Hamiltonian simulation algorithms for near-term quantum hardware

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Attosecond Physics

Definition

1 Attosecond (as) $= 1 * 10^{-18}$ s

- Shortest timescale available to us in experiments
- Special analysis methods are required

Pulses

Definition

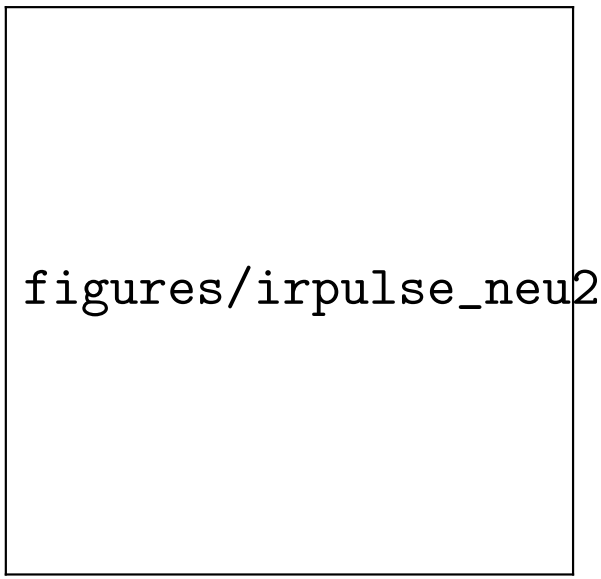
Complex Wavefunction $U(t) = |A(t)|exp(i[\omega_0 t + \varphi(t)])$

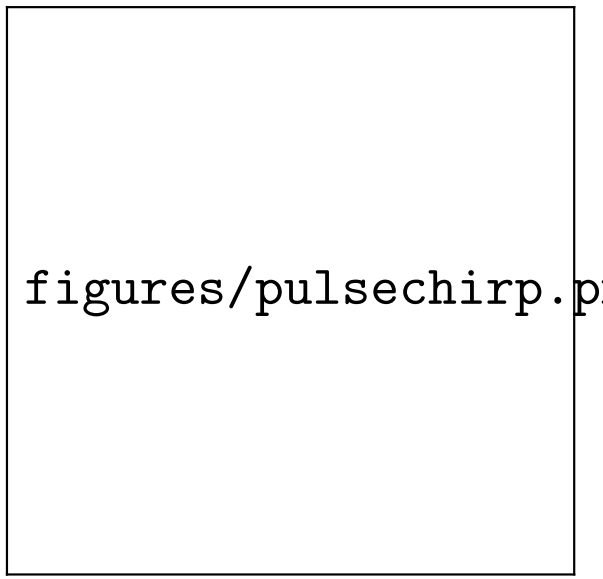
$|A(t)|$ magnitude of the envelope, angular frequency ω_0, phase $\varphi(t) = arg[A(t)]$

