INSTITUT P'

14émes Journées d'Echanges du
Réseau des Plasmas Froids

15-18 octobre

La Rochelle

Effets de pression générée dans l'eau par décharges électriques ou irradiation laser pulsée

Julien Deroy, Alain Claverie, Michel Boustie,
Ekaterina Mazanchenko, Michel Arrigoni

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie · Bmax shaping your future · ITHPP Ingénierie Electrotechnique Systèmes de Fortes Puissances · PAPREC RECYCLAGE · ENSTA Bretagne · cnrs · Université de Poitiers · ENSMA

Plan

- Contexte
- Méthodologie
- Décharge dans l'eau
- Simus
- Laser
- Cavitation
- Conclusions et perspectives

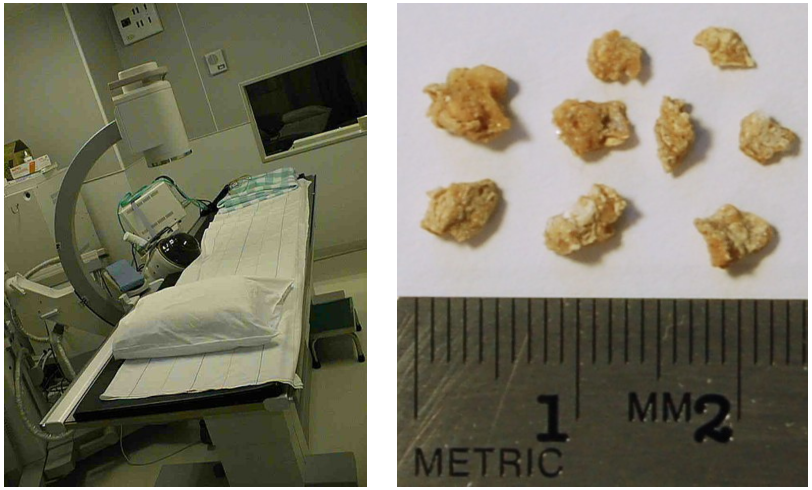
Introduction

High power electrical discharge in water:

- generation of shock waves,
- waves propagation and interaction with materials.

Applications:

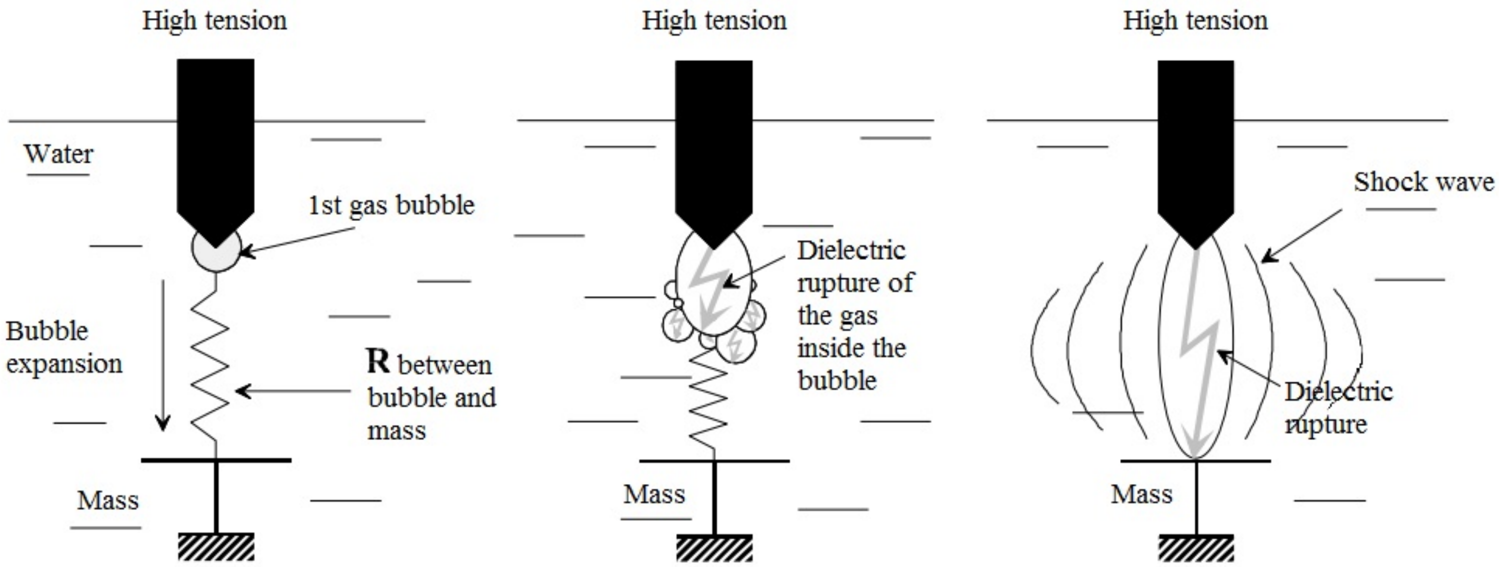
- medical,
- separation of materials,
- recycling.

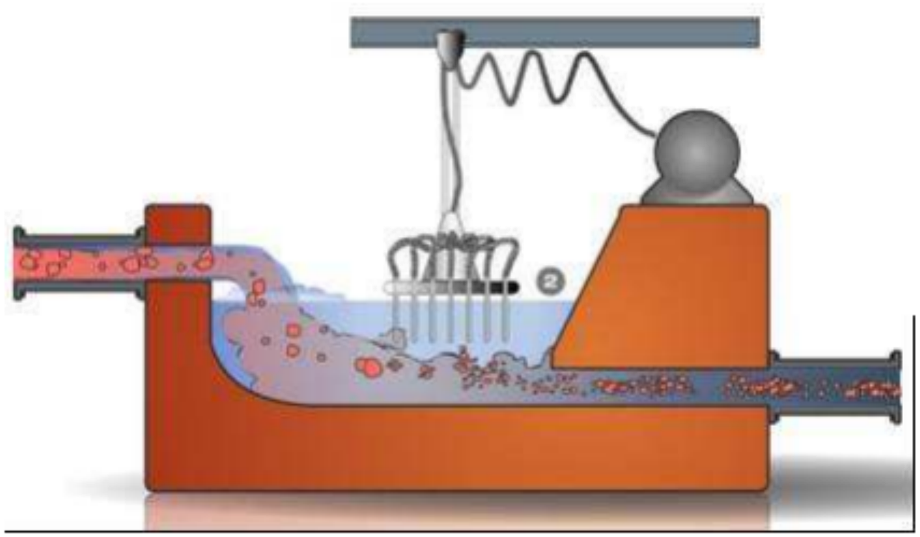


Lithotripter and fragments of a 1-cm calcium oxalate stone

Fig. from PhD thesis of Gilles Touya

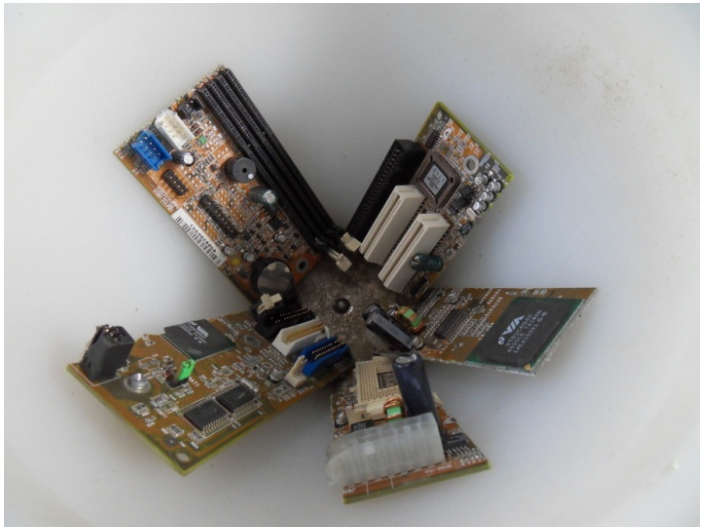
Problem definition





Concept

Examples of fragmentation, ITHPP



Before treatment

After treatment

Procedure

Experimental tests → Data → Simulation → Optimisation

- ITHPP generator (I(t), Δx electrodes);
- diagnostics

↔

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Objectives	Moyens expérimentaux
Caracterisation du terme source	Visus, strio, emission spectra
Waves propagation	Visus
Interaction with objet / Fragmentation	Visus + inverse measurements

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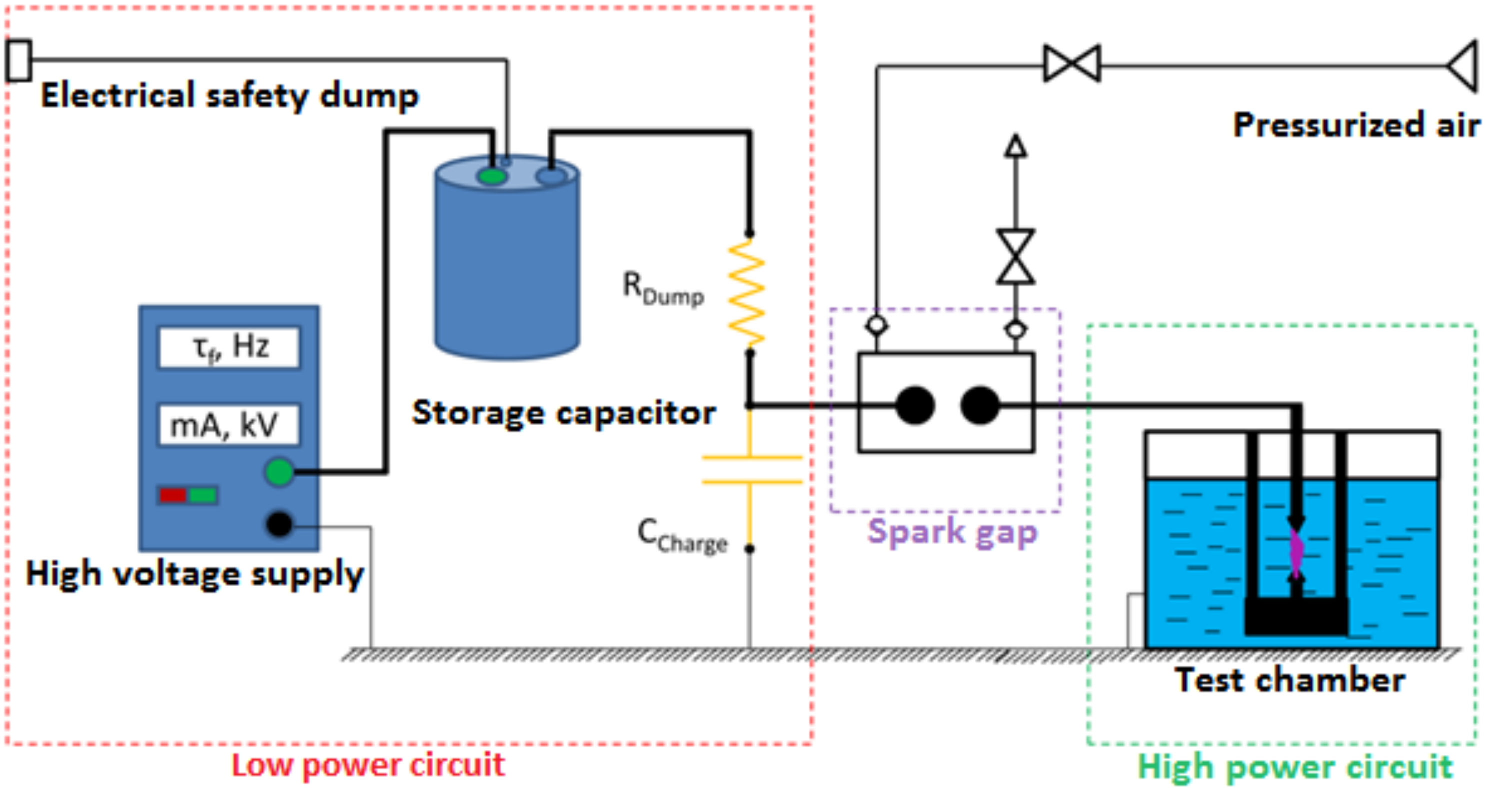
Schematic of experimental setup for high power pulsed underwater electrical discharge



