Ultrafast Dynamics in Dense Hydrogen Explored at FLASH

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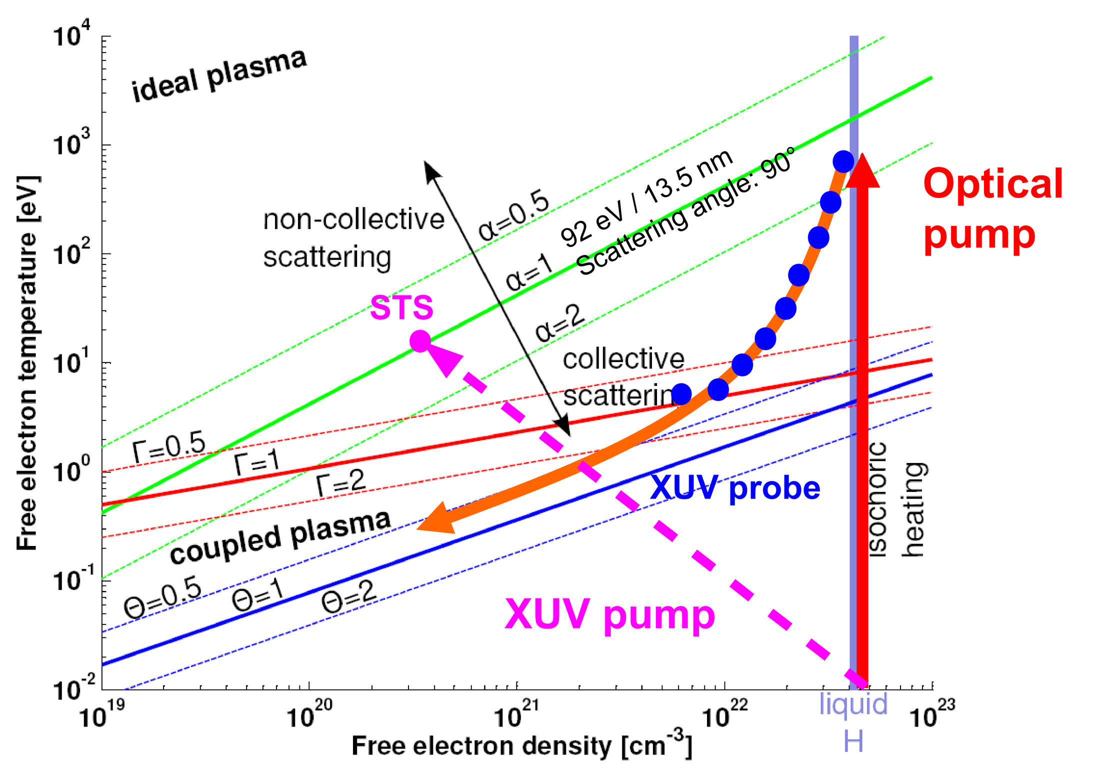
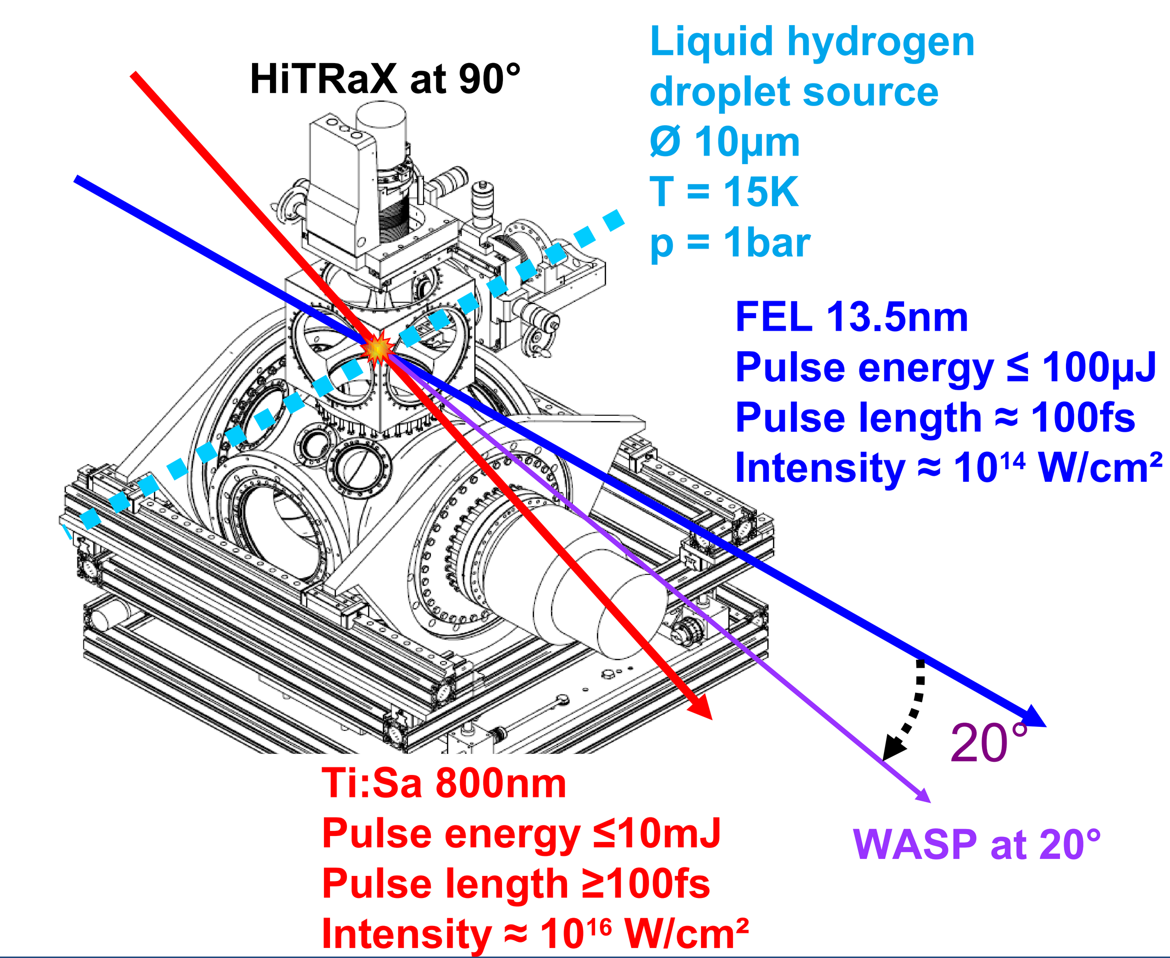
Abstract. We present the results of experiments performed at the Free-Electron Laser in Hamburg (FLASH). It is shown how fundamental plasma parameters *(T, n)* can be determined from a pump-probe experiment. We present preliminary results of a FEL-pump-FEL-probe and an IR-pump-FEL-probe experiment where droplets of liquid hydrogen and their scattering behavior for different pump-probe schemes were observed under multiple angles simultaneously. The object of inquiry was the total scattered intensity which shows a strong dependency on the pump-probe delay and the observation angle.

