Swamp Optics, LLC.
307 Shire Way
Lawrenceville, GA 30044
+1.404.547.9267
www.swamoptics.com

Swamp Optics Tutorial

GRENOUILLE's pulse-length specifications vary with wavelength!

Like other optical devices, such as spectrometers, GRENOUILLE's specifications vary somewhat with wavelength. This is because material properties, in particular, the *dispersion* (the variation of refractive index with wavelength), which plays a key role in GRENOUILLE's operation, itself varies with wavelength. Dispersion in the form of *group-velocity mismatch* (between the input pulse and its second harmonic) allows GRENOUILLE's second-harmonic-generation (SHG) crystal to spectrally resolve the pulse, but *group-velocity dispersion* in the same crystal also could distort the pulse to be measured if it is very short. These two effects, respectively, yield upper and lower limits to the pulse length that can be measured using a particular GRENOUILLE model. In short, the higher the crystal dispersion the better GRENOUILLE's spectral resolution, but also the greater the tendency to distort the pulse as it propagates through the crystal. Thus, the greater the dispersion, the longer the pulse that GRENOUILLE prefers to measure. And since the dispersion decreases with increasing wavelength, a given GRENOUILLE typically measures shorter pulses at longer wavelengths.

Figure 1 shows the measurable pulse lengths of the Model 8-50 GRENOUILLE vs. wavelength. The blue region (A = 3) shows the range of very accurately measurable pulse lengths. The green regions (A = 1) show the ranges of measurable pulse lengths where the measurement will be possible but somewhat be less accurate. The parameter A indicates the ratio of the pulse length to the resolution limit (or its reciprocal, depending on the limit). Just as with a spectrometer, it's best not to operate right at the resolution limits, indicated here by the green-white interface.

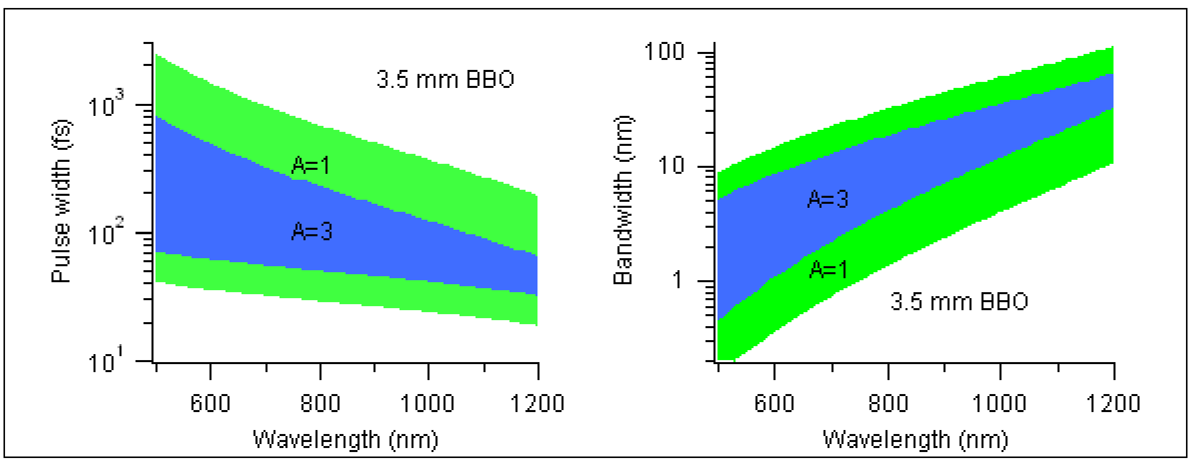

Fig. 1: The operating range of the Model 8-50 GRENOUILLE, which measures 800-nm pulses from ~ 50 to ~ 500 fs long, but 1100-nm pulses from ~ 30 to ~ 200 fs long. The blue region (A = 3) yields highly accurate measurements, and the green region (A = 1) yields somewhat less accurate measurements (however, the FROG code compensates by deconvolving out finite spectral resolution).

In any case, the point is that the Model 8-50, which accurately measures 800-nm pulses from about 50 to 500 fs, accurately measures 1100-nm pulses with a different range of pulse lengths: from about 30 to 200 fs.

