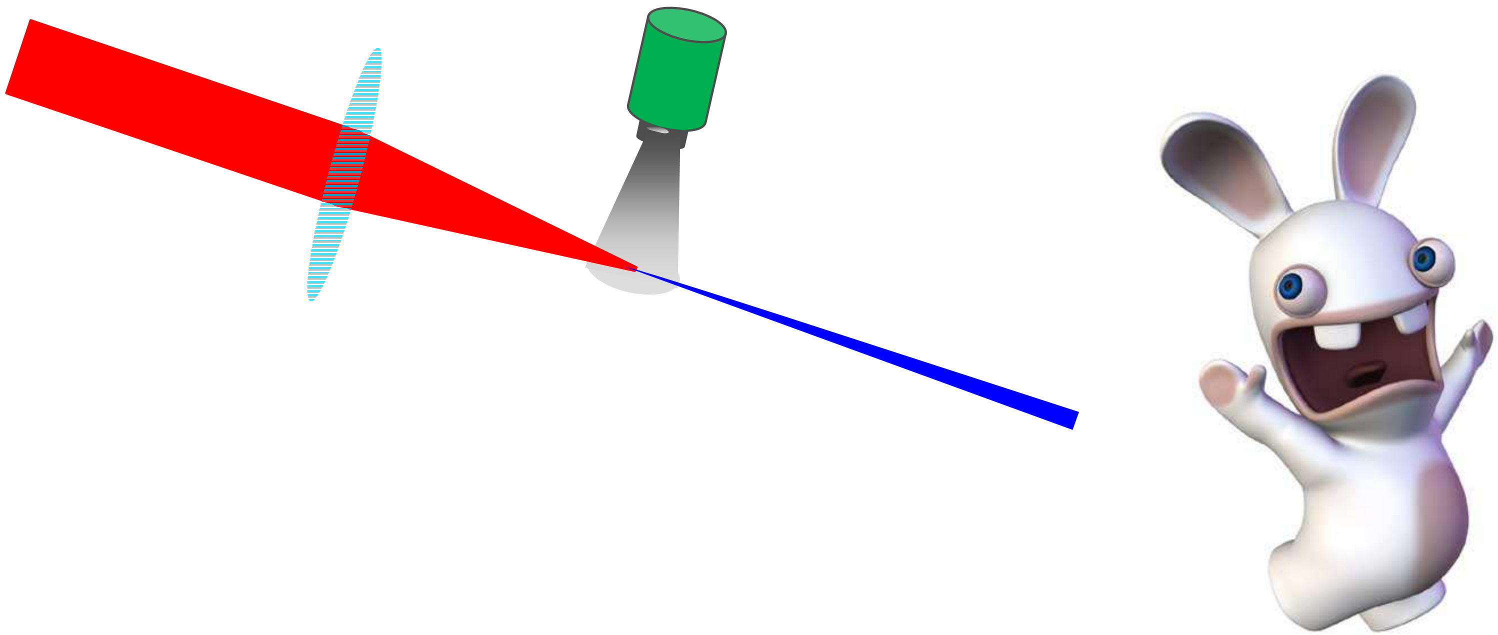
Characterisation and application of XUV pulses : the RABITT method

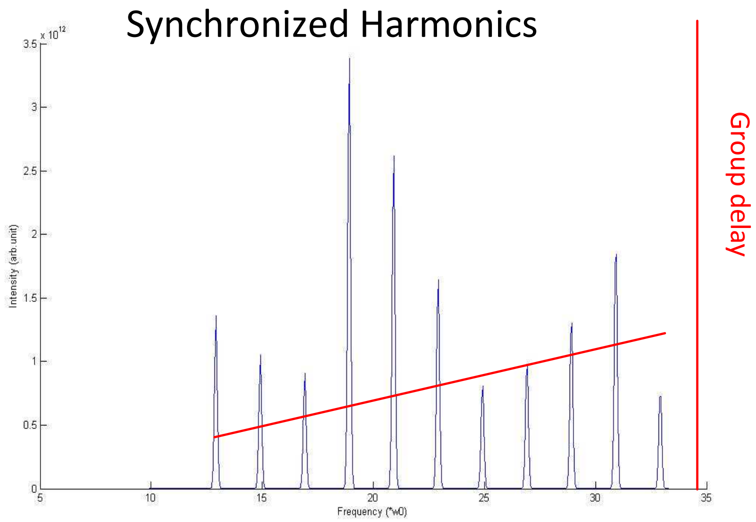
Reconstruction of Attosecond harmonic Burst By Interference in Two photon Transition

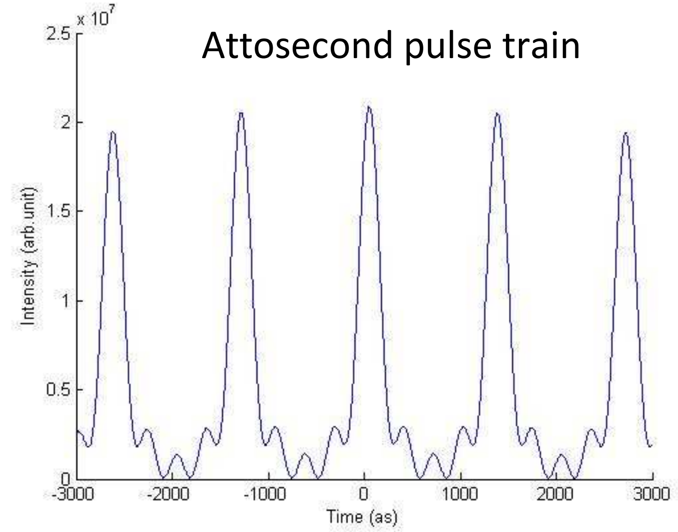


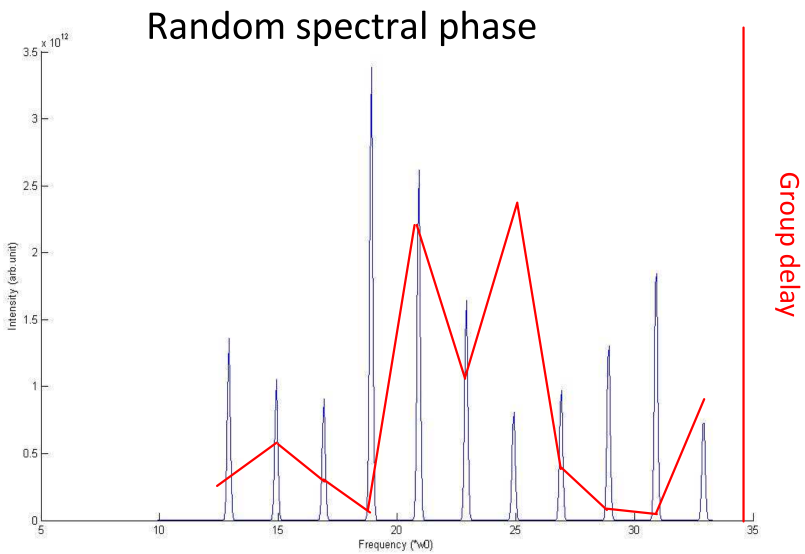
Diego Guénot Lund University (Sweden)

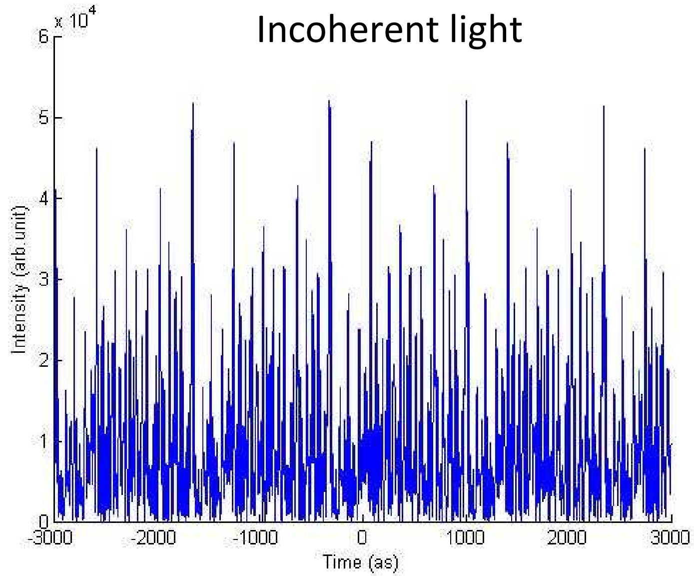
Temporal profile of a group of harmonics

Question: Are the phases of the different harmonics locked?