Hydrogen *T-n* Phase Diagram

Different regimes in the phase-space can be accessed by XUV-pumping (*13.5 nm*) or optical pumping (*800 nm*).

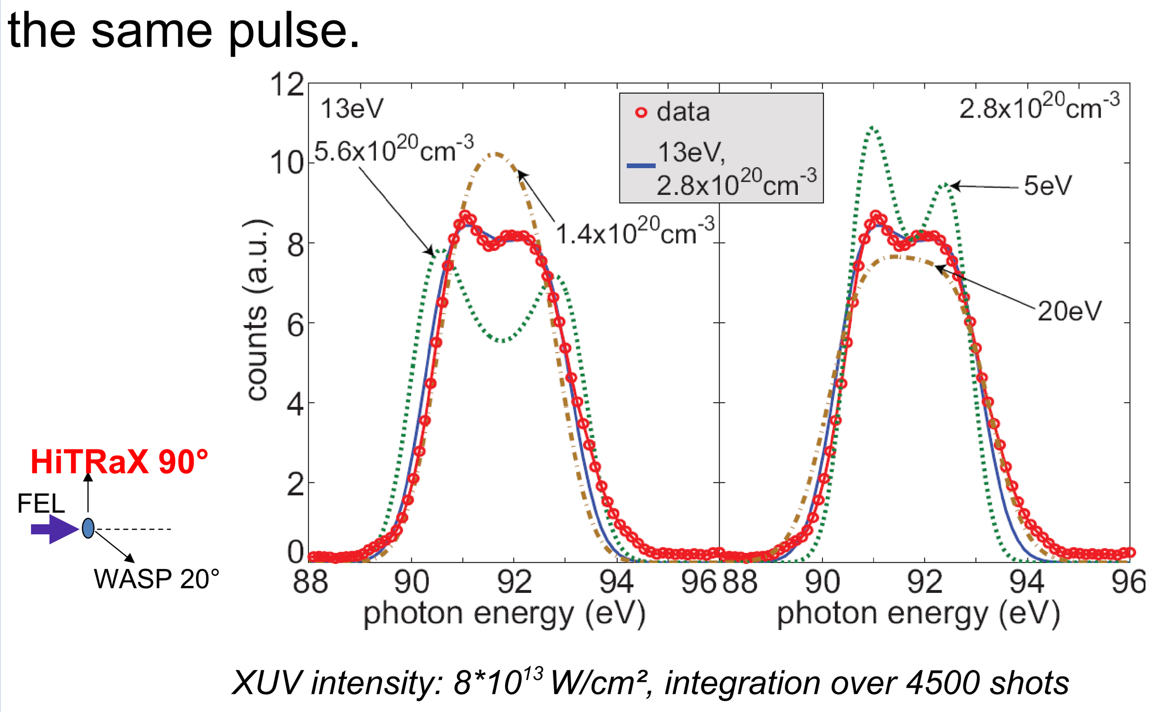


Experimental Setup



Self Thomson Scattering

For a XUV pump – XUV probe scheme, free electron density and free electron temperature can be retrieved. Heating and scattering happens within the same pulse.



*XUV intensity: 8*10^{13} W/cm², integration over 4500 shots*

R.R. Fäustlin et al., PRL 104, 125002 (2010)

Autocorrelator (Split-and-delay)

