Optimisation of Inverse Compton Scattering via spatiotemporal tailoring of scattering laser

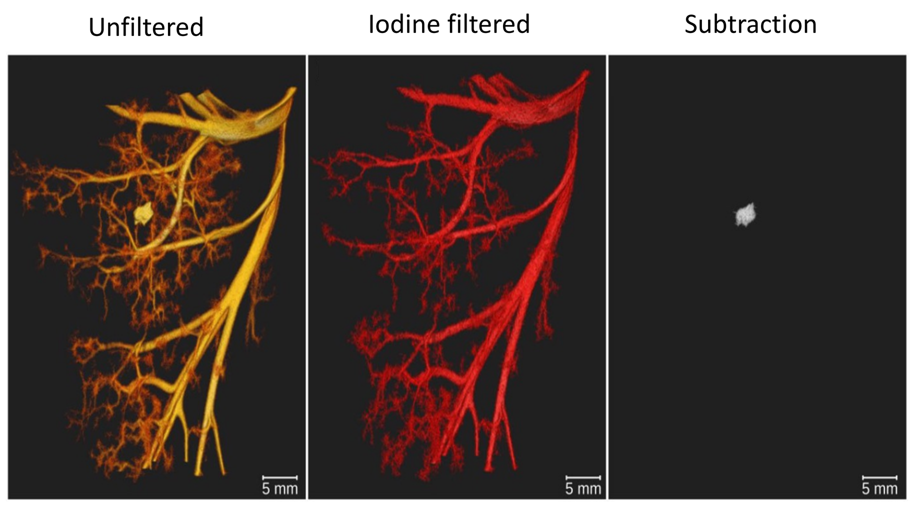
C. Mariani [1,2], M. Meisel [1], L. Martelli [1], K. Põder [1]

[1] Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany
[2] University of Hamburg, Department of Physics, Jungiusstr. 9, 20355 Hamburg, Germany

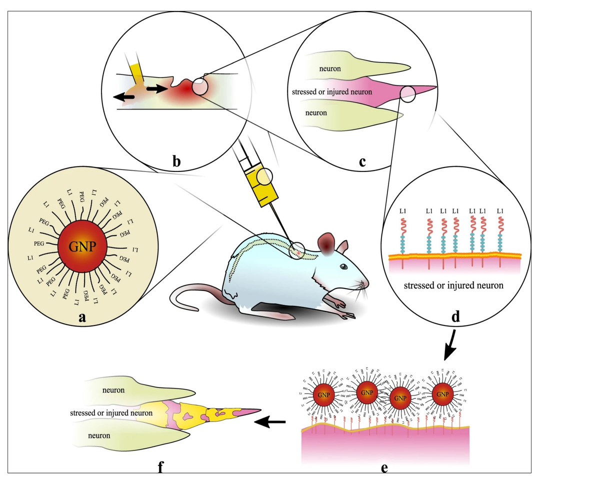
All-Optical High Energy X-rays Applications in medical and industrial field

Advanced imaging applications could benefit from compact, tunable sources, such as all-optical high-energy X-ray (~100 keV) sources based on Inverse Compton scattering.

