RERTR-2022
42ND International Meeting on Reduced Enrichment for Research and Test Reactors

Water channel thickness estimation through high frequency ultrasonic measurements

Post Examination of the Reactor high flux Single Element with Ultra-Sounds

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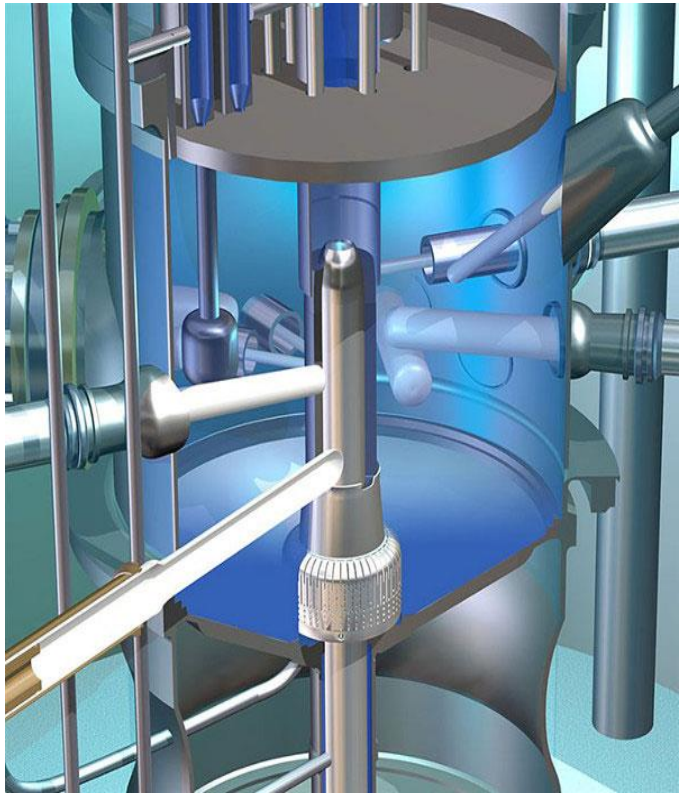
Project Challenge description

The ILL High Flux Reactor

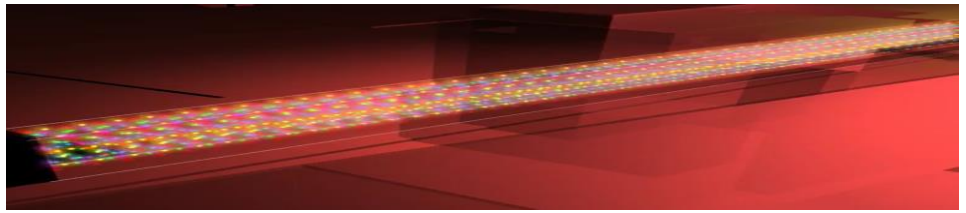
Objective: Development of a **high frequency ultrasonic** device for measuring **the inter-plate distance** to characterize the swelling of fuel plates.

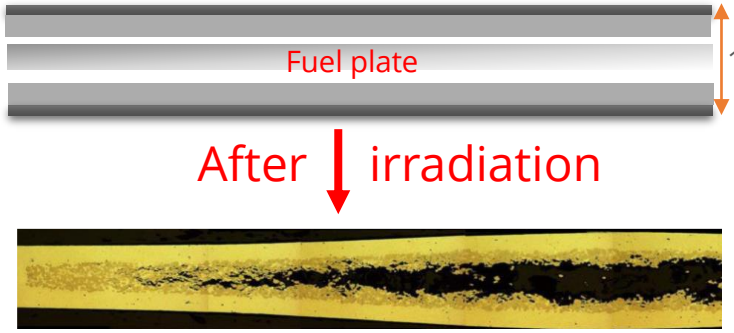
High Flux Reactor of 58 MW of thermal power