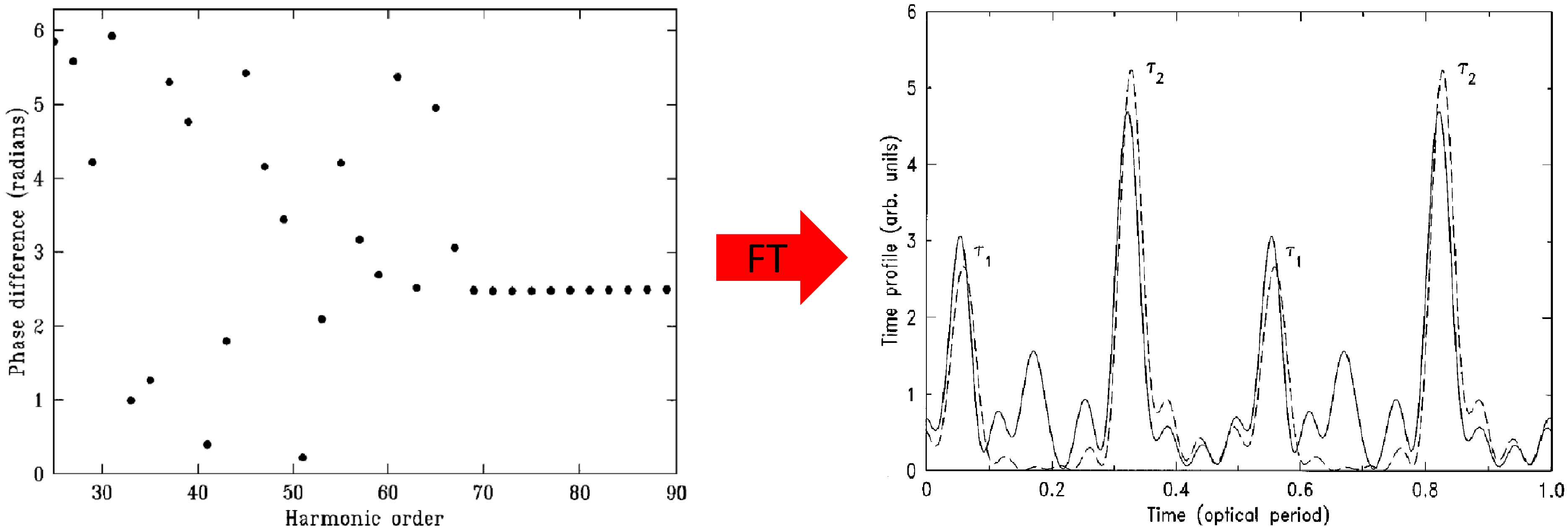




Prediction of the SFA

The spectral phase seems to be random

The temporal profile present 2 attosecond peaks per half period.



Contribution from the short and long trajectory!!

<u>Questions:</u>

_Can we select only one pulse ? ➡ Yes by phase matching

_Can we characterize it ? ➡ Yes using the RABITT technique

P. Antoine et al. Phys. Rev. Lett. 77, 1234 (1996)

Principle of the measurement (RABBIT)

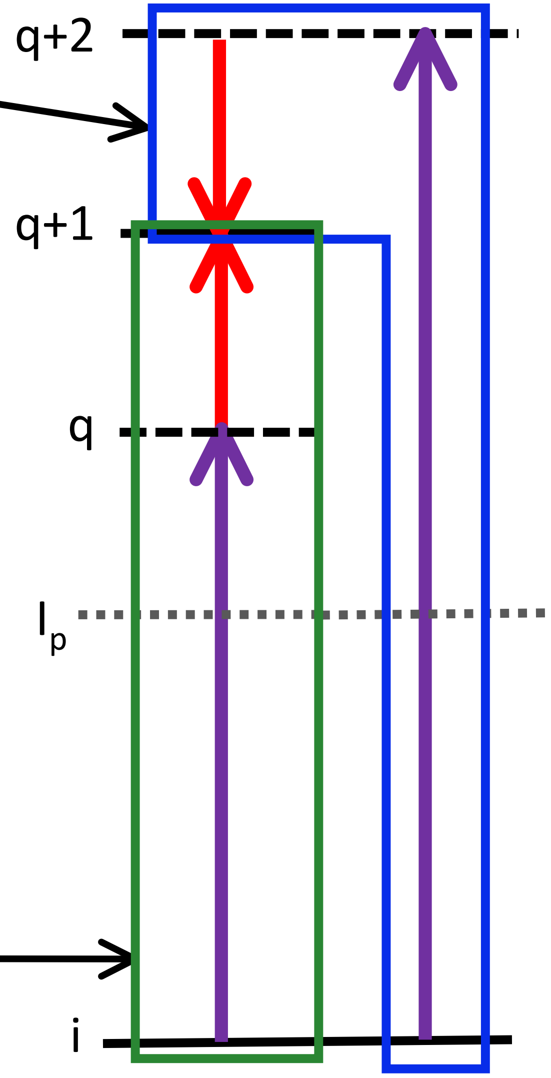
$\Phi_{harm}(q+2) - \omega t + \phi_{ionization}(q+2)$

_Ionisation with the XUV field in the presence of a weak infrared field

_Interference between two quantum paths

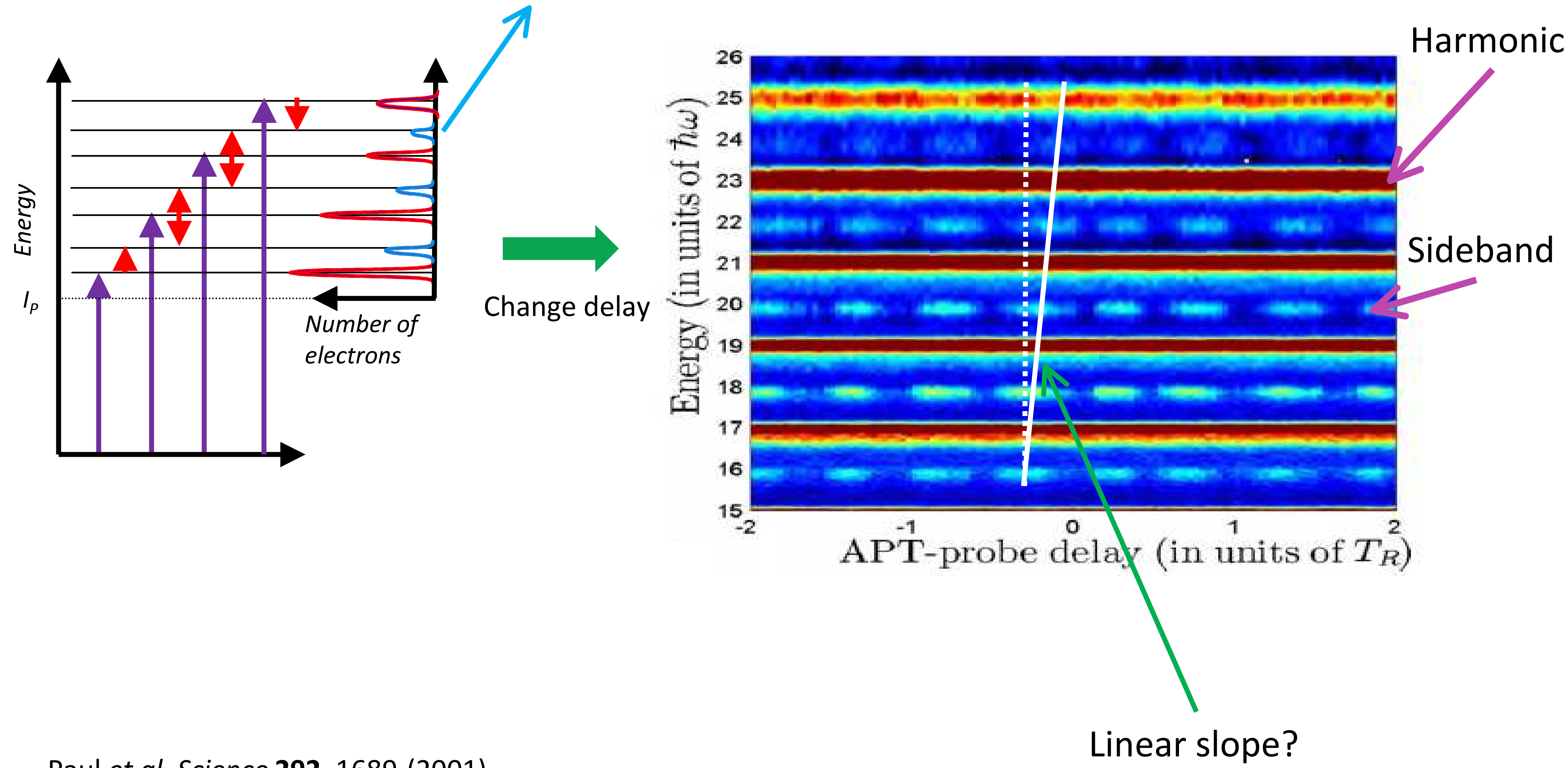
$$S_{q+1} = C_0 + S_0 * \cos(2\omega t - \Delta\phi_{harm} - \Delta\phi_{ionization})$$

