 cm x 4.5 cm x 11.5 cm | | 26 cm x 4.5 cm x 11.5 cm | |
| **Weight** | 1.2 kg | | 1.2 kg | |

1. Temporal and spectral ranges are the full-scale ranges, not the pulse FWHM (which is typically a factor of 3 smaller).

# ADDITIONAL NOTES

- Absolute wavelength is determined to a few nm by the calibrated crystal-angle dial.
- GRENOUILLE is a second-harmonic-generation (SHG) FROG and hence has an ambiguity in the direction of time, but this one-bit ambiguity can be removed easily. (In contrast, autocorrelation has infinitely many non-removable ambiguities.)
- Feedback on measurement quality is obtained from comparison with the retrieved trace.
- Input-beam mode quality should be good (but single transverse mode is not required).
- Free-running operation and triggered single-shot mode are both standard on all models. Just connect the USB cable; no power supply needed.


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