Dispersion-scan (re)meets neural networks

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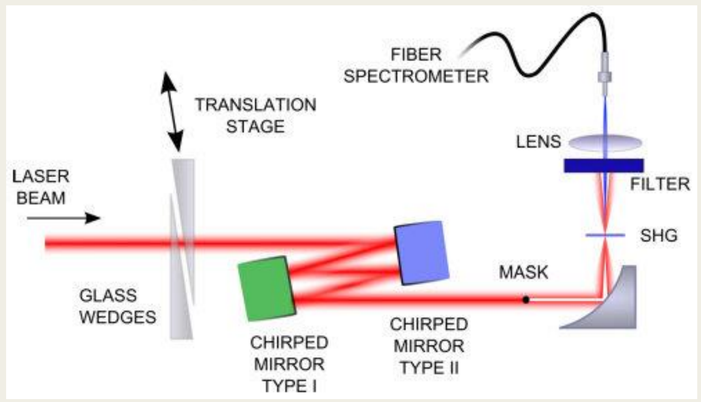
Aims

- Fast pulse retrieval from dispersion scan [1] traces using neural networks (NN), towards single-shot pulse characterization capability
- Leverage d-scan trace redundancy to retrieve the phase & spectrum, instead of relying in a separate measurement of the experimental spectrum
- Compare the execution speed of NNs against highly optimized conventional iterative algorithms



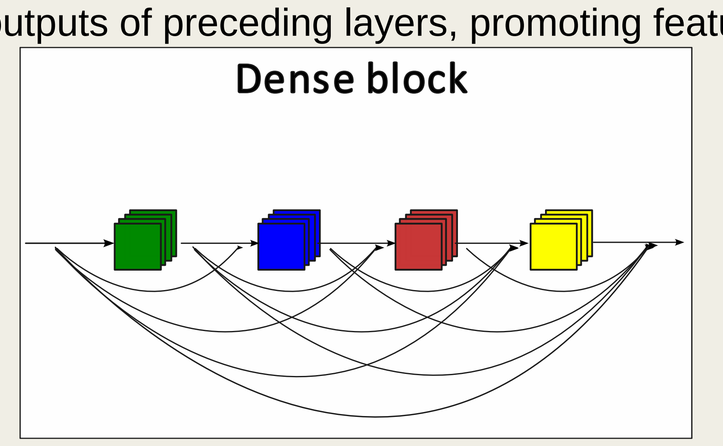
Schematic of a scanning dispersion scan apparatus [1]

Approach

Neural networks are mathematical constructs that can approximate a function, given known inputs and known outputs. They are comprised of layers containing weights and biases that are determined after a training process.

In this work, we will use the DenseNet architecture [1] as a base:

- Network comprised by dense blocks -> each successive layer receives the concatenated outputs of preceding layers, promoting feature reuse.



- Expected output: complex E-field -> implementation of a complex-valued neural network, i.e., complex weights and biases. Real-valued NNs were also explored.
- More efficient neural network training, by training the NNs against the electric field in the time-domain (instead of frequency-domain), as the pulse requires less points to be represented in this domain.
- Implementation of an optimized, single-threaded, C++ language based ptychographic retrieval algorithm [2] to serve as a benchmark.

Findings

- NN inference time obtained ~ 20 ms to 120 ms.
- Increased difficulty in retrieving the spectrum; experimental spectra may not always be well approximated by a sum of gaussian functions, during NN training process.
- Currently, conventional iterative retrieval algorithms (<15 ms) have an edge over NN, in terms of speed and quality of retrieval.