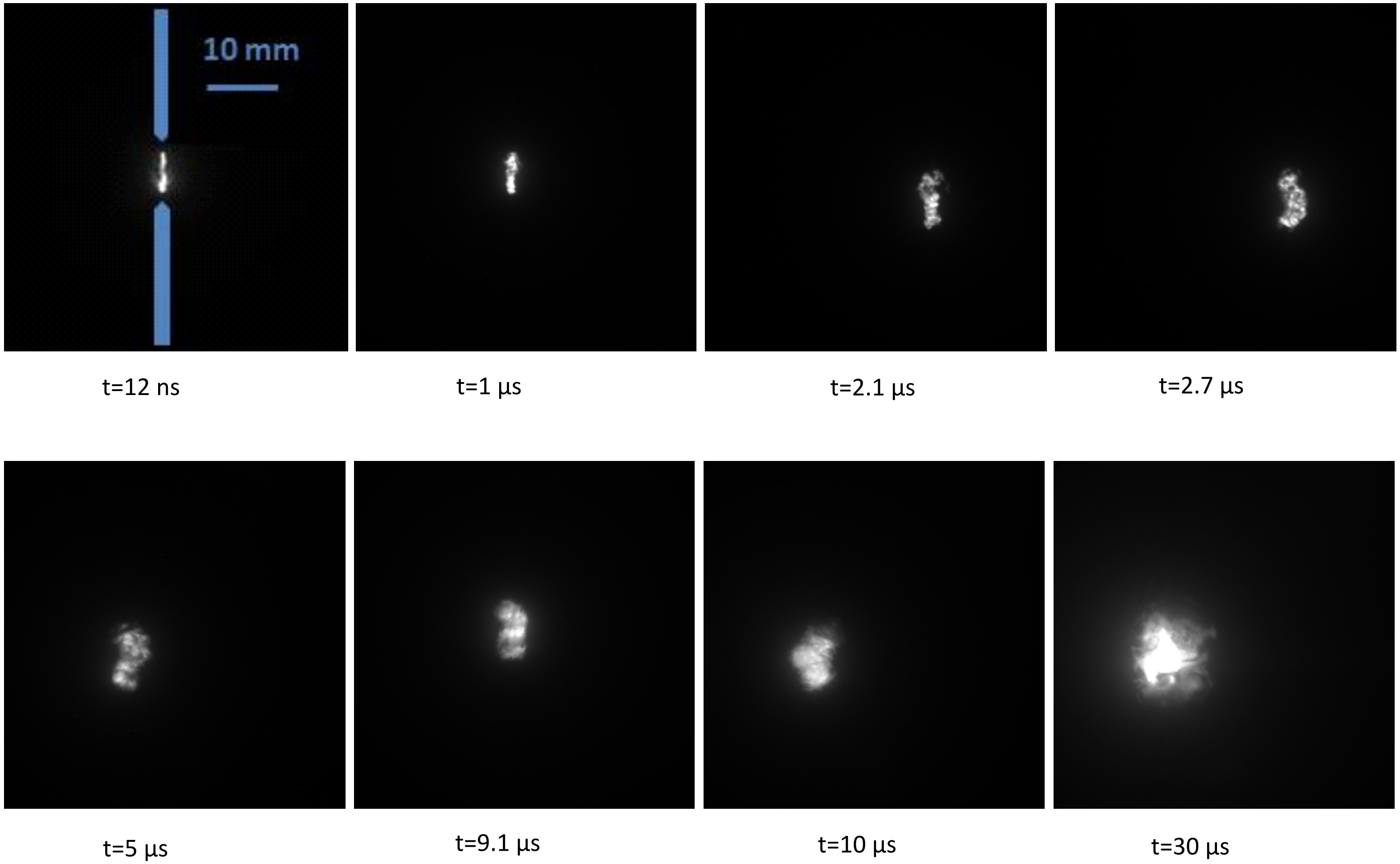
A. Claverie, J. Deroy, M. Boustie, G. Avrillaud, A. Chuvatin, E. Mazanchenko, G. Demol, B. Dramane. *Experimental characterization of plasma formation and shockwave propagation induced by high power pulsed underwater electrical discharge // Review of Scientific Instruments. 85, 063701 (2014).*

Experimental setup, Bmax

- Modular electrical discharge generator:
    - Capacitive storage of electrical energy
    - 1 to 9 capacitors of 1.85µF, maximum voltage of 40kV
    - Stored energy capability : approx. 1-10 kJ
- Discharge circuit:
    - Point-Point or Point-Plane electrodes configuration
    - Variable inter electrodes gap
- Available diagnostics:
    - Current and voltage probes
    - Pressure gauge
    - High speed cameras
    - Velocimetry measurement

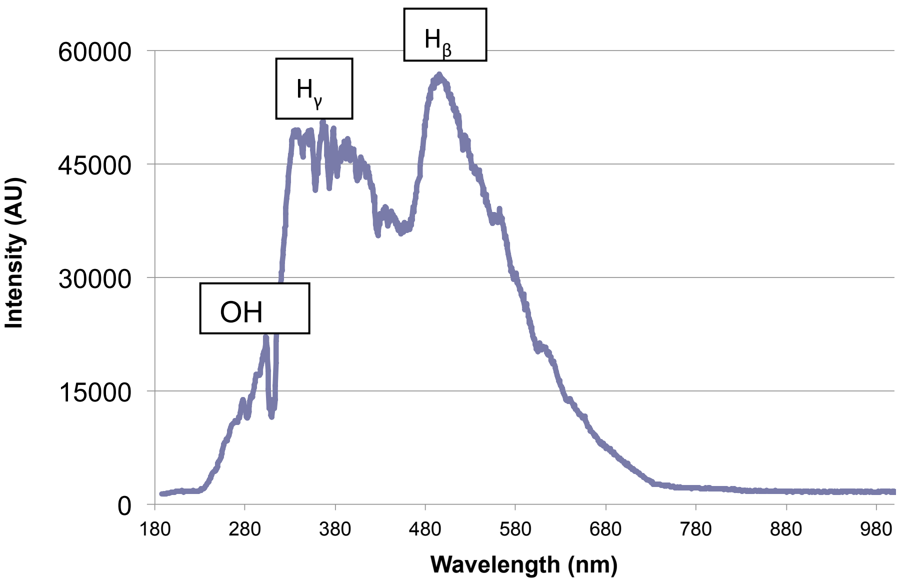
J. Deroy and all. Optical diagnostics for pulsed underwater electrical discharge characterization // 2013 APS-SCCM/ AIRAPT JOINT CONFERENCE (7-12 July, Seattle).

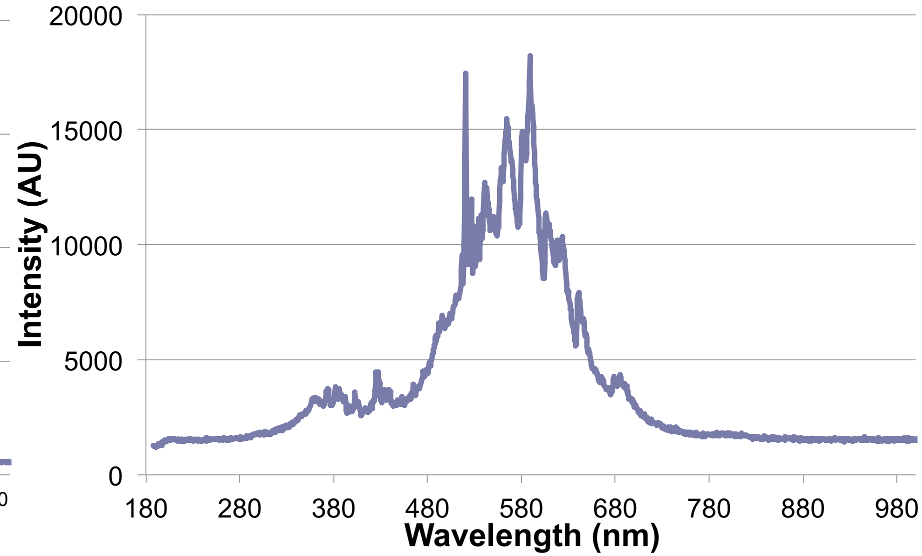
Visualization of the plasma through discharge channel



A. Claverie, J. Deroy, M. Boustie, G. Avrillaud, A. Chuvatin, E. Mazanchenko, G. Demol, B. Dramane. Experimental characterization of plasma formation and shockwave propagation induced by high power pulsed underwater electrical discharge // Review of Scientific Instruments. 85, 063701 (2014).

Typical emission spectra from high power underwater electrical discharge





obtained with trigger on discharge instant and 100 μs after discharge

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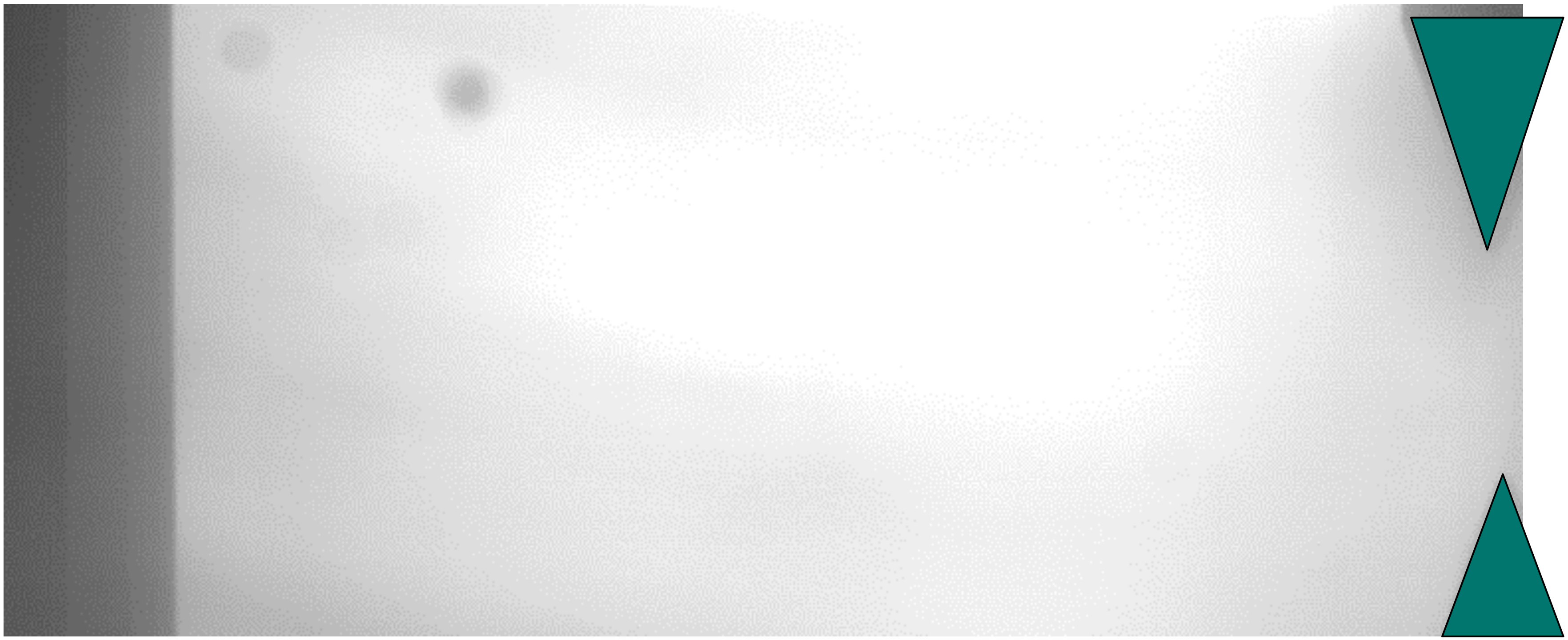
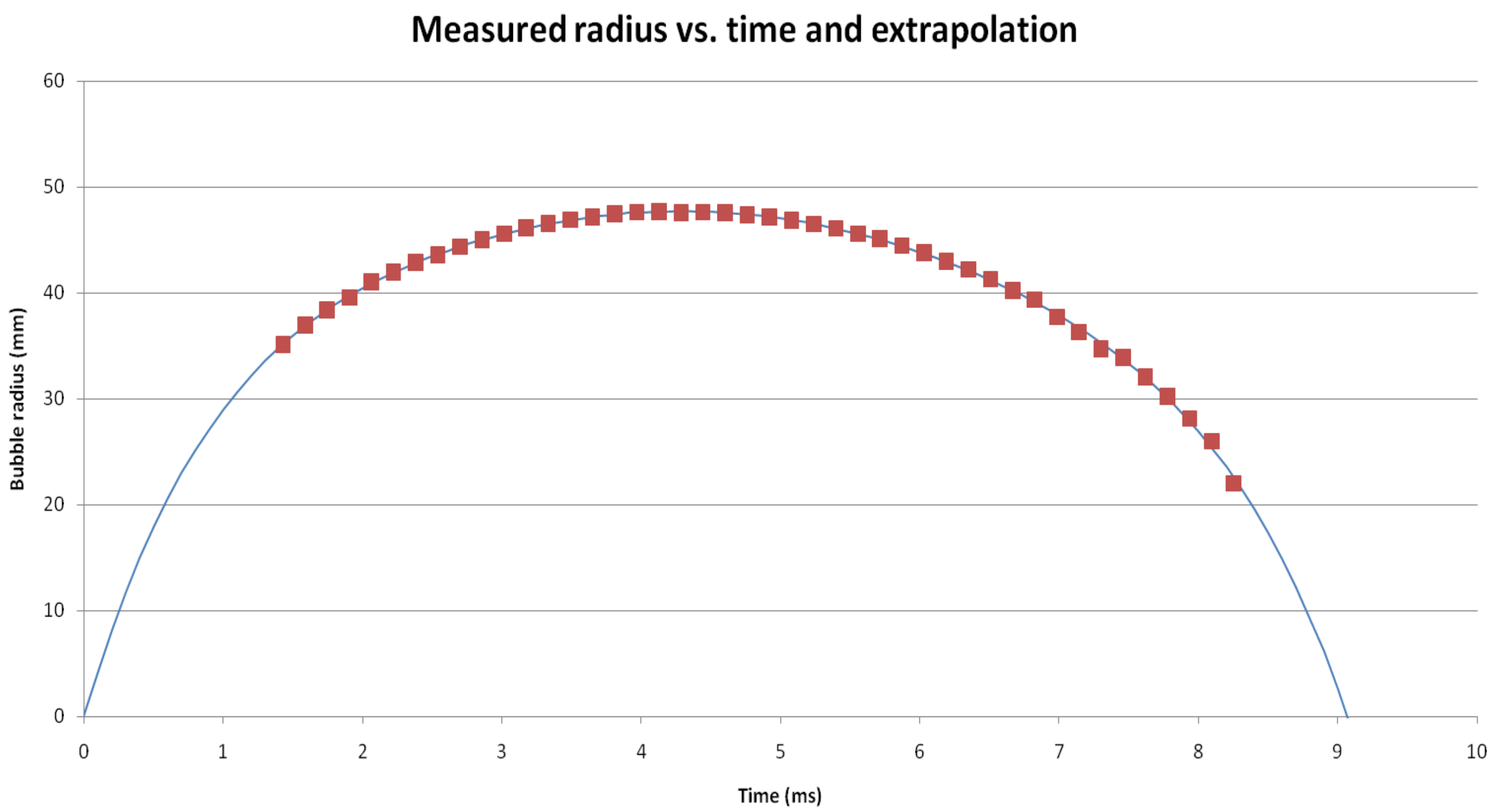
Bubble expansion, ITHPP