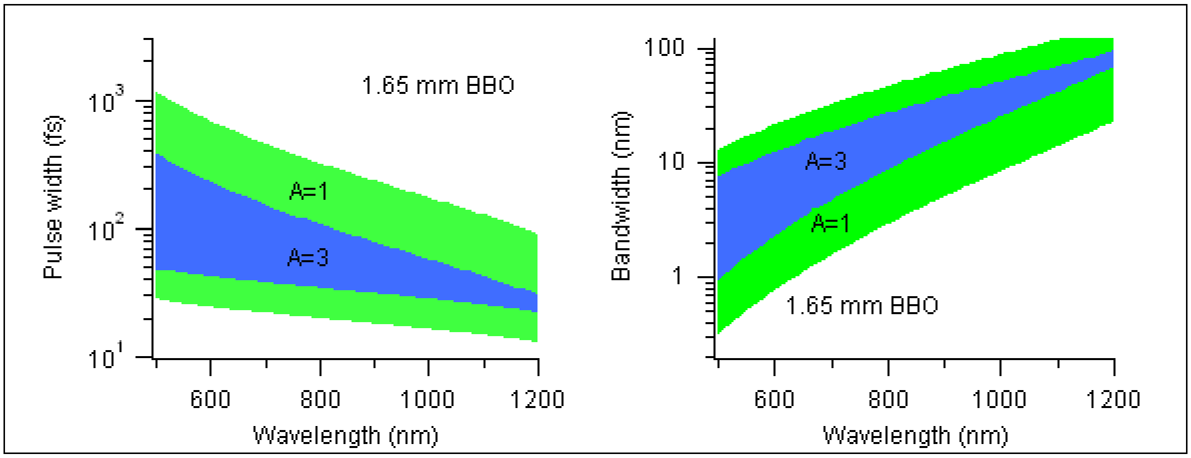

Fig. 2: The operating range of the Model 8-20 GRENOUILLE, which measures 800-nm pulses from ~ 20 to ~ 200 fs long, but 1100-nm pulses from ~ 15 to ~ 150 fs long.

The plot in Figure 3 shows analogous plots for the Model 15-100G, which uses a different crystal.

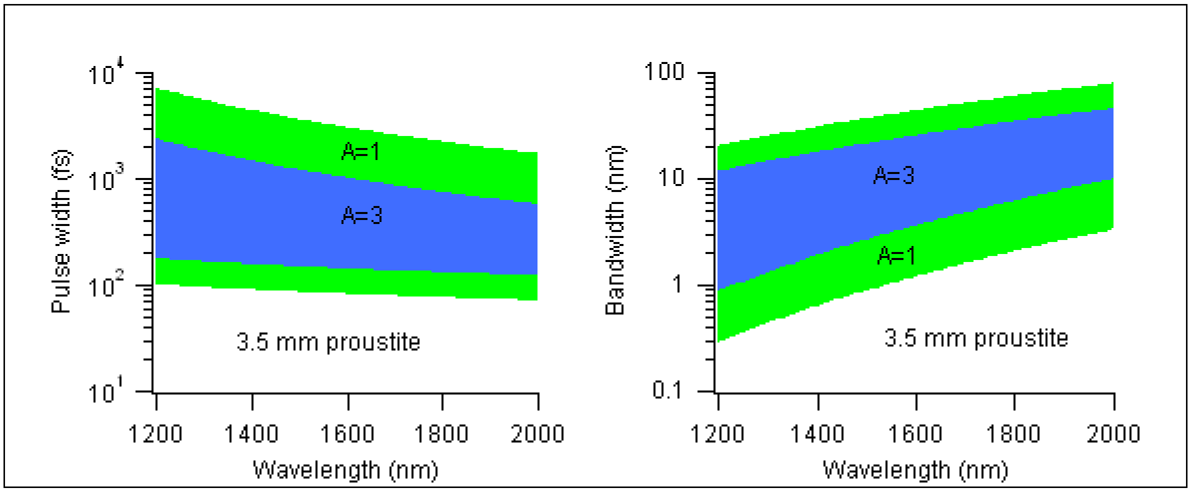

Fig. 3: The operating range of the Model 15-100G GRENOUILLE, which measures ~ 1500-nm pulses from ~ 100 fs to ~ 2 ps long. Its range is actually relatively constant throughout its 1300-to-1600-nm range. (The plots extend to other wavelengths because measurement at these wavelengths is possible with this crystal, although the GRENOUILLE Model 15-100G is not designed for this extended range.)

When can you push the limits? If your pulse is *shorter* than, or has temporal structure shorter than, the limit set by the green region, you're probably better off not measuring it with that model. Check out a shorter-pulse GRENOUILLE model. We should mention, however, that we used a somewhat more conservative condition (by about a factor of two) on the short-pulse side than on the long-pulse side of these plots, so you can operate at the green-white interface on the short-pulse side with confidence.

Also, if your pulse is *longer* than the limit set by the green region, you might also be able to measure it if it's merely chirped (and lacks spectral structure so that high spectral resolution is unnecessary). This upper limit is a measure of the smallest spectral structure that can be measured using GRENOUILLE. If your pulse is, say, 1 ps long, but is linearly chirped and has the bandwidth of a 200-fs pulse, then the Model 8-50 will accurately measure it. (The next limit is then the total delay range of GRENOUILLE, which is 2.4 ps for the Model 8-50, so don't try to measure a pulse longer than about 1 ps, or you'll crop the edges of the pulse FROG trace.) Interestingly, for long pulses, the finite spectral resolution is easy to deconvolve out, and the FROG software (VideoFROG versions later than 5.2 and QuickFROG versions later than 1.0) includes this option, so GRENOUILLE's range is actually better on the long side.

If your pulse is complex, with much temporal structure, then you'll have to make sure that you obey both limits.

Finally, all other GRNEOUILLE models are in fact hybrid GRENOUILLE/FROG arrangements, which use the Fresnel biprism (or bimirror) of GRENOUILLE for beam splitting and recombining, but use a diffraction grating (like FROG) to obtain spectral resolution. This means that these issues don't apply to them; their spectral and temporal resolutions remain approximately constant across their spectral ranges.