Fuel element

Neutron Flux

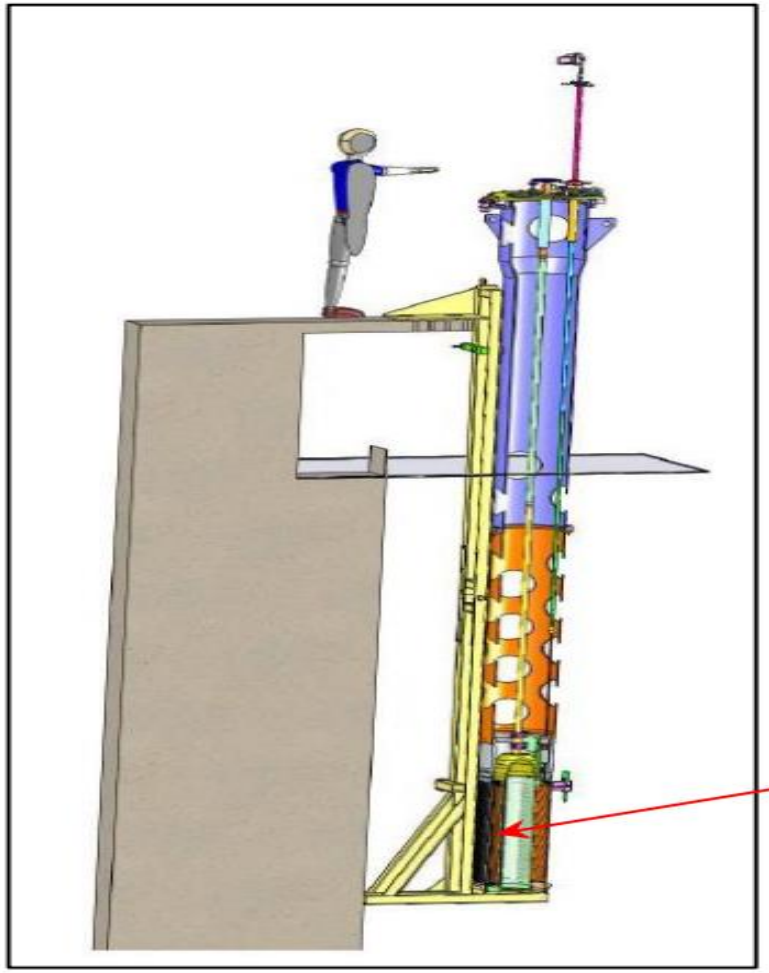




Fuel plate swelling

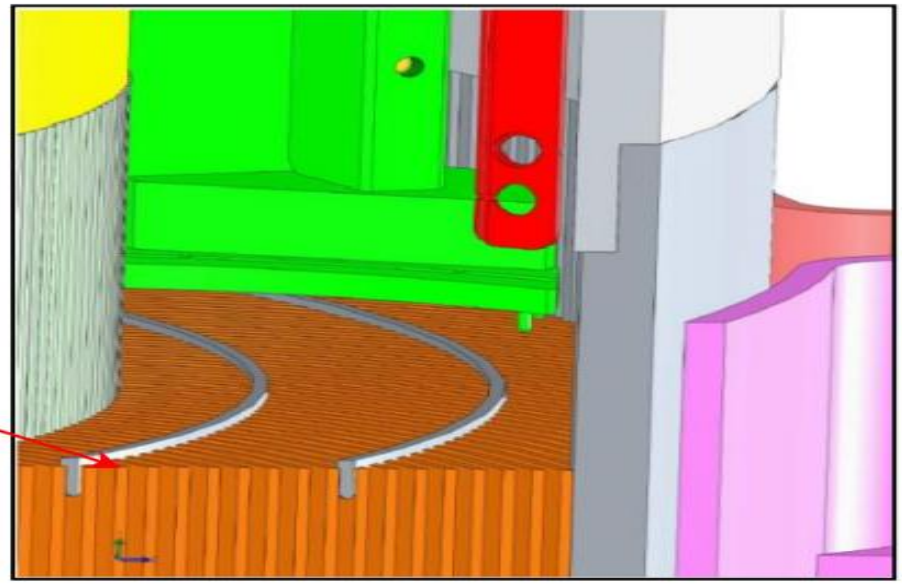
Measurement Constraints

The ILL High Flux Reactor



- Difficult access constraints;
- Microscopic structure modifications;
- High-radiative environnement.