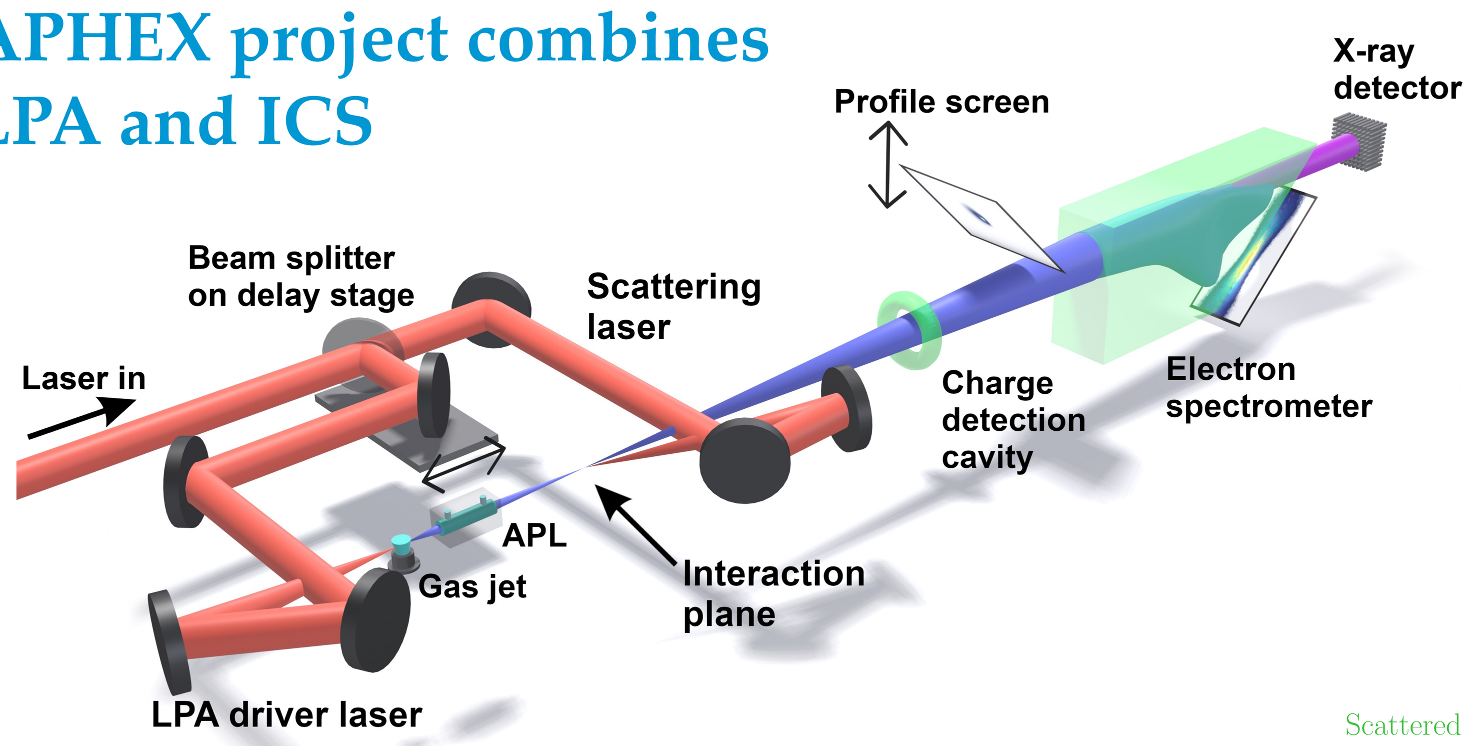
K-edge subtraction imaging [1]

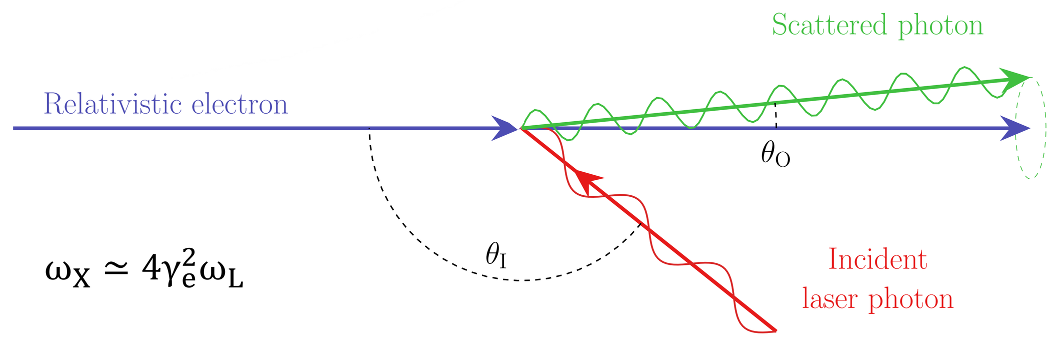


X-ray fluorescence imaging [2]



APHEX project combines LPA and ICS





$$\omega_X = \frac{2\gamma_e^2(1-\beta_e\cos\theta_I)}{1+\gamma_e^2\theta_O^2+a_0^2/2}\omega_L \xrightarrow[\beta_e\to 1,\ \theta_I\to\pi,\ a_0\ll 1]{} \omega_X \simeq 4\gamma_e^2\omega_L$$

