

X-Ray pulse-measurement by Chirped Pulse Laser Assisted Auger Decay

Letter of intent for LCLS
(Category C, instrumentation)

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1 Introduction and aim

LCLS will be the first x-ray FEL in the ultrafast regime opening up the way to a new era of inner-atomic and sub-atomic science. Exciting physics can not only be expected due to the brightness of LCLS which is by several orders of magnitude higher compared to other x-ray sources but also due to the efforts made towards the regime of ultrashort pulses.

A prerequisite for the proper use of ultrashort pulses in a time-resolved manner which shall give new insight into matter is the measurement and characterization of the pulses used. The setup of an appropriate measurement system including the necessary instrumentation is the content of this letter of intent.

2 Method

X-ray pulses generated at LCLS are considered to have a pulse duration of ~ 67 fs at a wavelength of λ between 1.5 nm and 0.15 nm. In principle, an x-ray pulse duration measurement can be done by measuring the x-ray generated photo- or Auger electron spectra with an additional dressing field, mostly provided by a fs laser [1-5].

Whereas [2-5] are cross correlation measurements using a time delay in a kind of x-ray pump/visible probe experiment, this is not easy to establish at the LCLS, since a jitter in the ps range (no intrinsic synchronisation) makes time delay studies extraordinarily difficult. That's why a single shot measurement is most straightforward at the expected conditions and is possible due to the high number of photons provided by LCLS.

The idea is to excite atoms, most likely in the gas phase (allows characterization of transmitted beams, see fig. 1), and measure a certain Auger line by detecting the Auger electrons by a TOF detector. An additional dressing field provided by a laser pulse will lead to the generation of sideband features due to 'free-free transitions' (stimulated inverse bremsstrahlung). The (first) sideband will be separated from the main Auger line by $E_L = \hbar\omega = 1.6$ eV at a laser central wavelength of $\lambda = 780$ nm (Ti:Sa). The use of an Auger line for this aim is ideal as the features of the line are independent of the spectral properties of the exciting x-ray pulse whereas a photoelectron line would mimic the spectrum of the x-ray pulse. To resolve sidebands the main band should be at least narrower than 3 eV (~ 2 times E_L) which can be provided by several Auger lines.

The $KL_{23}L_3$ line in Ar, for example, has a width of 0.93 eV and will be excited by radiation which has an energy of more than 3.2 keV.

Though, the temporal distribution of the Auger electrons ('the line') carries the information about the duration of the x-ray pulse convoluted with the Auger decay time (which is known from literature to be around 1 fs so that it is significantly shorter than the x-ray pulse duration) one cannot extract this information directly. The trick now is, that the laser pulse providing the dressing field carries a significant (linear!) chirp. As different temporal portions of the Auger electron bunch interfere with different portions of the laser pulse they will 'feel' different frequencies ω resulting in different energy shifts E_L . This leads to a broadening of the sideband which - in the case of a chirp-free electric field - would mimic the main band (see fig. 2). Given a linear chirp of 1 eV ($\lambda = 500 - 1000$ nm) in a laser pulse with $\Delta\tau = 300$ fs this would lead to a 0.25 eV broadening of the Auger line at a bunch 'length' (\approx x-ray pulse duration) of 75 fs. At an Auger line width of 1 eV, the reading would be 0.33% broadening/ fs pulse duration. Pulses at a duration of 60 fs and 90 fs, respectively, could be distinguished by spectra which differ by 10 %.

Additionally, the position of the sideband (at different single-shot measurements) gives exact information about the jitter of the system. Whenever the jitter is bigger than ± 150 fs, however, there will be no temporal overlap of the electron bunch and the laser pulse which results in no sideband. Delay times bigger than ± 100 fs (which can be seen in the position of the sideband) must be ignored as possibly only a part of the electron bunch interferes with the laser pulse.