Fuel plate

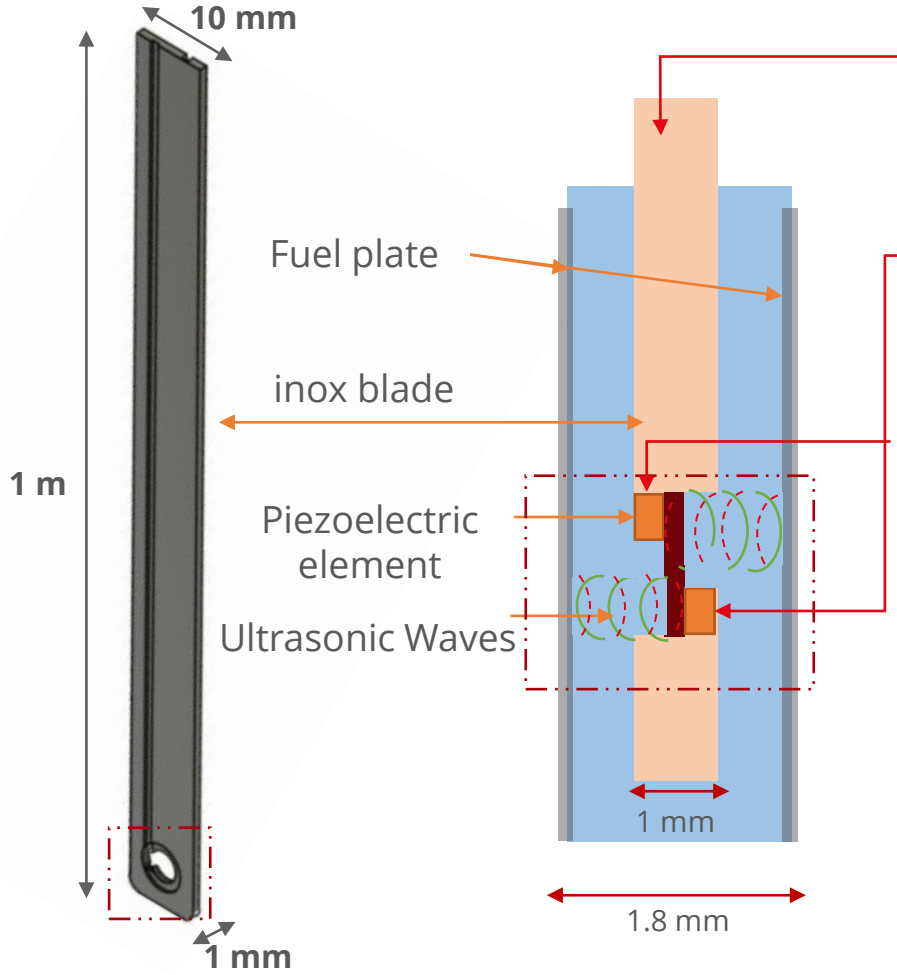


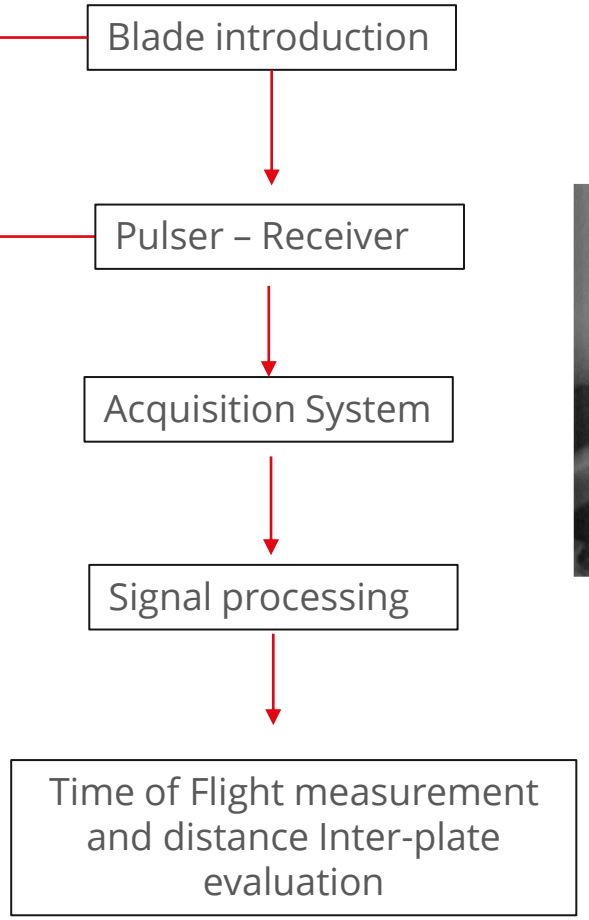
Outline

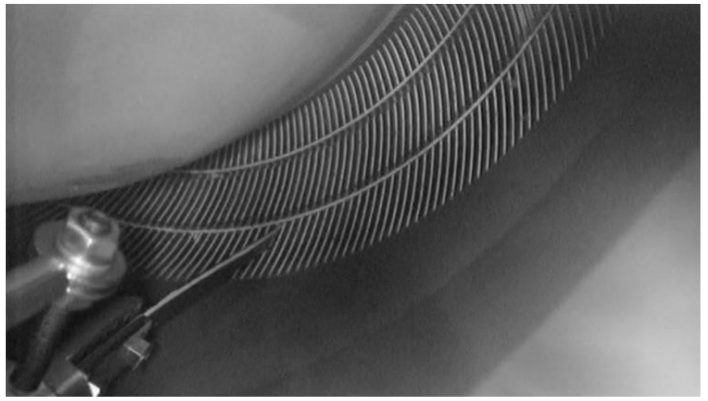
- Project Challenge description
- Non destructive high frequency ultrasonic device
- Ultrasound field modeling
- Laboratary experiment
- Conclusion and prospects

