Laser-driven Ion Acceleration from pre-expanded thin foils

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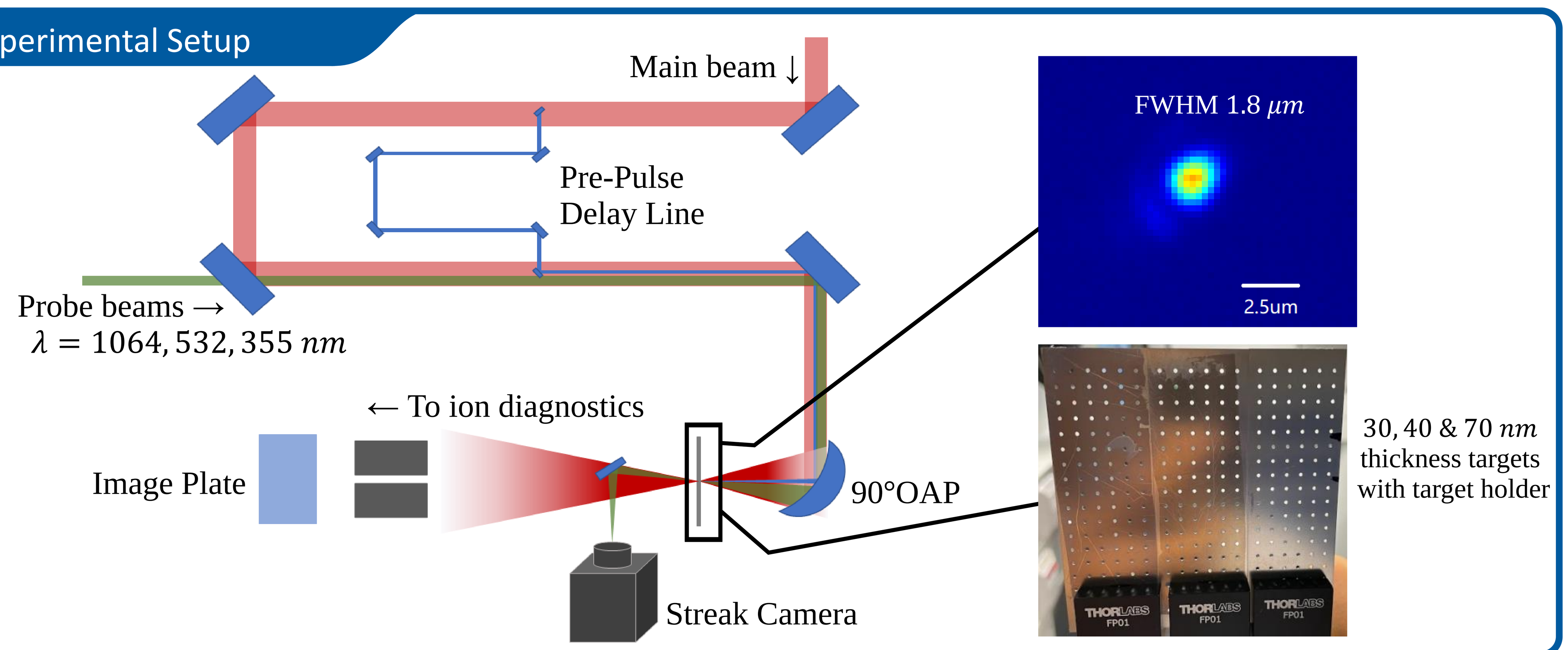
Abstrac

Laser-Ion acceleration typically uses thin foils as targets, where the density is typically a few hundred times the critical density (n_c). Targets with just a few times n_c constitute an interesting target system for laser plasma acceleration. Unfortunately, these densities are hard to achieve in experiment. In this poster we present an expanding foil experiment, were we pre-expand a thin foil via a dedicated pre-pulse ($10^{13}\ W/cm^2$) prior to the interaction with the main pulse ($10^{21}\ W/cm^2$). A Nano-second probing beams ($\lambda = 1064, 532, 355\ nm$) in combination with a streak camera is used to diagnose the state of the Plasma during expansion. This experiment is still ongoing and our aim is to diagnose the optimum plasma density for ion acceleration for preliminary results to be presented.

