

Laser pulse characterization and shaping

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Overview

Forward and inverse problem



The laser system: NEPAL

The laser system



Shaping experiments

The actuator

Waveshaper

- The waveshaper is a tunable optical filter which allows for spectral attenuation and phase control.
- The input light is spatially dispersed before hitting the liquid crystal matrix.
- By applying a voltage to the matrix elements, they can add individual phase shifts to the reflected signals.
- Control over time domain is governed by Fourier relationship.



Filter working principle

Fourier shaping technique

Considering $E_i(t)$ as the input waveform, we can describe the relation with the output $E_o(t)$ by moving in the spectral domain.

Here, by means of Fourier transform, input and ouput are represented as $A_i(f)$ and $A_o(f)$ respectively, where the waveshaper applies a filter F(f) such that:

 $A_o(f) = F(f) A_i(f)$

Limits:

- Output spectral content is a subset of the input spectrum
- Resolution is limited by the Waveshaper transfer function
- Guaranteed dynamic range is 25 dB



Some arbitrary shaping attempts

Spectral domain



Some arbitrary shaping attempts

Time domain



Flat-top electron bunch NEPAL X2





-20

-25

-15

-10

-5

0

5

10

15

20

25

ML approach

Data generation

Data are generated through RPfiber simulations.

- Each simulation takes a filter setting as input and returns the complex spectrum.
- Filter settings are randomly generated by sampling in time domain different pulse shapes.
- Time domain phase is described as a 4th order polynomial, whose coefficient is uniformly sampled based on fwhm.

| Shape | Gaussian | | | | | | Parabolic | Sech | Triangular | | | Flat top |
|-------|----------------------|---|---|---|---|------|----------------------|----------------------|----------------------|---|---|----------------------|
| Order | 1 | 2 | 3 | 4 | 5 | 10 | | | 1 | 2 | 4 | |
| FWHM | Uniform: 2ps – 40 ps | | | | |) ps | Uniform: 2ps – 40 ps | Uniform: 2ps – 40 ps | Uniform: 2ps – 40 ps | | | Uniform: 2ps – 40 ps |

Over Christmas 110k data points have been generated!

Data manipulation

- Both input and output data are converted to time domain by FFT
- And from complex 1D-array to real 2Darray (Real and Imaginary)



Architecture



Performance

- Model learns to predict filters for the given dataset
- However is not general enough and more diverse sampling is required.



Conclusions

Summary

- Cross-correlator allows for better pulse intensity profile characterization
- First shaping attempts show that waveshaper is quite flexible and can deliver up to 21 ps flat-top UV pulses
- Flat-top profile has been transferred onto electron bunch
- ML architecture and data sampling is still in definition

Challenges and next steps

- Working on data sampling
- Trying out different neural network architectures

Thank you