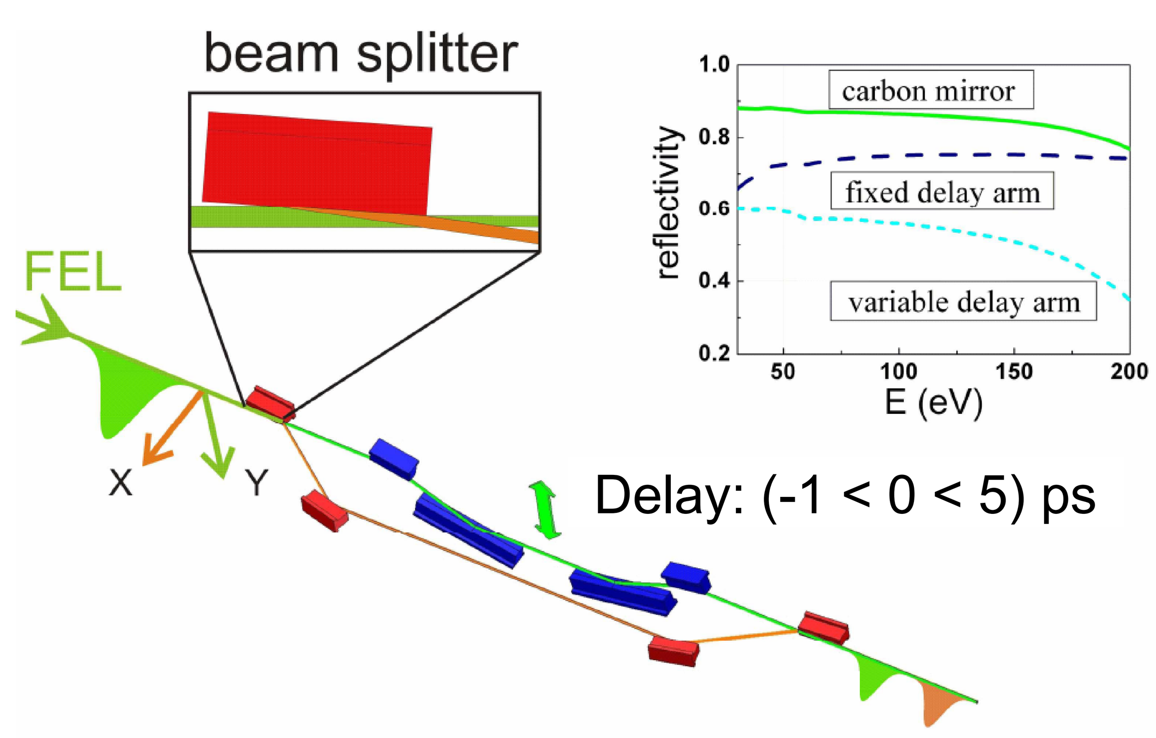
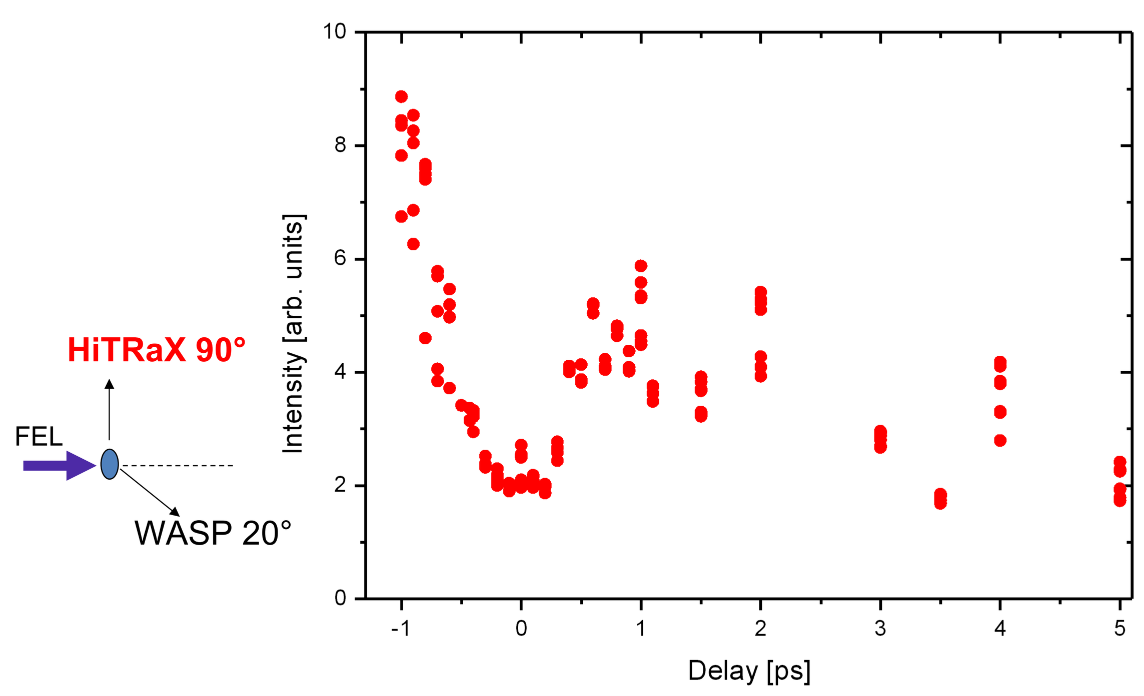


Fig. 1. (a) Schematic drawing of the layout of the autocorrelator. Grazing angles of 3° and 6° for the fixed and variable delay arms, respectively, are employed to ensure a high reflectivity of the soft x-ray radiation. (b) Calculated reflectivity for amorphous carbon coated silicon mirrors for hν = 30 to 200 eV. The full green line shows the reflectivity of a single mirror for a grazing angle of 6°. The beam size in x- and y- directions are 8 mm, respectively, at the position of the CCD camera.

