Interaction of a highly radiative shock with a solid obstacle

T. Michel[1], M. Koenig[1,2], R. Yurchak[1], C. Michaut[3], S. Laffite[4], E. Falize[4], L. Van Box Som[4], P. Barroso[3], A. Pelka[5], Y. Sakawa[6], T. Morita[7], Y. Kuramitsu[8], G. Gregori[9], B. Albertazzi[1,10], N. Ozaki[11], P. Tzeferacos[12], D. Lamb[12]

[1]LULI, Ecole Polytechnique, France; [2]Institute for Academic Initiatives, Osaka University;Japan [3] Observatoire de Paris, France, [4] CEA, France; [5] Helmholtz-Zentrum Dresden ,Dresden;Germany [6] ILE, Osaka, Japan;[7] Kyushu U., Japan; [8]NTU, Taiwan;[9]U. Oxford, UK; [10]U. Osaka, Japan; [11]U. Of Chicago, USA.

CONTEXT

Shock waves are ubiquitous in astrophysics, arising in many circumstances. Radiative shocks (RS) play a special role since it combines both hydrodynamics and radiation physics .

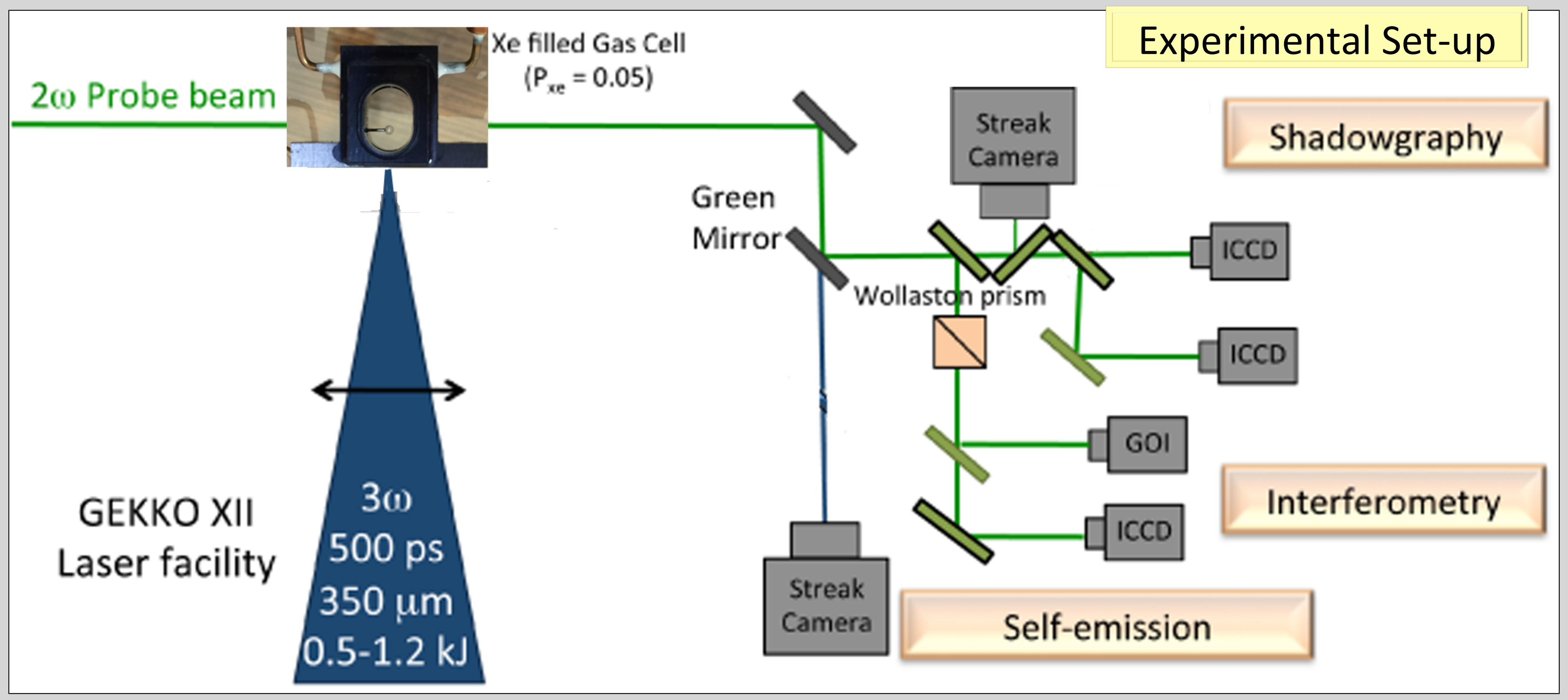
The RS experiments can also directly probe the shock physics and can provide validation of the complex computer codes used to interpret observations.

