Probing the evolution of solid microjets from grooved Sn samples and their impact on Asay foil and piezoelectric mass diagnostics using X-ray radiography

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Dynamically Compressed Matter with X-rays 12-14/03/2024

Introduction

1. **Experimental conditions**
   Set-up
   Configuration
   Diagnostics
2. **Ejection's physics**
3. **Ejecta and diagnostics interaction**
4. **Diagnostics response**

research goals of our ESRF experiment

Frame of our work: shock waves in metal

Emergence of shock wave at free surface with defects ➔ microjetting

- disrupt measurements
- damage nearby equipment
- safety hazards

➔ Important to characterize the ejecta could

- speed
- mass value & repartition

Ejection's physics

Effect of initial surface geometry on jet's mass, morphology and velocity

Mass diagnostics

Interaction of jets with probes

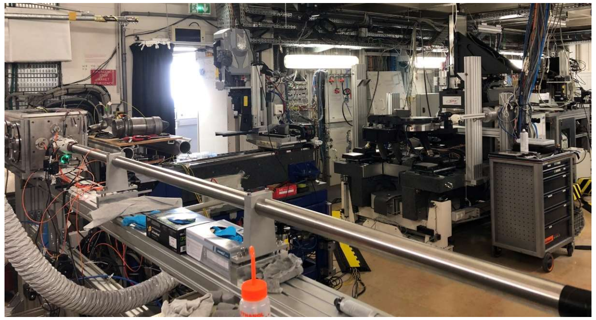
Correlation of the response of the probes with a X-ray determined areal density distribution

Experimental setup

Within the frame of Shock BAG

Performed on ID19 beam line

- Gas gun
  - Cu projectile velocity ≈ 800 m/s
  - grooved Sn target ➔ microjets
- Diagnostics
  - synchrotron-based radiography
    - 3 interlaced cameras for 16 bunches recording
  - PDV for surface and ejecta speed measurements
  - mass diagnostics
    - µAsay foils
    - µLiF
    - Piezo PIN



Experimental configuration

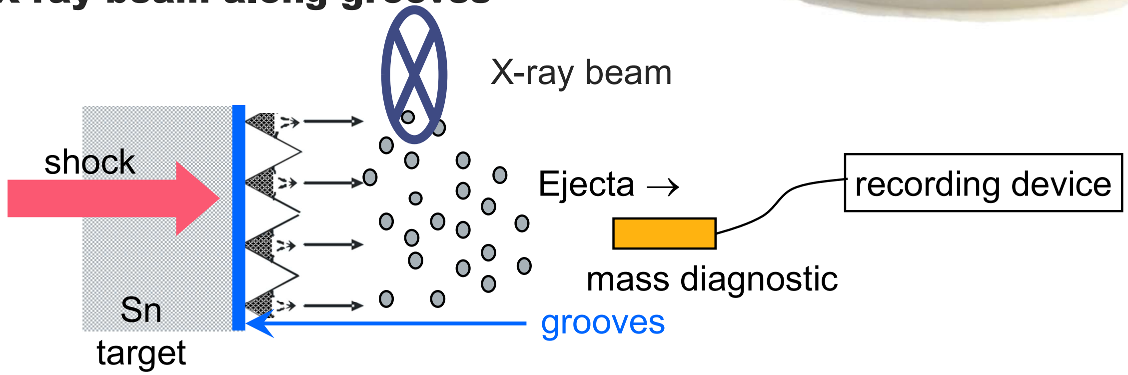
Sn target

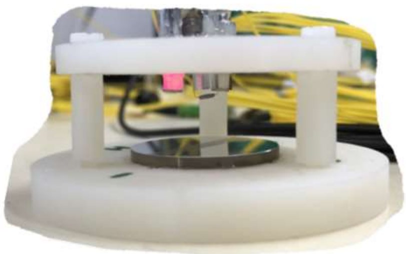
- Φ2.8 cm
- Grooves
  - linear
  - chevron, fly-cut and square profiles
  - single or multiple

