EPJ Web of Conferences **267**, 01051 (2022) https://doi.org/10.1051/epjconf/202226701051
EUROPHOTON 2022

Line-search FROG algorithm for retrieval of pulses from noisy datasets

Christoffer Krook[1], **Koen Claessen**[2], **Valdas Pasiskevicius**[1]
1. Department of Applied Physics, Royal Institute of Technology, Roslagstullsbacken 21, 106 91 Stockholm, Sweden
2. Department of Computer Science and Engineering, Chalmers University of Technology, Rännvägen 6, 412 58 Gothenburg, Sweden

Ultrashort-pulse solid-state laser systems are widely used today in a number of applications and often include stages of pulse shaping, spectral broadening, recompression, other processing steps. Experiments and applications in the femtosecond regime require reliable methods to characterize and measure the full electric field of the resulting pulses. Frequency-Resolved Optical Gating (FROG) is a common approach. The algorithms to retrieve pulses from measurement data typically employ gradient descent-based approaches, which tend to retrieve an average of the present measurement noise together with the pulse.

Conventional FROG retrieval algorithms using a gradient descent approach use the experimental data to generate a new guess. Traditional algorithms might reach local minima instead of converging further to the global minimum for complicated signals and noisy datasets. Recent a generic optimization algorithm was published, which presents what is best described as a structured random search of the available input space [1]. Here we have adapted it for pulse retrieval from any FROG geometry. This new algorithm, which we call Line-search FROG, generates two complex values in the complex plane surrounding the current field value along a randomly generated directional vector.

These three points can be considered to form a line in the complex plane, where the current field value intersects the line, and the two generated values make up the endpoints. These three points are evaluated by calculating the trace-area normalized FROG error G', after which the algorithm generates a new point on the line between the best two out of the three points and discards the worst point, effectively shrinking the line. This is repeated until a pre-set number of evaluations have been reached and the algorithm replaces the current guess with the best point of the current three, after which it starts over, generating a new directional vector and two new endpoints. If no better point was found during the iteration, the current guess is replaced with the second-best point from the previous iteration, thus "perturbing" the point a little bit, resulting in a reduced sensitivity to local minima. For a more precise description of the algorithm, we refer the reader to [2].

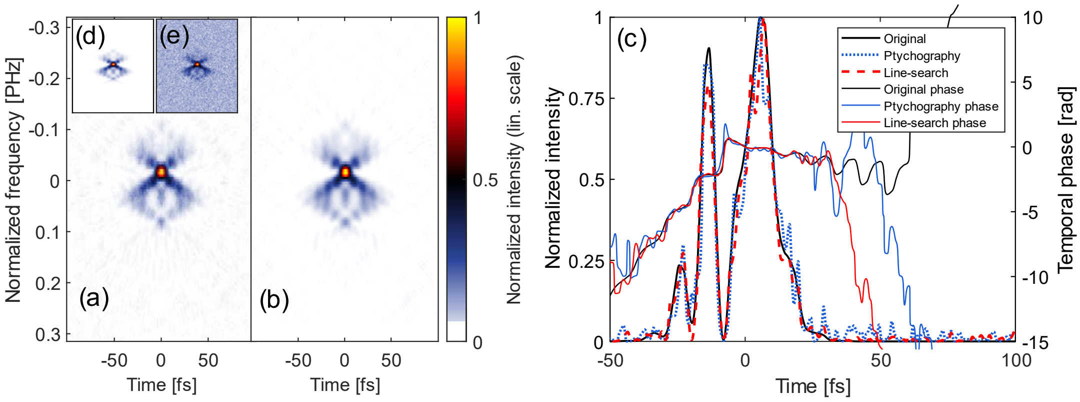

Fig. 1 Trace retrieved by (a) Ptychographic retrieval algorithm and (b) Line-search algorithm together with (c) temporal intensity and phase for retrieved pulses and original the pulse. Inset (d) and (e) show simulated trace before and after adding additive noise amounting to an SNR of 4 dB (the input of the algorithms).

Our results show that the line-search algorithm retrieves pulses with less noise compared to the popular Ptychographic retrieval algorithm [2]. This is evident by comparing both noise in the retrieved traces in Fig. 1 (a) and (b), as well as the noise present in the final pulse in Fig. 1 (c). Unlike for the ptychographic algorithm, each evaluation of the line-search algorithm does not take it closer to the solution, but rather it evaluates the previously mentioned line at several locations, after which it selects the best location. This increases the number of evaluations needed for an acceptable retrieval. For the sake of comparison, both retrieved pulses in Fig. 1 (c) are from 10 000 iterations of each algorithm respectively. The algorithm never sees the evaluation of G', but just the number it returns. Due to this, by changing the evaluation function to match that of for example X-FROG or TG-FROG, the algorithm can work for any FROG geometry. Simulations also show that the algorithm can retrieve pulses from partial datasets the same way as described in [2], as well as blind FROG.

References

[1] Z. Ramezane, K. Claessen, et.al, "Testing Cyber-Physical Systems Using a Line-Search Falsification Method," IEEE Trans. Comput.-Aided Des. Integr. Circuits Syst. doi: 10.1109/TCAD.2021.3110740 (2021)
[2] P. Sidorenko, O. Lahav, et. al, "Ptychographic reconstruction algorithm for frequency-resolved optical gating: super-resolution and supreme robustness," Optica **3**, 1320-1330 (2016)