In this study, we try to observe the interaction of a strong RS with an obstacle (either a simple aluminium foil or a microballoon).

Explore configuration similar to our future LMJ experiment
-> observe the influence of radiation generated by a high velocity shock wave on a spherical obstacle "mimicking" processes occurring in molecul…

Gekko experiment intend to prepare LMJ shots by achieving similar velocities (up to 160 km/s). To this end, due to "low" Energy and short pulse duration (500 ps), the total mass of the pusher has to be low.

Experimental Set-up



EXPERIMENTAL PARAMETERS

Two types of targets were studied

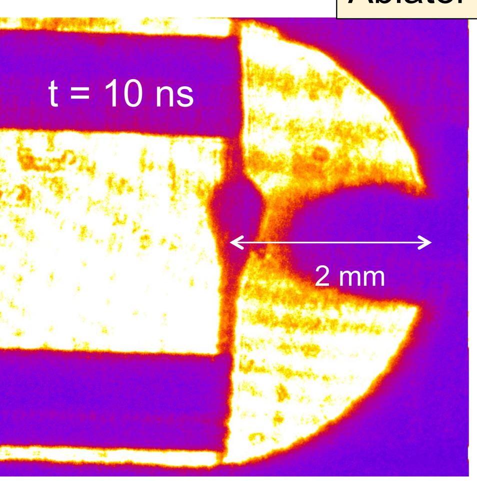
- gas cell with a 20 µm Al foil situated at 2 mm from the ablator-pusher foil
- Gas cell with a 1 mm diameter microballoon

The visible diagnostics gave us access too

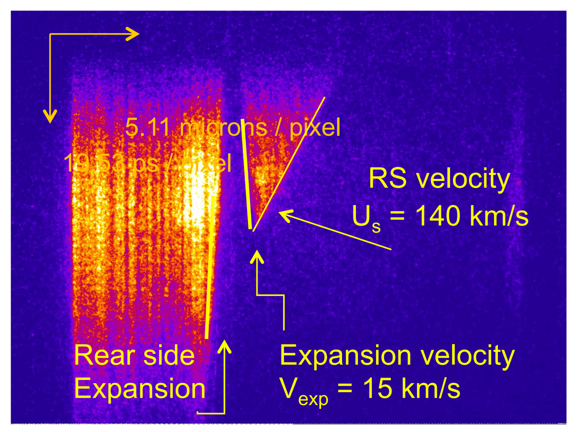
- Shock and precursor velocities versus time (SOP and Shadow)
- Electron density in the gas between the shock front and obstacle (GOI, ICCD)
- Shock temperature (SOP)
- Obstacle expansion (Shadow)
- Microballoon collapse (ultraneo)

Aluminum Obstacle results

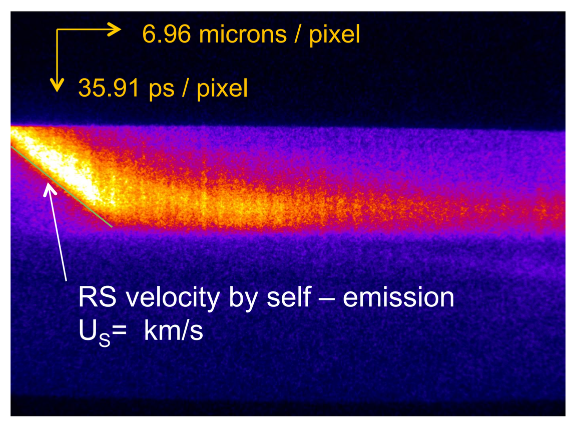
I_{Laser} = 1,1 x 10^{15} W.cm^{-2}
P_{xenon} = 50 mBar
Ablator-pusher: 25 µm CH – 4 µm Sn