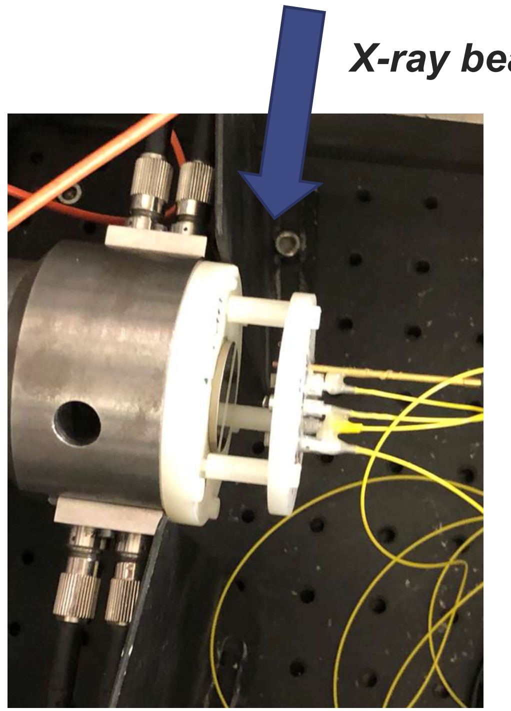
Diagnostics

- Probes parallel to the groove
- In a single line with varying distances from the target

X ray beam along grooves







Mass diagnostics description

Based on momentum conservation assumption

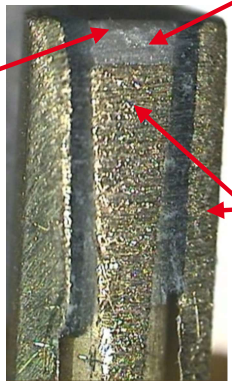
PIN:

electric field ⇔ pressure

µAsay & µLiF: measure of displacement with triature PDV system

µAsay: displacement ⇔ momentum

µLiF: displacement ⇔ pressure

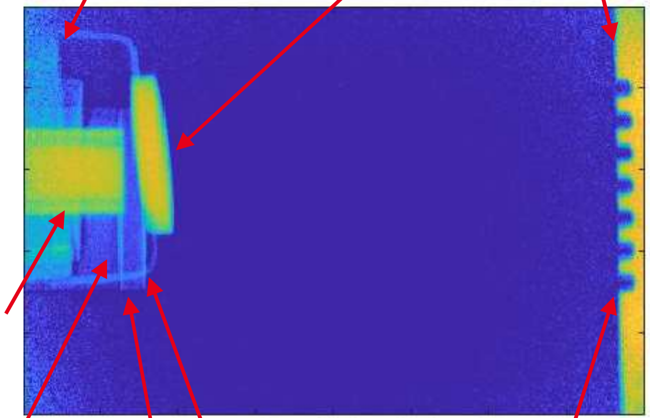


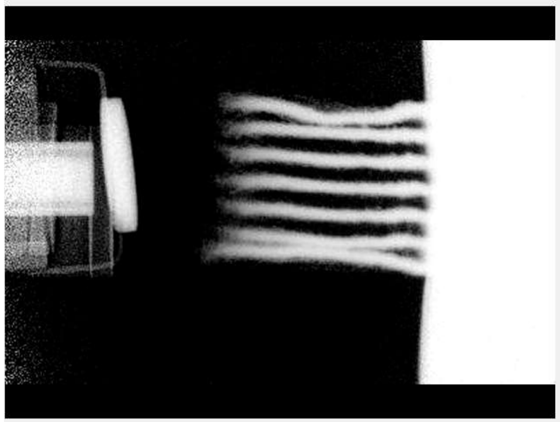
PIN

µAsay

µLiF