Gap 15 mm
U_0=25 kV
C=1.85 μF
E_0=327 J
Pressure diagnostic - PVDF

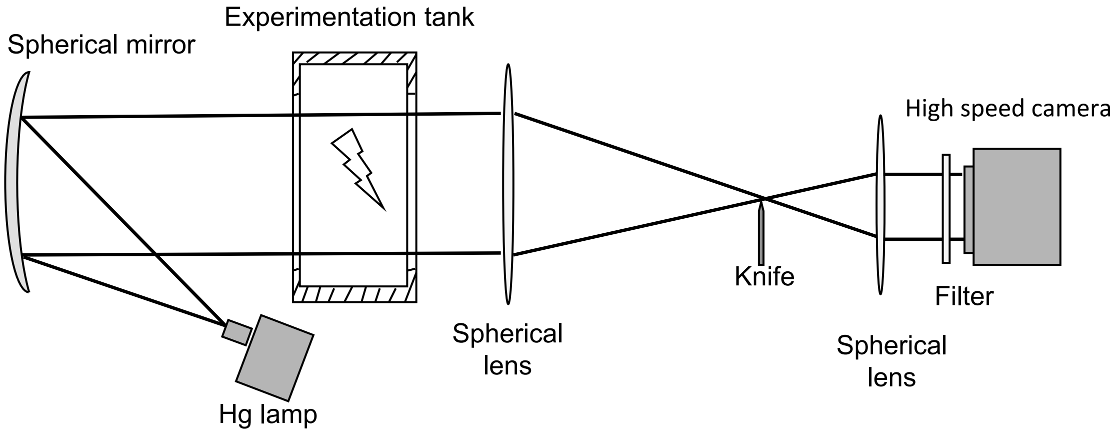
Direct observation - Bubble expansion



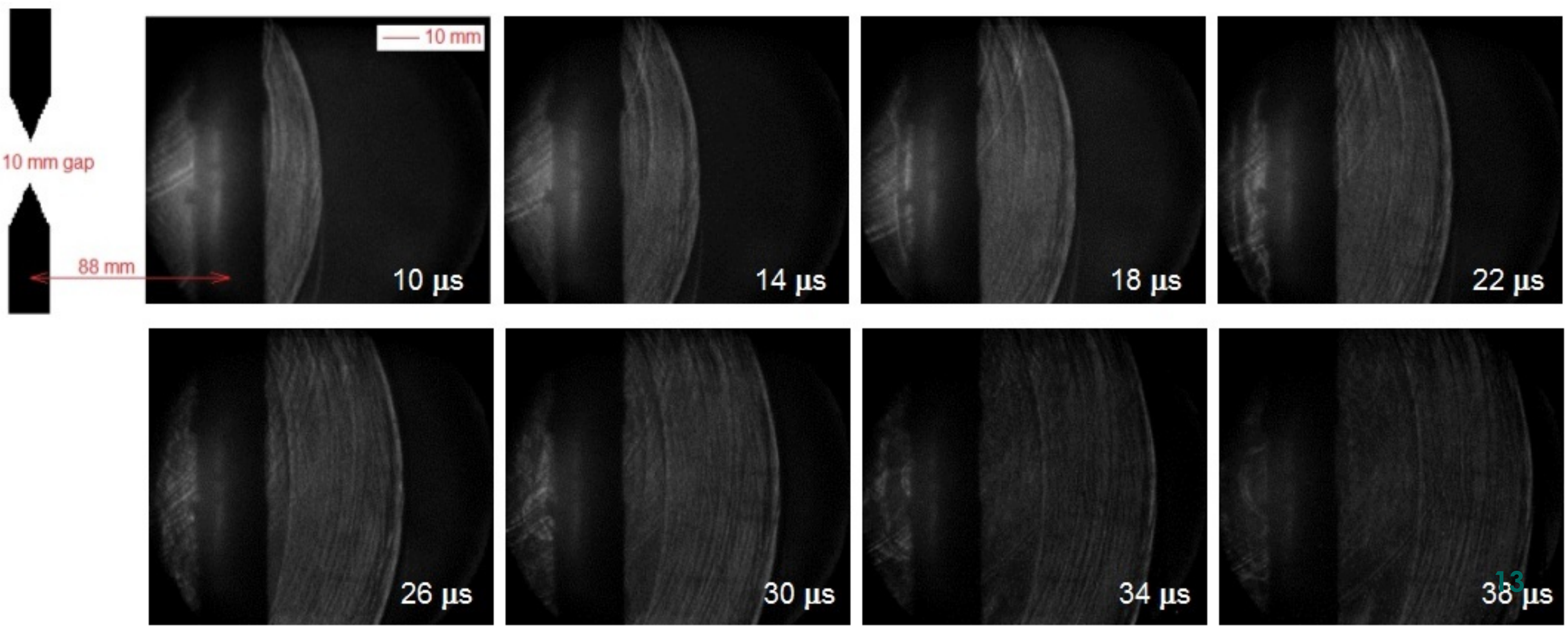
Measured deposited electrical energy: 111.6 J (total), 75.7 J (1st "arch" of power deposition)

Estimated deposited electrical energy from potential energy at r=Rmax: 67.9 J

Pressure wave propagation observation



Ultra High Speed Camera (by LCD): Shimadzu HPV-2 camera up to 1M frames/s (312x260 pixels)

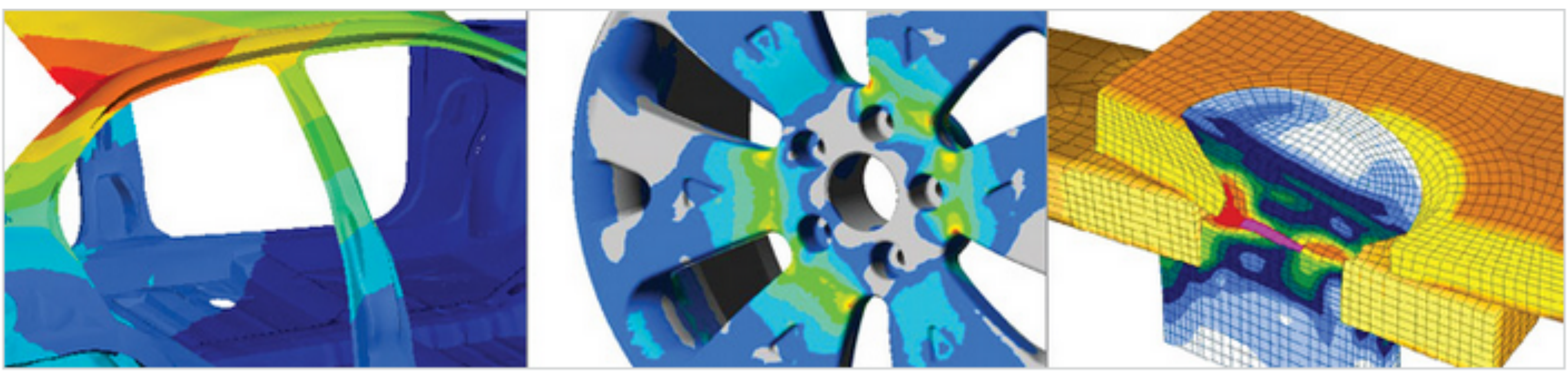


RADIOSS

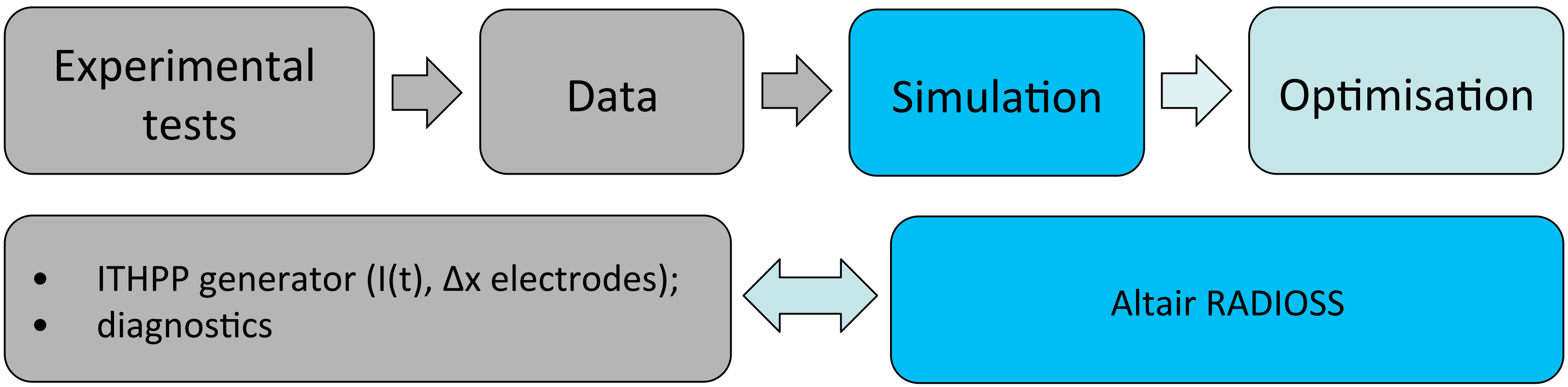
Numerical simulation has been provided with Altair HyperWorks products: HyperMesh, HyperCrash and RADIOSS code.

RADIOSS:

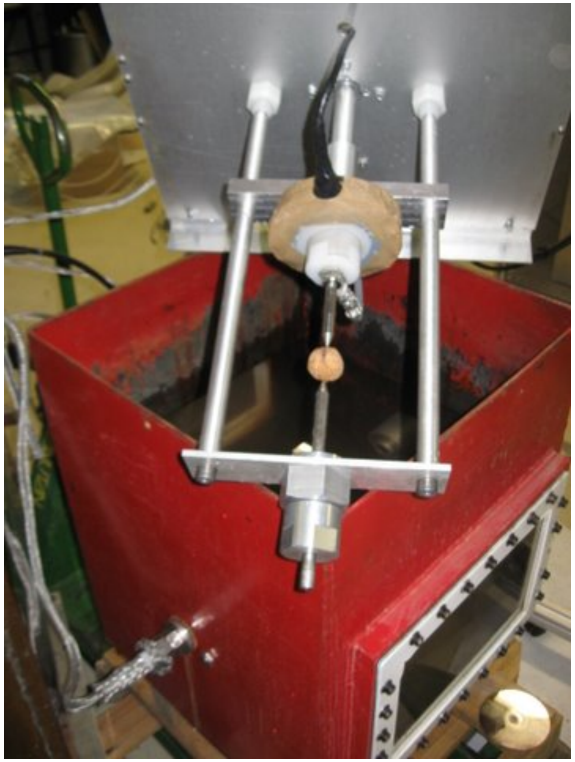
- Finite Element Solver,
- linear and non-linear simulations (structures, fluids, fluid-structure interaction, mechanical systems etc.),
- high-speed impact simulation – over 20 years,
- easy transition to OptiStruct and HyperStudy.



Procedure

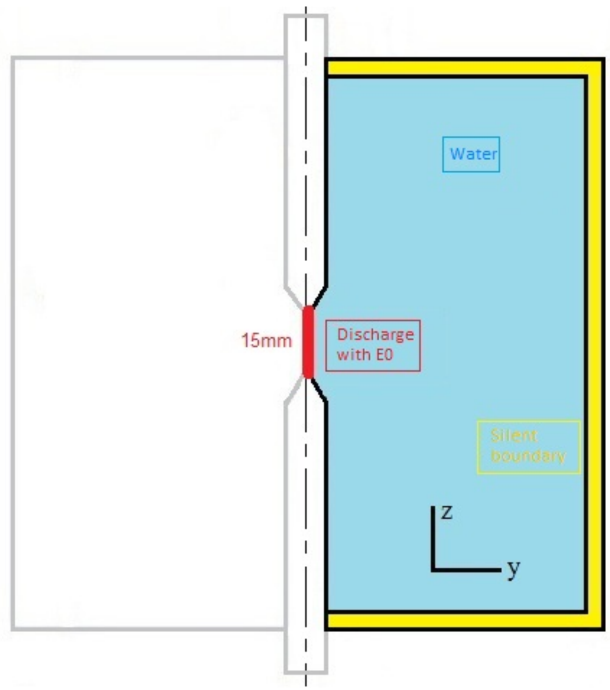

Experimental tests
Data
Simulation
Optimisation
• ITHPP generator (I(t), Δx electrodes);
• diagnostics
Altair RADIOSS

Experiment to simulate

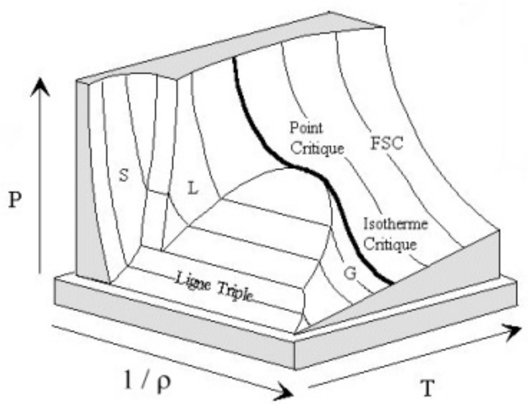


Tests were carried out at the tank 60x60x53 cm (LxWxH).
Gap between electrodes: 5 to 15 mm.
Max stored energy - to 35 kJ.
Time (shock risetime): 530 ns.

