Laser-Driven Proton Acceleration from Liquid Micro-Droplets

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

Institute of Optics & Quantum Electronics JENA
Friedrich Schiller University

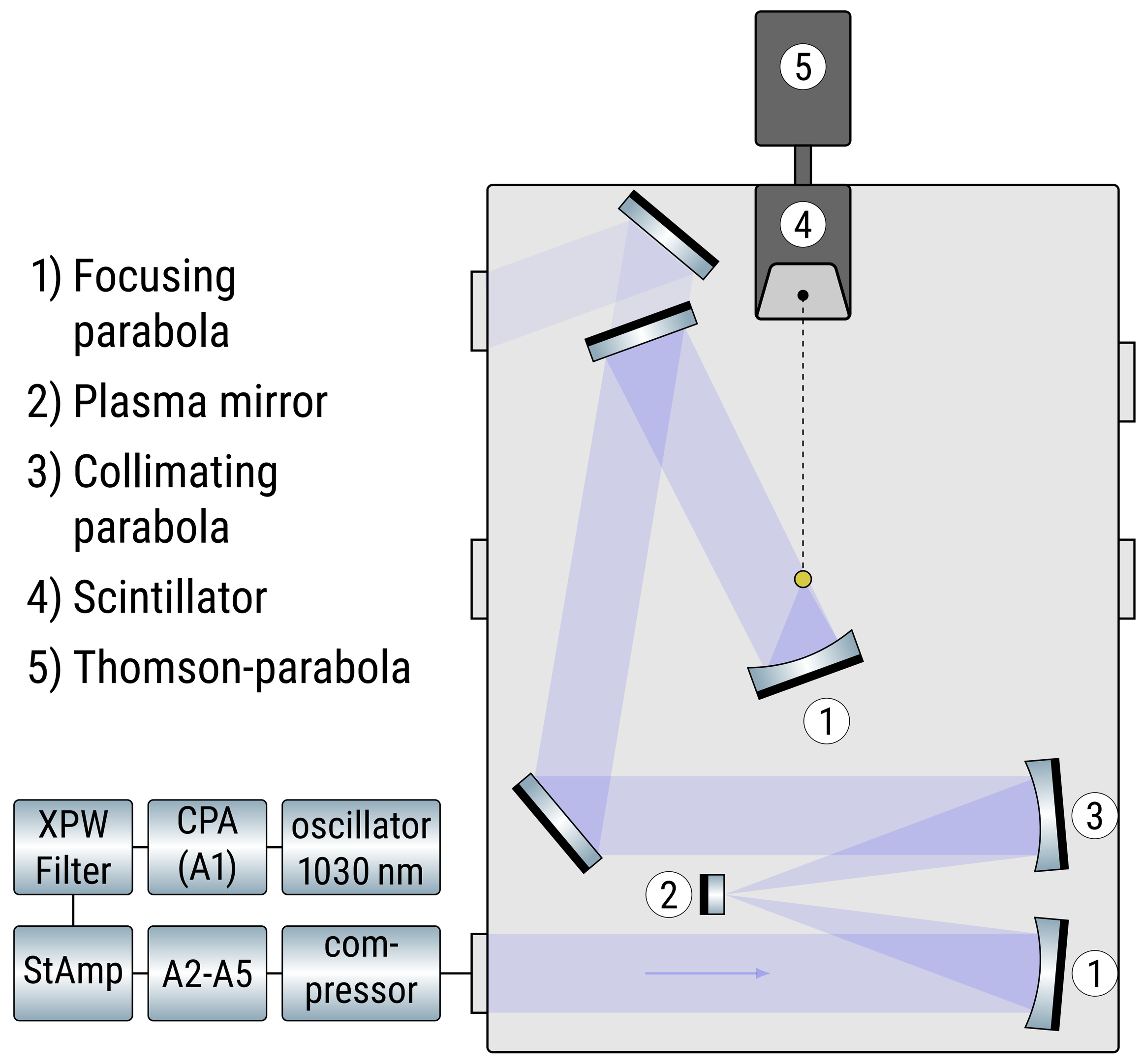
M. Nolte[1], G. A. Becker[1], M. Beyer[1,2], M. B. Schwab[1,2], M. Hornung[1,2], M. Hellwing[1], and M.C. Kaluza[1,2]