References

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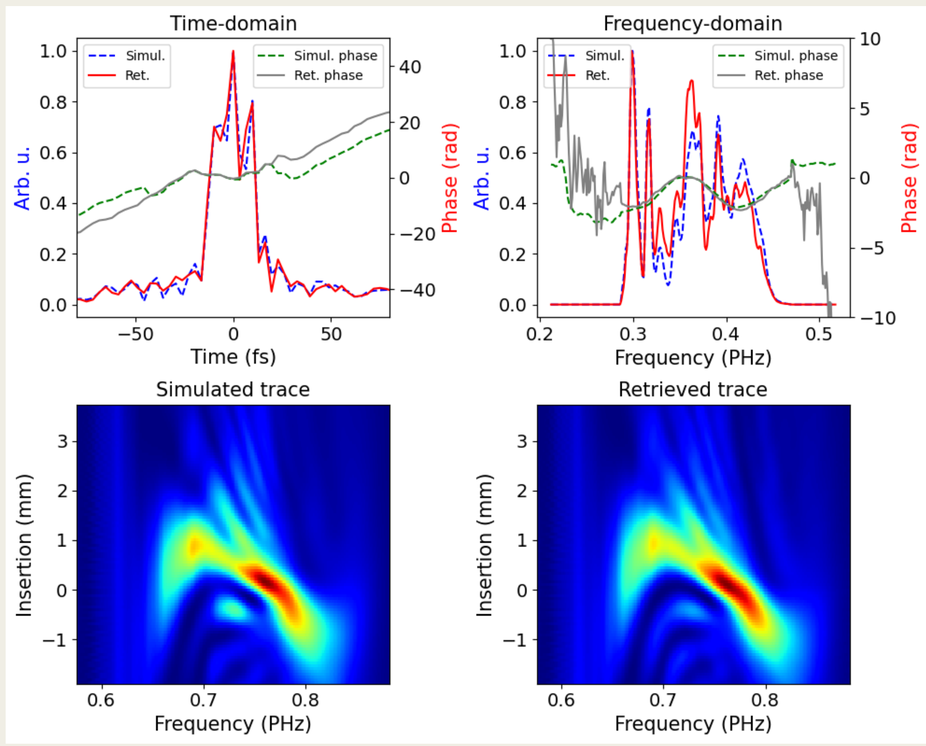
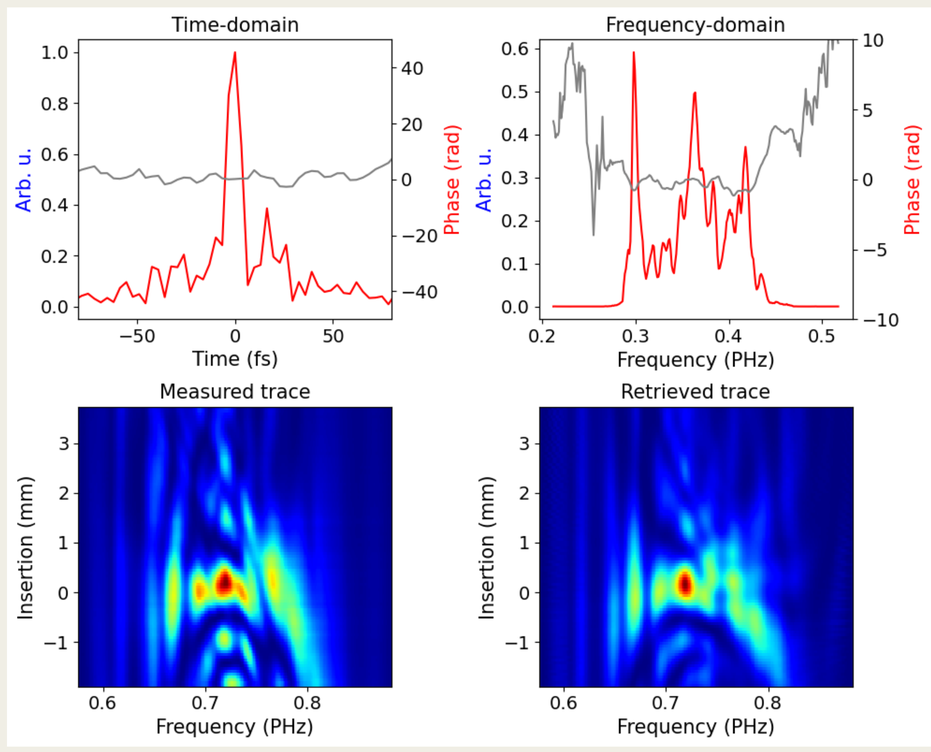
2. S. Kleinert, A. Tajalli, T. Nagy, and U. Morgner, "Rapid phase retrieval of ultrashort pulses from dispersion scan traces using deep neural networks," Opt. Lett. 44, 979 (2019).
3. A. M. Wilhelm, D. D. Schmidt, D. E. Adams, and C. G. Durfee, "Multi-mode root preserving ptychographic phase retrieval algorithm for dispersion scan," Opt. Express 29, 22080 (2021).

Neural network – test data



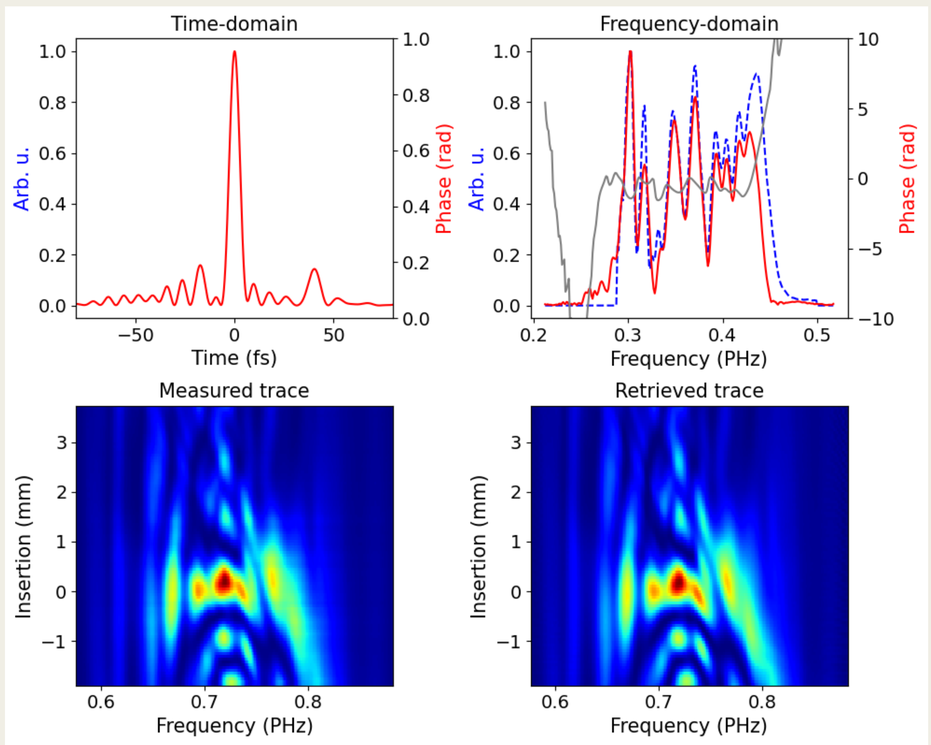
Complex-Valued DenseNet (CV-DenseNet) retrieval of simulated d-scan trace

Neural network – measured data



CV-DenseNet retrieval of measured d-scan trace

Iterative algorithm



Ptychography-based retrieval algorithm

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