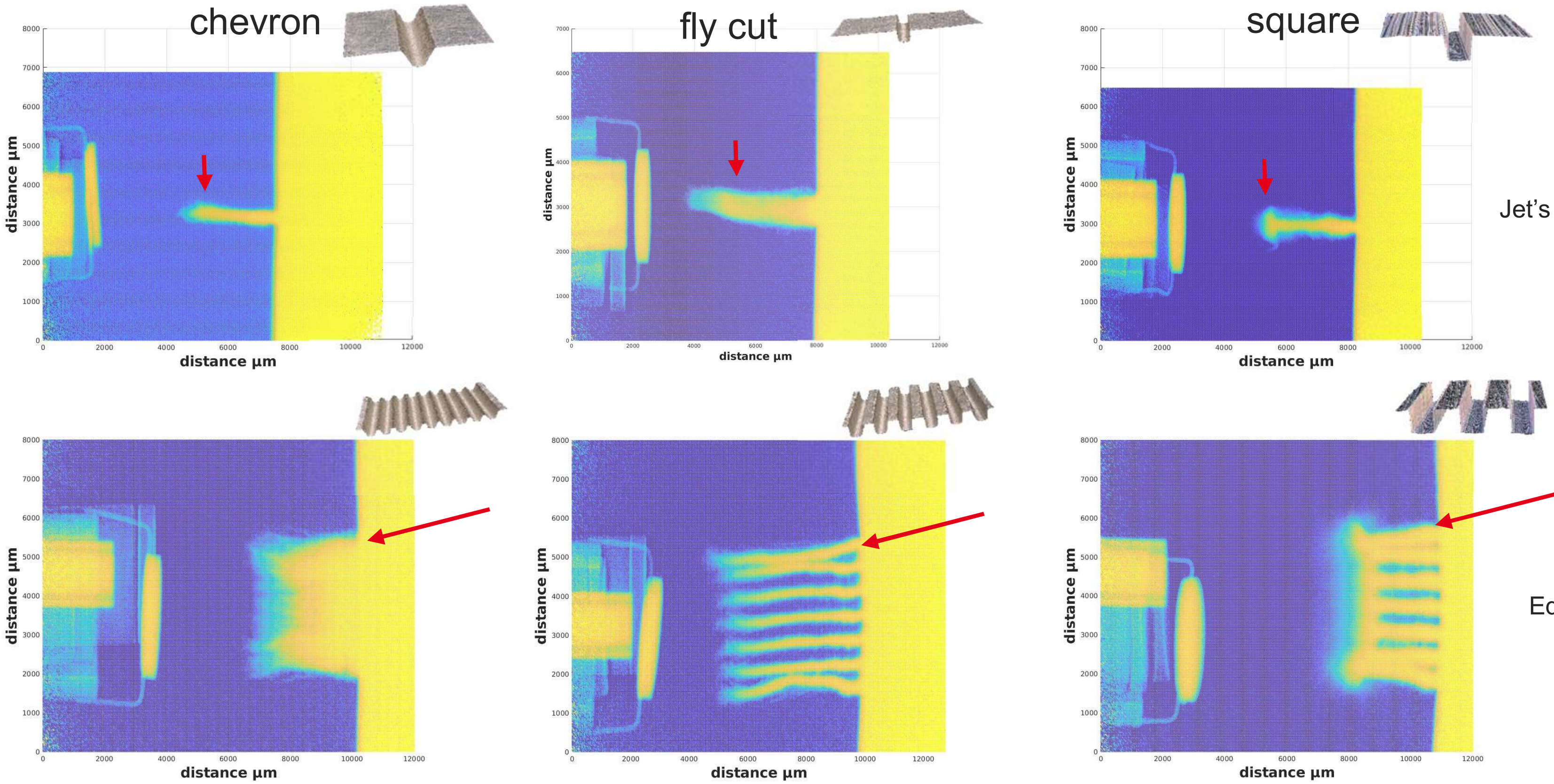
Radio overview





Ejection's physics

jet morphology



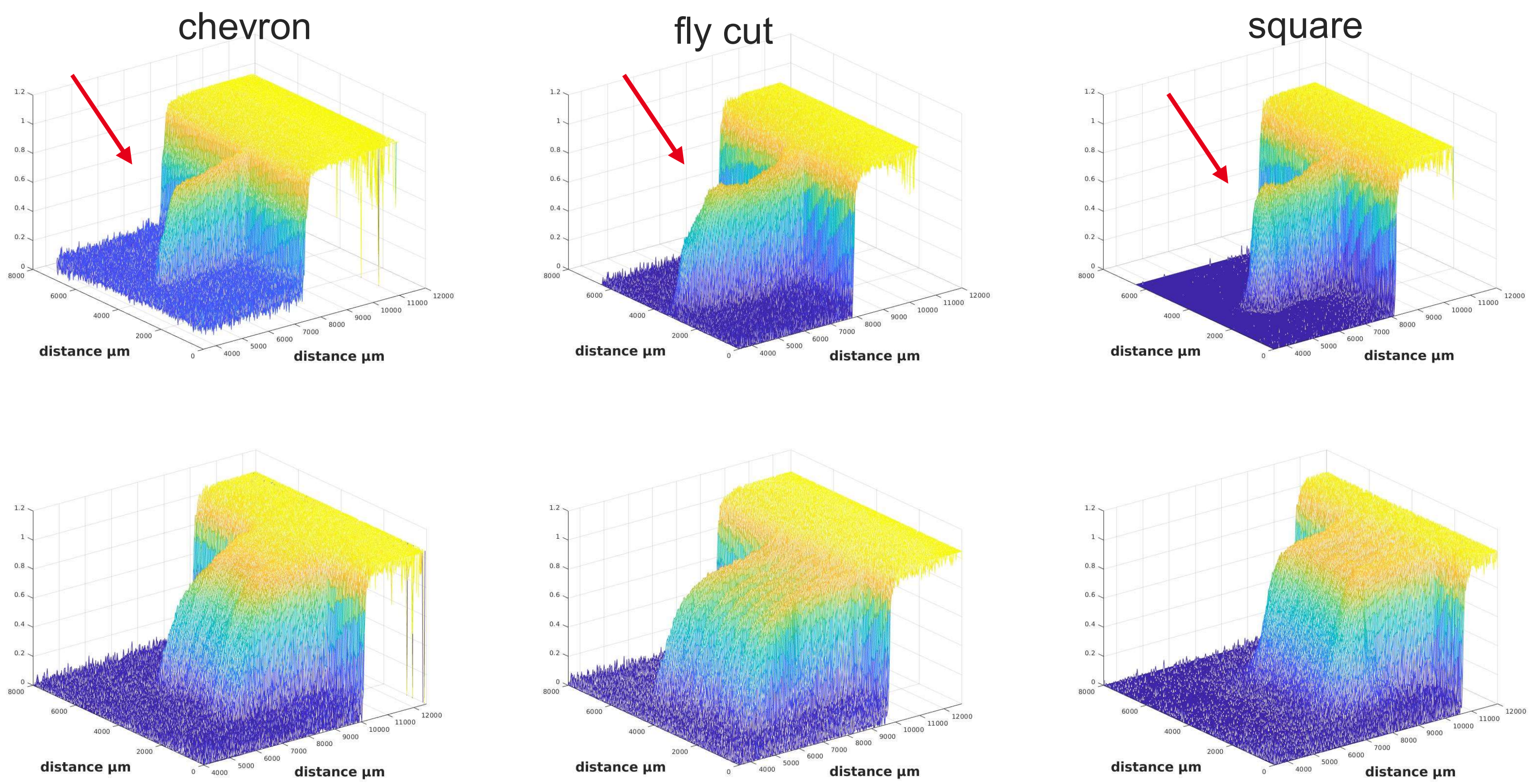
Jet's structure

Edge effects

2,8 µs after shock arrival @ Sn surface

jet density

Impact on density repartition within the jet