Shadowgraphy GOI



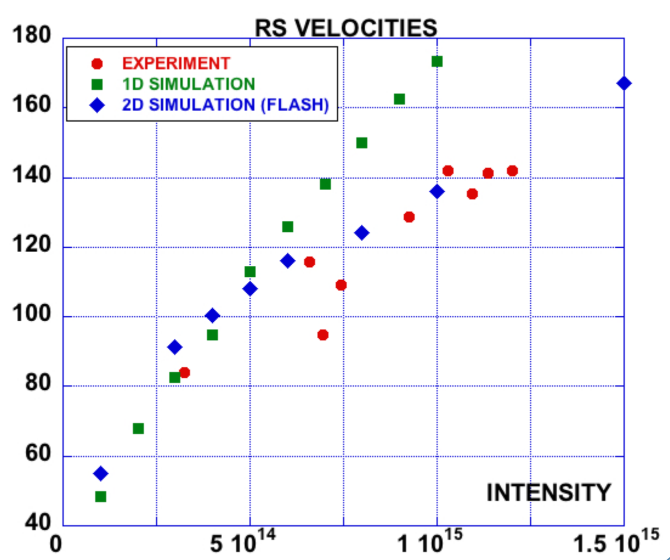
Shadowgraphy Streak



SOP

VELOCITIES

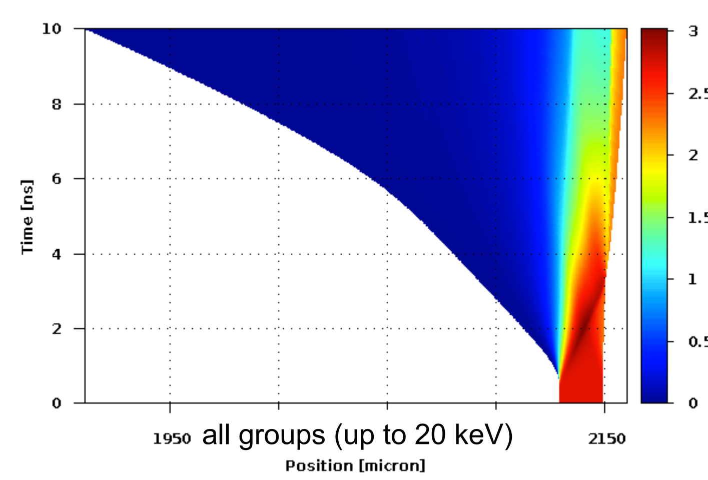
RS velocity is an important variable to be measured as it constraints the simulations performed to analyse the data
Simulations have been performed with MULTI (1D) RDH code, FLASH for the 2D case.

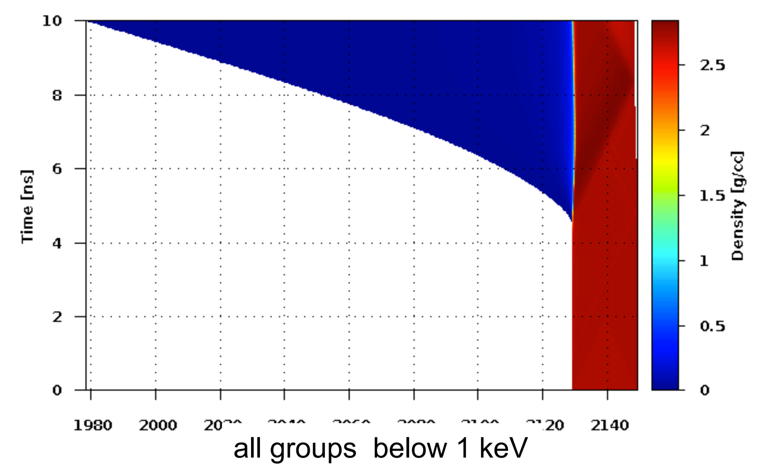


Data Analysis

Influence of the preheating

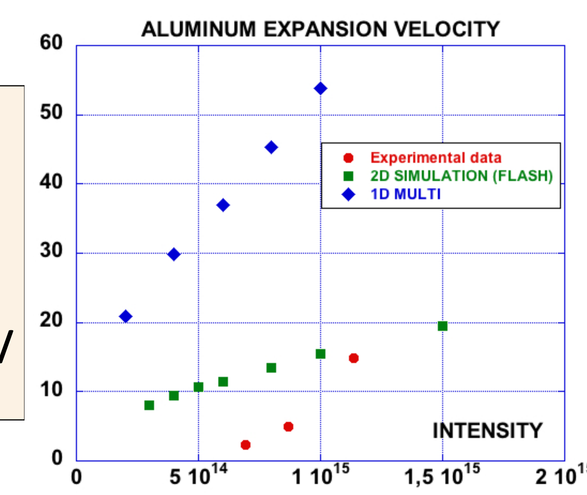
The foil expansion is due either to radiative precursor and/or some remaining preheating due to hard x-ray from the corona. The target thickness in the GEKKO experiment had to be small enough to achieve high RS velocities.
To infer the possible effect of preheating, we performed two type of 1D simulations