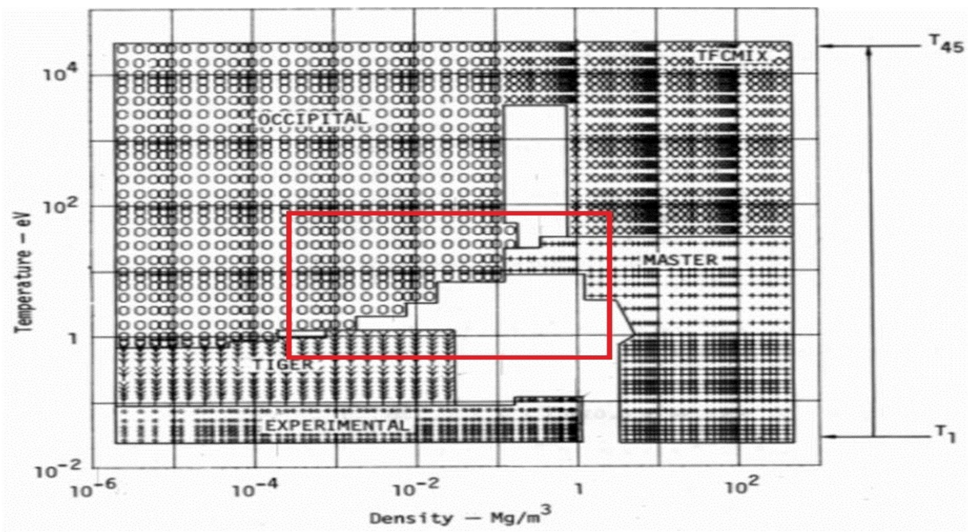
RADIOSS model definition



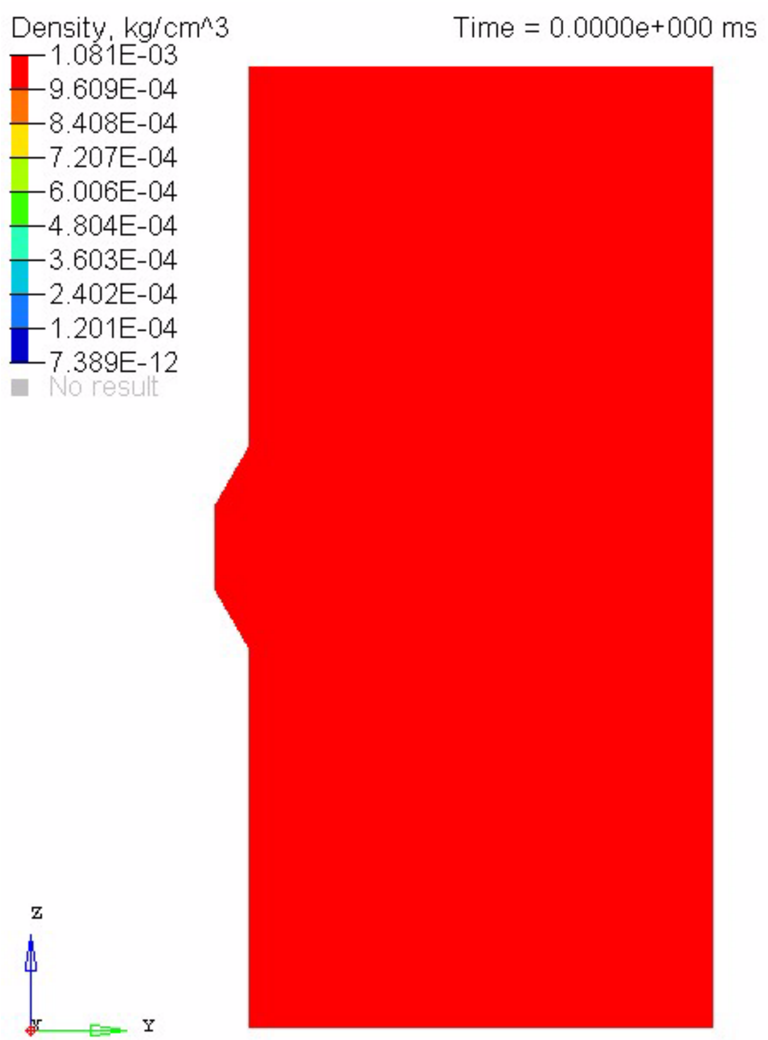
- 2D axisymmetric
- QUAD elements 0.5x0.5 mm
- Gap is 15 mm,
- deposited energy 327 J