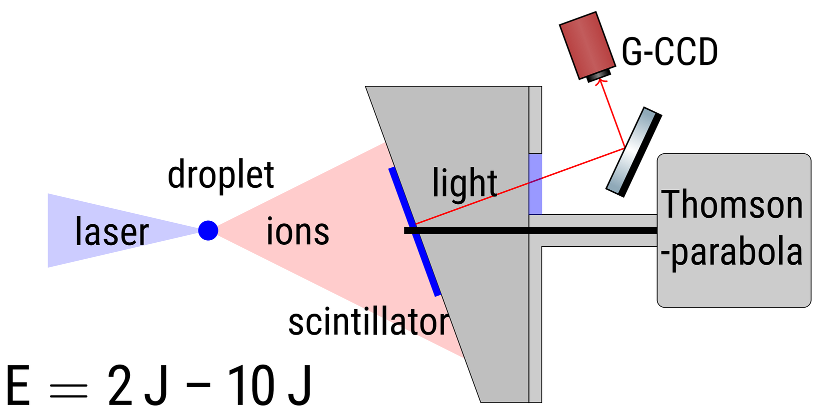
[1]Institute of Optics and Quantum Electronics, Jena, Germany
[2]Helmholtz Institute Jena, Jena, Germany

Motivation

In laser-driven particle acceleration the choice of the target material can have a large impact on the acceleration process. Commonly used targets are thin foils. However, there, electrons can leave the interaction zone along the targets rear side, which can weaken the electric field. To avoid this problem, mass limited targets like liquid micro-droplets, can be used. A laser-driven proton acceleration experiment was conducted at the POLARIS laser system, where liquid micro-droplets made of water or ethylene glycol were used as targets. In this poster the creation of micro-droplets is presented. Furthermore, the resulting proton beam shape in these experiments is shown [1].