$\varphi(t + t_0) \approx \varphi_0 + \varphi' t + \frac{1}{2}\varphi'' t^2$

$I(t) = I_0 exp(-2t^2/\tau^2)$

$A(t) = A_0 exp(-t^2/\tau^2) exp(iat^2/\tau^2)$





short-time Fourier Transform

Definition

$$\Phi(\nu,\tau) = \int P(t)G(t-\tau)exp(-i2\pi\nu t)dt$$

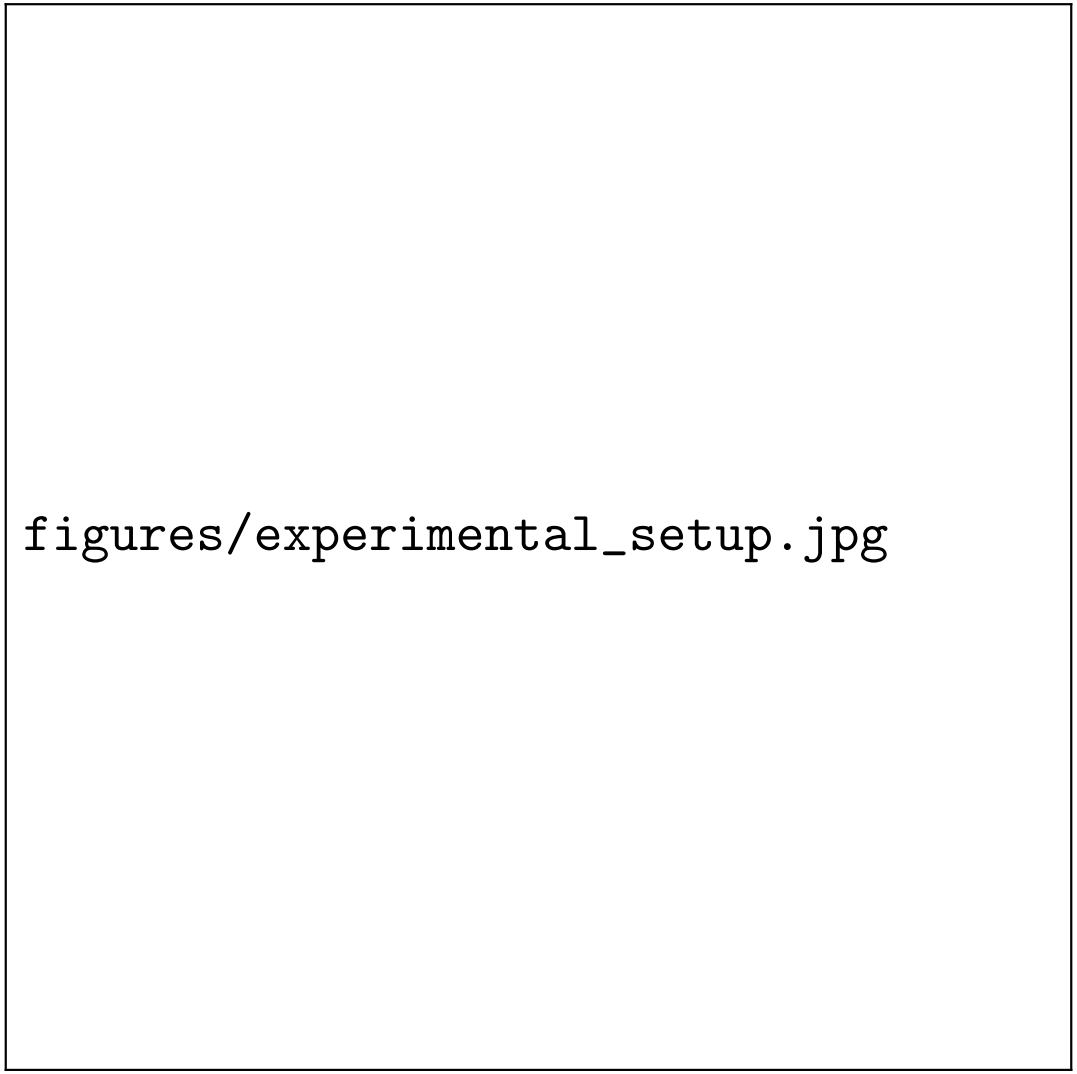
Gate : $G(t-\tau)$
Gated Pulse : $P(t)G(t-\tau)$

figures/5signal.png

Spectrogram: $|\Phi(\nu,\tau)|^2$
$2\sqrt{2}sin(4\pi t + cos(2\pi * 0,25t))$:

figures/5spectrogram.pdf

Attosecond Streaking Spectroscopy



Direct Measurement of Light Waves, E.Goulielmakis, 2004, Science

Applying FROG to Attosecond Streaking

Attosecond Streaking Formula:

$$\Phi(p,\tau) = \int_{-\infty}^{+\infty} E_X(t) d(p + A_L(t+\tau)) e^{-i\phi(p,t+\tau)} e^{i(p^2)/2 - \Omega_X + W)t} dt$$

Modified Spectrogram:

$$\hat{S}(p,\tau) = \frac{|\Phi(t,\tau)|^2}{|d(p)|^2} \approx \left| \int_{-\infty}^{+\infty} E_X G(t+\tau) e^{\frac{i}{2}p^2 t} dt \right|^2$$