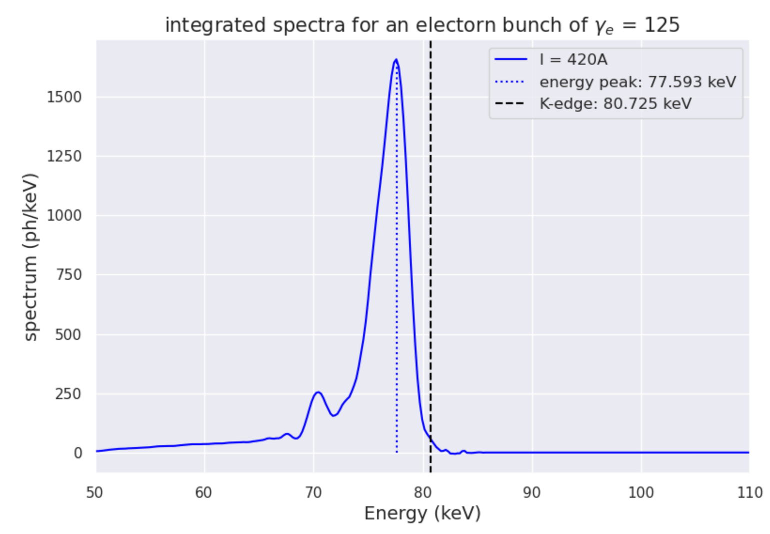
Radiation spectral bandwidth contributions

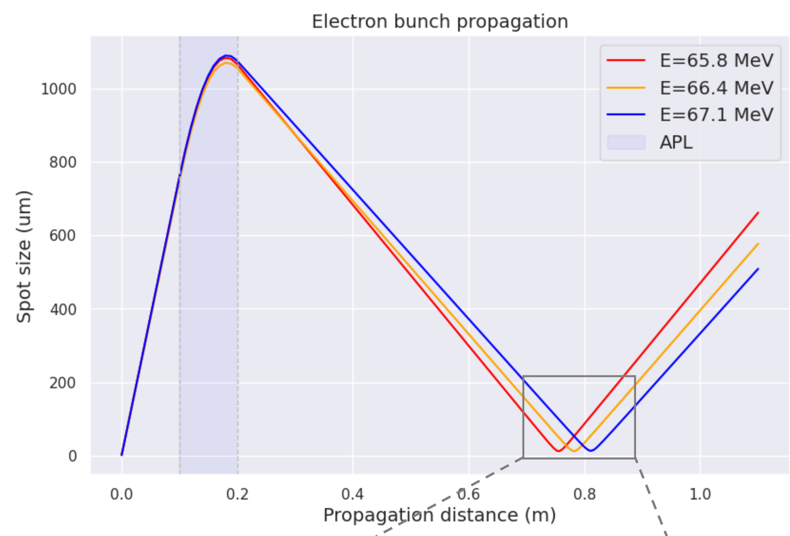
$$\frac{\Delta\omega_x}{\omega_x} = \sqrt{\left(\frac{2\delta\gamma_e}{\gamma_e}\right)^2 + \left(\frac{\gamma_e^2\sigma_\theta^2}{4}\right)^2 + \left(\frac{\delta\omega_L}{\omega_L}\right)^2 + \left(\frac{a_0}{2}\right)^2}$$

Electron beam energy spread | Electron beam divergence | Ti:Sa laser bandwidth | Ti:Sa laser strength

Reduction of the bandwidth down to 4-5% [3][4] with an active plasma lens[3].