R. Mitzner et al., Opt. Express ***16****, 19909 (2008)*

FEL pump – FEL probe: Observation at 90°

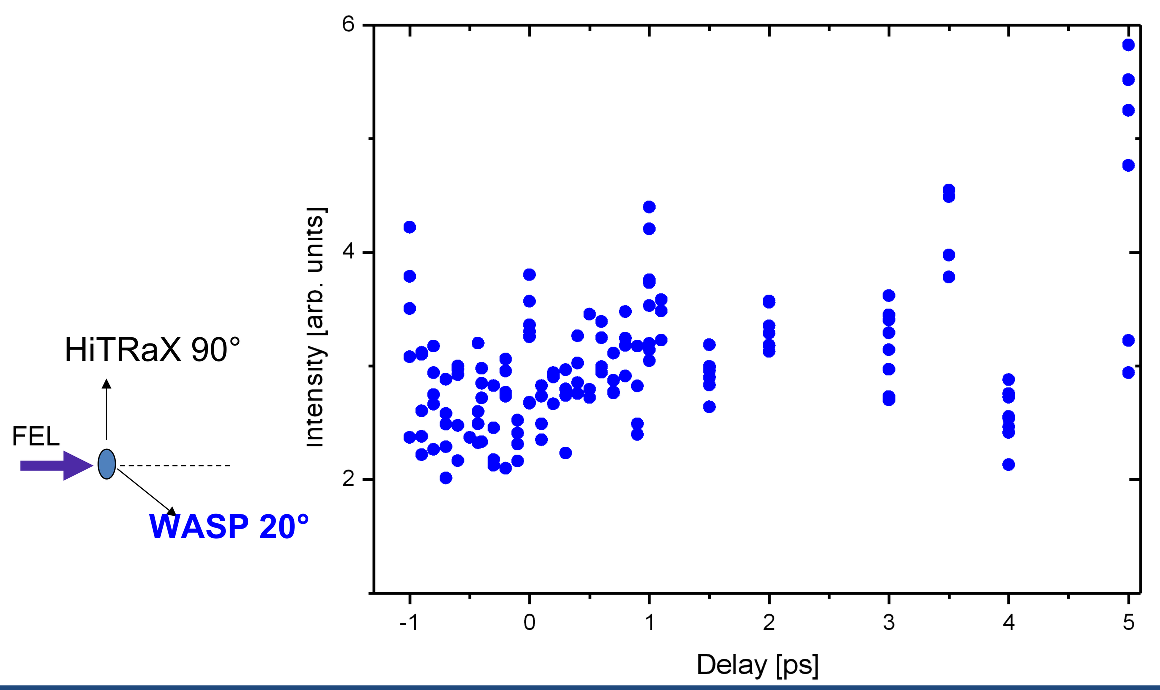
The Integration over the spectrum yields the scattered intensity. We observe a distinct delay dependency. The signal is asymmetric while the pulse should have been split 1:1 with 25% of the total power in each arm.



