Amplitude ambiguities in second-harmonic-generation frequency-resolved optical gating: reply to comment

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The error calculations in our Erratum [Opt. Lett. **33**, 2854 (2008)] are correct and consistent with the numbers presented in the Comment [Opt. Lett. **34**, 2602 (2009)] on our Letter [Opt. Lett. **32**, 3558 (2007)]. However, we still find that the pulses in Fig. 3 pose a problem in correctly reconstructing the electric field shape.

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In our Letter [1] we presented one class of "ambiguity." According to the authors of the Comment [2], this is trivial to second-harmonic-generation frequency-resolved optical gating (SHG FROG), because the pulses in Example One (Fig. 1 of [1]) can be distinguished by changing the beam splitter with an etalon [3]. We wish to pointout that, although their new setup is based on $\chi^{(2)}$ it is not the same as the symmetric SHG FROG; hence what is trivial to the new setup (POLKADOT [3]) cannot be claimed trivial to SHG FROG.

The FROG error presented in our Erratum [4] is correct and is consistent with the calculation in [2]. We correctly calculated the trace-normalized FROG error ($\Delta_e = G$) using the definition of G according to Eq. (19) of [5] (and *not* G' as interpreted by [2]). The difference between our value ($\Delta_e = G = 8\times10^{-4}$) and the value in [2] ($G = 2.4\times10^{-3}$) can be explained by differences in trace sampling and the number of points used. Our value is obtained using the entire FROG trace (generated with circular fast Fourier transforms using $N=512$ and a sampling of $\delta t = 1.2$ fs), consistent with the definition of FROG error [5,6], G, used during reconstruction. The purpose of using this 512×512 matrix with visual zero regions (although not fully shown in Fig. 3 of [1] for visual clarity) was to determine if, for a highly sampled FROG trace, reconstruction yields ambiguous results (as explained in the next paragraph). Choosing 128×128 points from the central region of these traces yields $G = 2.5\times10^{-3}$, close to the value in [2]. This choice eliminates meaningless zeros but is inconsistent with the FROG error (G) definition [5,6], which requires using the entire FROG trace that is compatible in sampling for the reconstruction algorithm. However, calculations consistent with the definition of G for $N=128$ elements (and the same sampling of $\delta t = 1.2$ fs) result in $G = 1.5\times10^{-3}$. Therefore, the reason for differences with the calculations in [2] is the differences in choices for N and δt. We note that our value for $\Delta_e = G$ is not the intensity-weighted G'; for which we obtain a value of 0.024 (with $N=512$ and $\delta t = 1.2$ fs).

Our SHG FROG reconstructions demonstrate that the pulses in Fig. 3 in [1] pose a problem. Starting from Spectrogram One (generated using Pulse One in Fig. 3(a) in [1]) and random intensity as input, we obtained (using the PCGPA algorithm [6] with 100 iterations) a reconstructed pulse that looks similar to Pulse Two in Fig. 3(b) in [1] nearly 23% of the time and 37% of the time a pulse that differs from both Pulse One and Pulse Two. Starting with Spectrogram Two, we obtained Pulse Two most of the time ($>66\%$), Pulse One 2% of the time, and other pulse shapes rest of the time. Similar results were seen with the Femtosoft SHG inversion algorithm when $G < 10^{-3}$ was used as convergence criteria [6]. Further, it is known from previous work of [2] that SHG FROG algorithms do not produce correct results nearly 20% of the time for complex or multiple pulses [6]. The "ambiguity" in [1] provides one possible explanation for such behavior.

In [1] we did not conclude that autocorrelation methods are a better alternative to FROG. We simply pointed from the simulation results (Δ_m) that, for certain pulses (like in Fig. 1), interferometric autocorrelation measurements have a better sensitivity than SHG FROG. The main motivation in our work was to show that a set of significantly different pulses with SHG FROG traces that differ by $G \sim 10^{-3}$ or less can be generated. This is important because, in many experiments, the convergence criteria used during reconstruction is typically 10^{-2}–10^{-3}.

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