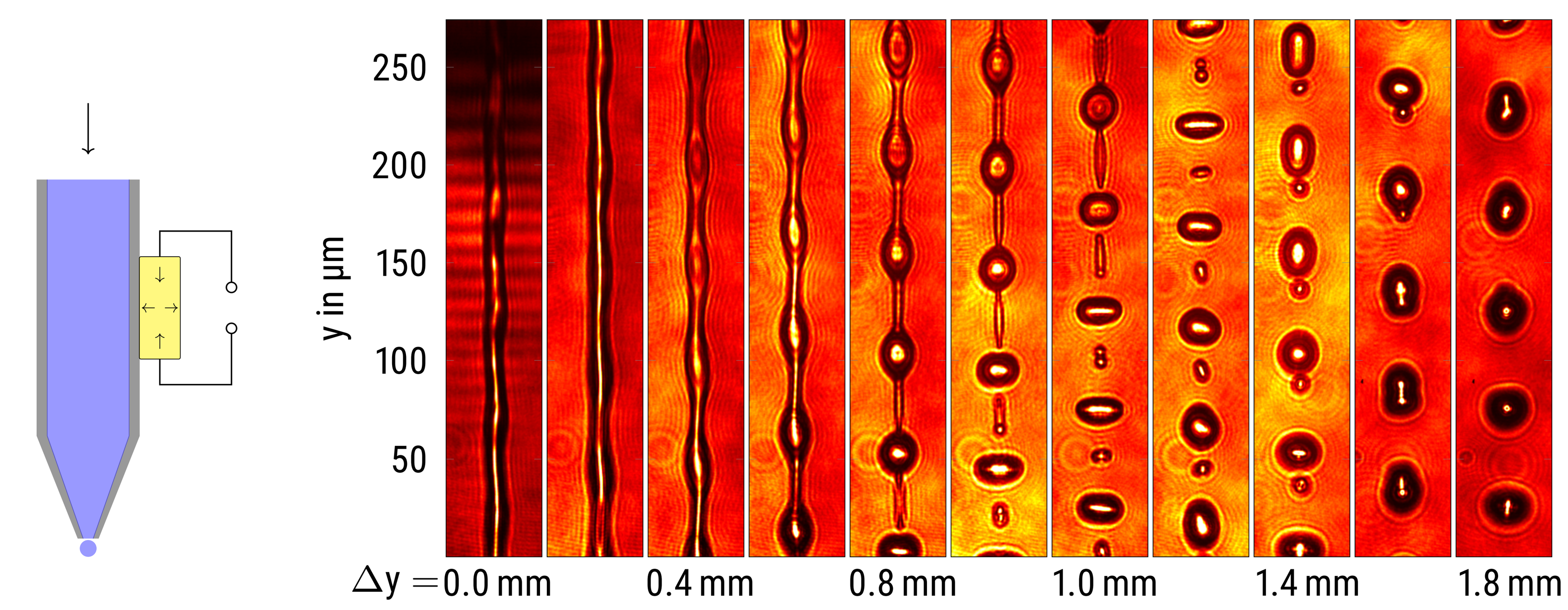
Setup of the POLARIS Target Chamber





- $\lambda = 1030$ nm, E = 2 J – 10 J
- FWHM = 140 fs
- $A_{FWHM} = 20\ \mu m^2$
- Ions accelerated via the TNSA-mechanism
- Beam profile can be observed with scintillator and gateable CCD
- Energy spectrum measured with Thomson-parabola

Droplet Breakup from Liquid Jets



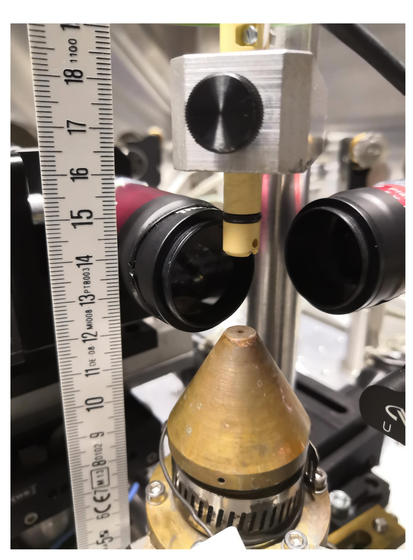
- Liquid jet from pressured capillary nozzle ($\varnothing = 10\ \mu m$)
- Perturbation via piezo element
- Laplace pressure leads to perturbation growth
- Jet breaks up into main droplets ($\varnothing = 20\ \mu m$) and smaller satellite droplets ($\varnothing \leq 10\ \mu m$)
- Satellite droplets can merge with main droplets
- Synchronize piezo element with laser pulses

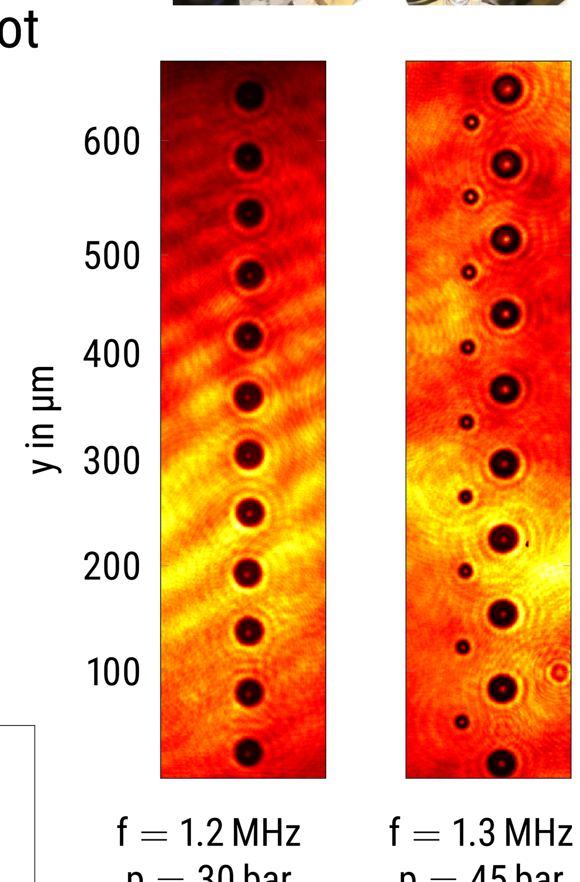
$\Rightarrow$ Droplets are stable in space for each laser shot