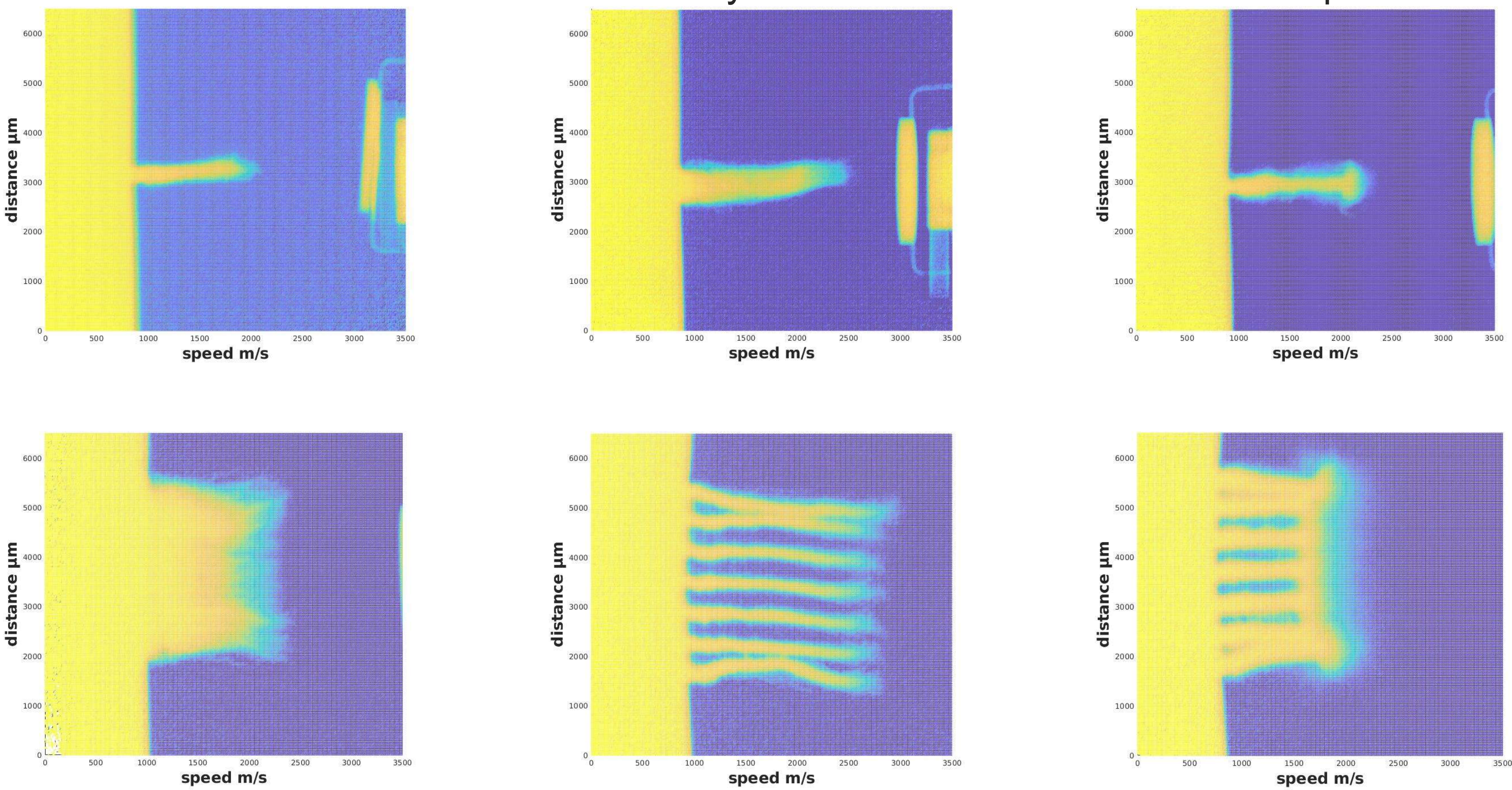


2,8 µs after shock arrival @ Sn surface

jet speed

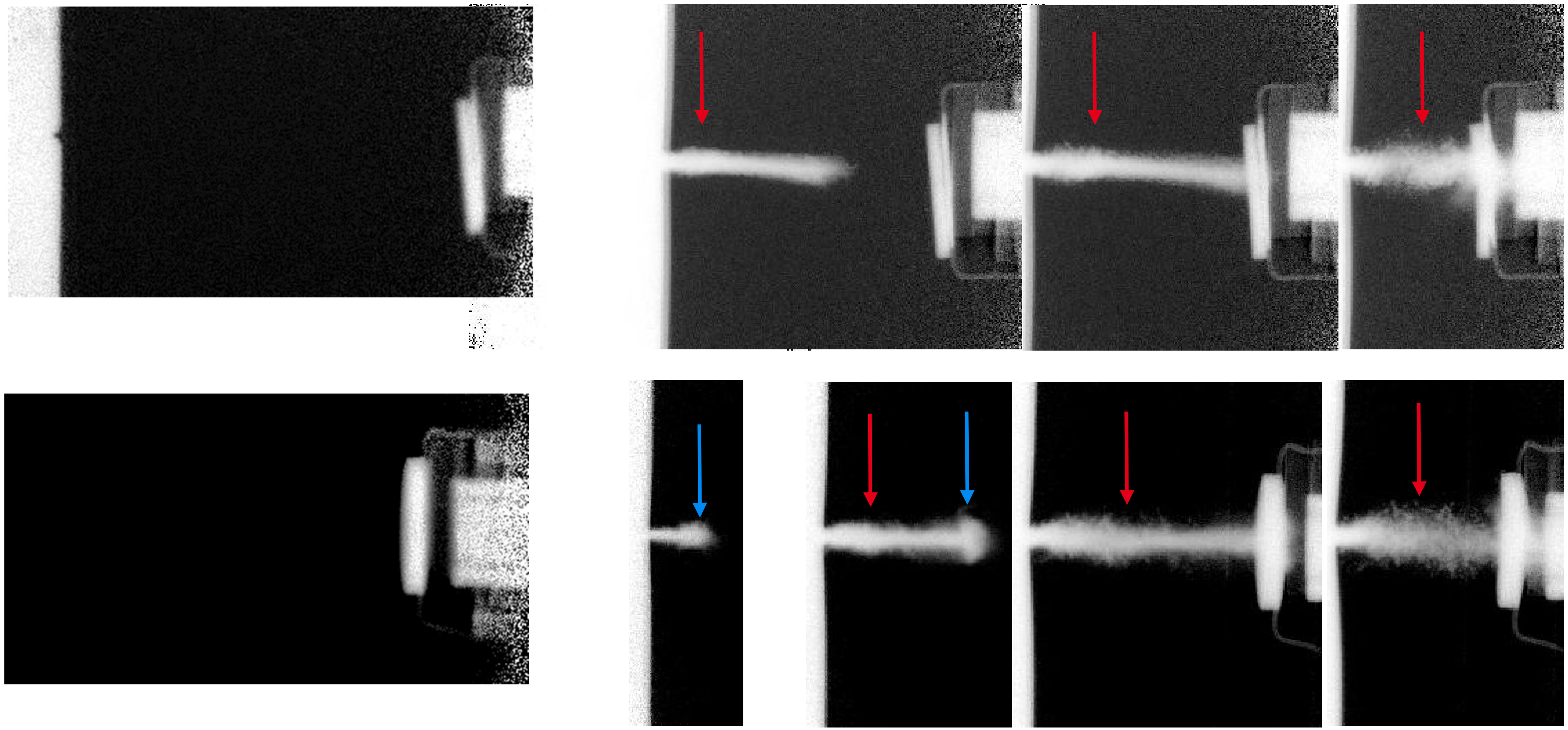
Impact on speed of the fastest ejecta

chevron fly cut square



jet fragmentation