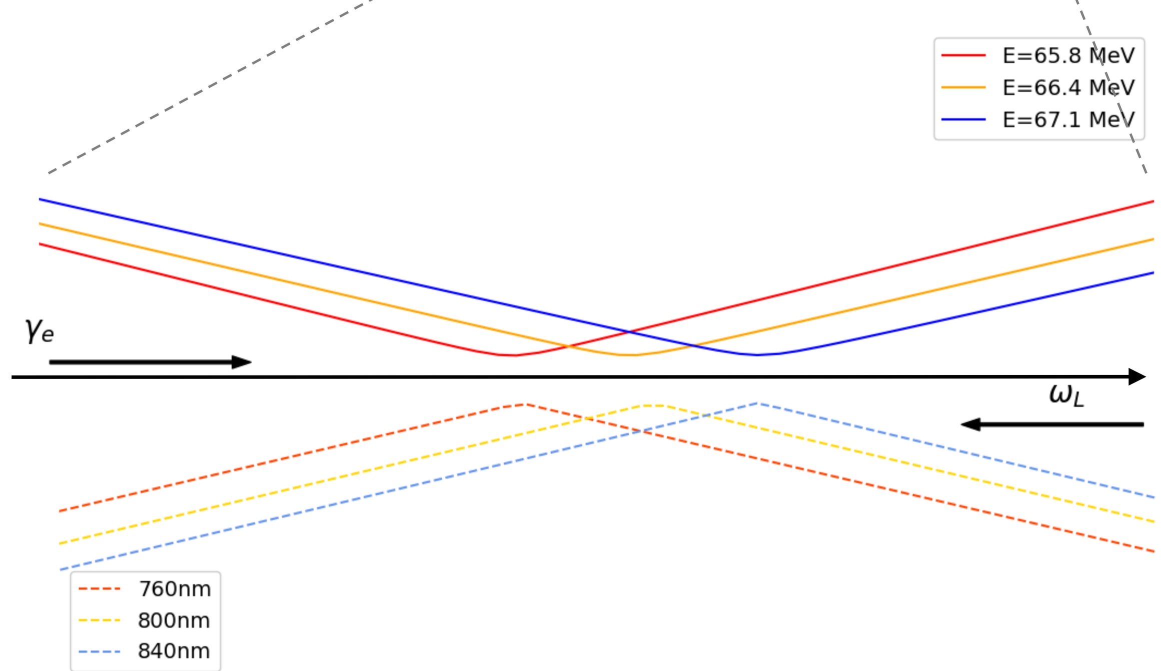
Spatiotemporal shaping of the laser pulse to overlap it with the electron beam





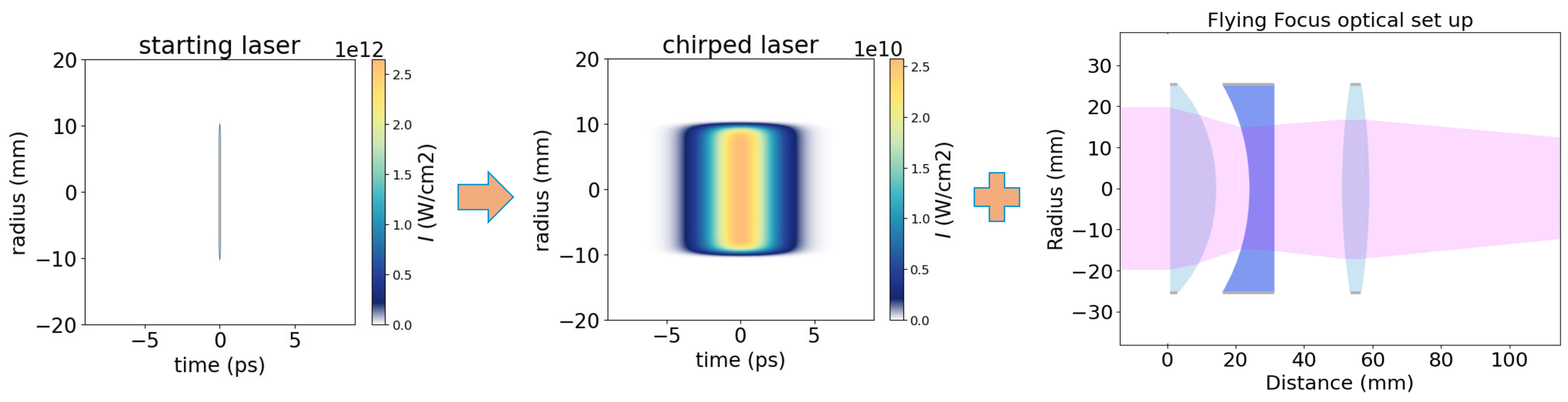
Advantages of the Flying Focus in the ICS process

Tailoring the scattering beam with a flying focus allows matching the electron bunch chromaticity and increases X-ray photon production.