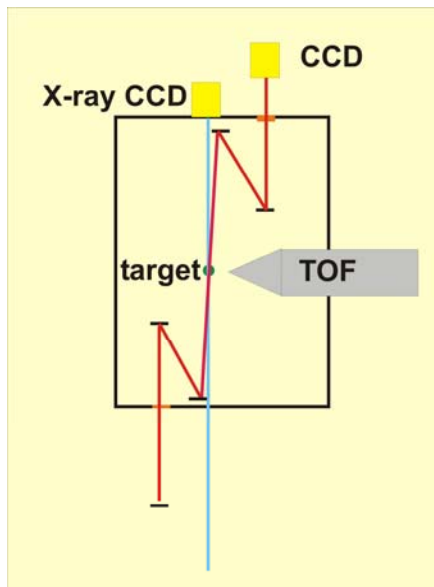


Fig. 1: Setup of the experiment. Blue: x-rays, red: laser providing a dressing field.

3 Experimental Setup:

A laser focal spot size of $d = 500 \mu\text{m}$ together with a laser intensity of $5 \times 10^{11} \text{ W/cm}^2$ - which seems to be optimum for laser assisted photoionization or Auger decay [2-4] - results in a necessary pulse energy of 0.3 mJ at a pulse duration of 300 fs, carrying a wavelength of $\lambda = 500 - 1000$ nm, as mentioned above. This can be obtained in a hollow fiber system using 1 mJ pulses provided by a standard laser amplifier system. The stretching to 300 fs can be done in a dispersive medium, e.g. 10 mm of SF59 glass.

After a delay stage the laser pulses enter the vacuum chamber and then are focused to the gas target in an angle of 10 mrad towards the x-ray beam (1 cm space for a mirror @ 1 m distance

from the target), so that the broadening of the correlation width due to geometric factors is negligible [3].

First the position of the target nozzle is aligned to the x-ray focus using a x-ray CCD camera, then the laser focus is overlapped using a 'normal' CCD camera.

As a check of the TOF one can measure ATI electrons produced by the tighter focused unchirped laser pulse in the gas jet.

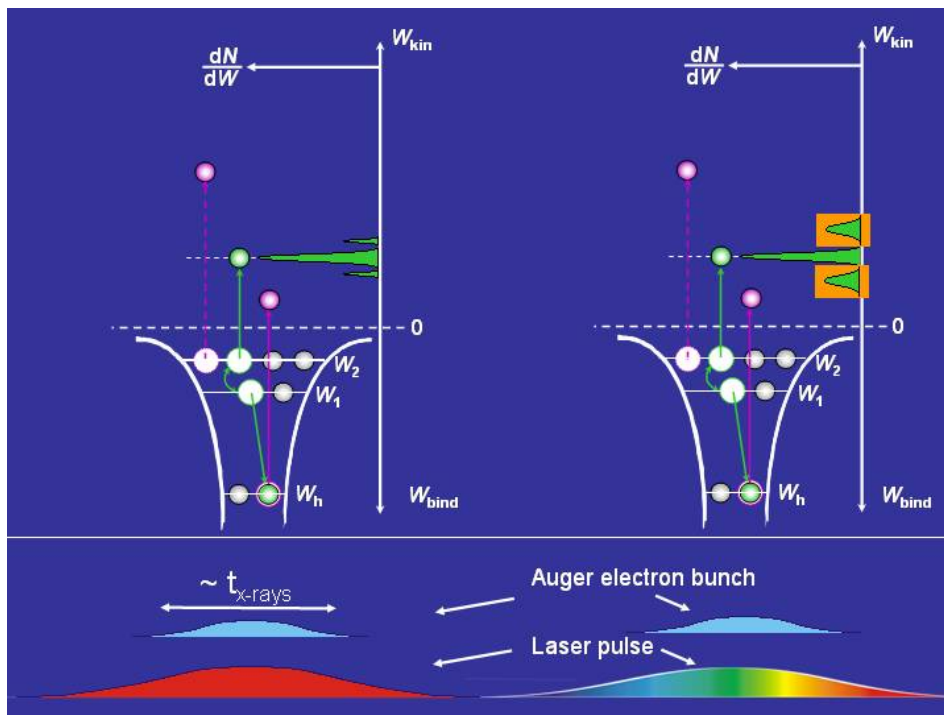


Fig. 2: sidebands produced by the dressing field of a laser pulse without and with chirp, respectively

References

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