Fragmentation mechanism along the jet and lateral speed



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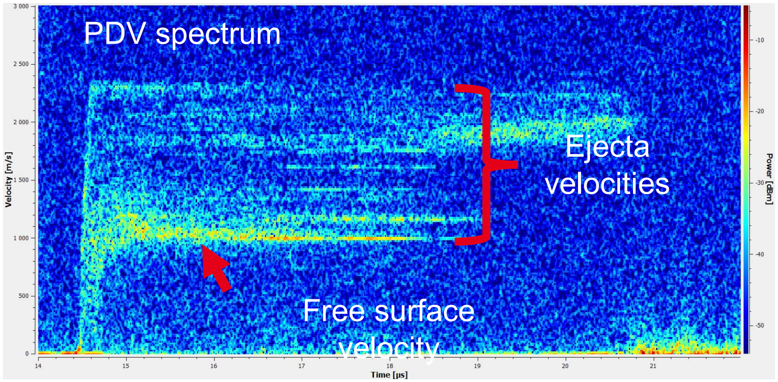
Ejecta and diagnostics interaction

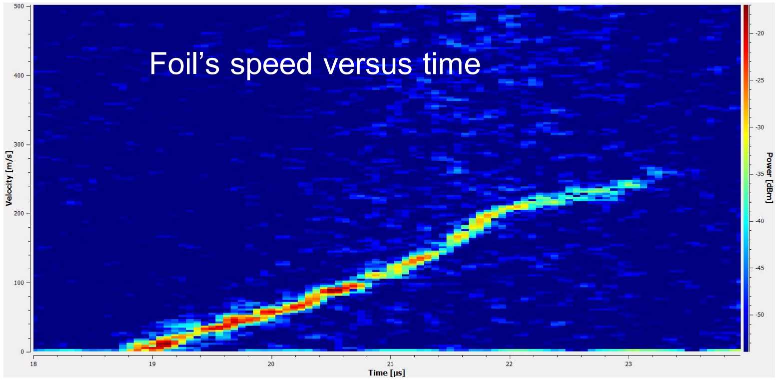
Areal mass density extraction from µAsay measurements