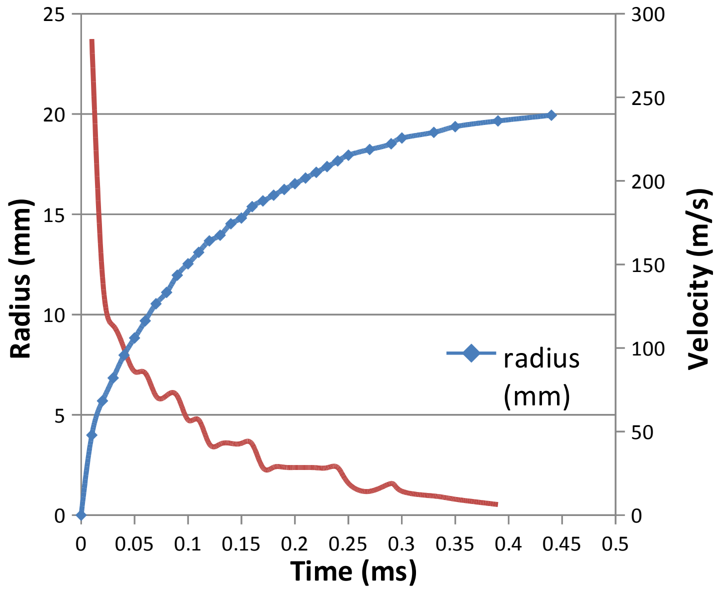


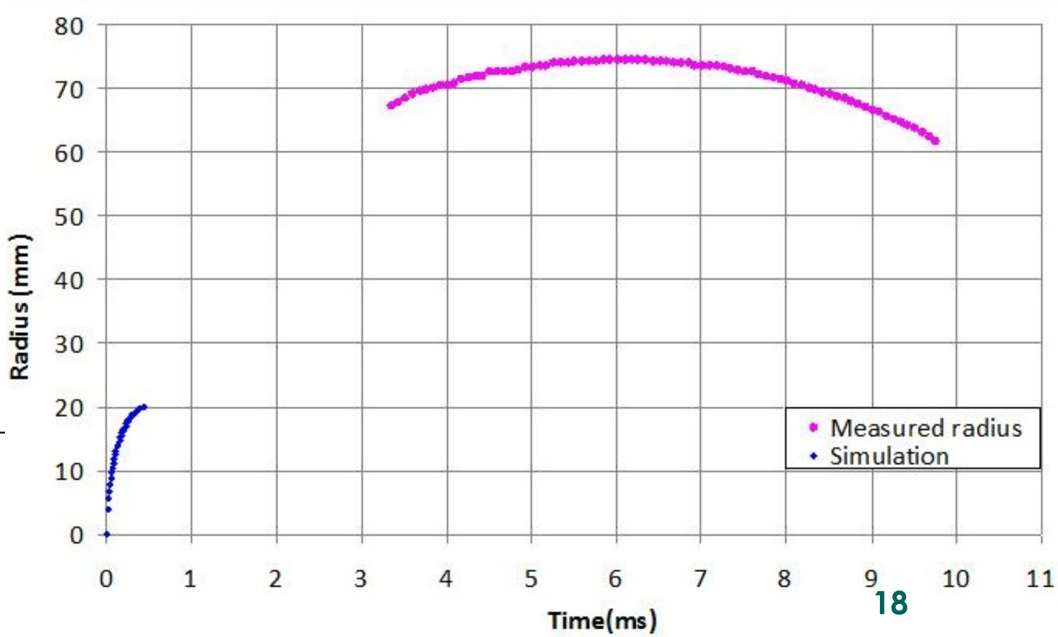
SESAME law presentation



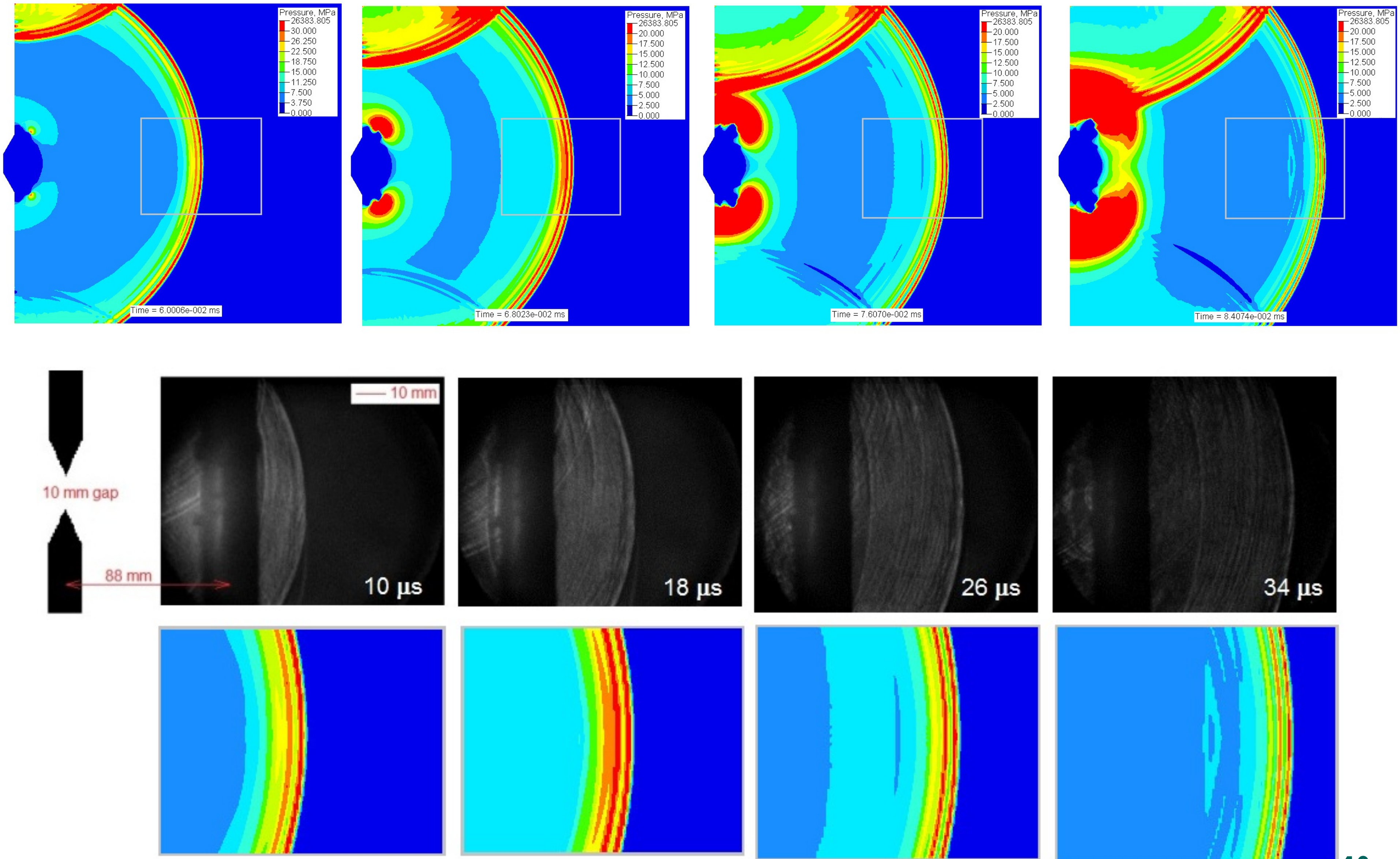
Evolution of the bubble



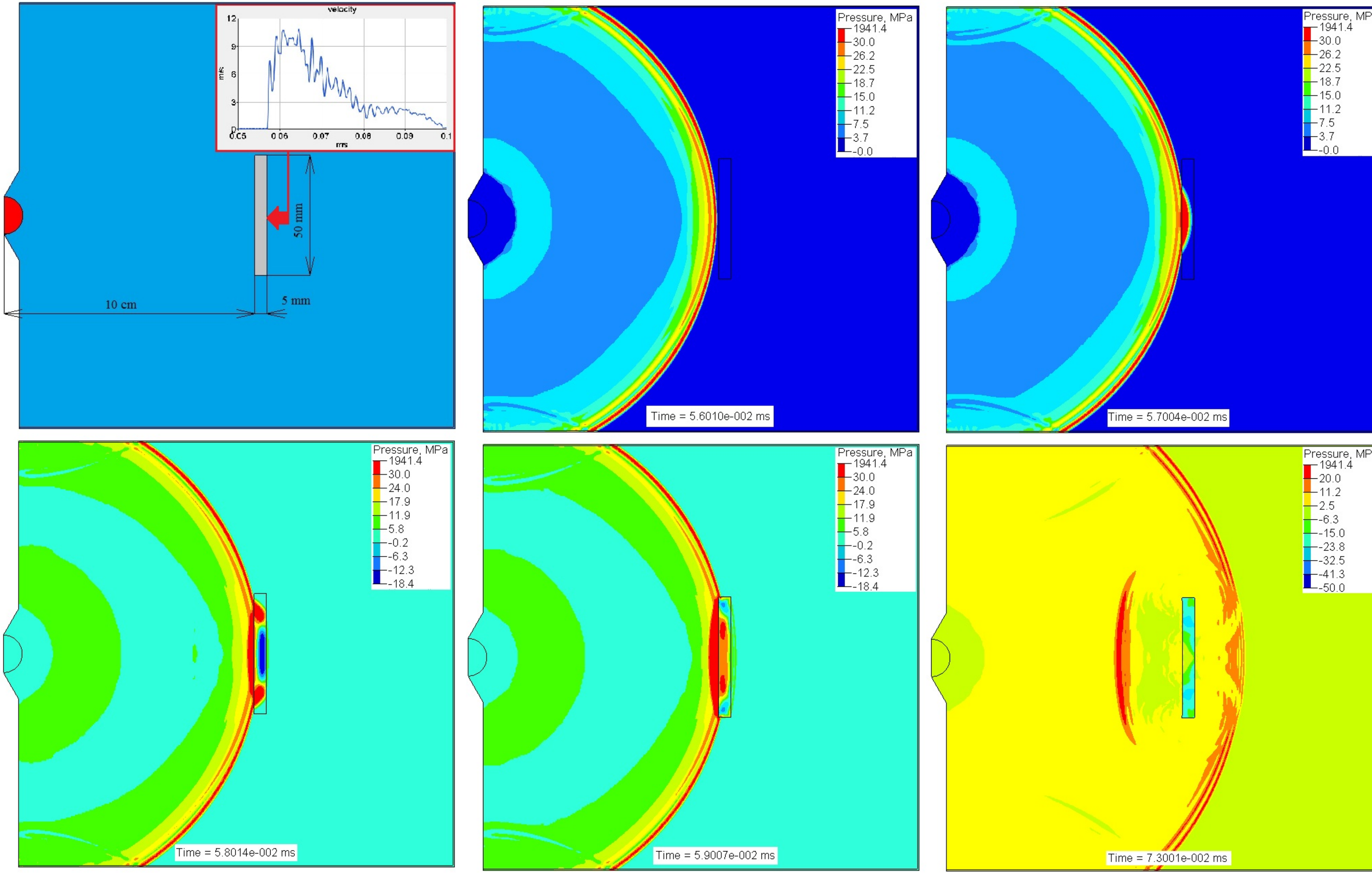




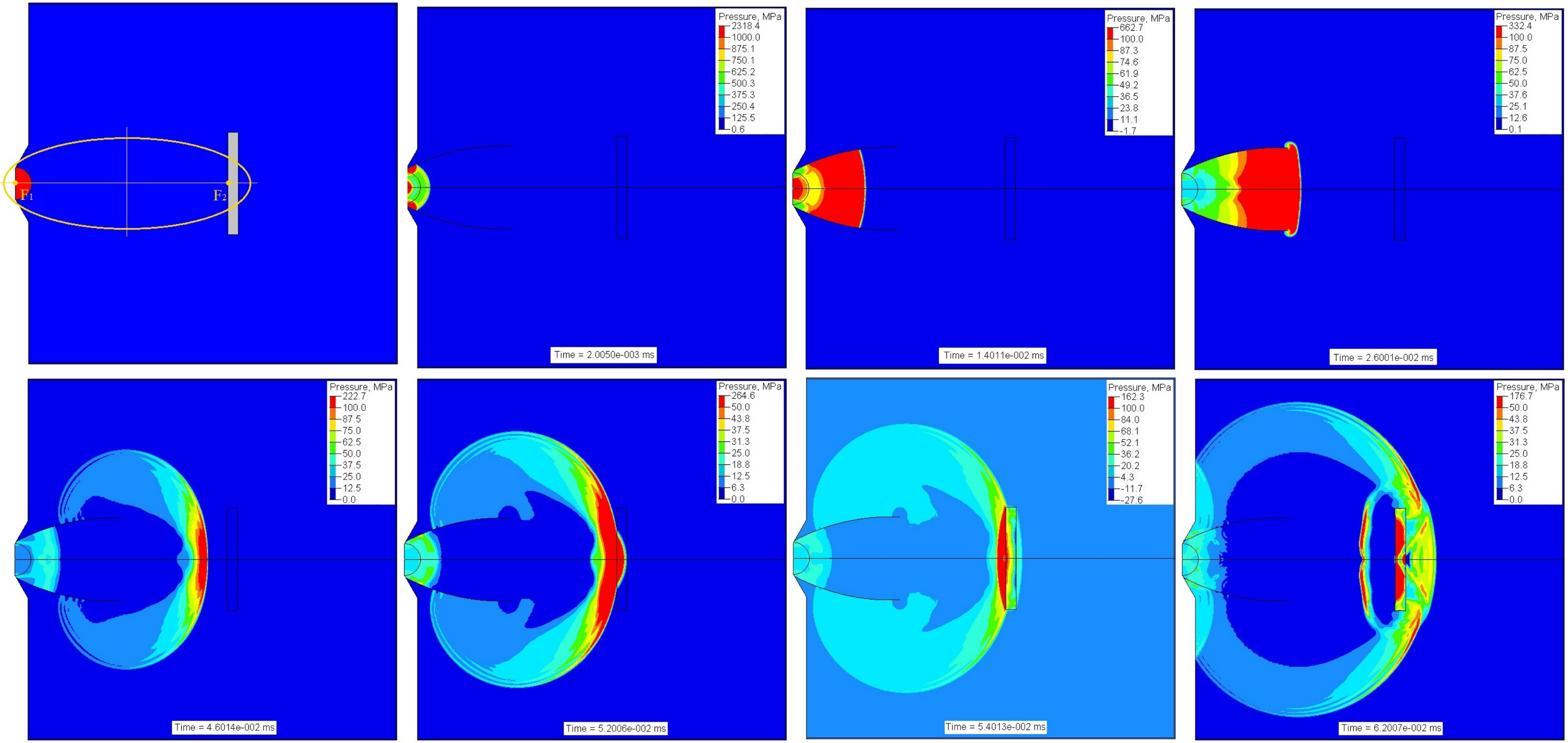
Pressure wave propagation



Interaction with aluminium foil



Optimization: reflector



Possible mechanical amplification of shock waves – an ellipsoidal reflector.

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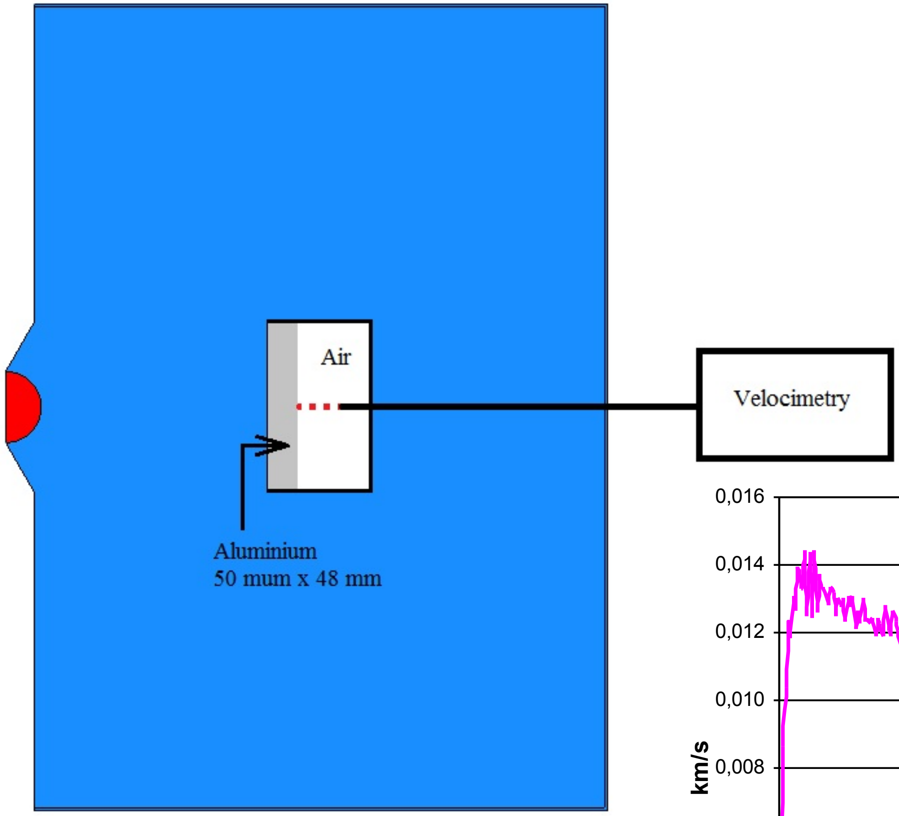
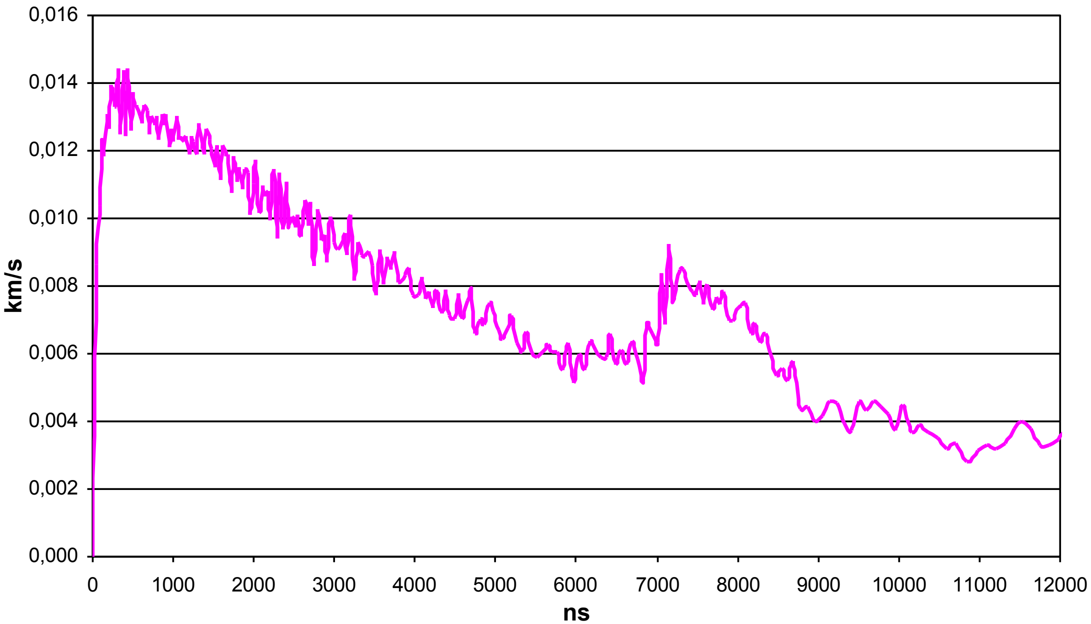
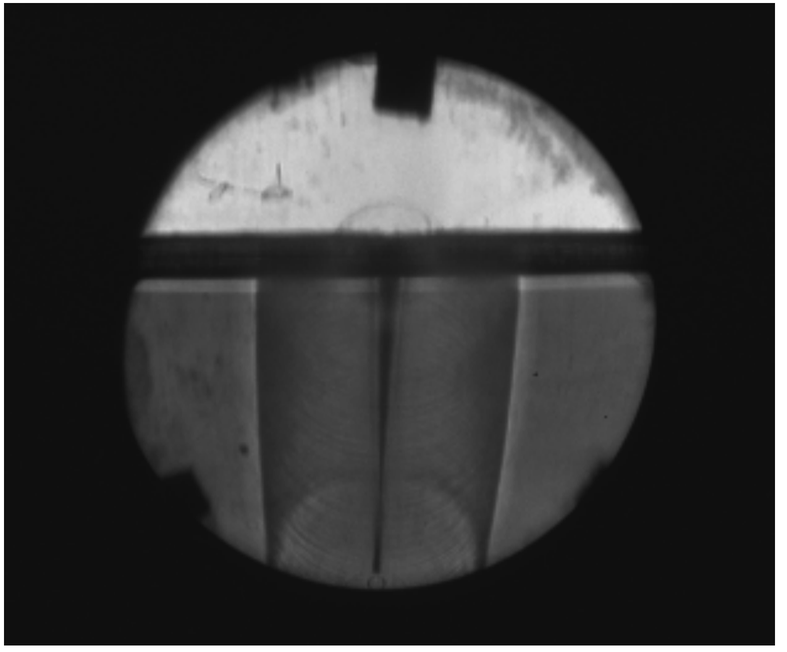
Indirect velocimetry calibration of pressure gage