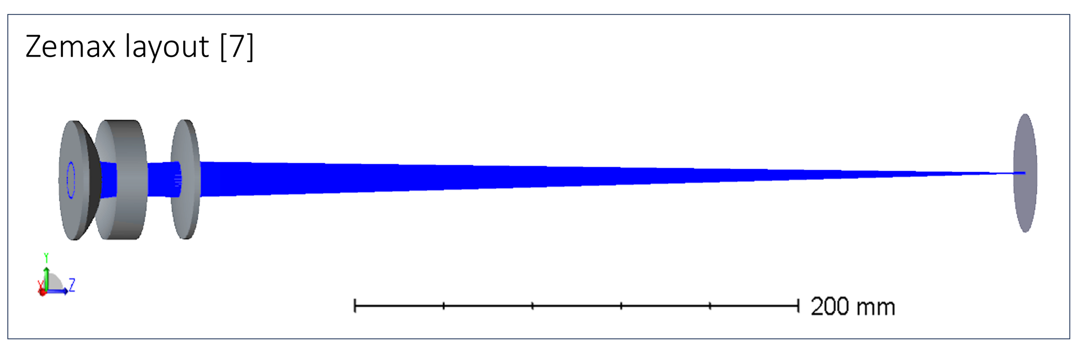


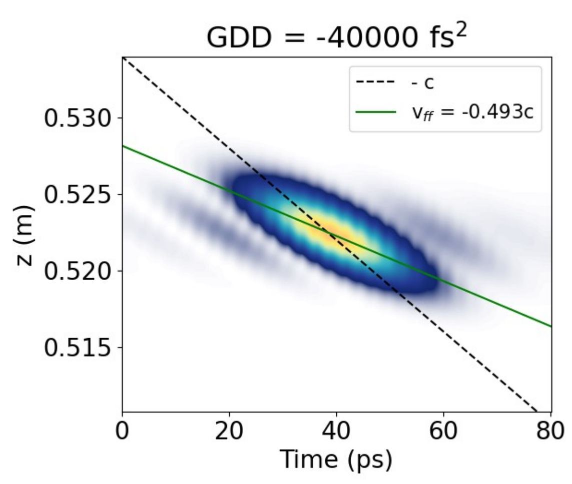
Implementation of Flying Focus through chirping and a chromatic focusing set up

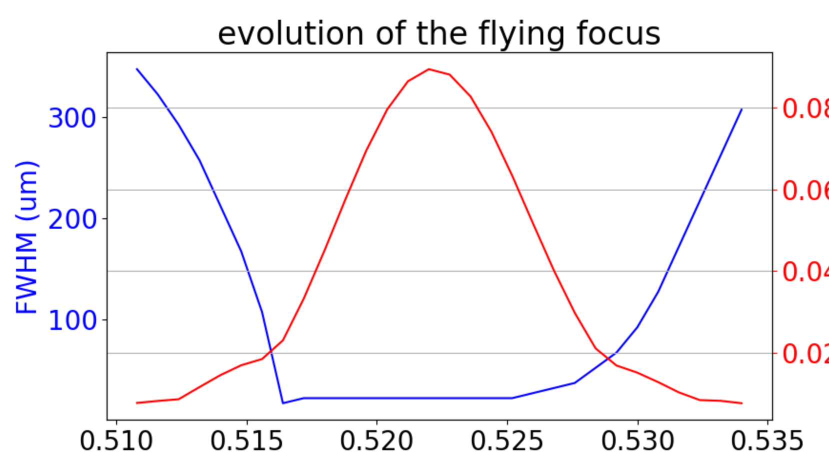
The scattering pulse is first chirped [5], and then sent through a chromatic focusing set up [6][8].