Non destructive high frequency ultrasonic device

Distance Measurement Principle



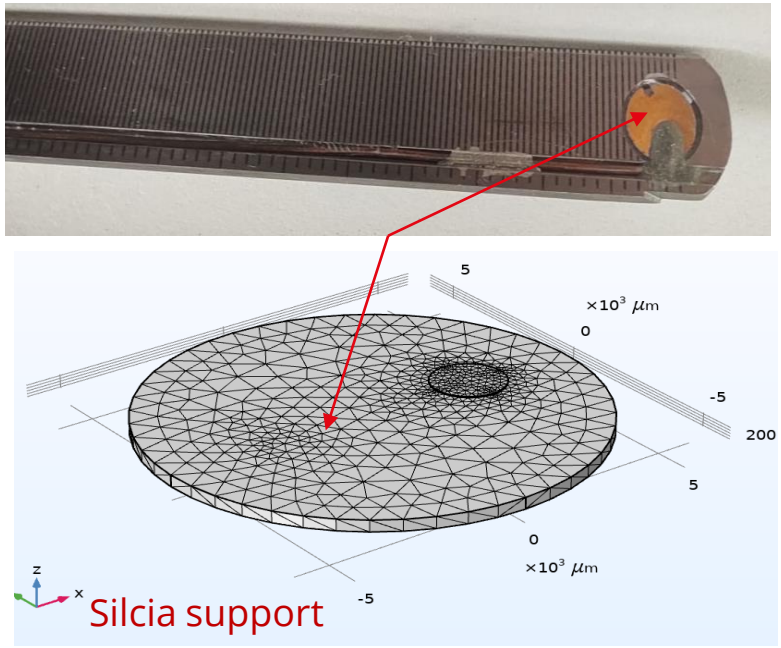




Fuel plate

Non destructive high frequency ultrasonic device

Resonance Frequency of transducers

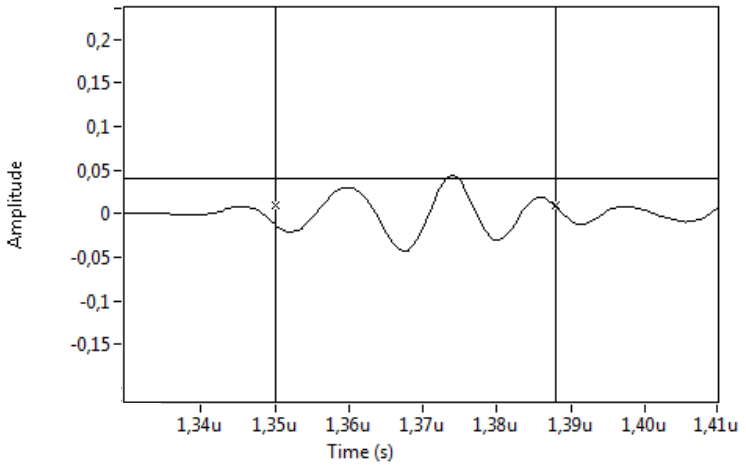


Silcia support

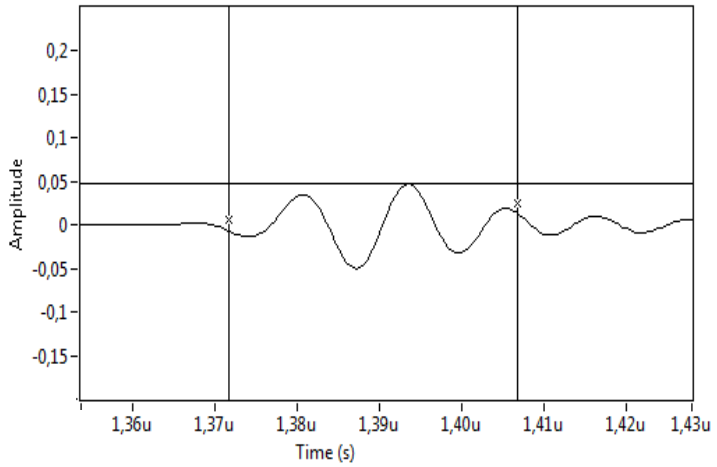
Transducer 1	Tansducer 2
$f_{rés} = 70\ MHz$	$f_{rés} = 72\ MHz$

