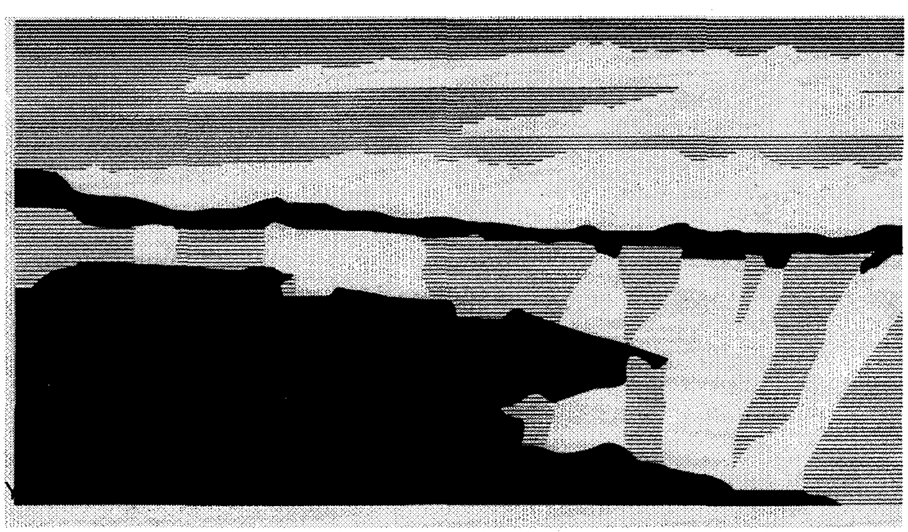
LA-UR-99- -114

Title: PHASE RECONSTRUCTION FROM FROG USING GENETIC ALGORITHMS

Author(s): F. G. Omenetto
J.W. Nickolson
D.J. Funk
A.J. Taylor

Submitted to: Ultrafast electronics and Optoelectronics



Los Alamos
NATIONAL LABORATORY

Form No. 836 R5
ST 2629 10/91

DISCLAIMER

DISCLAIMER

Phase reconstruction from FROG using genetic algorithms

F. G. Omenetto, J. W. Nicholson, D. J. Funk, and A. J. Taylor
Los Alamos National Laboratory, MS K764, Los Alamos, NM 87545
omenetto@lanl.gov, jeffn@lanl.gov, djf@lanl.gov, ttaylor@lanl.gov
phone : (505) 665-5847, fax : (505) 665-7652

Abstract

We describe a new technique for obtaining the phase and electric field from FROG measurements using genetic algorithms.

Frequency-Resolved Optical Gating (FROG) has gained prominence as a technique for characterizing ultrashort pulses [1]. FROG consists of a spectrally resolved autocorelation of the pulse to be measured. Typically a combination of iterative algorithms is used, applying constraints from experimental data, and alternating between the time and frequency domain, in order to retrieve an optical pulse.

We have developed a new approach to retrieving the intensity and phase from FROG data using a genetic algorithm (GA). A GA is a general parallel search technique that operates on a population of potential solutions simultaneously. Operators in a genetic algorithm, such as crossover, selection, and mutation are based on ideas taken from evolution [2].

The fitness of an individual in the population of electric fields is defined using the FROG error:

$$G = \left\{ \frac{1}{N^2} \sum_{\omega,\tau=1}^{N} \left[I_m(\omega,\tau) - I_r(\omega,\tau) \right]^2 \right\}^{1/2}, \qquad (1)$$

where I_m, the measured FROG trace and I_r, the recovered FROG trace, are functions of frequency (ω) and delay (τ) between pulse replicas in the autocorrelator. N is the number of frequency and

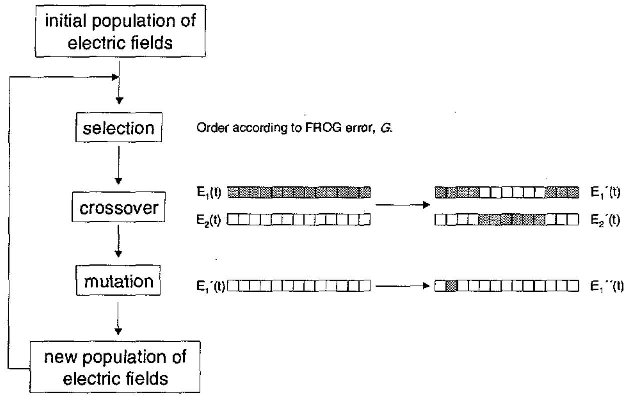


Figure 1: A single generation of the genetic algorithm, detailing the selection, crossover, and mutation operators.

delay points in the trace (assumed to be square). G is of the order of 10^{-3} to 10^{-4} for experimentally measured data.

A generation of the genetic algorithm consists of first sorting the population with respect to FROG error. Then a crossover operator is applied that selects two individuals and exchanges the genetic material, producing two new offspring. Finally the electric field at single points has a low probability of being randomly mutated to a new value. The process is then repeated, allowing the new children to compete with their parents. A generation of the GA is illustrated schematically in Fig. 1.

We have applied this algorithm to experimental and theoretical PG and SHG FROG traces. Of particular interest are the results from the SHG FROG recovery. SHG FROG contains an ambiguity in time; for a particular FROG trace there are two, time reversed pulses that generate the same FROG trace. This ambiguity has been shown to cause difficulties in the retrieval of pulses with flat temporal phases using the standard iterative algorithm. Genetic algorithms, however, are less susceptible to being trapped by degenerate solutions, due to the parallel nature of their search.

The results of the reconstruction of a theoretical pulse measured with SHG FROG are shown in Fig. 2. An asymmetric pulse with flat temporal phase was chosen (solid lines), and 3% additive

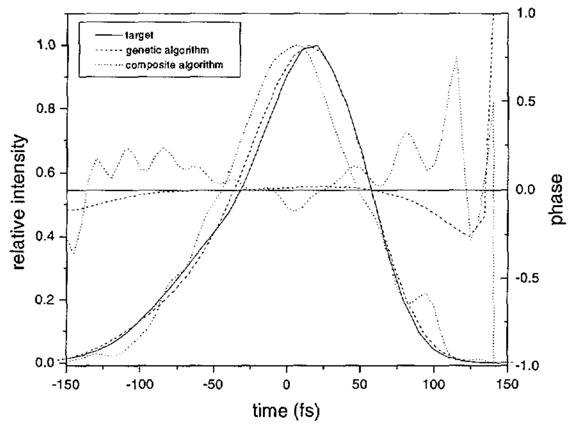


Figure 2: Target intensity and phase (solid lines), intensity and phase retrieved from the genetic algorithm (dashed lines), and the intensity and phase from the composite algorithm (dotted lines) in the SHG FROG case. The genetic algorithm returned an error of 0.00175, and the composite algorithm returned an error of 0.00256.

and multiplicative noise was added to the FROG trace. The pulse was then reconstructed from the FROG trace using the genetic algorithm, and a composite iterative algorithm, available commercially. Whereas the composite algorithm (dotted lines) stagnates on a chirped symmetric pulse, the genetic algorithm was able to successfully retrieve the pulse.

In conclusion, we have demonstrated phase reconstruction from FROG using a genetic algorithm. Even though only the most basic evolutionary operators were used, the genetic algorithm returned lower FROG errors on certain types of experimental and theoretical pulses then the standard composite iterative algorithm.

References

[1] R. Trebino *et al.*, Review of Scientific Instruments **68**, 32773295 (1997).

[2] M. Mitchell, *An Introduction to Genetic Algorithms* (MIT Press, Cambridge, Mass., 1996).