FEL pump – FEL probe: Observation 0°…40°

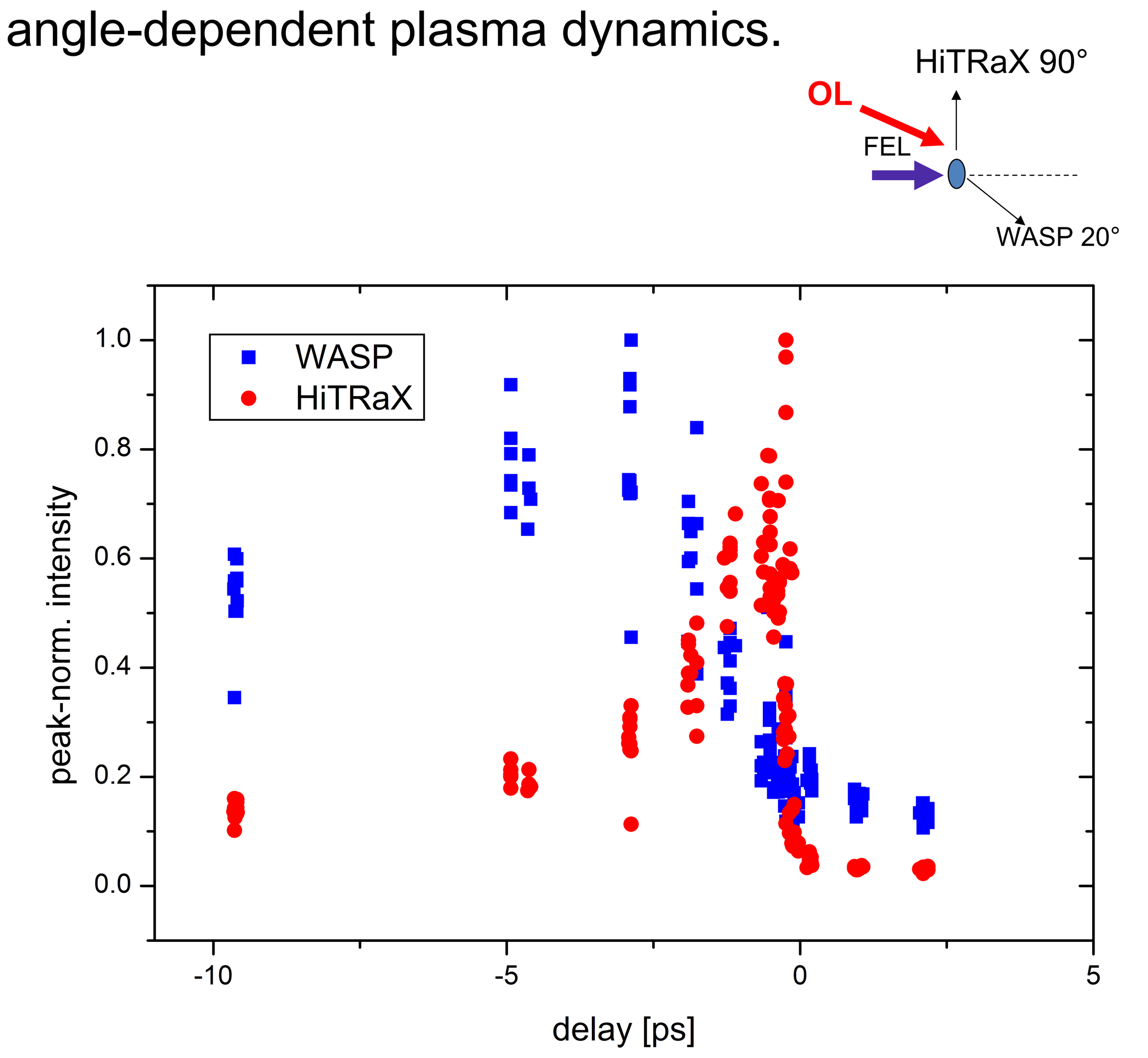
A delay effect in forward scattering direction, if at all present, is very weak.

As an open question the influence of polarization in the splitted beams and the dependency on FEL-split ratio has to be evaluated.