Simulate the Flying Focus



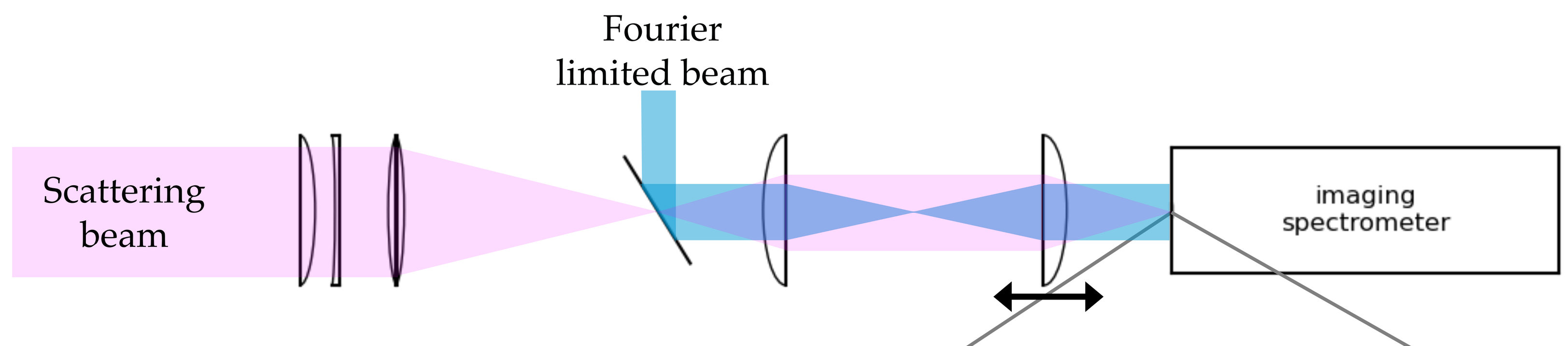


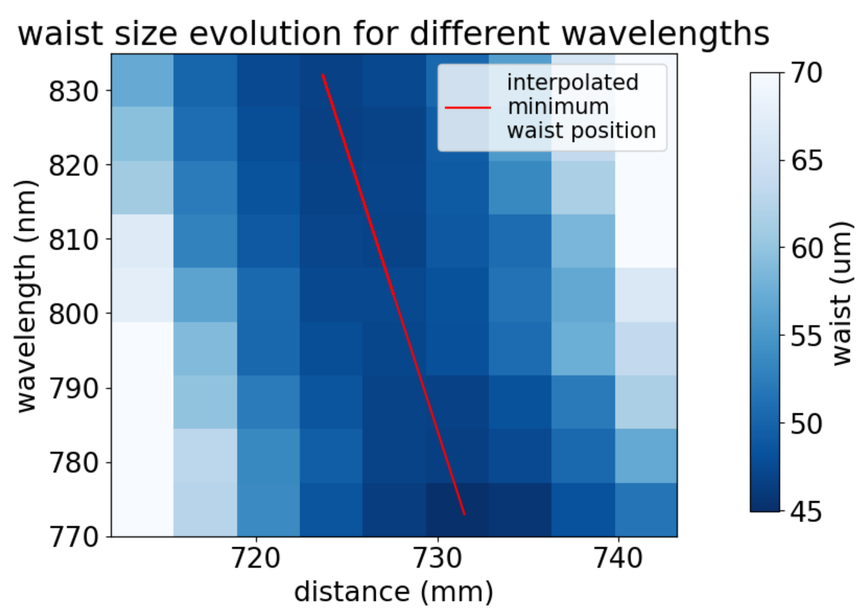


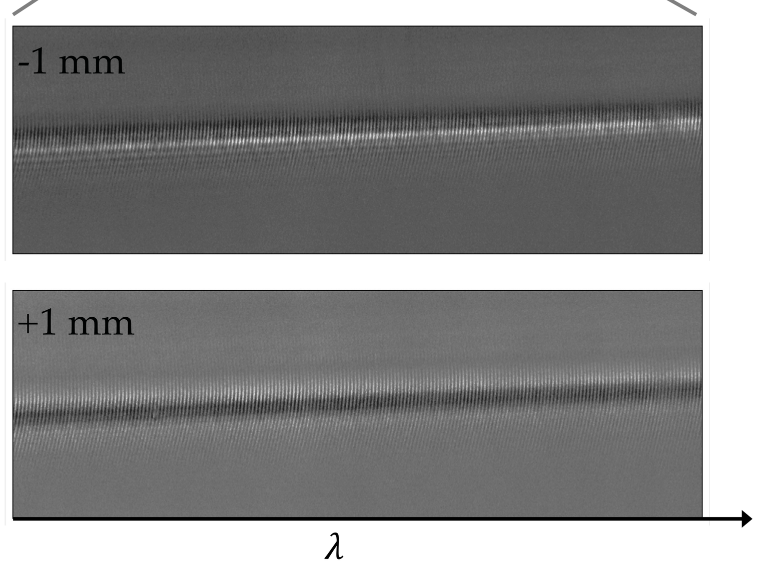
It's possible to reach:

- a_0 far from non linear effects
- Elongated focus
- Chromatic focus
- Backward propagation

First prototype of the set up shows promising results







The Flying Focus speed is calculated by interferometry of the scatter beam and a Fourier limited beam [8].

$$v_{ff} = \frac{c}{1+c\frac{dt}{dz}} \cong -0.12\,c$$

References

[1] S. Kulpe et al., Scientific Reports 9, 13332 (2019).
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[8] S. W. Jolly et al., Opt. Express 28, 4888-4897 (2020)

Contact:
cristina.mariani@desy.de
plasma.desy.de

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