Introduction

Over the past decade, ion acceleration from near-critical density (NCD) targets has been a hot research topic [1]. The near-critical term arises from the fact that the laser frequency w_L is resonant with the plasma frequency w_P where the transparency threshold of the propagation in the plasma is marked[2]. Studies have shown that this regime can actually be beneficial for ion acceleration. Compared to solid targets, more laser light is absorbed by the near-critical density targets leading to the conversion of the laser energy to electrons kinetic energy; producing hot electrons that enhances the acceleration in turns[3]. Relativistic self focusing [4], and the self phase modulation [5] of the laser pulse also take place in NCD plasma due to the varying refractive index along the way. The relativistically induced transparency [6] phenomenon occurs when a laser with peak intensity above the relativistic limits ($10^{15}\ W/cm^2$) hits a thin overdense target. This phenomenon is also know to enhance the laser-ion acceleration process.

Experimental Setup



Experimental Method

The experiment is performed with Ti:Sapphire laser system in Helmholtz Institute Jena. Laser pulse of 800 nm, 25fs duration and 2 J Energy is focused on a nm-scale thickness (Formvar) plastic foil. The FWHM focal spot is 1.8 μm diameter leading to an Intensity of ($3{,}14 \times 10^{21}\ W/cm^2$). The pre-pulse of 2mm diameter intensity was calculated to be around $10^{13}\ W/cm^2$.

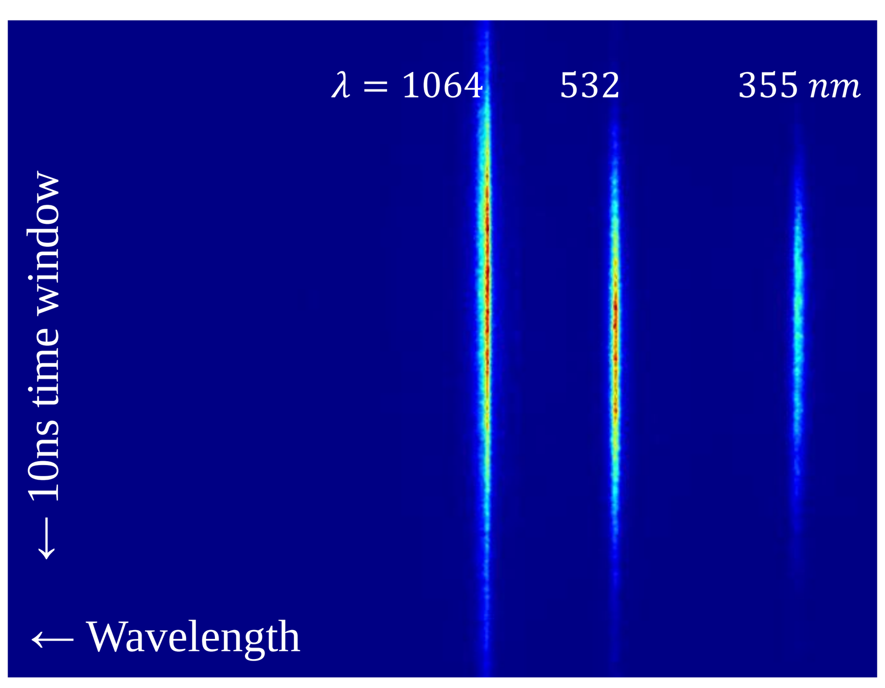
A Nano-second laser system is used to probe the plasma produced by the pre-pulse. The probe beam is then directed to the Streak Camera after passing through the plasma.

The ion beam travel a distance of L=140 mm and fall on an image plate which is then scanned by the image plate scanner. A step filter is also placed before the image plate to help us identify the energy of the accelerated protons.