$\Phi_{harm}(q) + \omega t + \phi_{ionization}(q)$



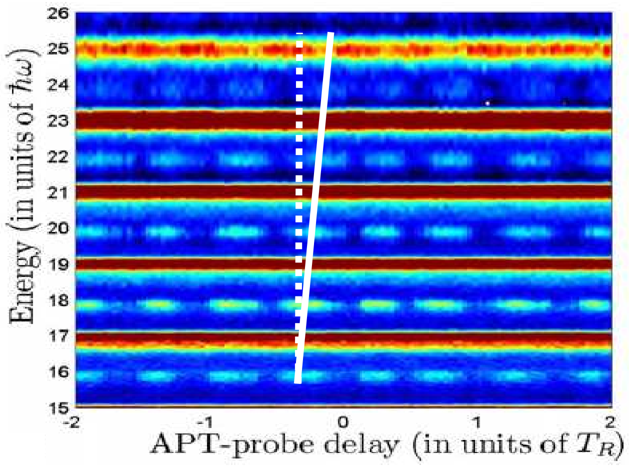
Photoelectron spectrum

$$S_{q+1} = C_0 + S_0 * \cos(2\omega t - \Delta\phi_{harm} - \Delta\phi_{ionization})$$



Paul *et al*. *Science* **292**, 1689 (2001)

How to analyse the photoelectron spectrum



Sideband intensity:

$S_{q+1} \sim \cos(2\omega t - \Delta\phi_{harm} - \Delta\phi_{ionization})$

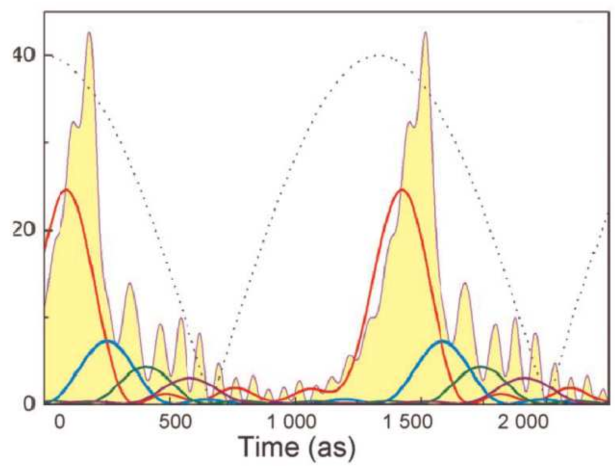
$$\Delta\phi_{harm} = \phi_{harm}(q+2) - \phi_{harm}(q)$$
$$\sim 2\omega_0 {*} d\phi_{harm}(q+1)/d\omega$$
$$\sim 2\omega_0 {*} \mathbf{t_e(q+1)}$$

Emission time

The linear slope means that the emission time varies linearly between the harmonics ➡ Constant chirp (Group delay dispersion)!!!

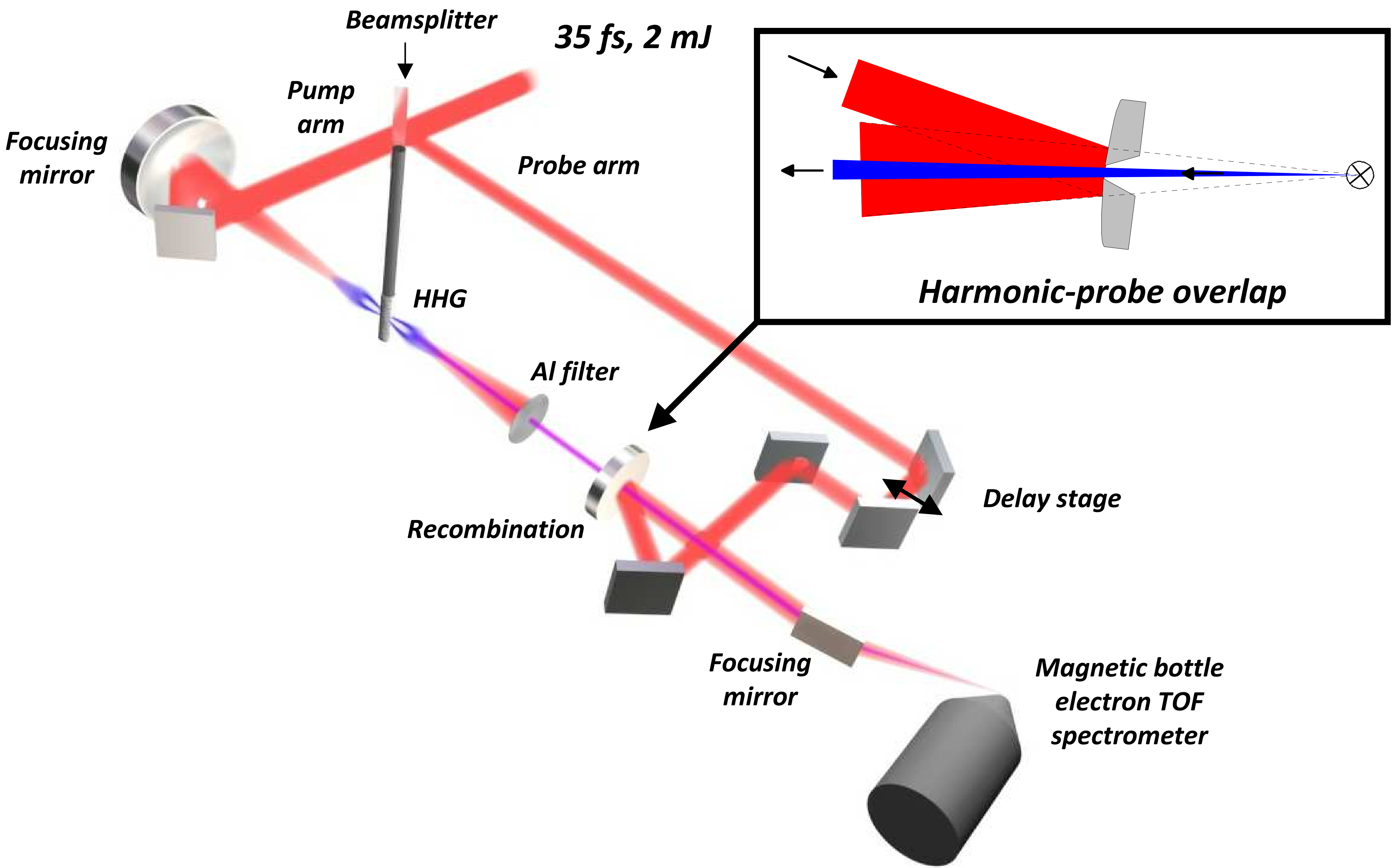
$GDD = d^2\phi_{harm}/d\omega^2$

Reconstruction of the pulse (130 as):