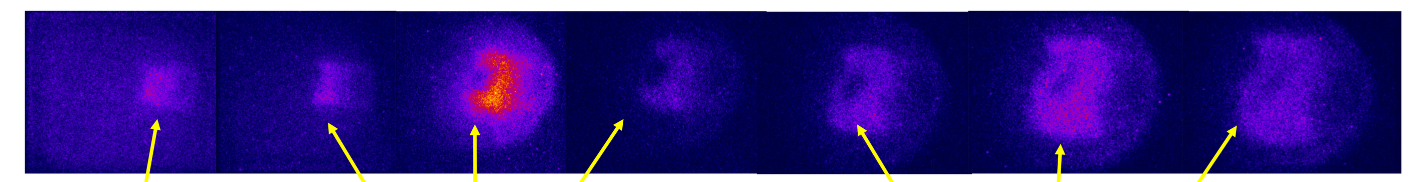
ALUMINIUM FOIL EXPANSION

- **On GOI, we measure RS mean velocity. On streaked diagnostic (shadowgraphy and SOP), we deduce instantaneous velocities**
- **We observe a clear expansion of the aluminium foil due to radiative precursor and/or some hard x-ray preheating ?**
- **The aluminium rear side expansion is less important (3 km/s) to be compared to the front side (15km/s)**

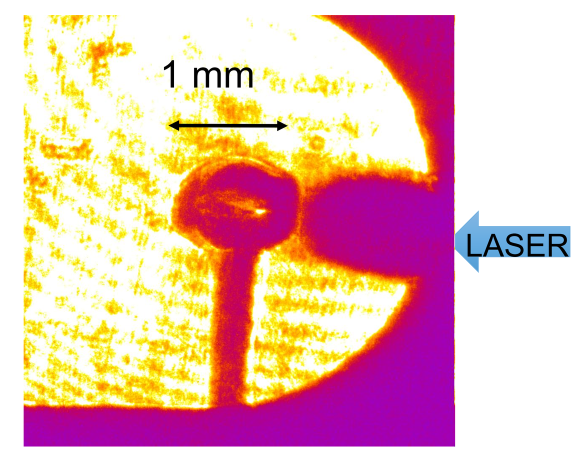


Microballoon Obstacle results

Self-Emission snapshots (every 5 ns)