Time signal response

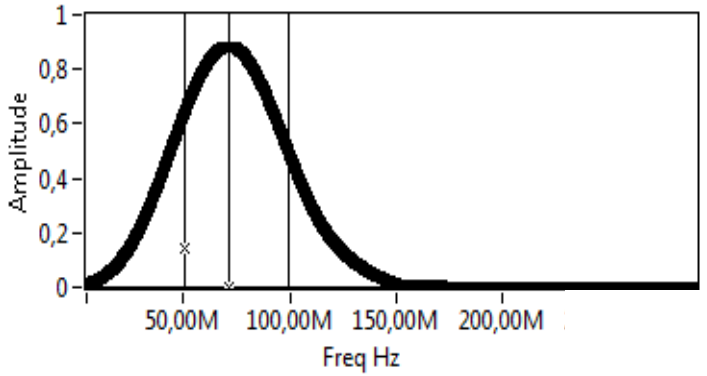
Transducer 1

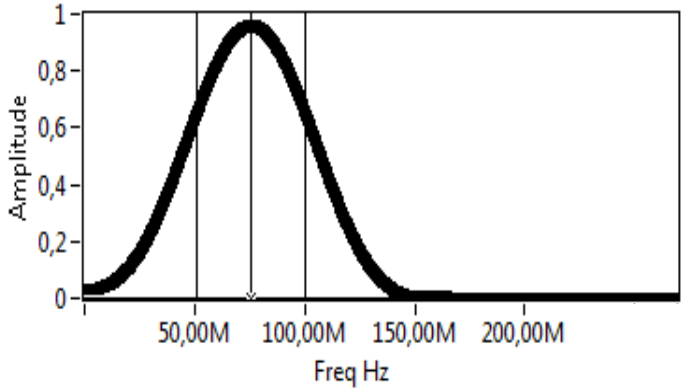


Transducer 2



Central frequency of the ultrasonic transducer





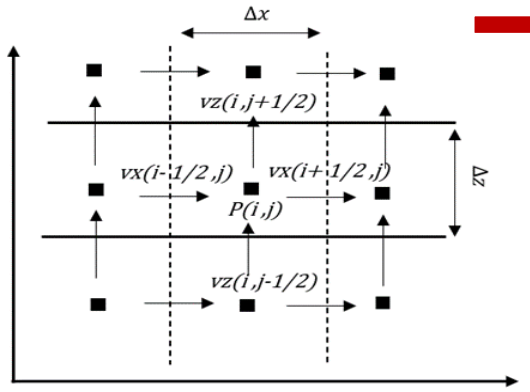
INSTITUT D'ÉLECTRONIQUE ET DES SYSTÈMES

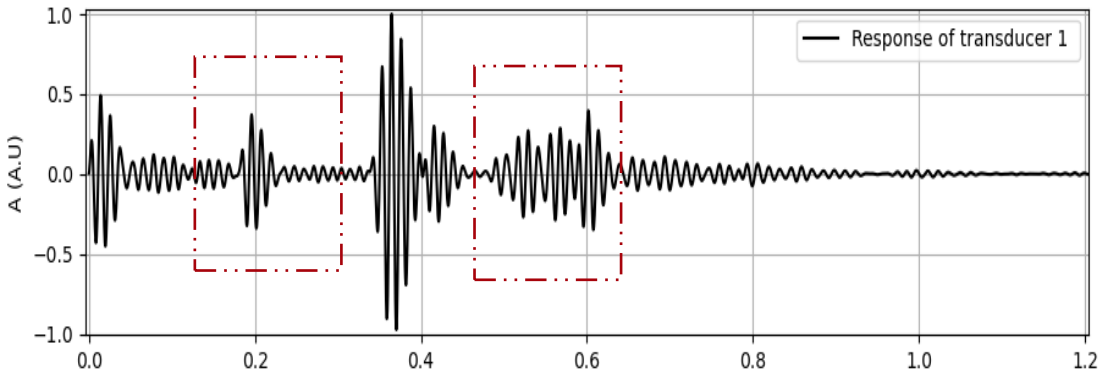
NEUTRONS FOR SCIENCE

Ultrasound field modeling

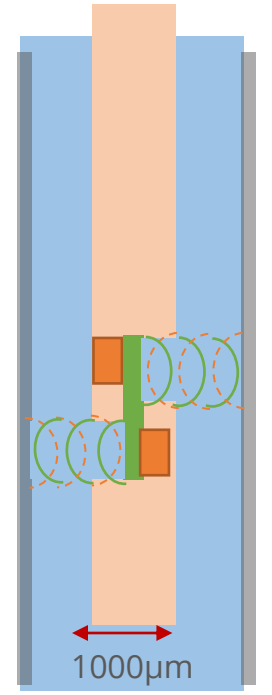
Implementation of Finite Difference Time Domain (FDTD) method

- Estimate the behavior of the acoustic field
  - Understanding the generation of the signal and evaluate the cross talk within the transducers
    - Modeling the wave equation in the time domain
      - Approximation of the spatial and temporal derivatives
        - Rectangular mesh