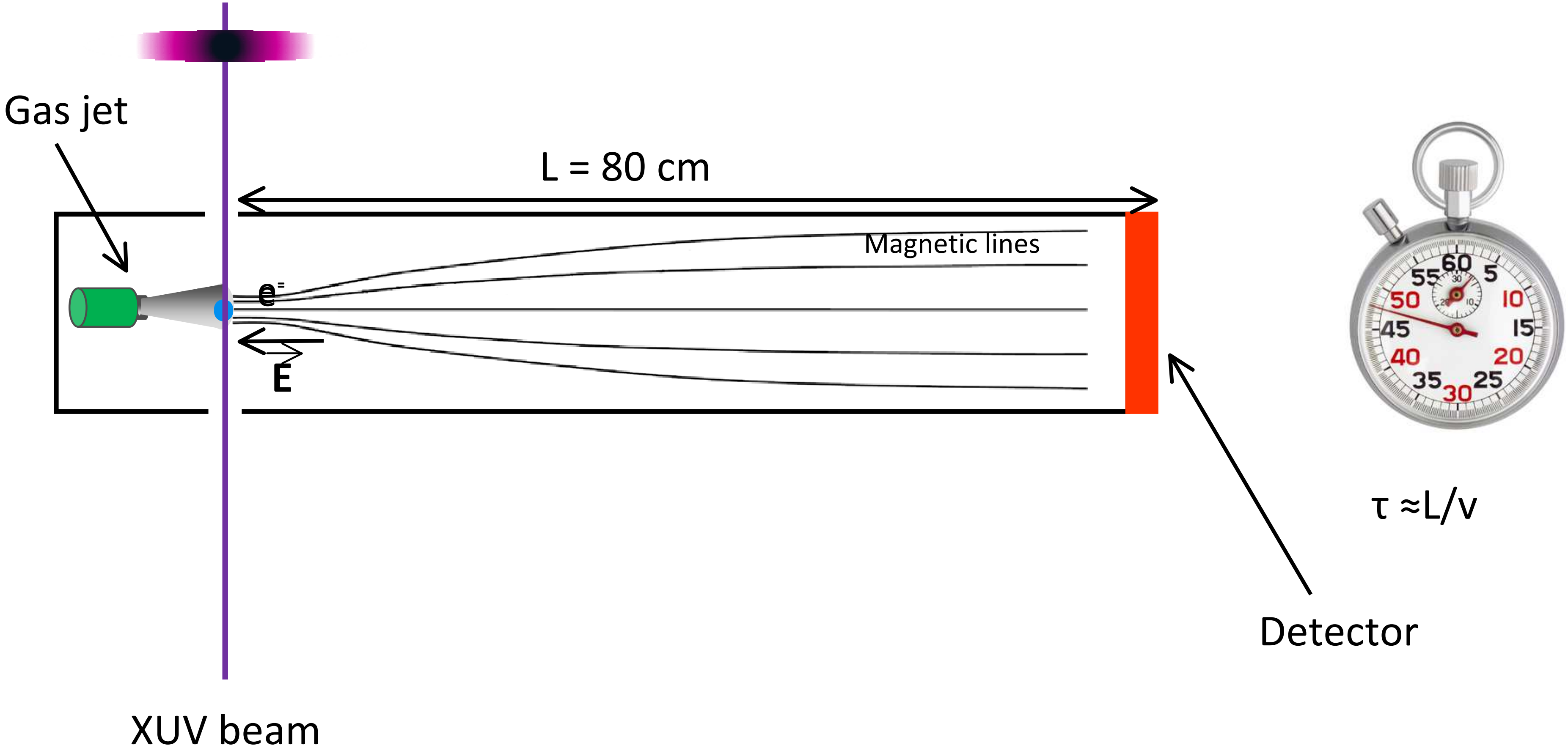


Y.Mairesse et *al* Science 302, 1540 (2003)

Cross-correlation setup

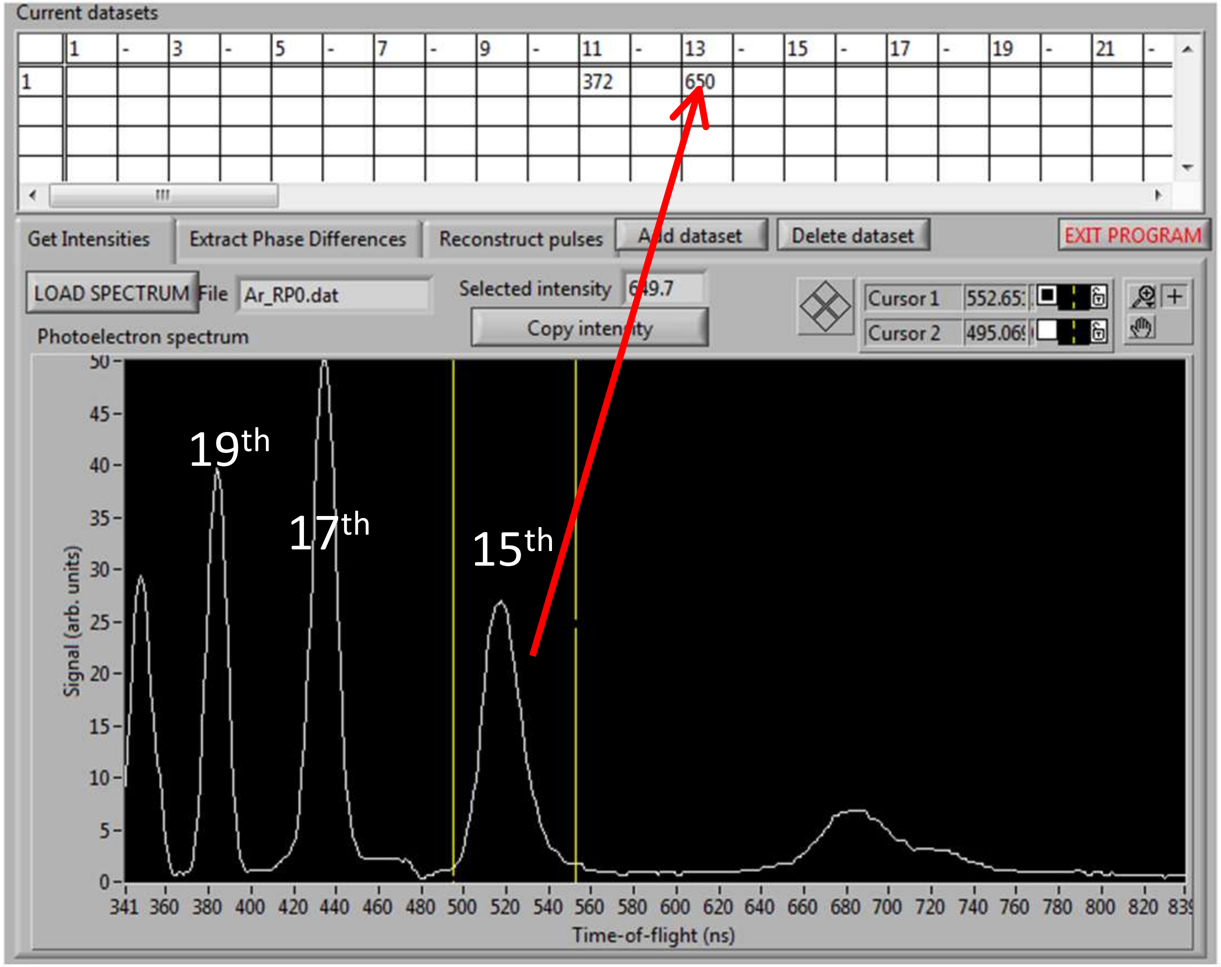


Magnetic Bottle Electron Spectrometer (MBES)