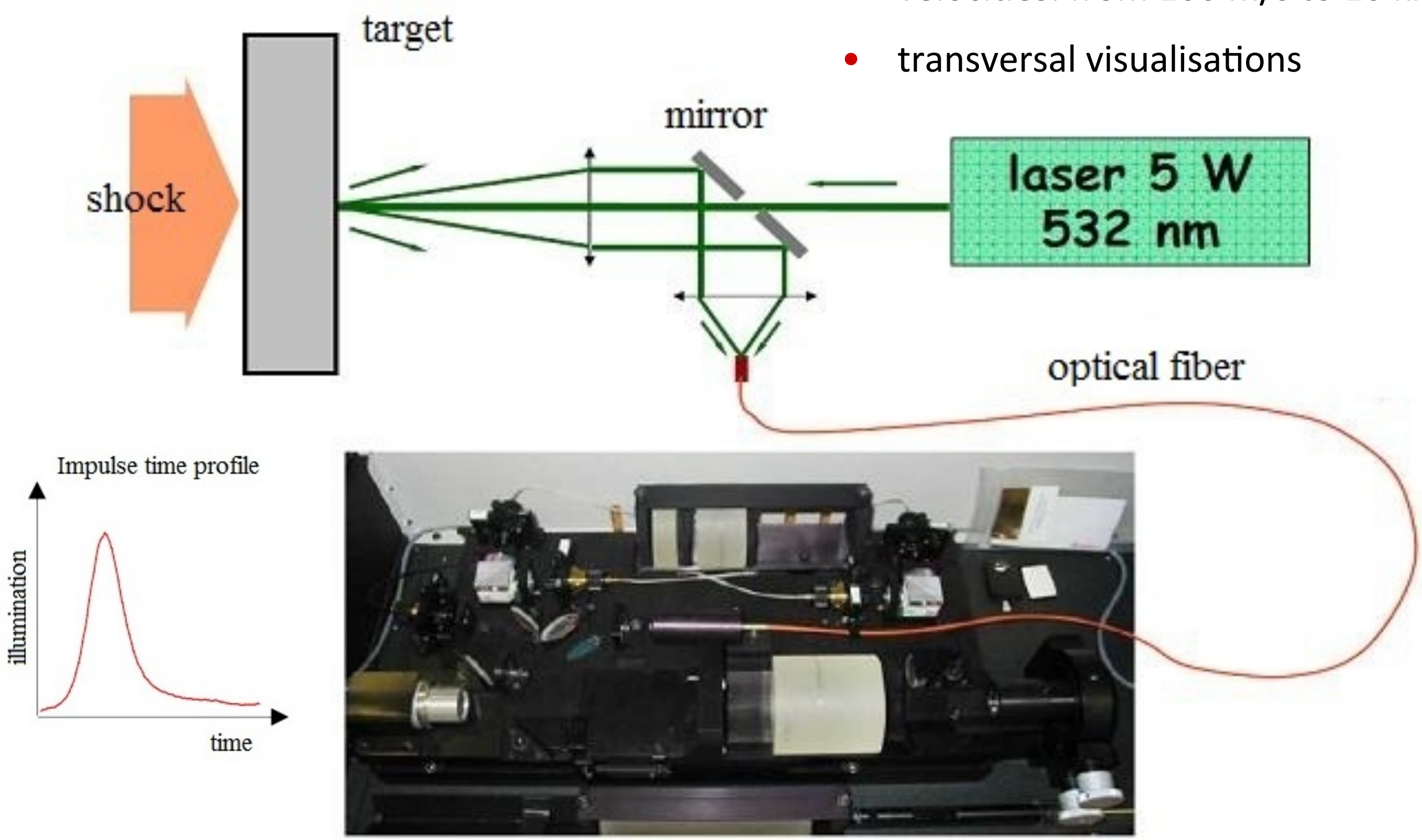
Transition vers laser

Shock waves generated by laser, PPRIME

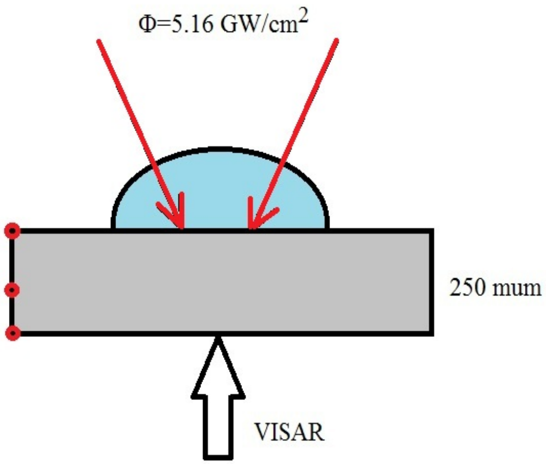


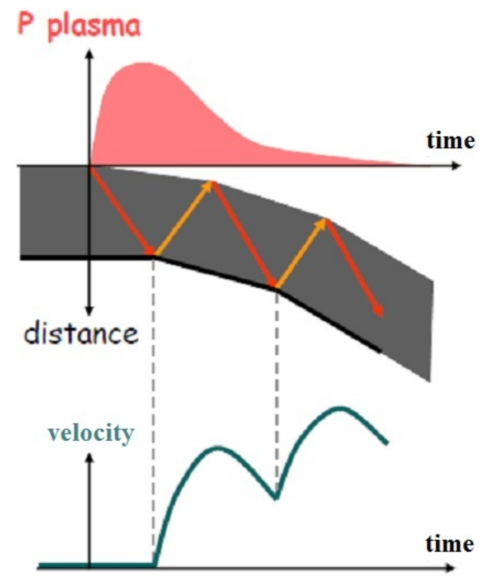
Velocity Interferometer System for Any Reflector (VISAR)

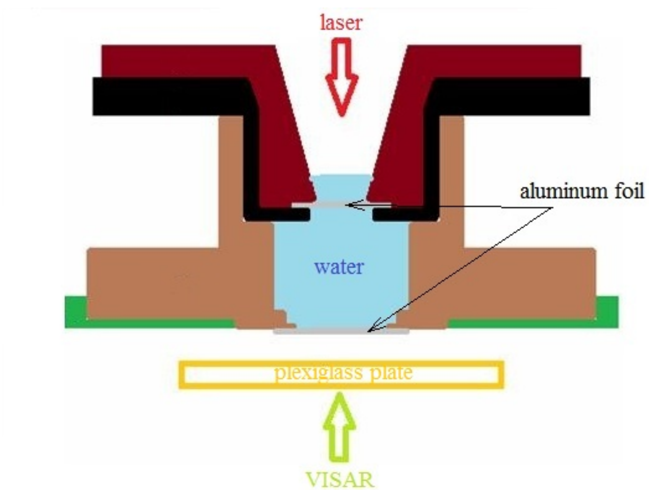
- velocities: from 100 m/s to 10 km/s
- transversal visualisations

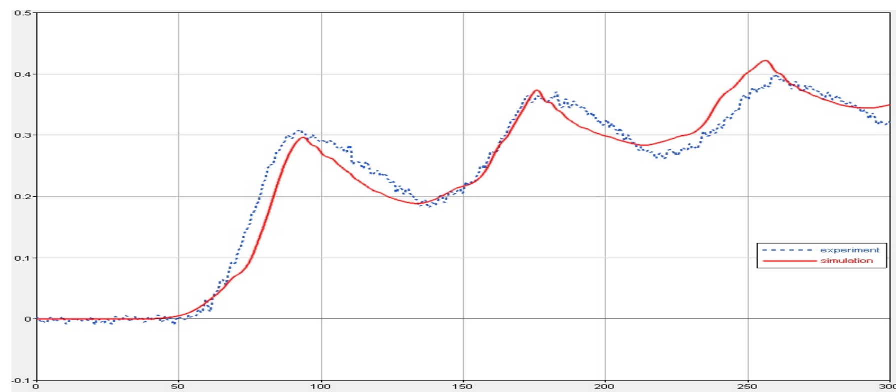


Shock calibration



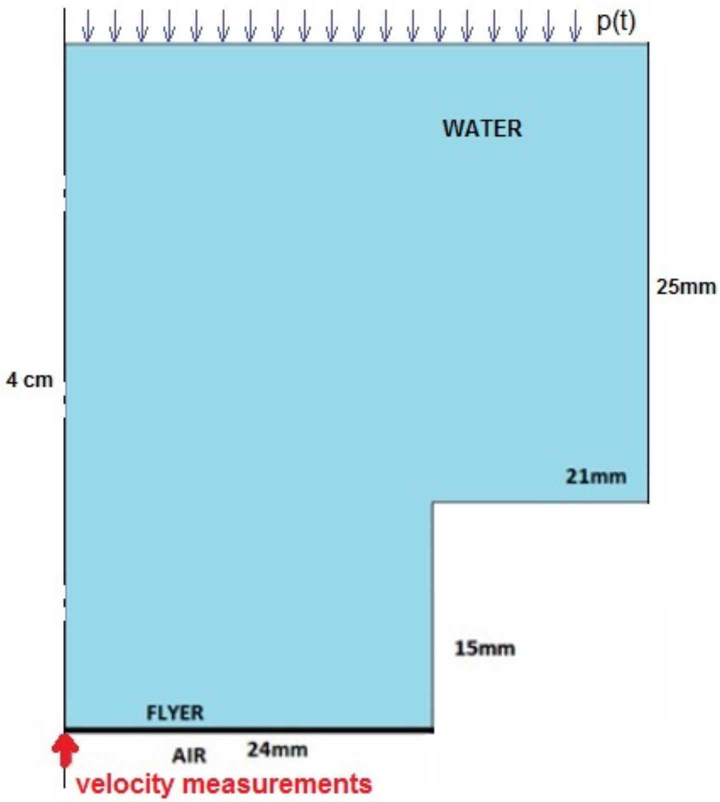


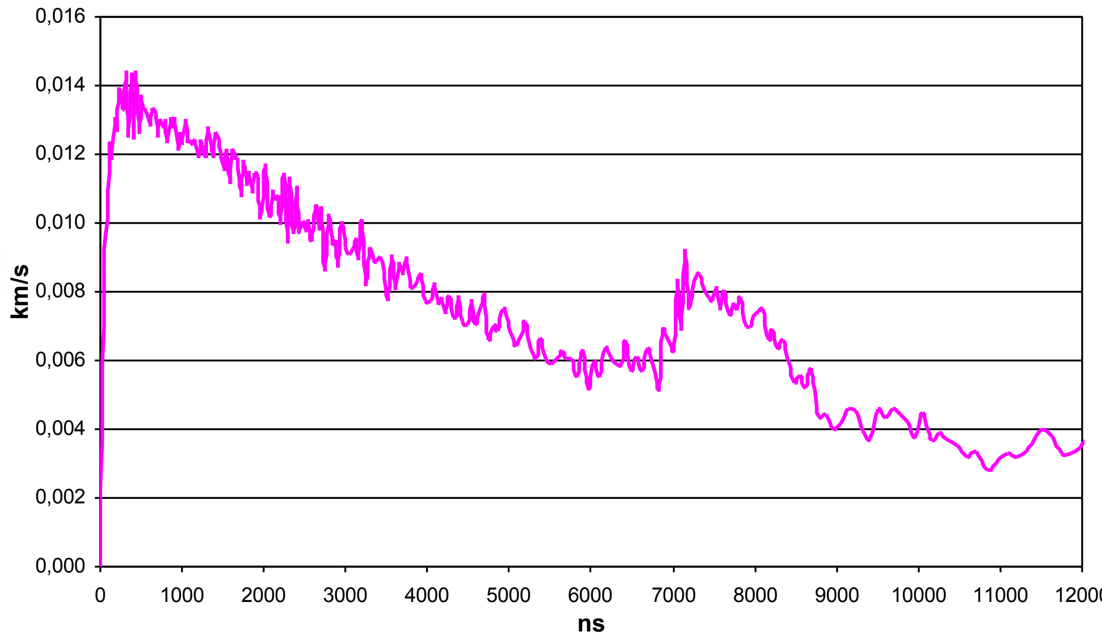




Experimental data and simulation of laser/alu interaction

Pressure simulation by inverse analysis





2D model with hydro water law and alu 50 mum: pressure varied to feet experimental velocity profile, and then initial energy E0.

Bubble pictures

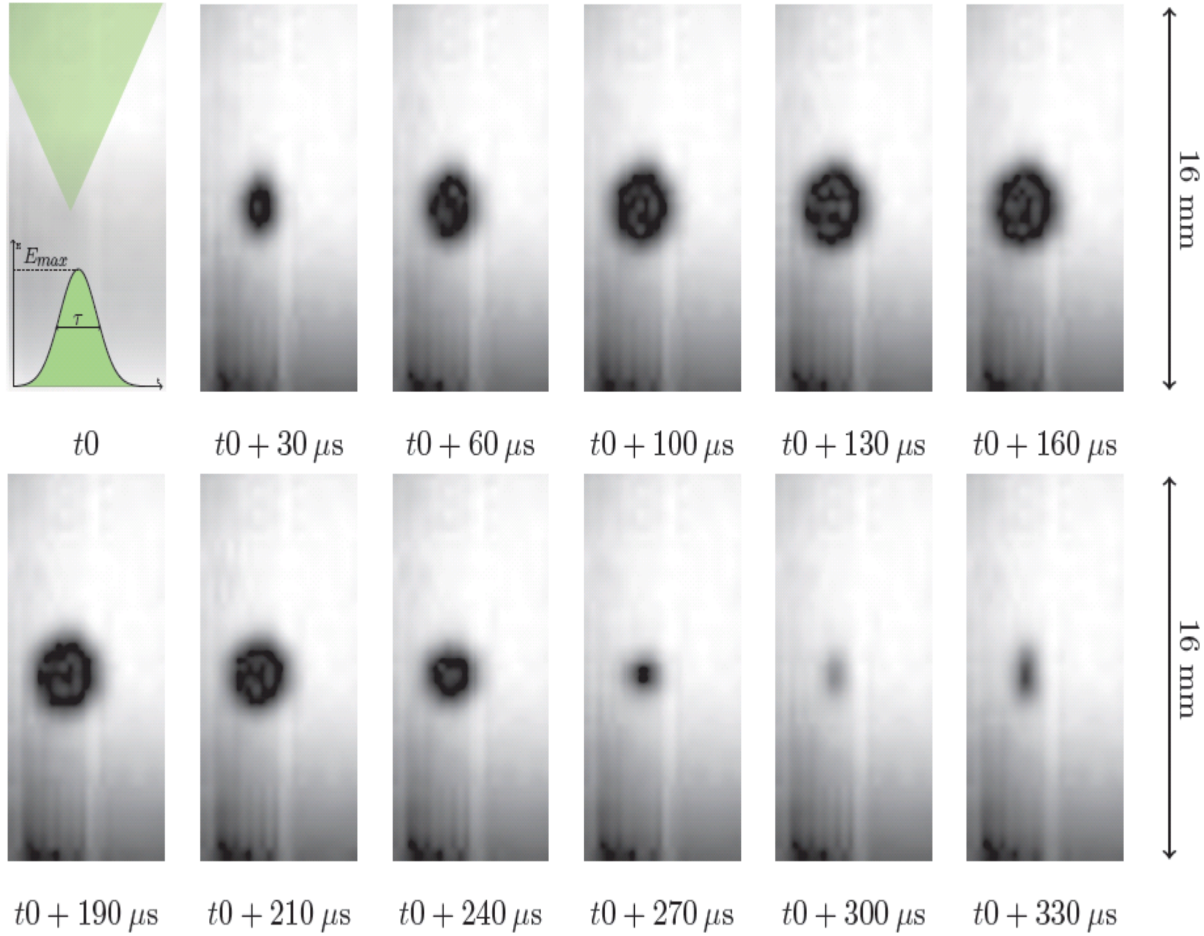


Figure 4: Dynamic of a vapour bubble created by optical cavitation in a large aquarium obtained with high speed camera (100000 frames per second, original images size 128x32 pixels), created with Nd:Yag laser (λ = 532 nm, E_{max} = 800 mJ, τ =9 ns).