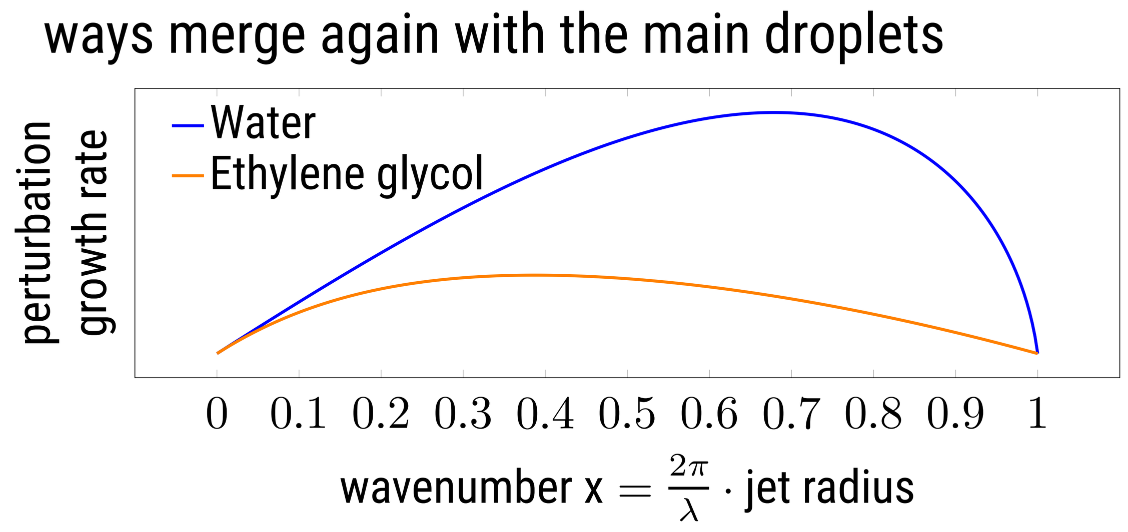
- Growth rate depends on the viscosity and the surface tension (Ohnesorge number)

$\Rightarrow$ water ($\sigma = 0.7\ \mu m$) is more stable than ehtylene glycol ($\sigma = 0.9\ \mu m$)

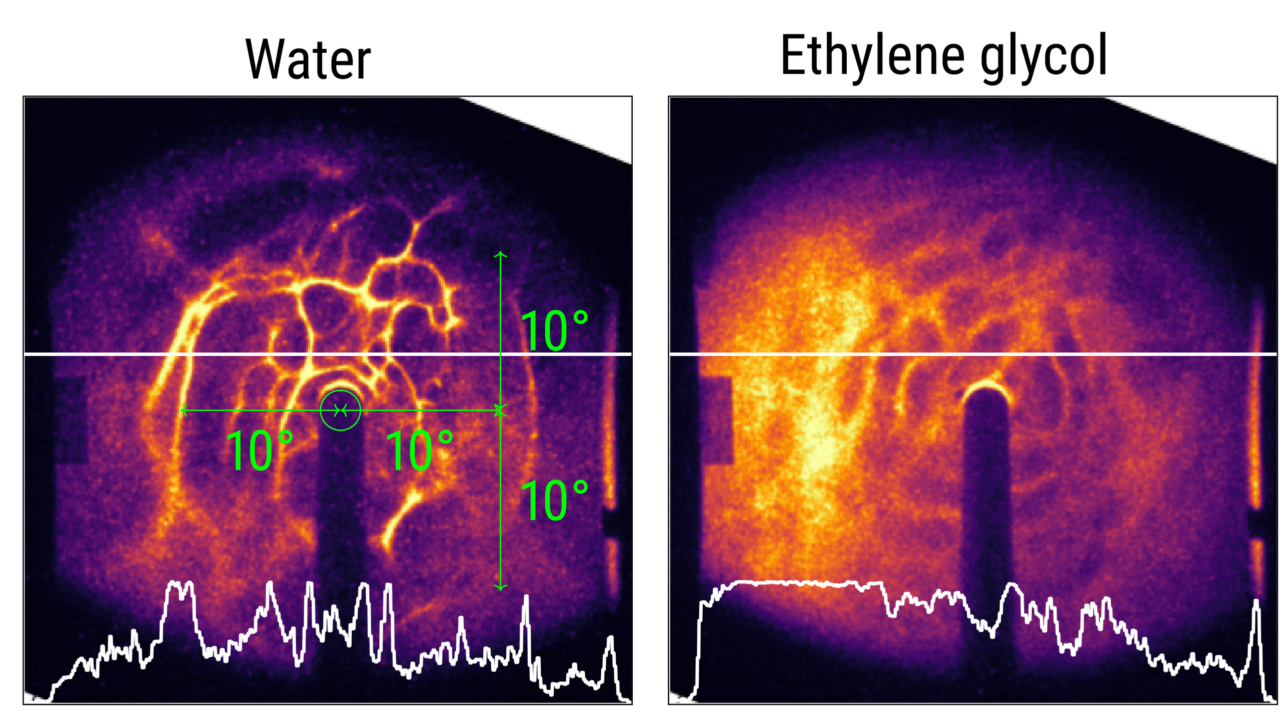
- Higher stability at higher pressure
- Piezo driving frequency must be adapted to the pressure and the used liquid
- At higher pressures satellite droplets do not always merge again with the main droplets