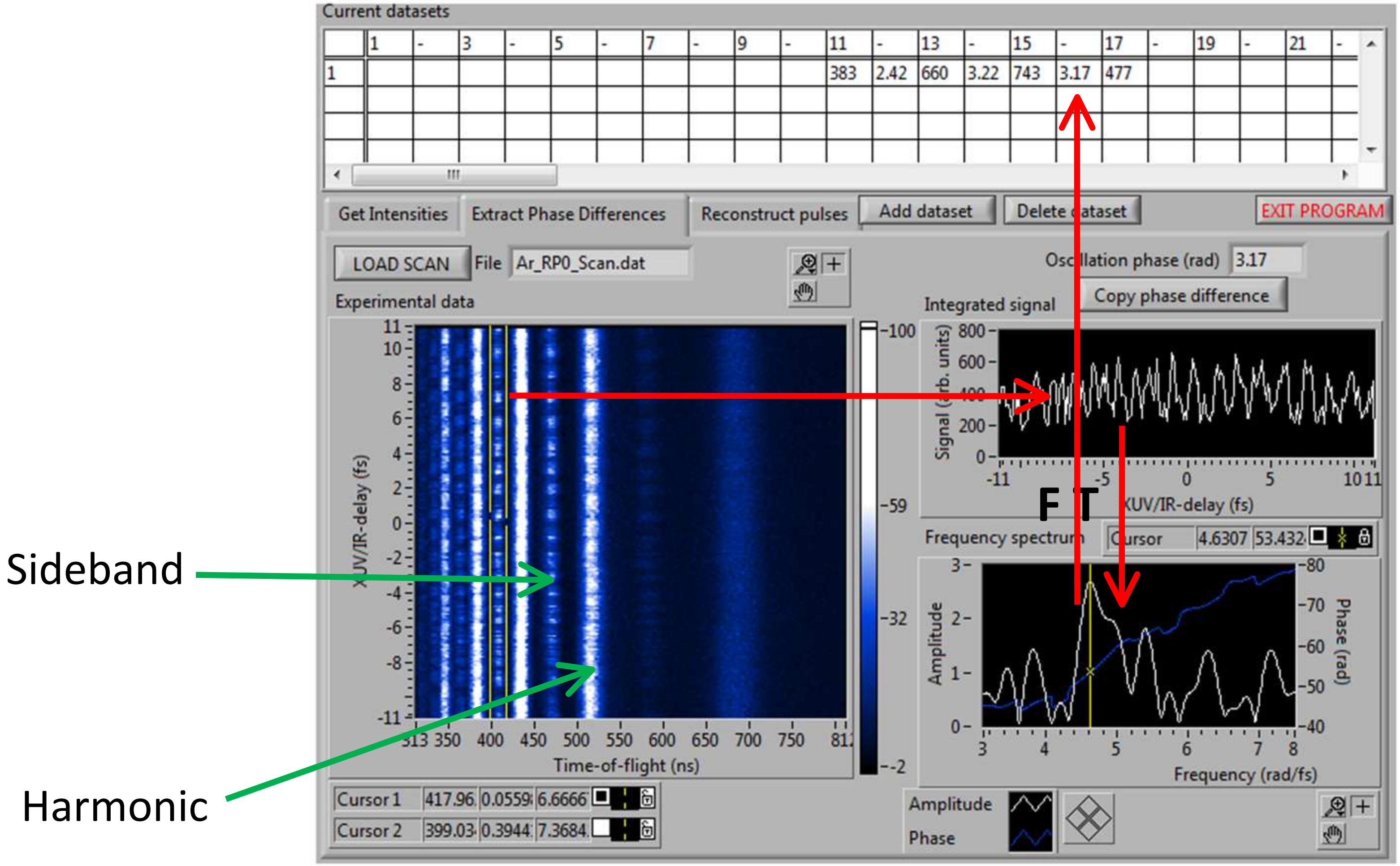


P Kruit and F H Read, J. Phys. E: Sci. Instrum., Vol. 16. 1983.