Measure of

- ejecta and free surface velocities
- foil's speed

multiple chevron groove





Under momentum conservation hypothesis

Areal mass distribution calculation

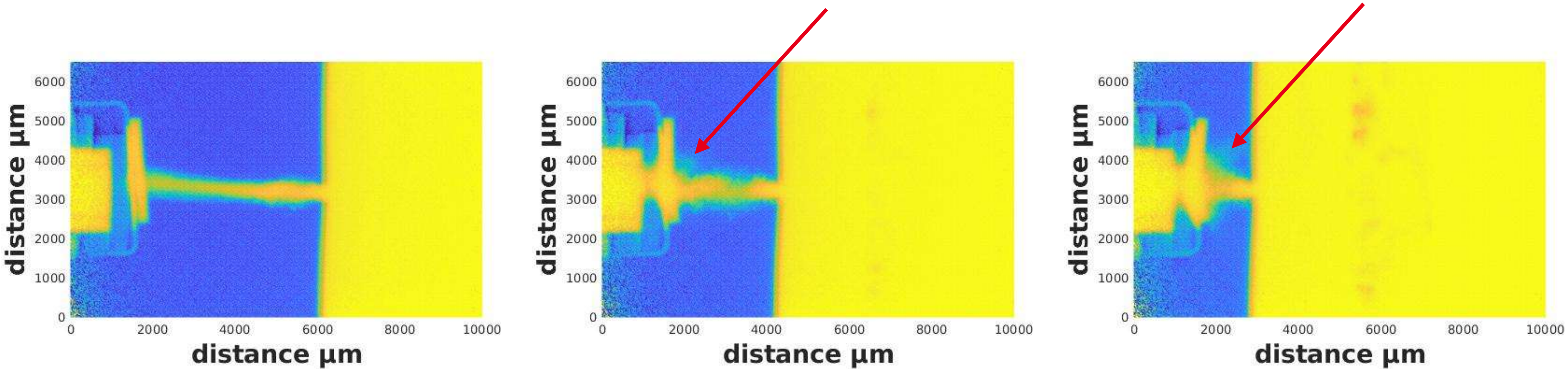
$$V_{particules}(t) = \frac{1}{t - t_{éjection}}(d_{éjection} + d_{cible}) = \frac{1}{t - t_{éjection}}\left(d_{éjection} + \int_{t_{éjection}}^{t} V_{cible}(t)\, dt\right)$$

$$MS_{éjectée}(t) = M_{cible} \cdot \frac{\int_0^{V_{cible}(t)} t(V_{cible})\, dV_{cible}}{d_{éjection} - \int_0^{V_{cible}(t)} t(V_{cible})\, dV_{cible}} = M_{cible} \cdot \frac{-\int_0^t V_{cible}(t)\, dt + (t - t_{éjection}) \cdot V_{cible}(t)}{d_{éjection} + \int_0^t V_{cible}(t)\, dt - (t - t_{éjection}) \cdot V_{cible}(t)}$$

Jet & probe interaction

Splashing effect

Parts of the incident ejecta are not aggregated but bounced on the foil ➔ impact on the mass momentum assumption