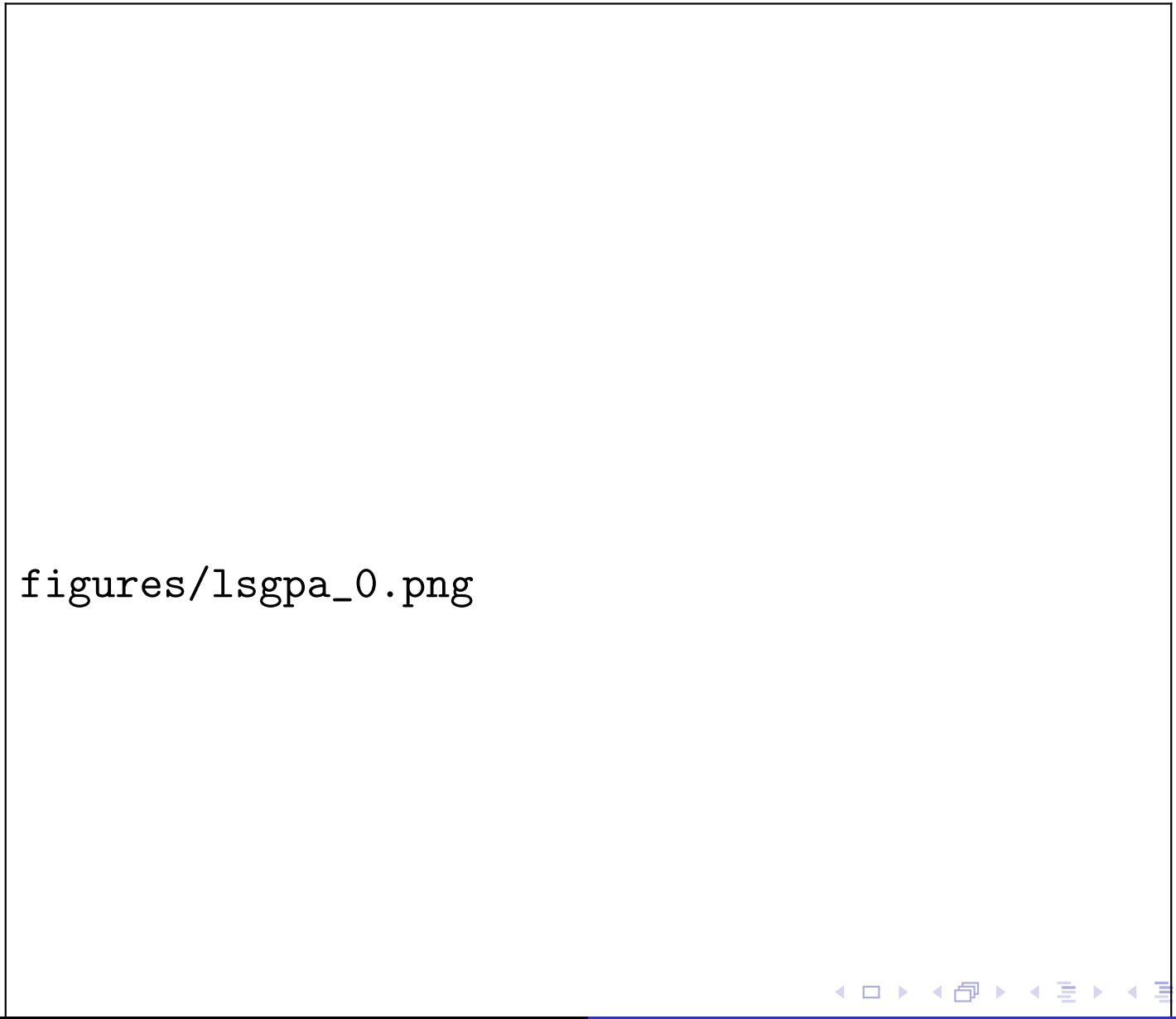
FROG Spectrogram:

$$\tilde{S} = \left| \int_{-\infty}^{+\infty} P(t) G(t+\tau) e^{i\omega t} dt \right|^2$$

The accurate FROG characterization of attosecond pulses from streaking measurements, J.Gagnon et al., 2008, Appl.Phys. B 92, 25-32

Least Squares Generalized Projections Algorithm

Initial Guess:



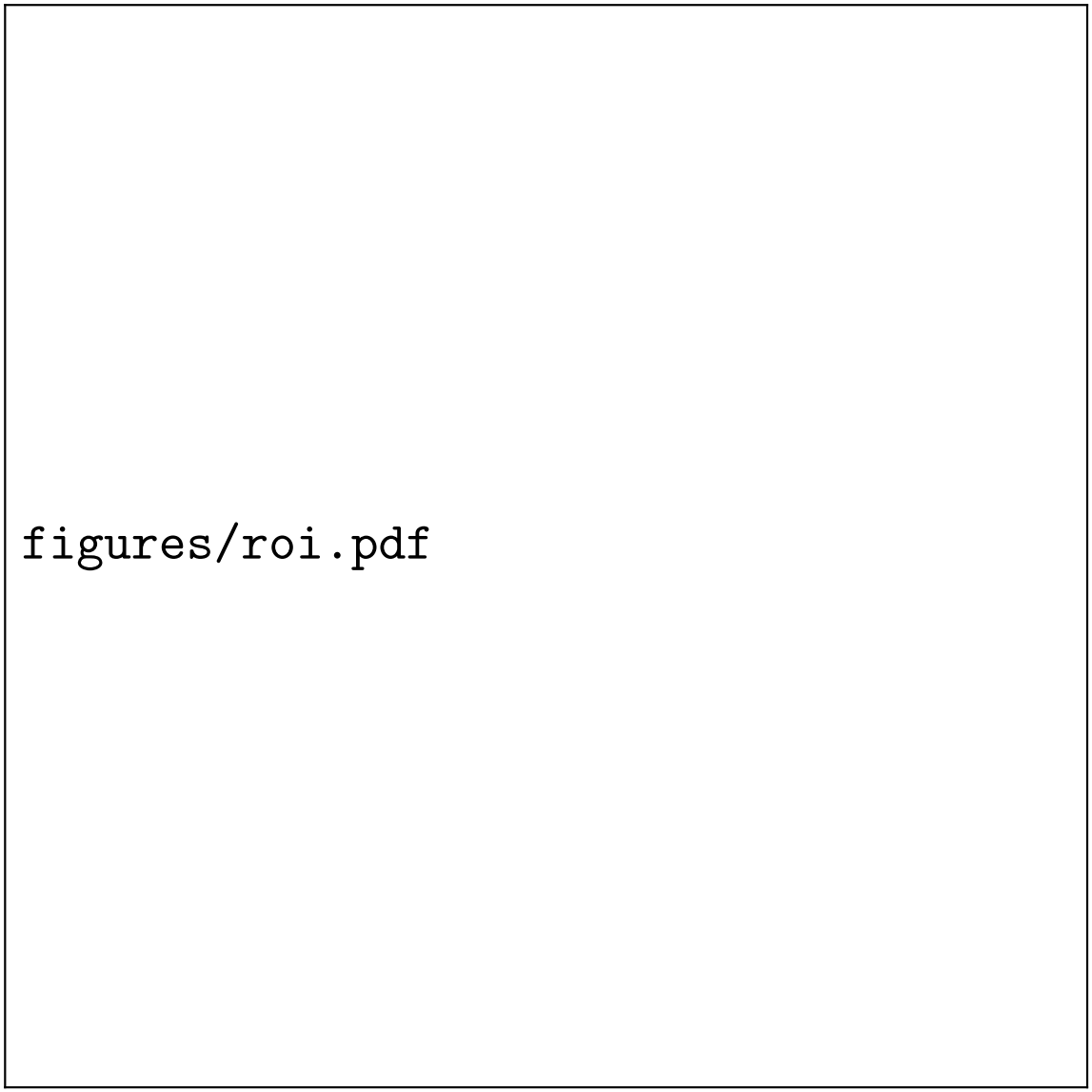
Least Squares Generalized Projections Algorithm

LSGPA Loop:

- apply alternating constraints in time-/freq. domain

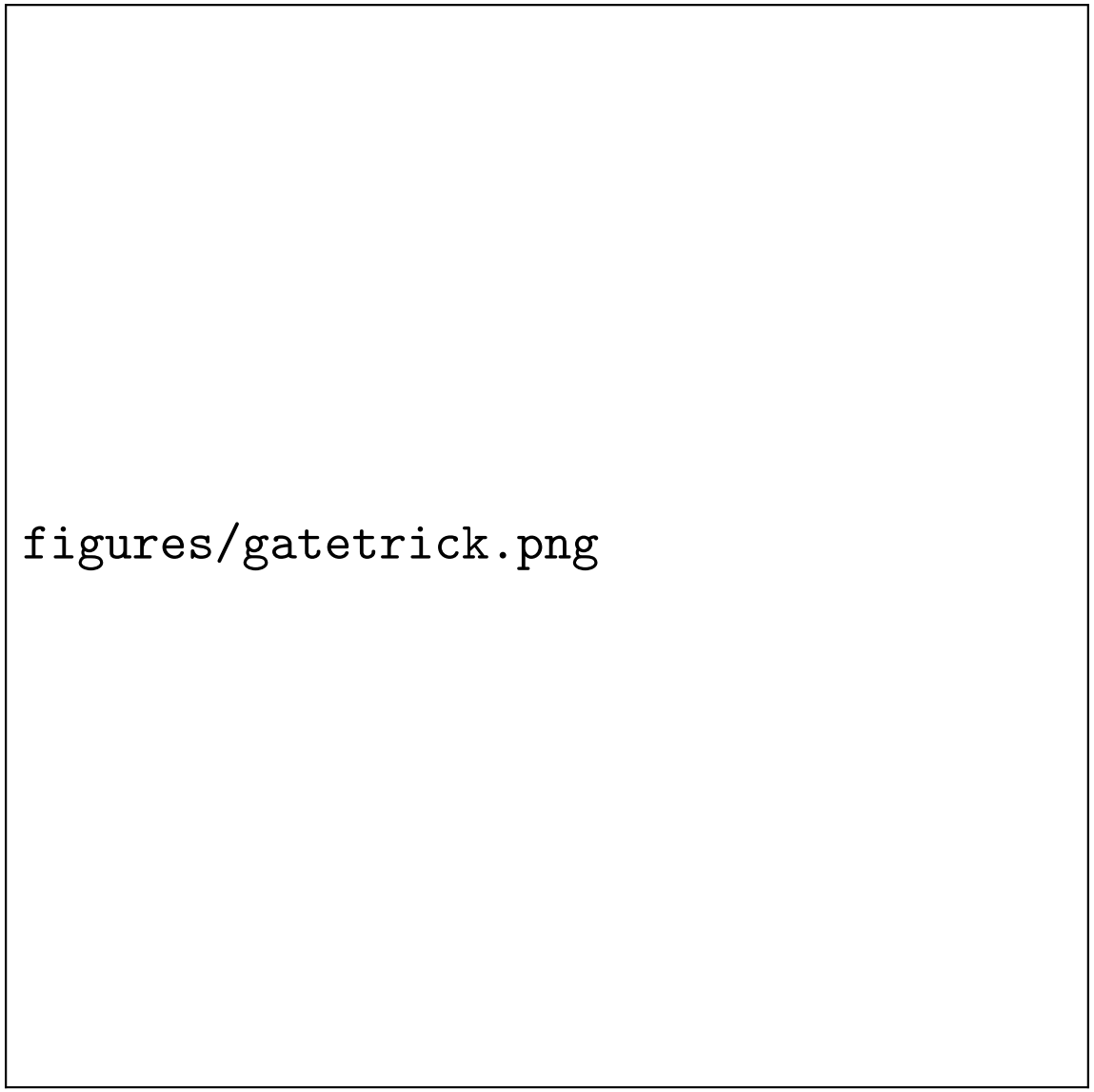
figures/lsgpa_1.png

Problem Statement



- Identify Regions-Of-Interest
- Setup the data structures
- Satisfy the data constraints
  - FFT
  - LSGPA