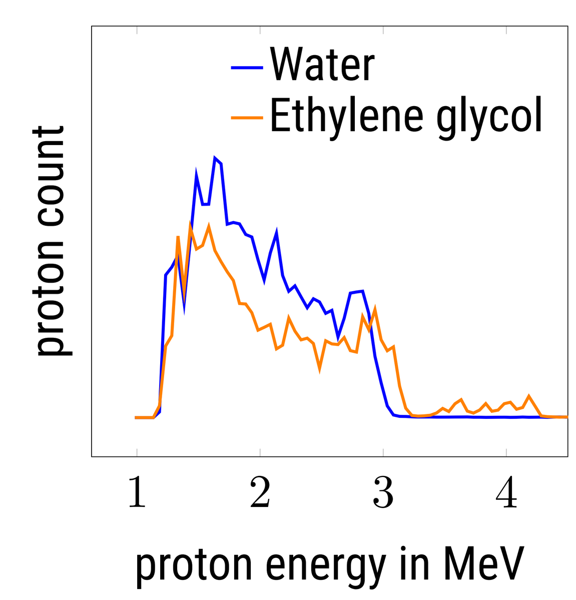






Proton Beam Profile





- In acceleration experiments the proton beam profile was measured with a scintillator
- Proton energy spectrum was simultaneously measured locally with a Thomson-parabola
- Left image from water droplets, right image from ethylene glycol droplets
- Modulations in the proton beam density
- Modulations are more pronounced for water
- Laser light ionizes background gas and separates charges
- Resulting fields deflect the proton beam [2]
- Lower vapor pressure of ehtylene glycol ($p_{vap} = 0.08$ mbar) compared to water ($p_{vap} = 23$ mbar) $\Rightarrow$ less modulations at comparable proton spectra

Conclusion

A method for creating liquid-micro droplets is shown. The breakup process could be investigated. Liquid micro-droplets made out of water and ethylene glycol were used in proton acceleration experiments, where the shape of the beam profile was observed. The beam profile showed density modulations, which were less severe for ethylene glycol, which is attributed to its lower vapor pressure compared to water.

References:

[1] M. Nolte, Characterization of Liquid Micro-Droplets for Laser-Driven Proton Acceleration, Master Thesis, Friedrich-Schiller University, 2023

[2] L. Obst-Huebl *et al.*, All-optical structuring of laser-driven proton beam profiles, Nature Communications, 2018

This poster presentation has received support from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.

EUROPEAN NETWORK FOR NOVEL ACCELERATORS
EuroNNAc4
NPACT supported by EU via I-FAST
iFAST