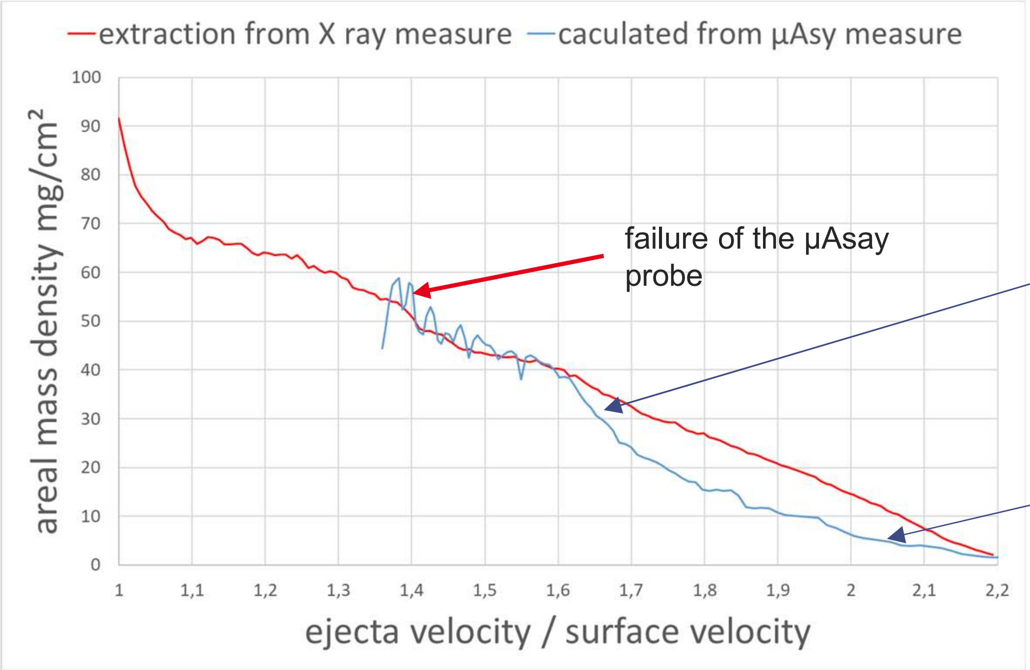
single chevron groove

Comparison between X-rays and probes areal mass densities

Ejecta areal mass density versus speed

X-rays: obtained from the optical density within the jet

µAsay: calculated from the foil's speed assuming mass momentum conservation



Re-colection of ejecta due to particle / particle interaction ?

Splashing's impact ?

multiple chevron groove

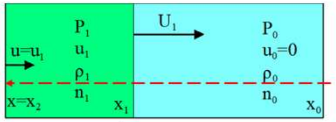
Diagnostics response

Correcting factor for µLiF

a correcting factor "a" has to be applied on PDV and displacement measure through shocked LiF

Commonly used value for 1D shock effect: a = 1.2669

Interface behind a shock wave



$$u_1^* = -\frac{d}{dt}\left[n_0.(x_0 - x_1) + n_1.(x_1 - x_2)\right]$$

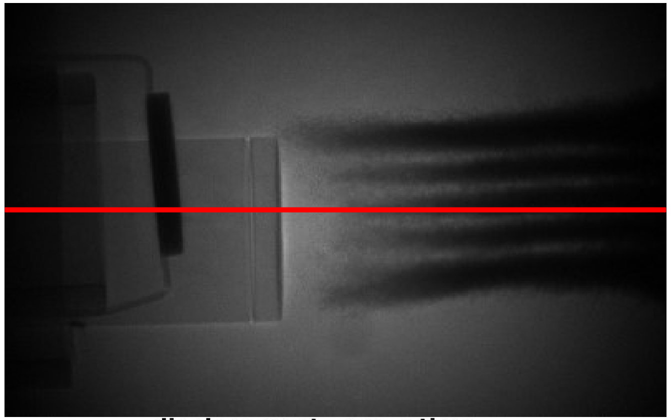
$$u_1^* = -n_0 \not{u_0} + U_1.(n_0 - n_1) + n_1.u_1$$

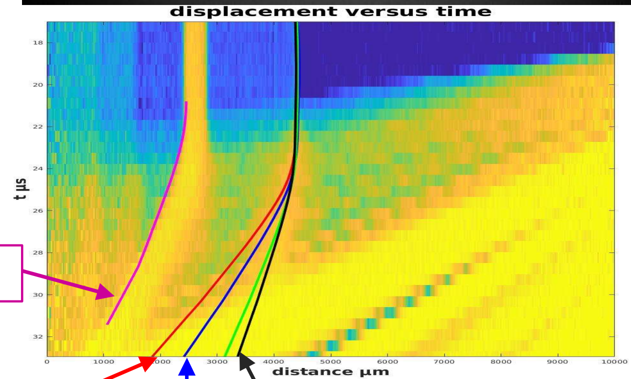
$$n_1 = \frac{U_1^* - u_1^*}{U_1 - u_1} = \frac{U_1.n_0 - u_1^*}{U_1 - u_1}$$

$$n_i = a + b.\rho_i$$

$$\rightarrow u_1 = \frac{u_1^*}{a}$$

u_1 true particle velocity





fly cut groove

µLiF crystal

due to edge effects

correcting factor is revised to a value of 2-2.5

Conclusion

This study allowed us to analyze

- impact of the surface geometries on the ejecta jet formation
  - form, speed, density repartition
  - edge effects
  - fragmentation scheme
- interaction with mass diagnostics
  - splash on foils
- correlation between diagnostic response and jet density repartition
  - ➔ calculations in progress

It rises also a lot of interesting subjects

- origin of the edge effects
- what would be the impact of different shock strength
- better understanding of the jet interaction with the diagnostic
- are these effects similar with other materials, other surface geometries
- …

Thank you