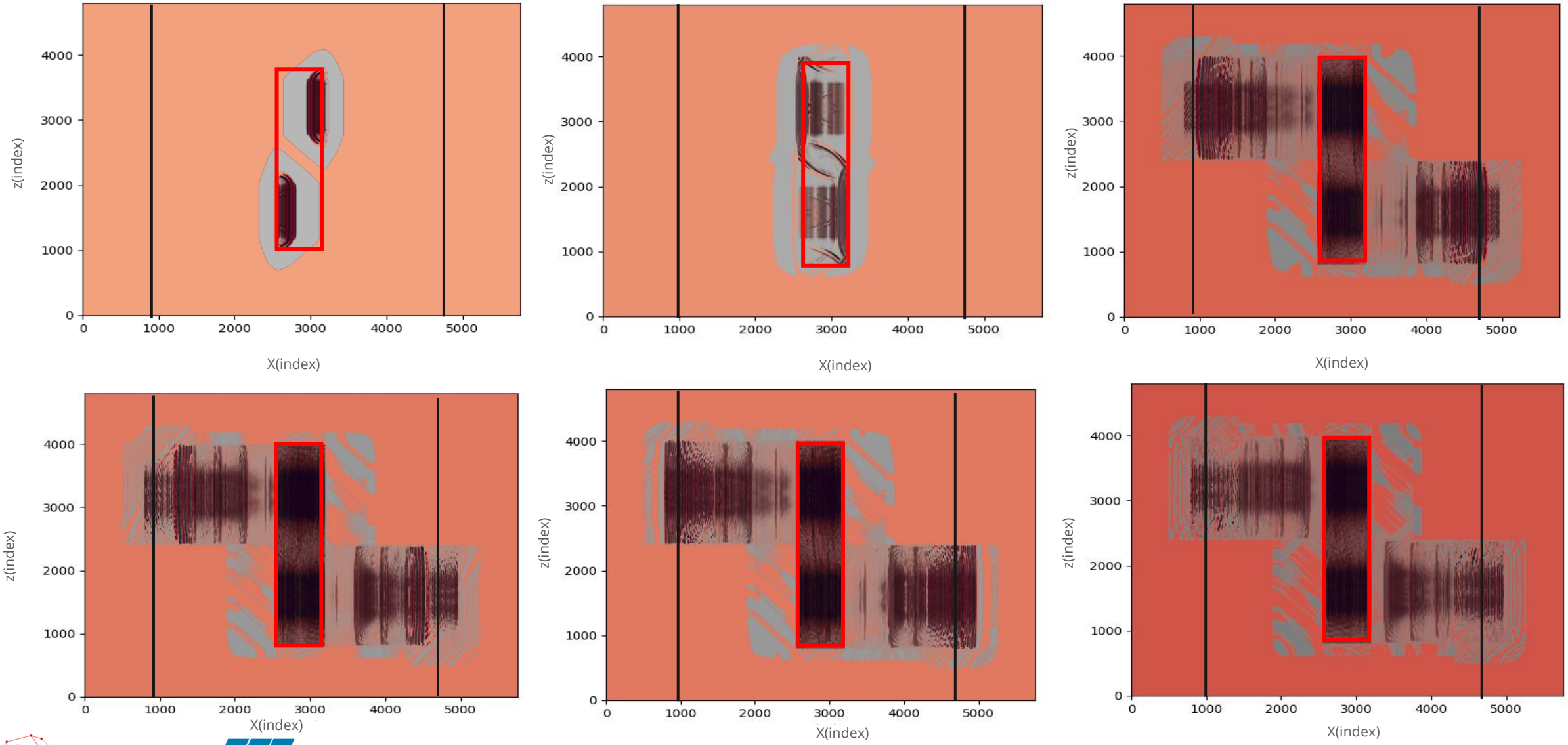


Reflection in the silica



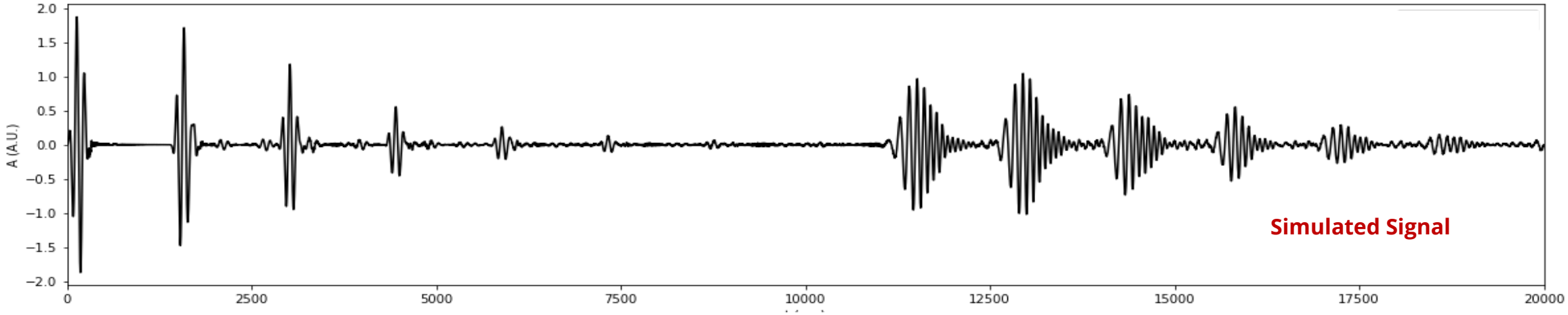
Model Structure

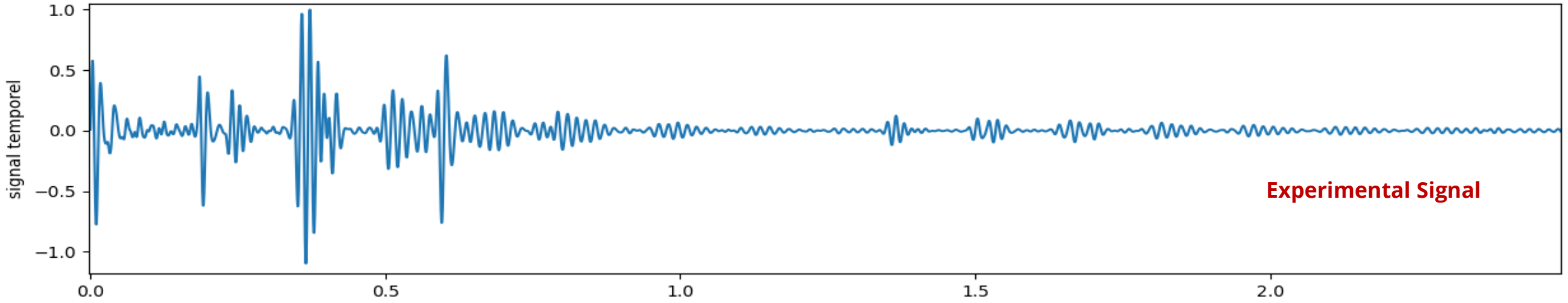
FDTD Computation of the wave propagation in the model structure



FDTD Computation of the wave propagation in the model structure