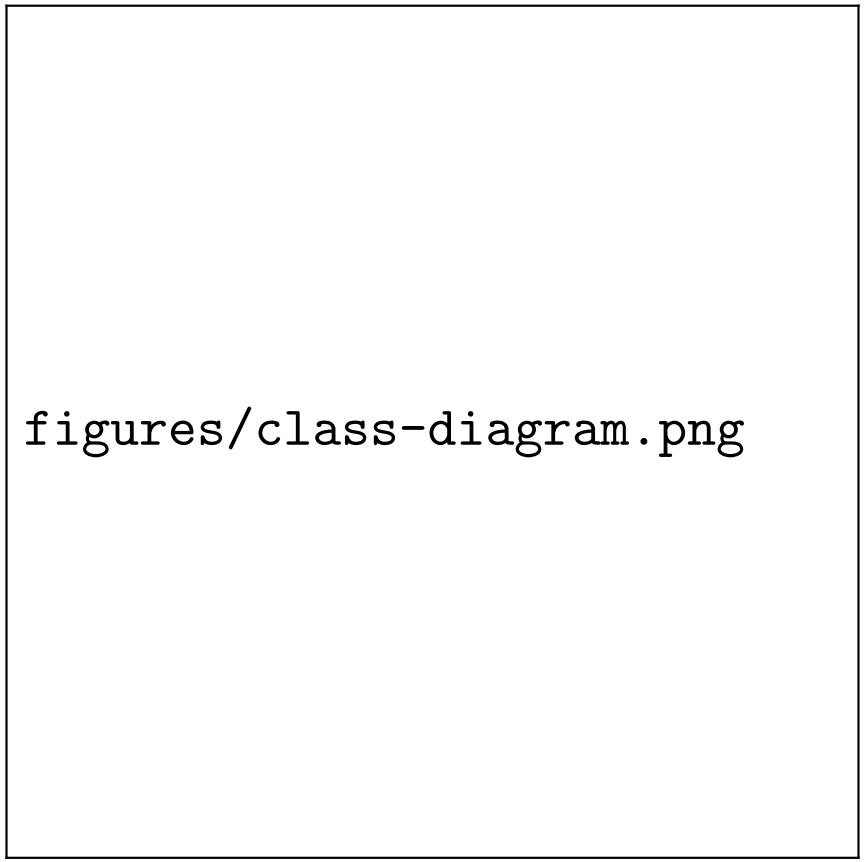
Data Constraints



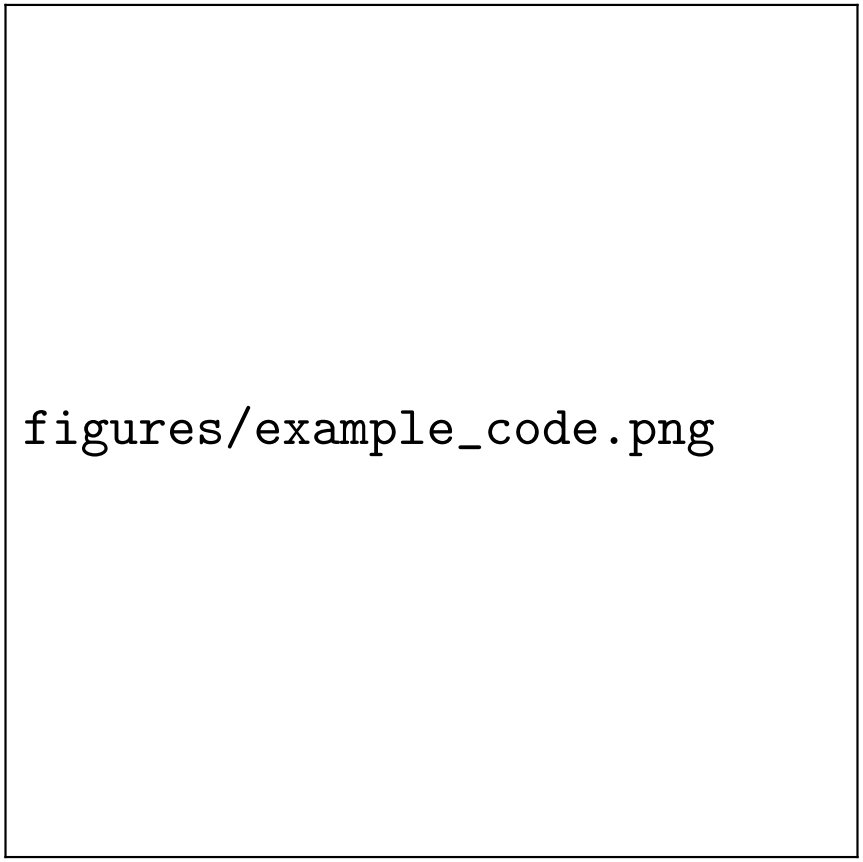
The accurate FROG characterization of attosecond pulses from streaking measurements, J.Gagnon et al., 2008, Appl.Phys. B 92, 25-32

Data Structures

- object-oriented
- modularized
- expandable
- built on top of the Scan framework