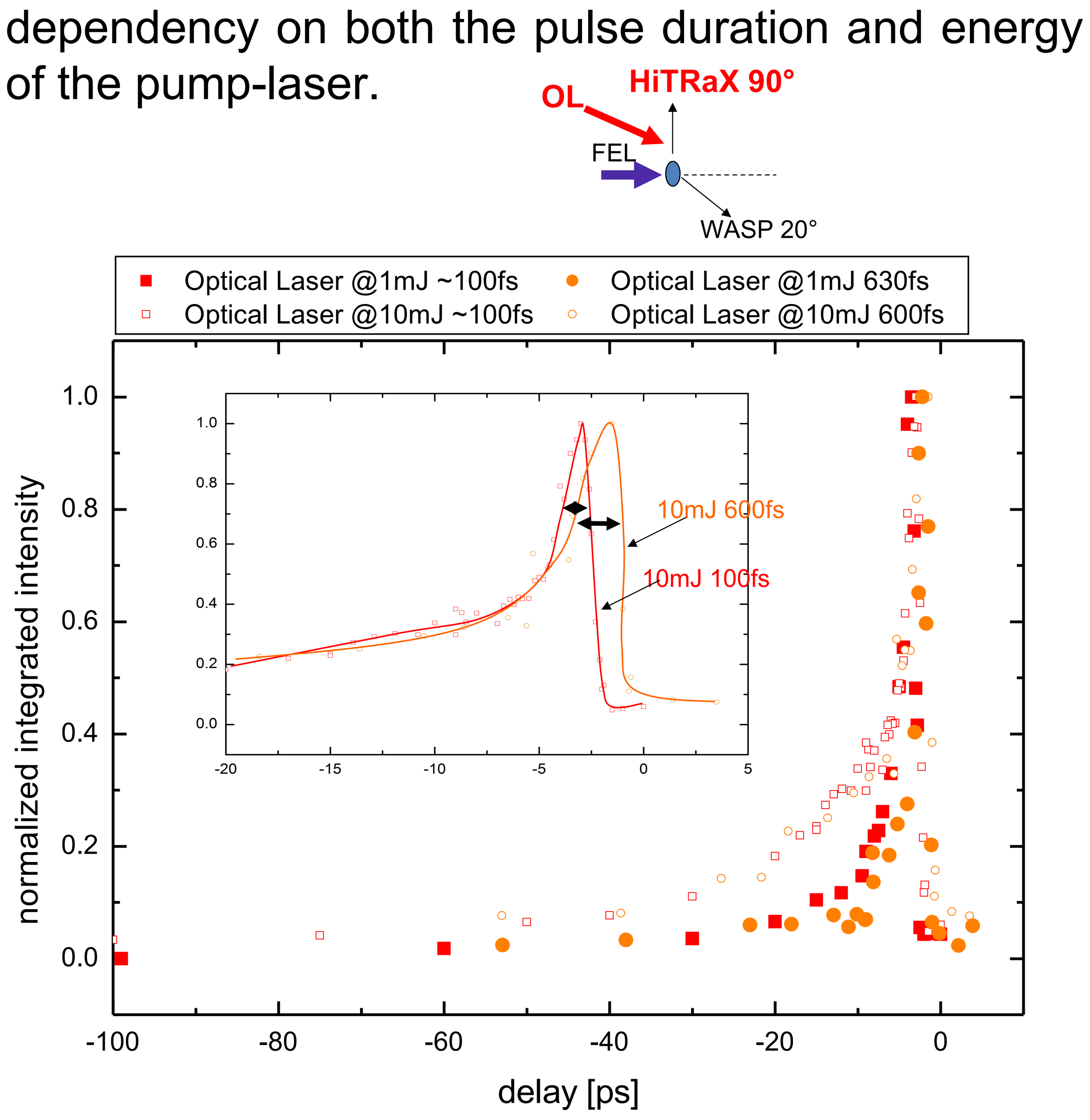
Optical Pump – FEL Probe

When integrating the intensity over the spectral range of the FEL we observe a distinct pump - probe effect in both spectrometers, showing scattering-angle-dependent plasma dynamics.



Optical pump – FEL Probe: Observation at 90°

For a scattering angle of 90° we observe a dependency on both the pulse duration and energy of the pump-laser.



Results

The fundamental plasma parameters *(T, n)* for Self-Thomson-scattering can be determined from the scattered spectrum.

In the pump-probe case, the scattered intensity at 90° rises very sharply to a peak at < 1ps, and decays rather quickly, while the intensity scattered in forward direction at 20° rises significantly slower to a peak at ~ 3ps, and decays slower.

One possible explanation for this effect is that the 90° scattering signal is dominated by a thin heated front layer, whereas in forward scattering we mainly observe how the remaining part of the droplet is heated and thus leading to a longer time-scale.

Acknowledgements.

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