Results

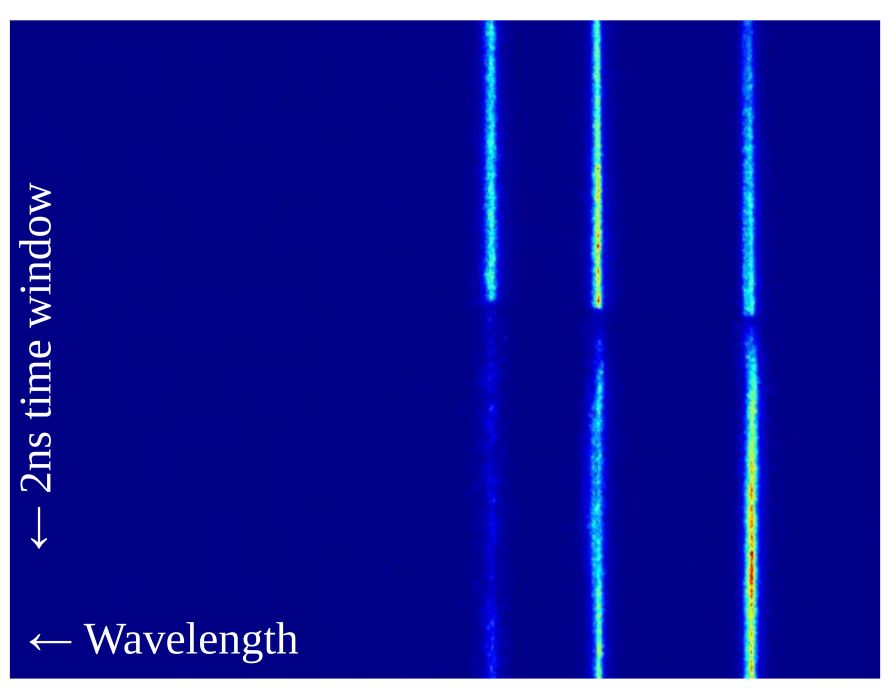
Results from the Streak Camera

a)



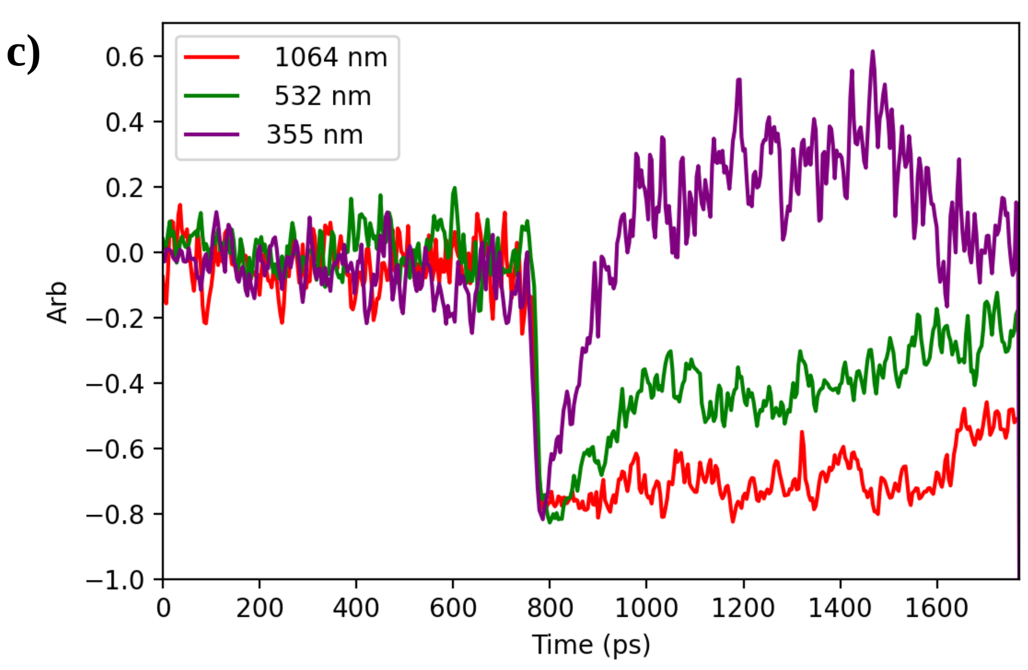
Reference Shot. The streaks of the three Probe beams having gaussian profile

b)



$5 \times 10^{17}\ W/cm^2$ main pulse beam focused on 40nm target

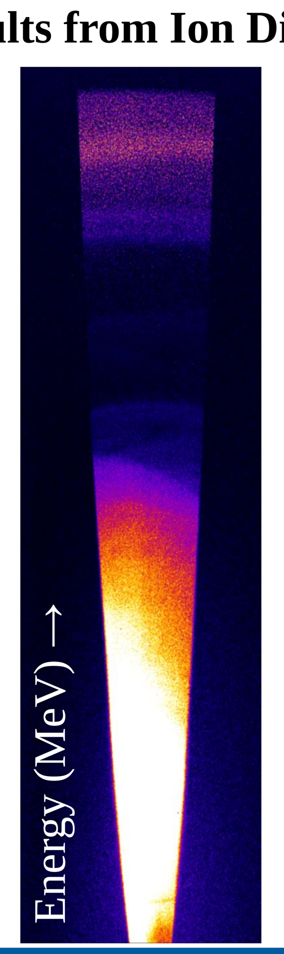
c)