Example Code



Setup Function

figures/setup_code.png

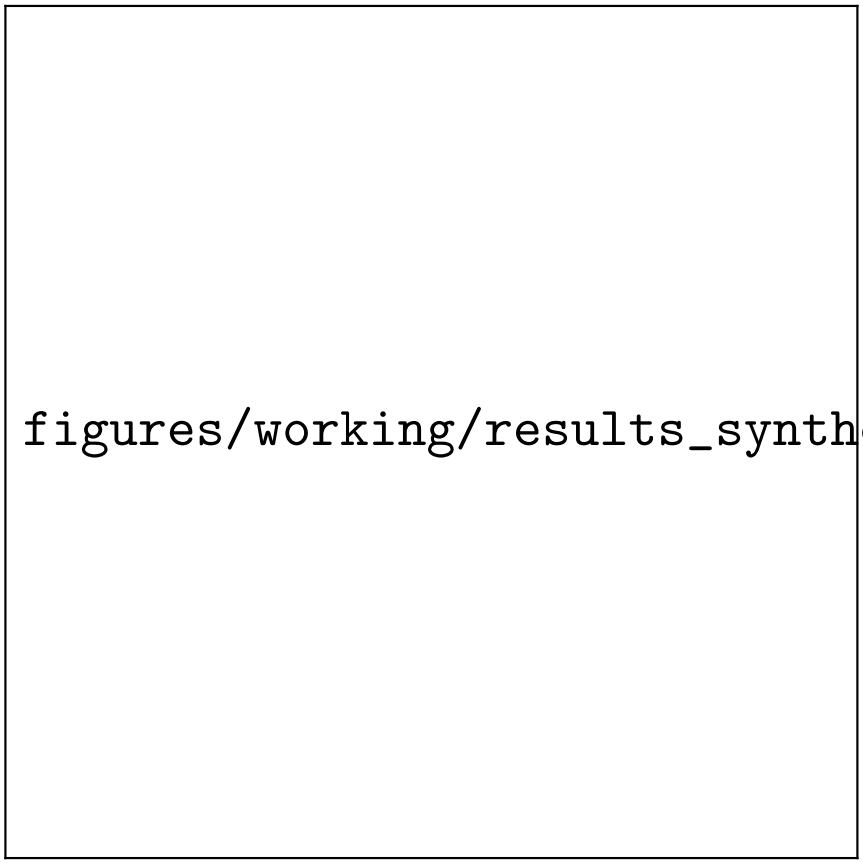
figures/setup1.png

Run the Algorithm

figures/run_code.png

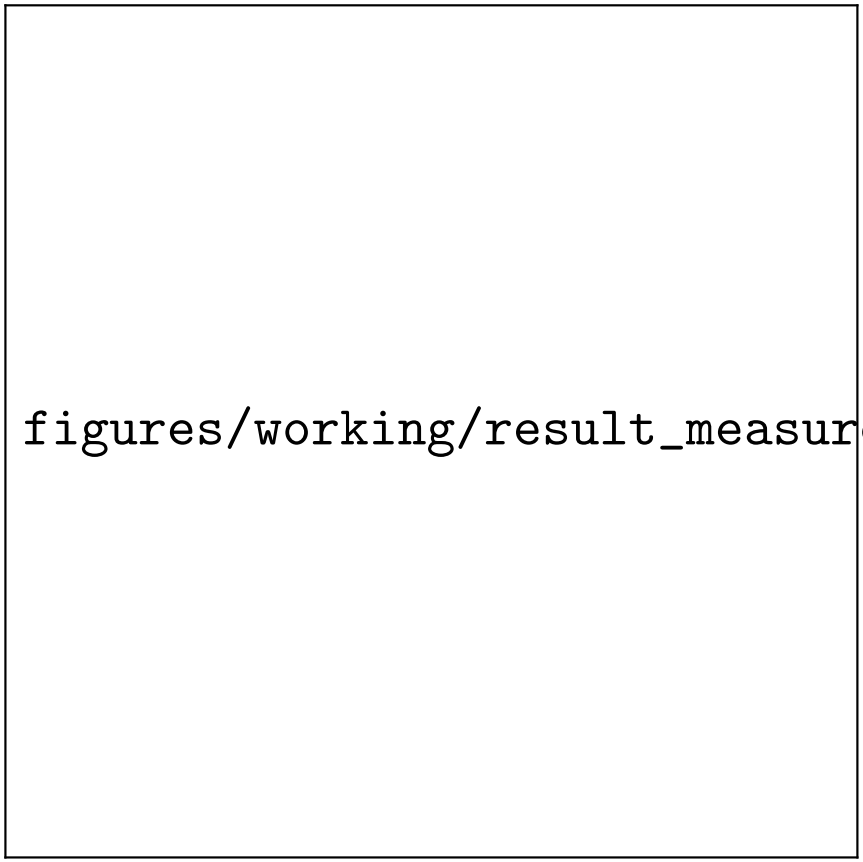
figures/lsgpa_1.png

Results: synthesized data



$$\text{Merit} = \sqrt{\sum_{i=1}^{N_\epsilon} |S_{1,i} - IFFT(\tilde{S}_{2,i})|^2}$$