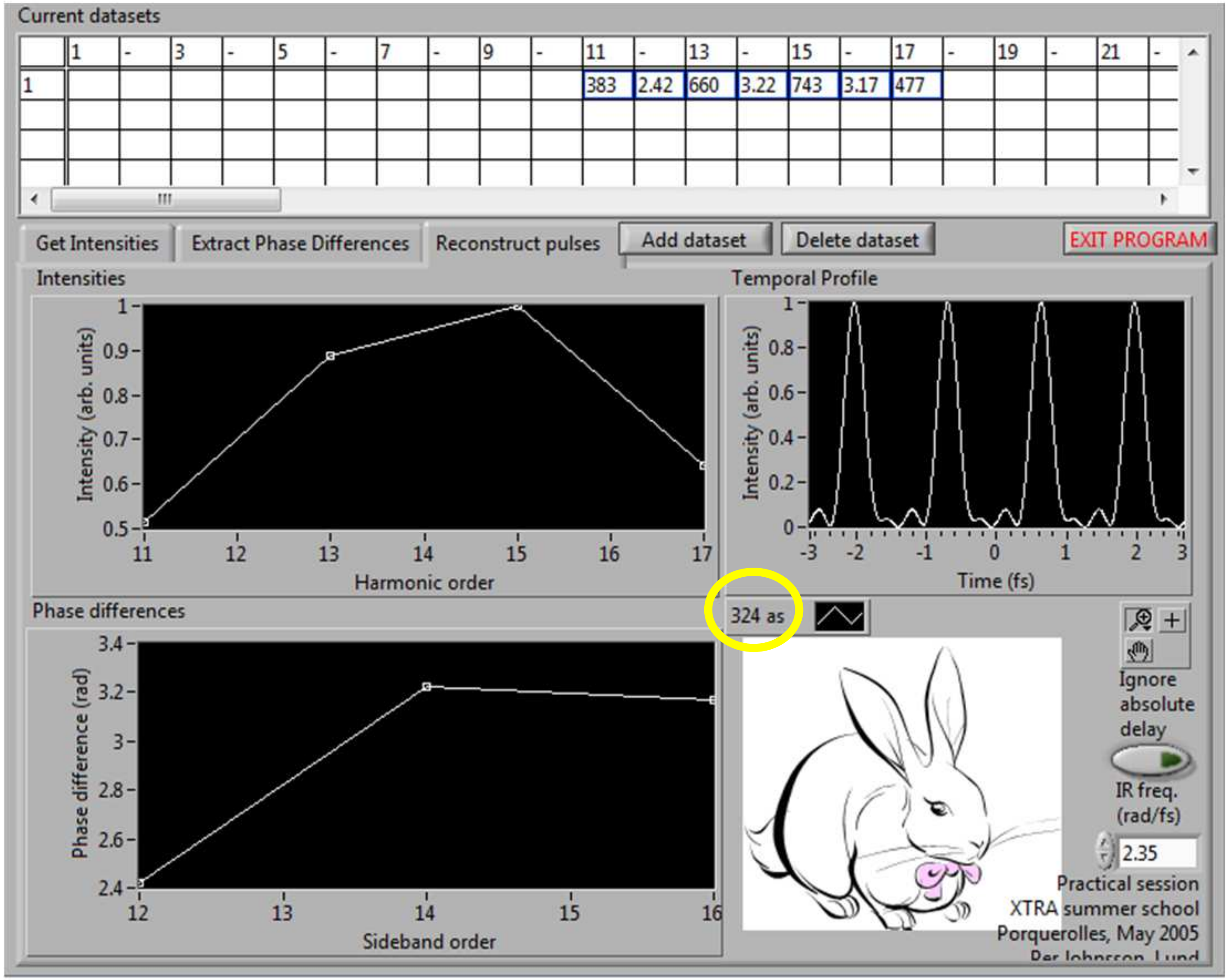
Labview program



Labview program



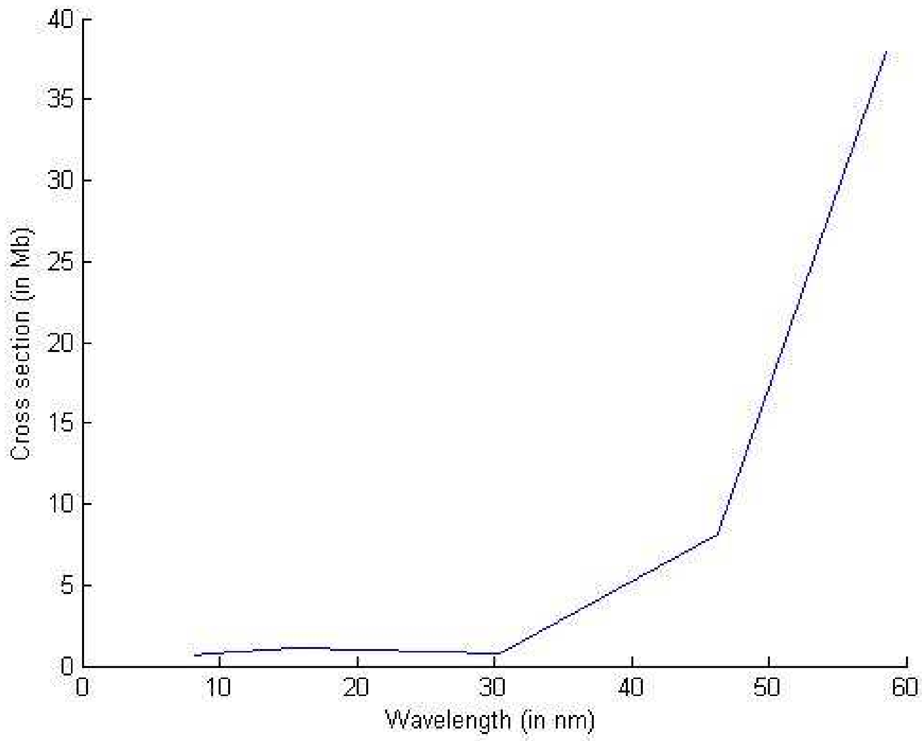
Labview program



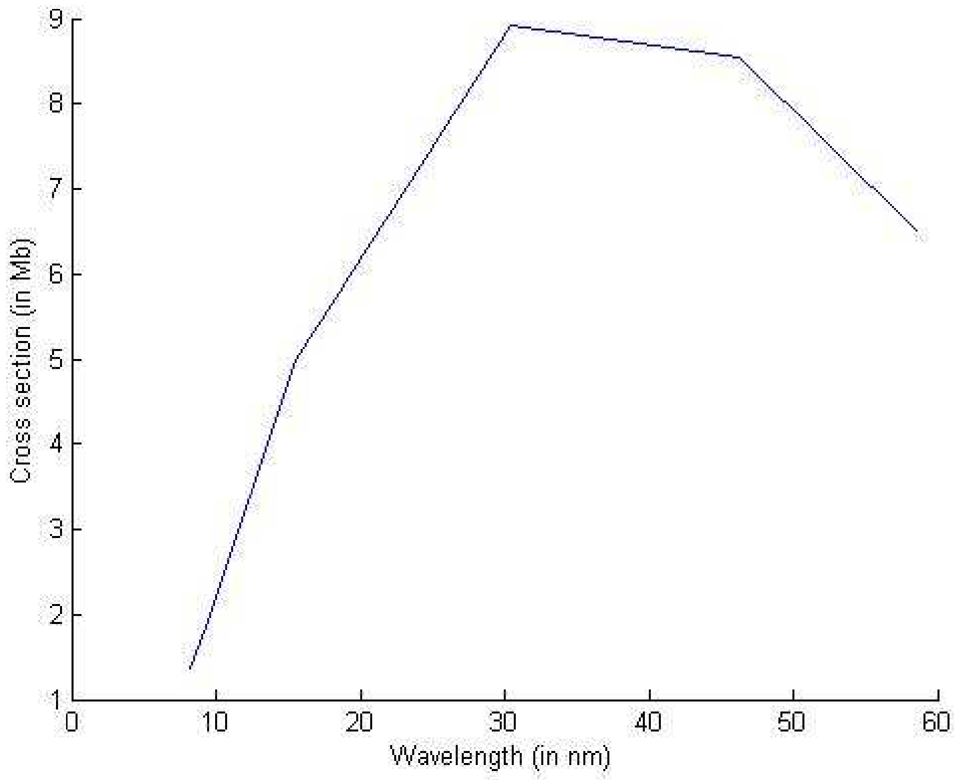
Useful data

Cross section

Argon (Ip=15.76 eV)



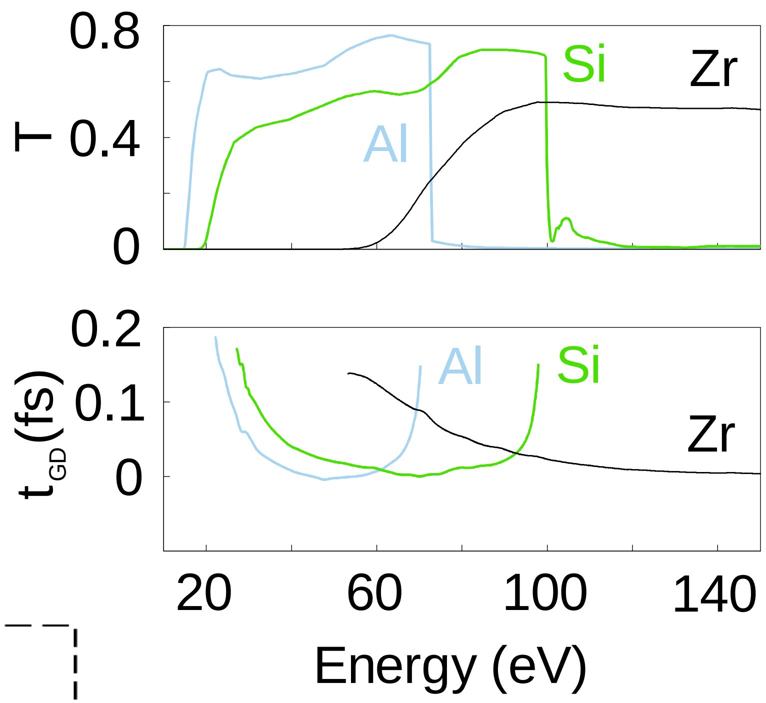
Neon (Ip=21.56 eV)

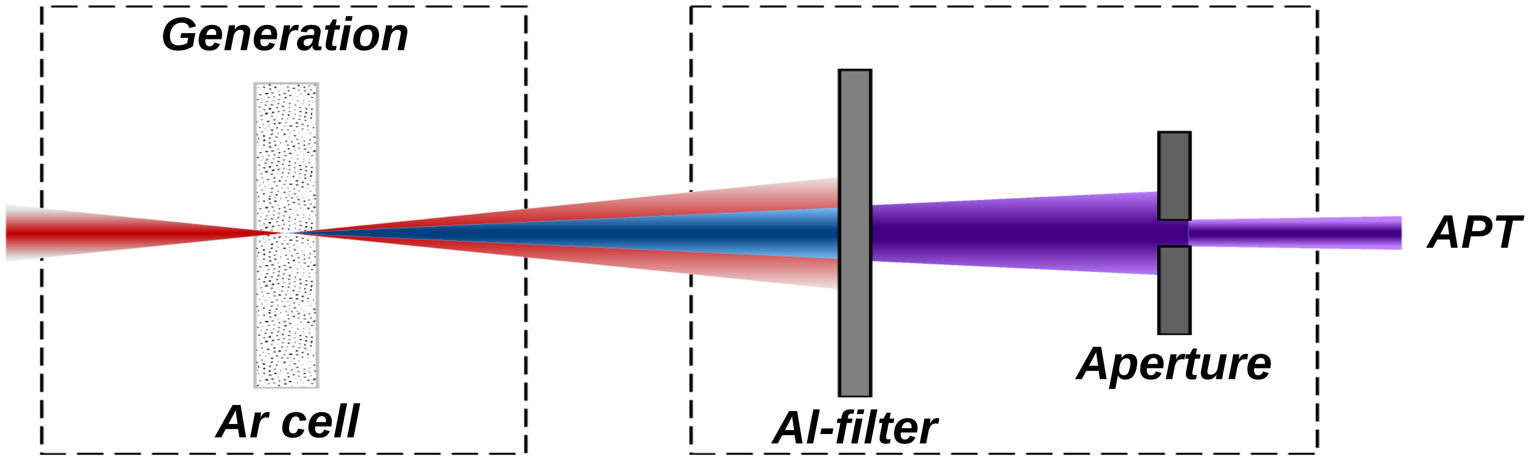


Application 1:
Pulse compression using filters

Can we compensate the attosecond chirp?