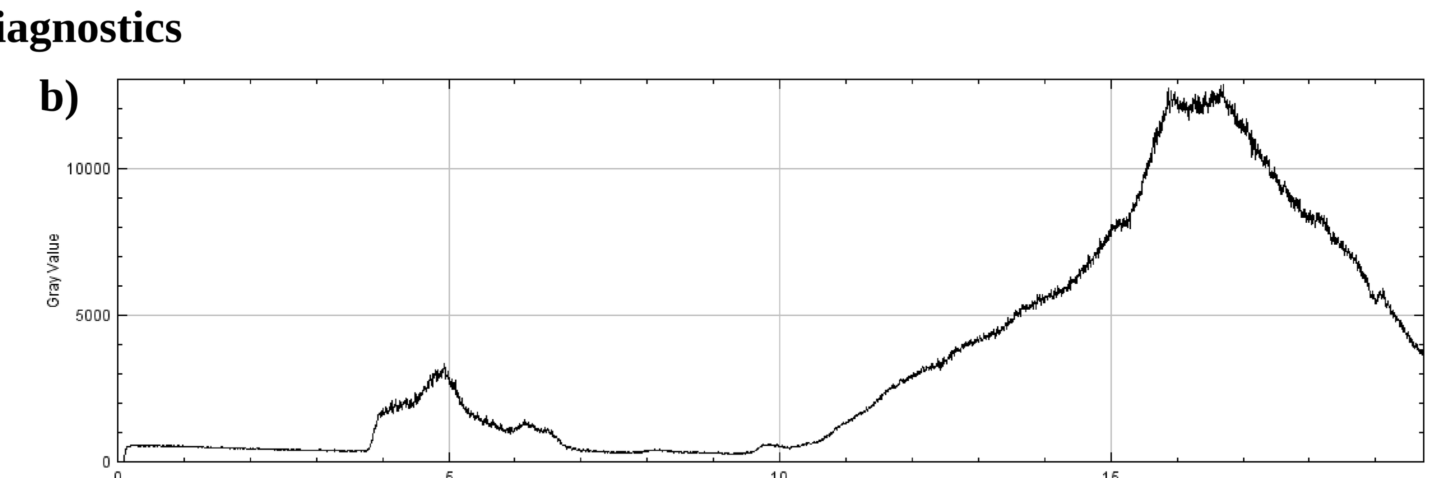
Transmission time of the probe beams through the plasma in time

Results from Ion Diagnostics

a)



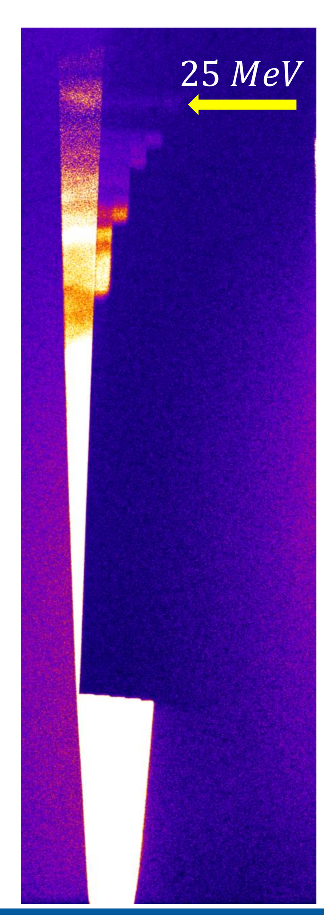
b)



a) Ion signal on the Image plate, scanned by the IP scanner. Parameters: Main pulse focused on 40nm target. No Pre-Pulse was used, solid target was shot directly with the main beam. Mono-energetic ion beam is observed

b) Line out of a) where we can see the signal plot in colour scale.

c)



c) Parameters: Main pulse focused on 50nm target. No Pre-Pulse was used, solid target was shot directly with the main beam. A step filter is placed infront of the image plate to identify the proton signals from the mixture of Carbon and Oxygen ions.

Protons with Energy up to 25MeV (on the 5th step) is observed.

References

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Acknowledgement

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