Results: measured data



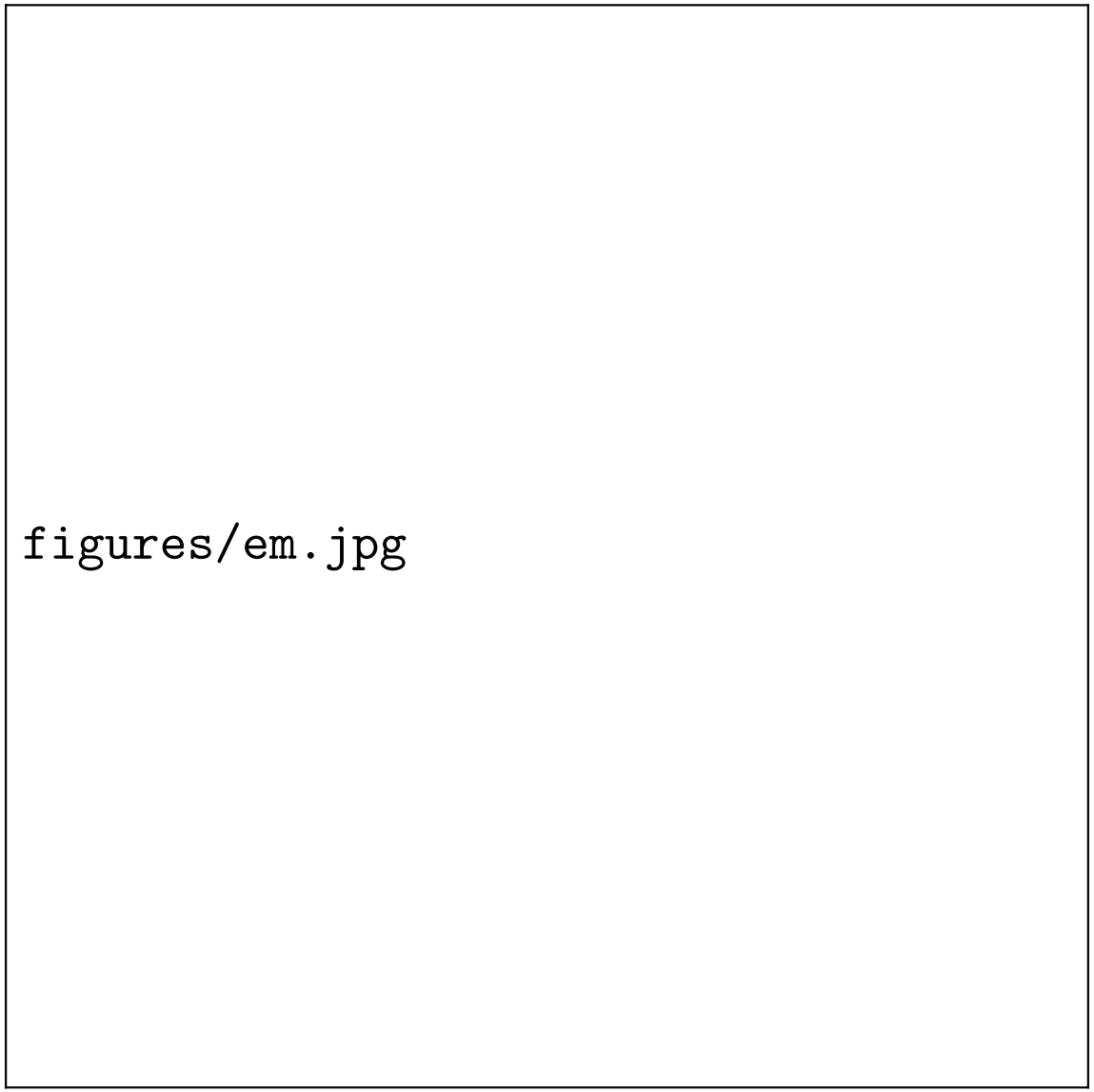
$$\text{Merit} = \sqrt{\sum_{i=1}^{N_\epsilon} |S_{1,i} - IFFT(\tilde{S}_{2,i})|^2}$$

Outlook

- Make the algorithm run perfectly, fix the bug
- Research Interest: get the delays between two traces

Thank you for your attention!

EM spectrum



source: Melissa Petruzzello et all., Encyclopædia Britannica Inc., 2017

Attosecond Streaking Formula

$$\Phi(p,\tau) = \int_{-\infty}^{+\infty} E_X(t) d(p + A_L(t+\tau)) e^{-i\phi(p,t+\tau)} e^{i(p^2)/2 - \Omega_X + W)t} dt$$

$$\varphi(p,t) = \int_t^{\infty} (pA_L(t') + \tfrac{1}{2} A_L^2(t')) dt'$$

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