Relativistic laser-plasma interaction with prepulse generated liquid metal microjets

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Outline

✓ Introduction
✓ Experimental setup
✓ Contrast effect
✓ Optical pump-probe experiments
✓ 3D3P PIC simulations
Introduction

A micro-structured target with an intensity of $I < 10^{17} \text{W/cm}^2$ shows a huge enhancement in: hard x-ray yield and hot electron energy.

For intensities of $I > 10^{17} \text{W/cm}^2$, a preplasma is generated.

Our approach involves a liquid metal target with a repetition rate up to 1 kHz.
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Experimental setup

x-ray detectors (PMT with NaI(Tl) scintillator, Si-PIN Amptek XR-100CR

half-wave plate

laser pulse from Ti:Sa laser system

\( \tau = 55 \, \text{fs} \)

\( \lambda = 800 \, \text{nm} \)

\( E = 1 \, \text{mJ} \)

I \approx 10^{17} \, \text{W/cm}^2

10 \, \text{Hz}

contrast 10^{-400} \approx 10^{6}
Ga plasma x-ray spectrum

$I = 10^{17}$ W/cm$^2$

- $K_{\alpha}$ (Ga) – 9.3 keV
- $K_{\beta}$ (Ga) – 10.3 keV
- $K_{\alpha}$ (Cu) – 8.4 keV
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X-ray yield nanosecond contrast dependence

Best results at pulse contrast ~50

Corresponding prepulse energy – 20uJ
Comparison with solid targets

Hot electrons temperature, keV

- s-polarized, Ga
- p-polarized, Ga
- p-polarized, Si
- s-polarized, Si
- p-polarized, SiO$_2$
- s-polarized, SiO$_2$
$K_\alpha$ yield contrast dependencies

- $K_\alpha$ yield vs. pre-pulse amplitude
- $K_\alpha$/X-yield ($>6$ keV) vs. pre-pulse amplitude

Legend:
- p-polarized
- s-polarized
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Optical pump-probe shadowgraphy

Delay 1-15 ns

KDP 96%

BS 4%

CCD

Pulse energy 200 uJ that corresponds to the contrast of 0.2 in main experiments
Dense microjet formation
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Electron acceleration along jets


**Laser pulse**
- Duration 50 fs
- Focal spot 3 um
- intensity $5 \times 10^{16} - 10^{18}$ W/cm$^2$

**Target:**
- Proton + electrons
- Density $10^{22}$ cm$^{-3}$
- Thickness 1 um

**Jet:**
- Protons + electrons
- Density $10^{22}$ cm$^{-3}$
- Jet length 5 um
- Jet diameter 0.5 um

**Preplasma:**
- Proton+electrons
- Density changes from 0 to $1.2 \times 10^{21}$ cm$^{-3}$
- Thickness 4 um
Electron acceleration along jets
Electron acceleration along jets
Electron acceleration along jets
Electron acceleration along jets
Electron from 3D3P PIC modeling

--- no jet
--- with jet

5x10^{16} \text{ W/cm}^2

10^{18} \text{ W/cm}^2
Conclusions

- Action of the pre-pulse leads to formation of micro jets of liquid metal. This enhances hot electron energy and hard x-ray yield from the plasma.

- Our approach opens up the road to implementation of new schemes for electron and ion acceleration at much higher, relativistic intensities.
Thank you for your attention!