Bubble pictures

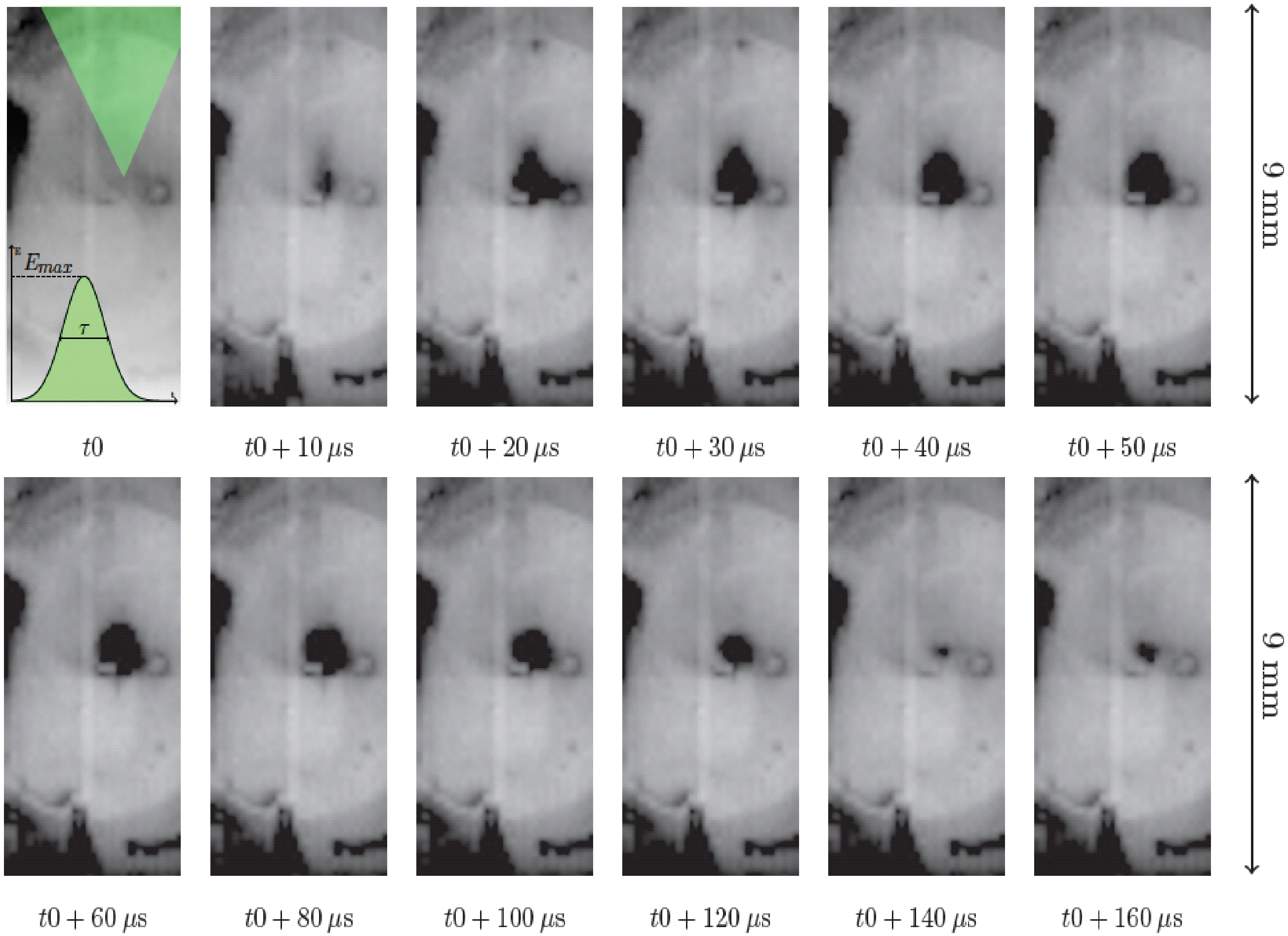


Figure 5: Dynamic of a vapour bubble created by optical cavitation in a plexiglass spherical container (R_{int} = 6.55 mm) obtained with high speed camera (100000 frames per second, original images size 128x32 pixels), created with Nd:Yag laser (λ = 532 nm, E_{max} = 800 mJ, τ =9 ns).

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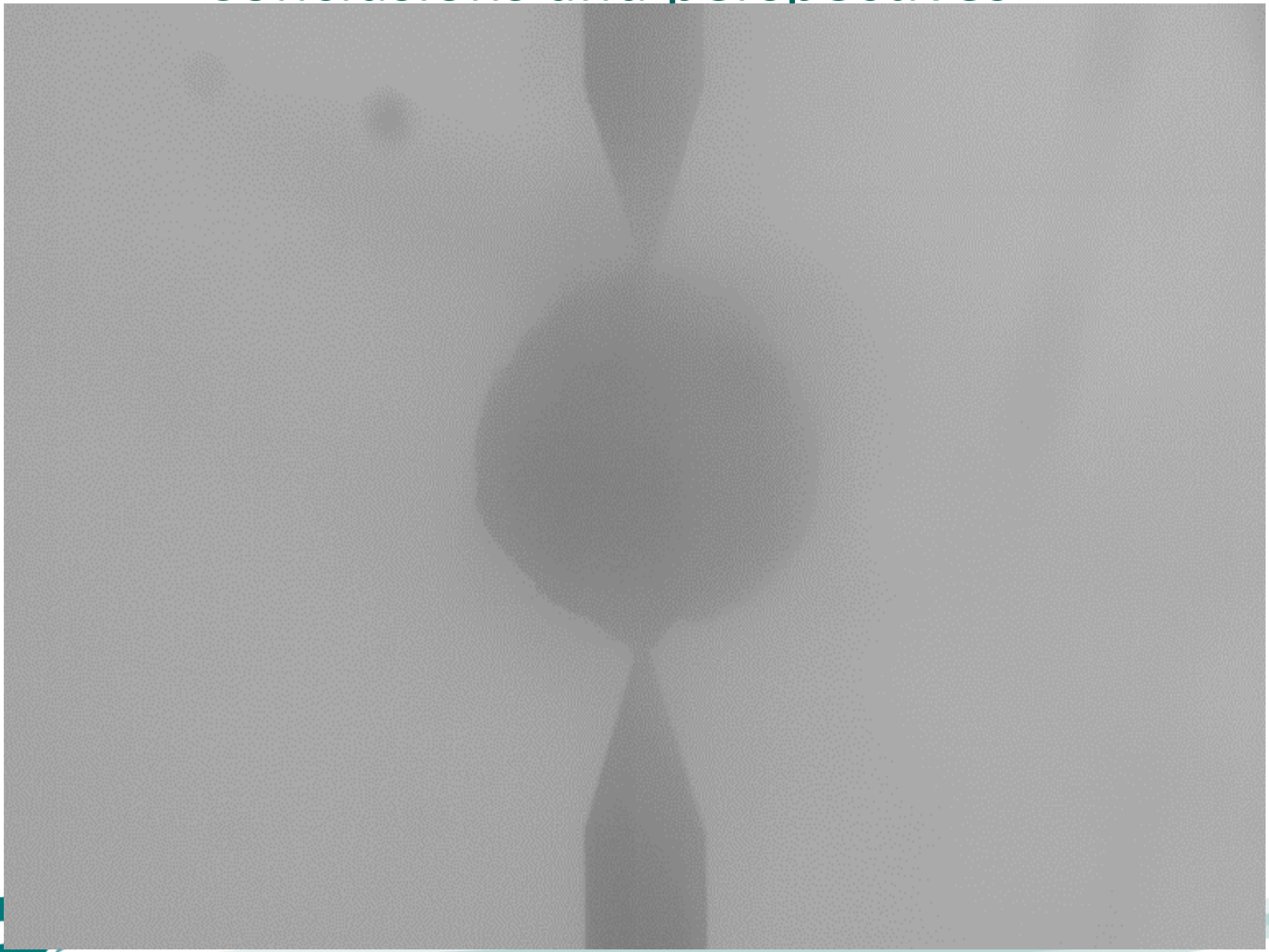
Conclusions and perspectives



Annexes

AIDER project: «Application Industrielles des Décharges dans l'Eau pour le Recyclage»

PAPREC Groupe, La Courneuve:

Independent French specialist in recycling (papers, cartons, confidential archives, plastic, industrial garbage, metals, wood, batteries, vehicles etc.)

PPRIME Institute (CNRS-ENSMA), Poitiers:

LMPM + LCD

ADEME

Agence de l'Environnement et de la Maîtrise de l'Energie

ITHPP

Ingénierie Electrotechnique Systèmes de Fortes Puissances

International Technologies for High Pulsed Power, Thegra:

Realization of the prototypes for clients tests in research and defence.

Bmax

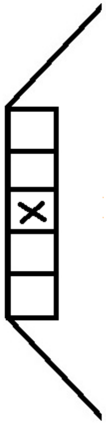
shaping your future

Bmax (I-Cube research), Toulouse:

Expertise and research in forming, welding and crimping using extreme deformation speeds.

Different ways to load energy, EMA Multi-physics

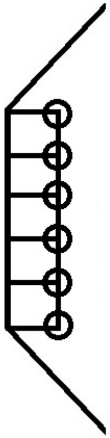
1 Initial energy in the material



$$E_0, \frac{mJ}{mm^3}$$

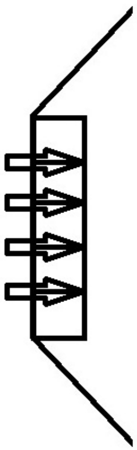
Liquid water / water vapor in discharge zone