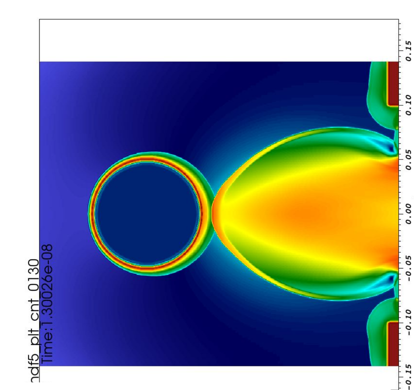


2D Shadowgraphy

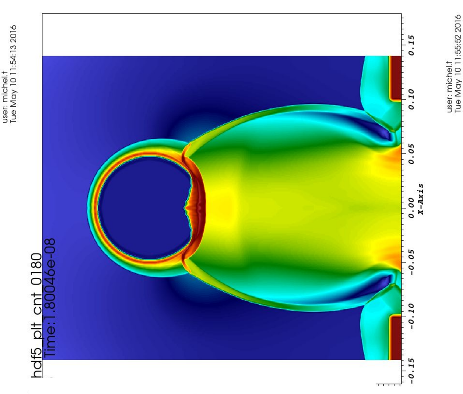


The wall thickness is ablated
The RS impacts the balloon

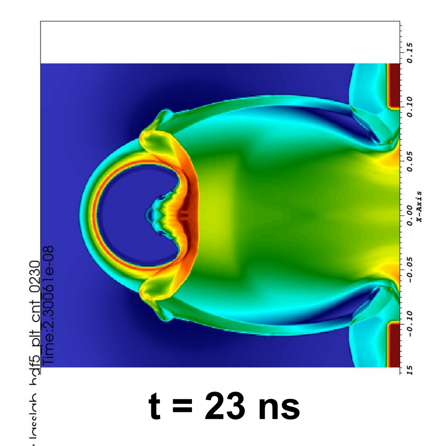
FLASH SIMULATIONS



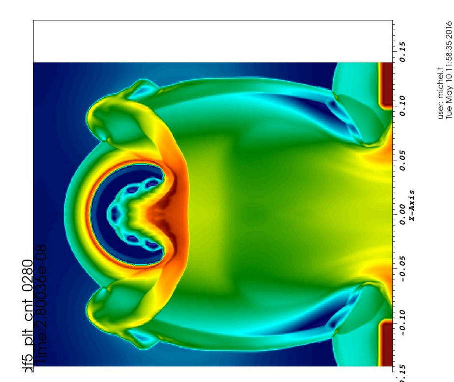
t = 13 ns



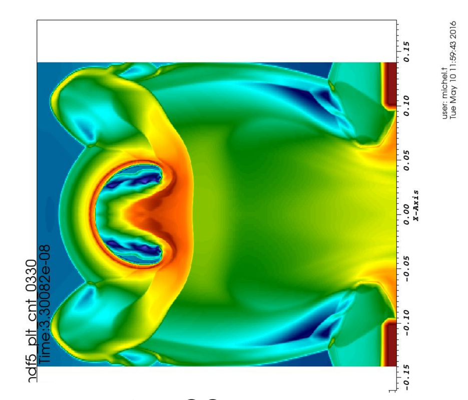
t = 18 ns



t = 23 ns



t = 28 ns



t = 33 ns

LMJ Experiment

Observables

- **Understand the behaviour and the structure of a radiative shock at v ≈ 200 km/s**
- **Observe the interaction of the radiative precursor on a spherical object (SiO2 foam ball) ->**
- ✓ ***Signature of radiative precursor***

Observables

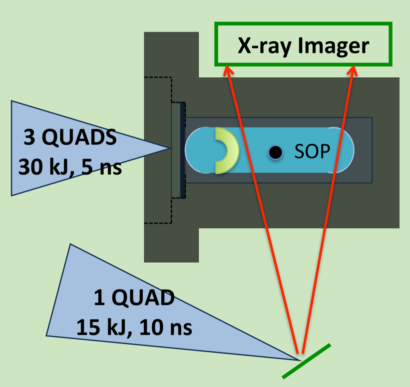
The characterization of these strong RS requires determination of:

- **The shock velocity**
- **The shock structure (shape, thickness, density)**
- **the radiative flux and the precursor length -> interaction with object**

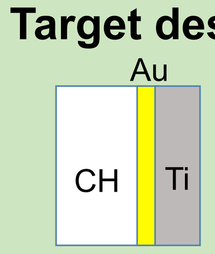
Observables

On LMJ we will have both type of diagnostics

- **visible to infer velocities, "temperature", …**
- **X-ray coupled to a framing camera to follow the RS propagation and its "density"**

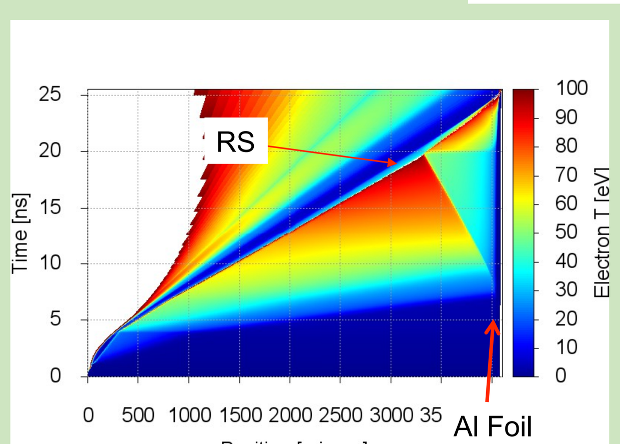


Target design



Constraints

- Optimise the velocity
- Minimise the preheating



Good compromise
30 µm CH- 4 µm Au – 13 µm Ti
Preheating < 1 eV

Conclusions

- The experimental shock velocities are close to the simulated velocities and very high (up to 160 km/s)
- We achieved RS conditions similar to the one expected on LMJ
- Due to low mass solid target, X-ray preheating makes the expansion of Aluminium obstacle to start earlier
- The final expansion velocity is the same (up to 15 km/s), with or without X-rays preheating
- A new design for the ablator-pusher solid target, dedicated to LMJ have been made

Acknowledgments

The authors would like to thank the ILE staff for their great support
The GEPI target fabrication has to be acknowledge
Part of this work was supported by the Scientific Council of the Observatoire de Paris.