Yes, using metallic filters (GDD < 0)

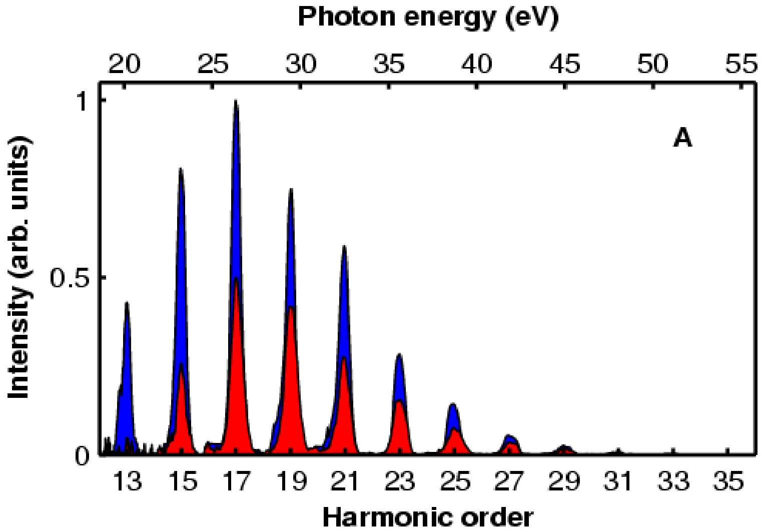




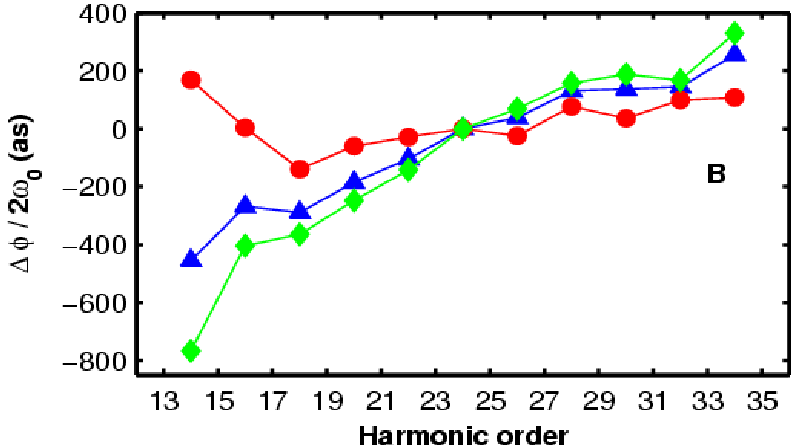
K. T. Kim et al., *Phys. Rev. A,* ***69****, 051805* (2004)

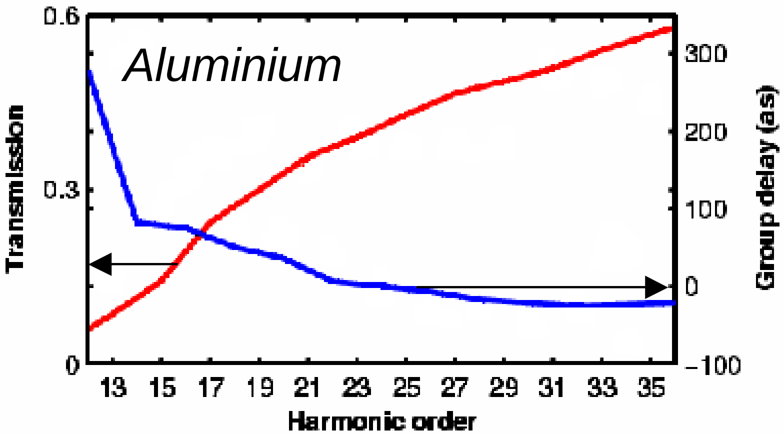
Aluminium filters

Harmonic Spectrum

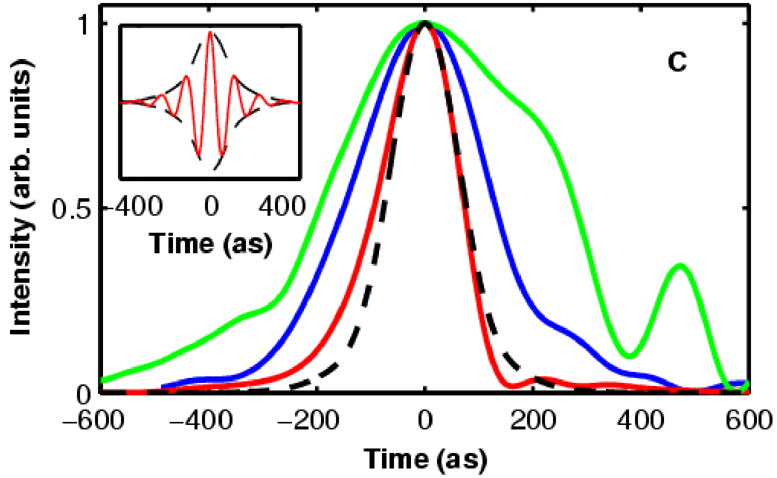


Harmonic phase difference (delay)





Reconstructed pulse

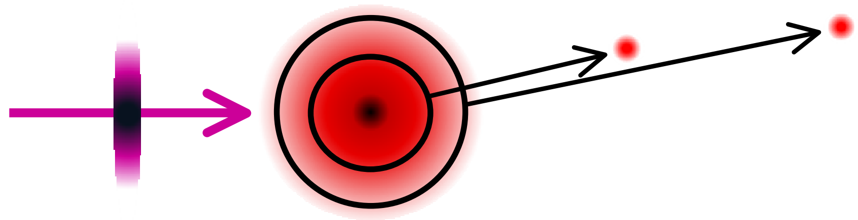


- *No Filter, 480 as* (green)
- *200 nm Al, 280 as* (blue)
- *600 nm Al, 170 as* (red)

López-Martens et al., *Phys. Rev. Lett.*, ***94***, *033001* (2005)

Application 2:
Photoemission measurement delay

How long does it take for an electron to be photoionized?



- Group delay of an electron wave packet during photoemission

electron propagation:

$$\hbar \frac{d\eta}{d\epsilon} = \tau_{\mathrm{W}}$$

← Scattering phase

Wigner time delay

optics: pulse propagation

$$\phi(\omega) \Rightarrow GD(\omega) = \frac{d\phi}{d\omega}$$

Scattering phase: phase of the one photon matrix element.

$$M_a^{(1)}(k_a) \propto e^{i\eta_1(k_a)}$$

How do we measure τ_W?

Principle of the measurement (2) (RABBIT)

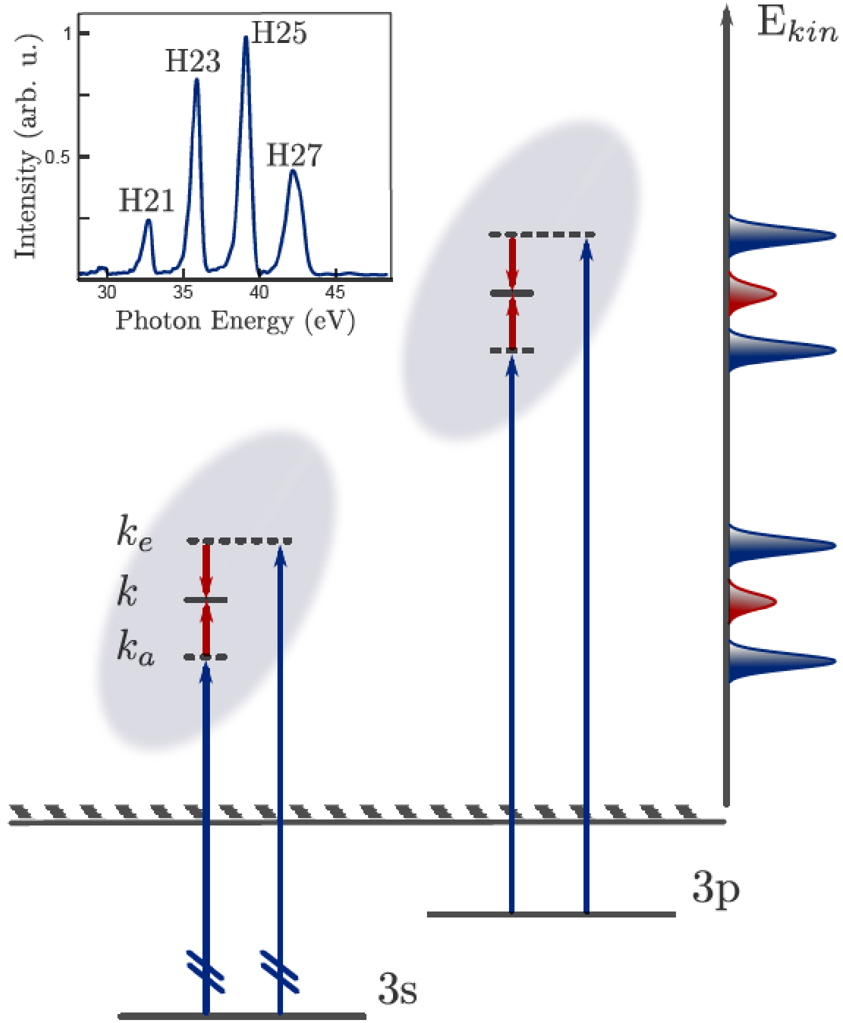
Ionisation from two differents states (3s-3p)