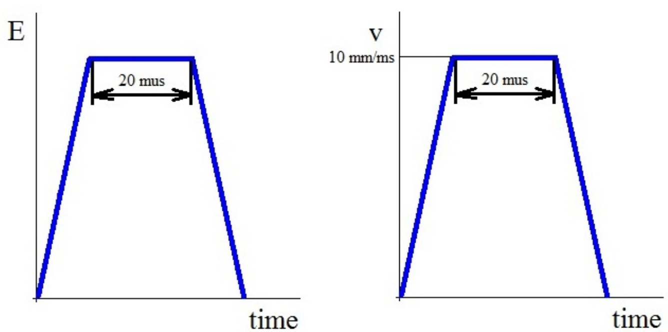
2 Temperature on boundary elements



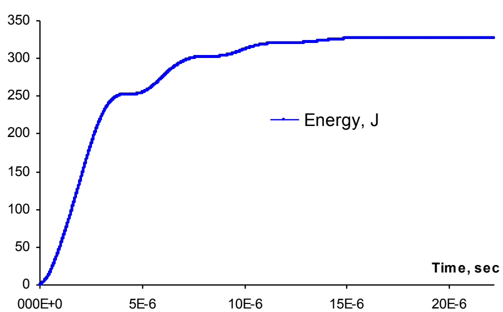
Imposed T~9000 K

3 Energy on boundary elements





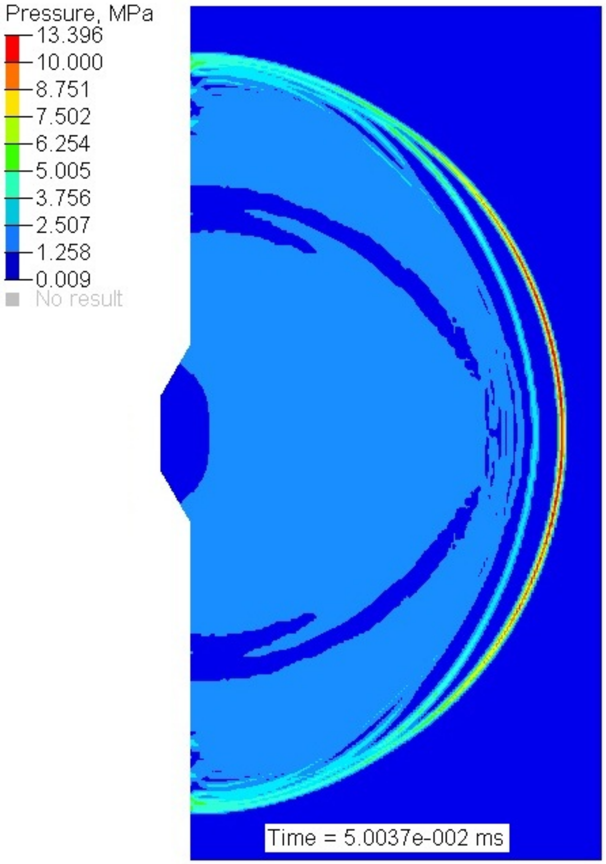
$$\int_0^{20\mu s} E_0 v S dt = E$$



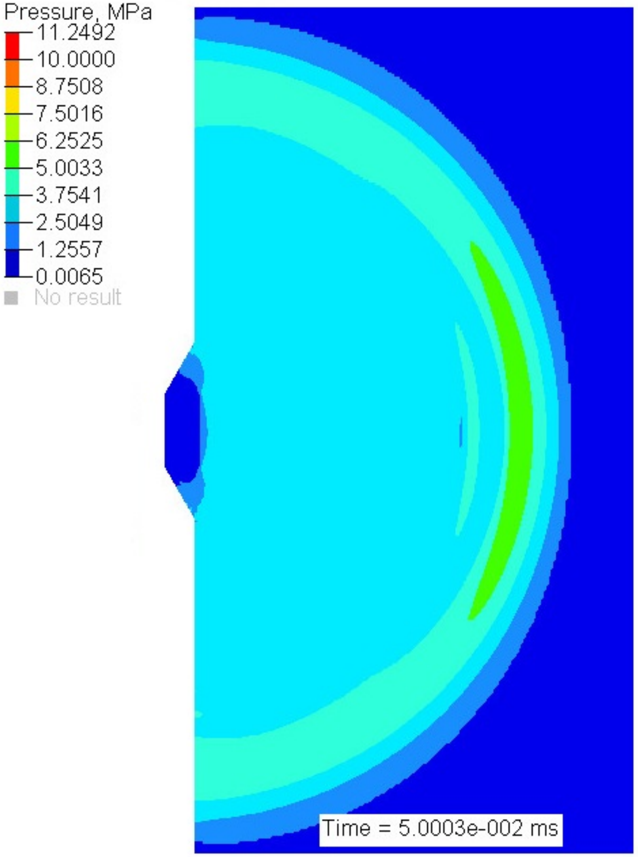
Real energy profile

Pressure evolutions for different loadings of energy

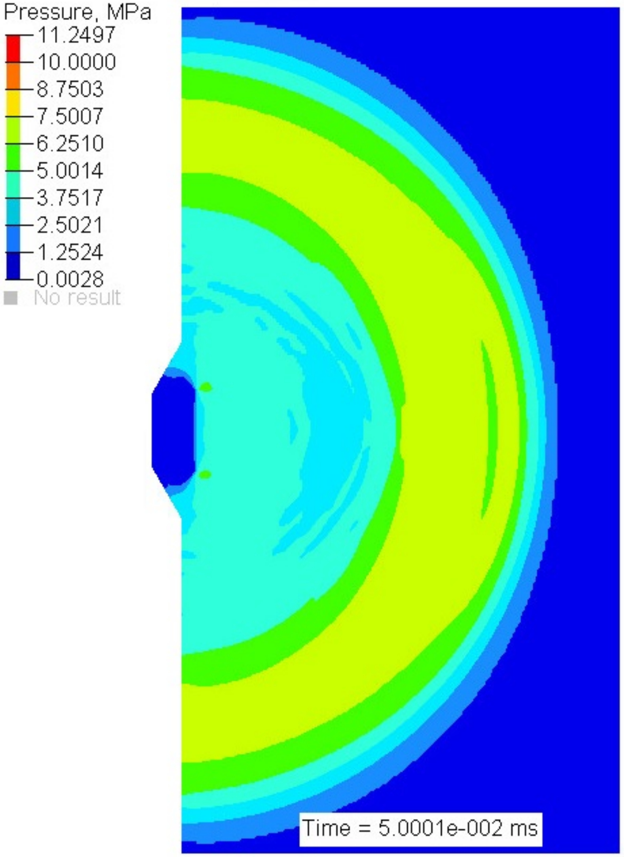
1) Energy loading in the water



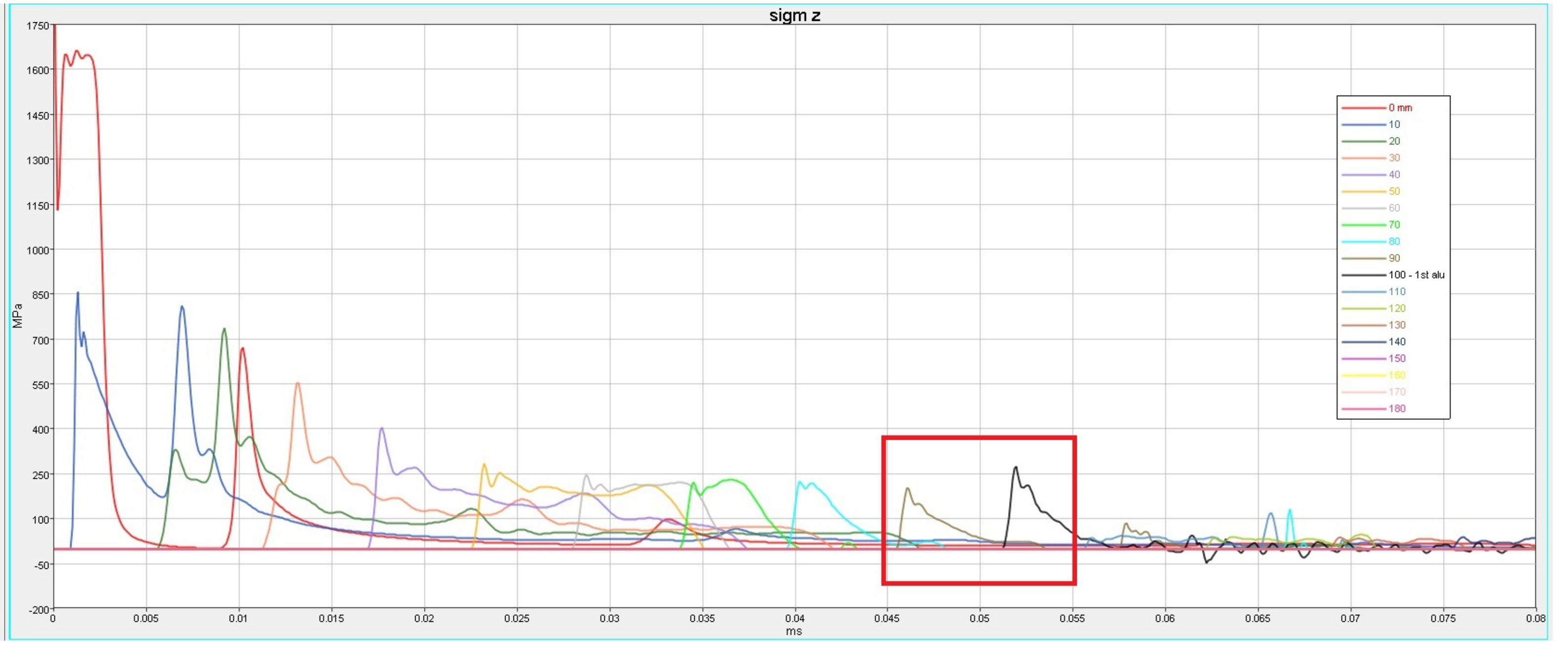
2) Temperature loading at boundary elements

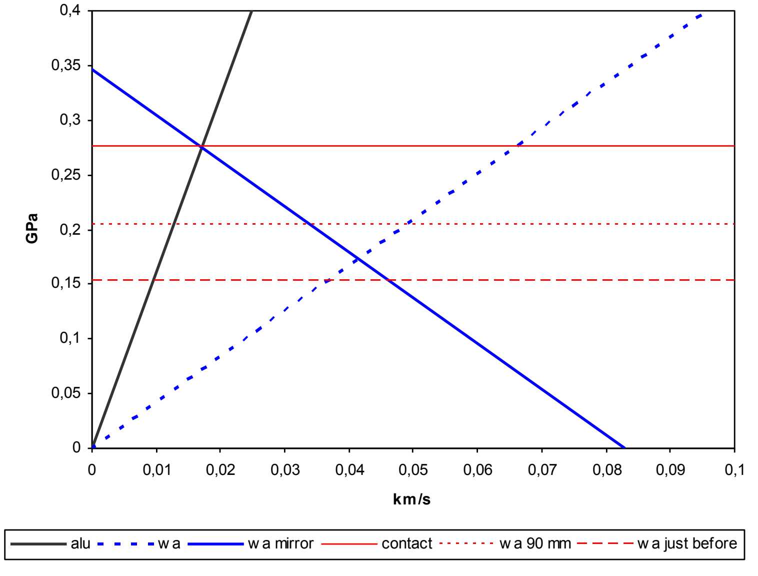


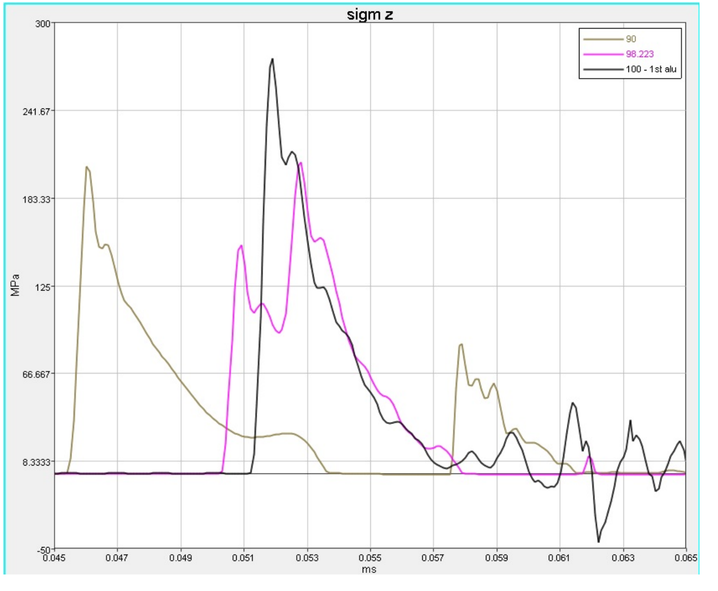
3) Time-depended energy at boundary elements



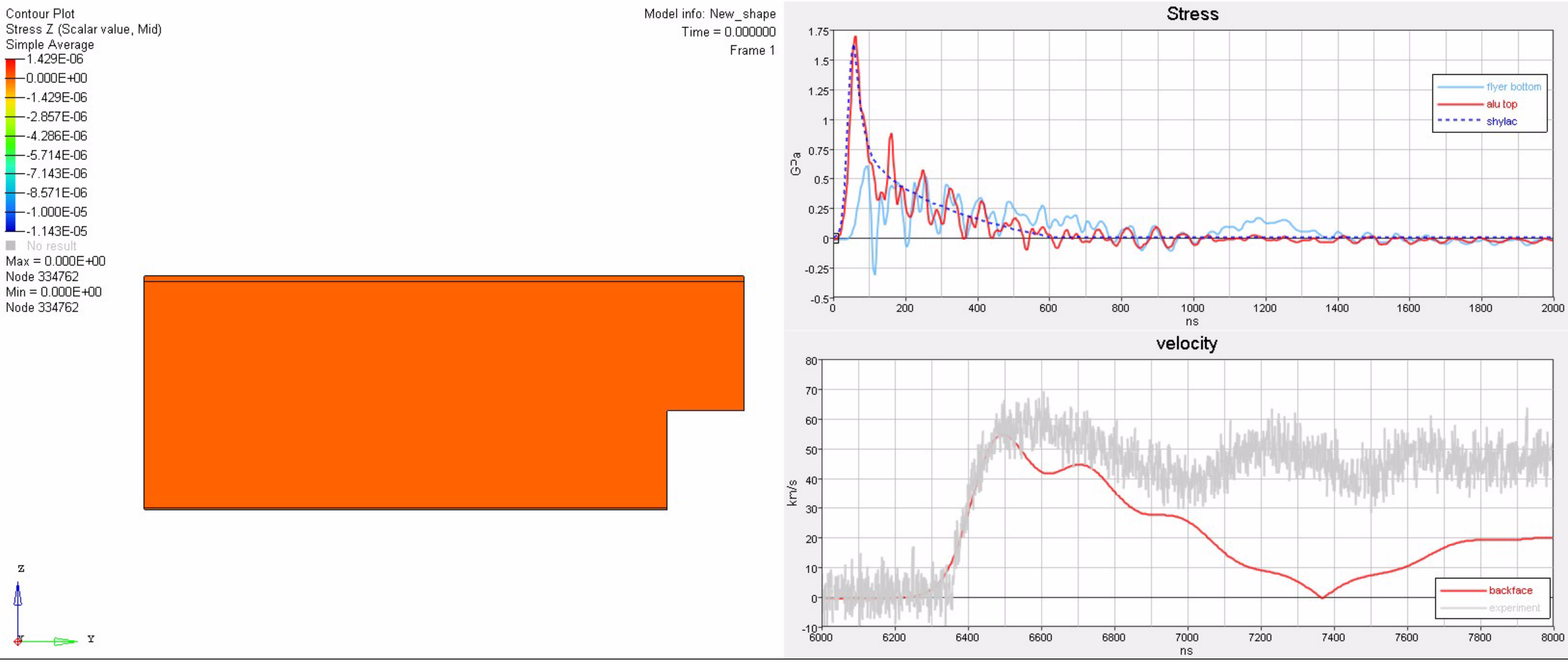
Pressure near contact zone







Modeling 2D case



Demonstrator ITHPP