Oscillations of the sidebands:

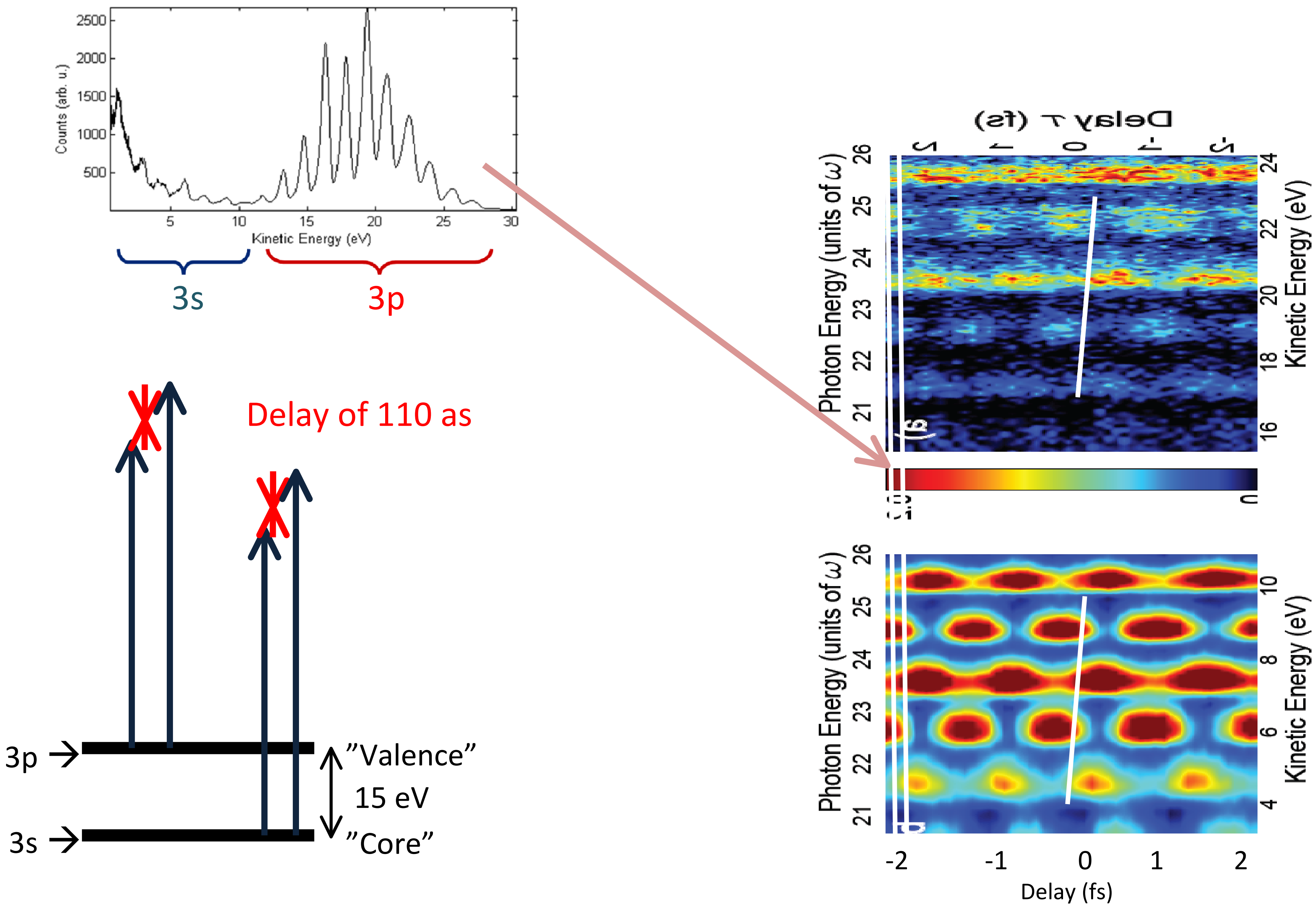
$\cos(2\omega t + \Delta\phi_{harm} + \underline{\Delta\eta(3p) + \Delta\phi_{cc}(3p)})$

Shift!

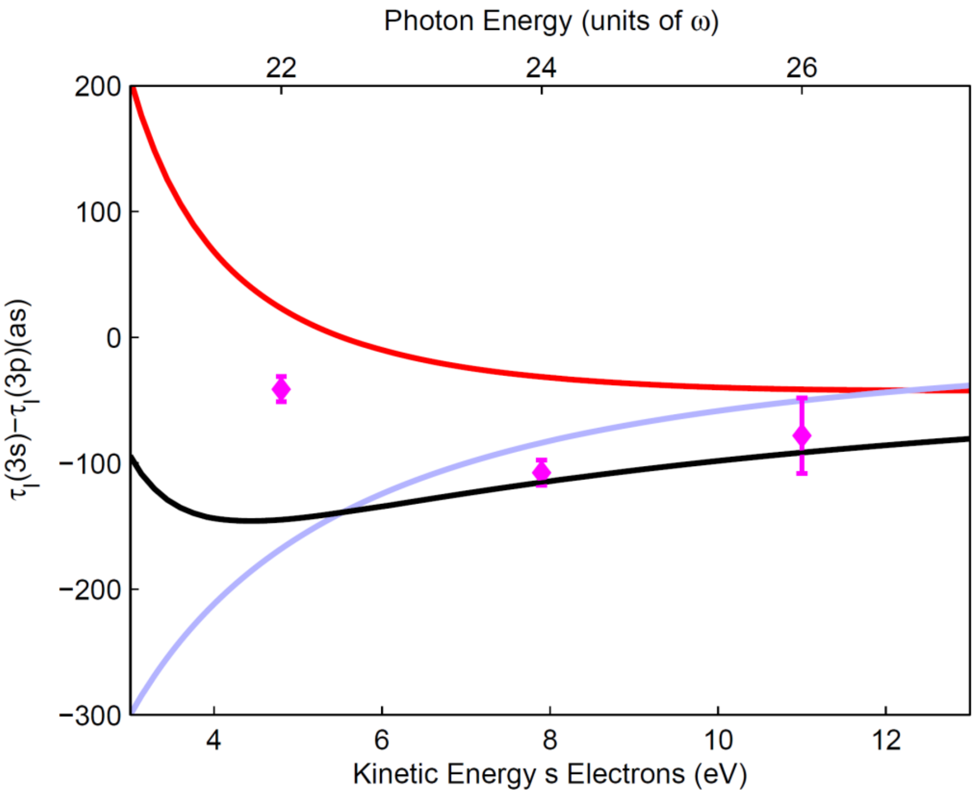
$\cos(2\omega t + \Delta\phi_{harm} + \underline{\Delta\eta(3s) + \Delta\phi_{cc}(3s)})$



Experimental results



Experimental results



Wigner time delay:

$$\hbar \frac{d\eta}{d\epsilon} = \tau_{\mathrm{W}}$$

Continuum-continuum contribution

Total

Experiment

Good agreement at high energy

Low energy: contribution from the core and resonance

Klünder et al., arXiv:1012.3863.

Labview program: change settings