Acquired reflected ulrasonic and simulated signals comprising the two series of echoes.





Laboratory Experiments

Guiding system for device control

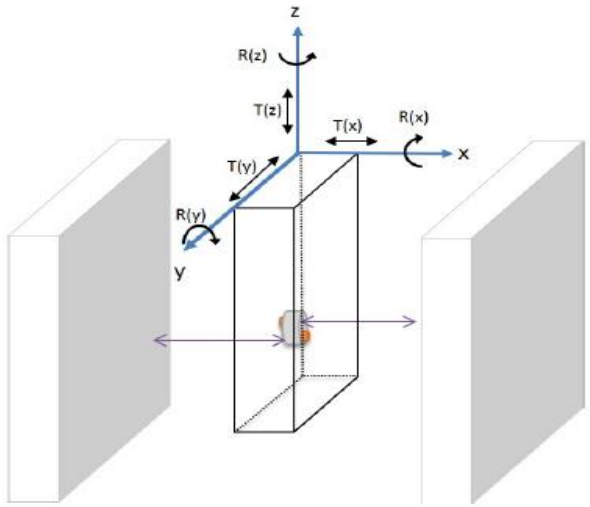
- Stabilized ultrasonic device positionning system allowing acqusitions at 70 MHz .

Alignement :

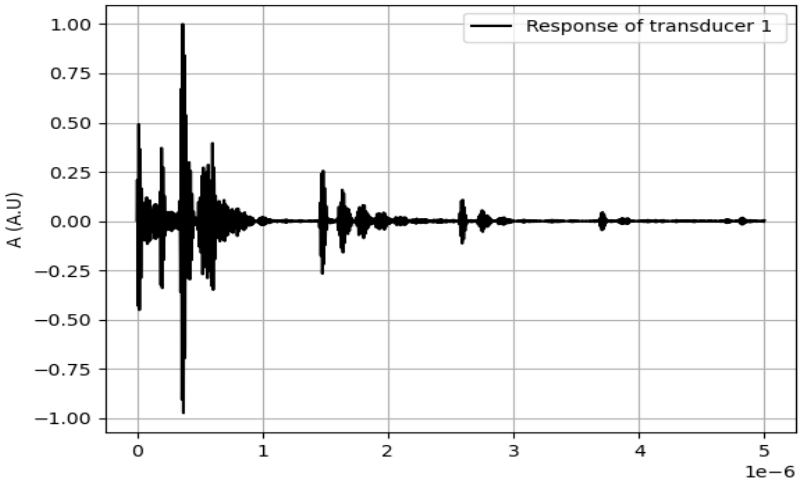
- R(x) , R(y) , R(z)

Distance inter-plaque measurement:

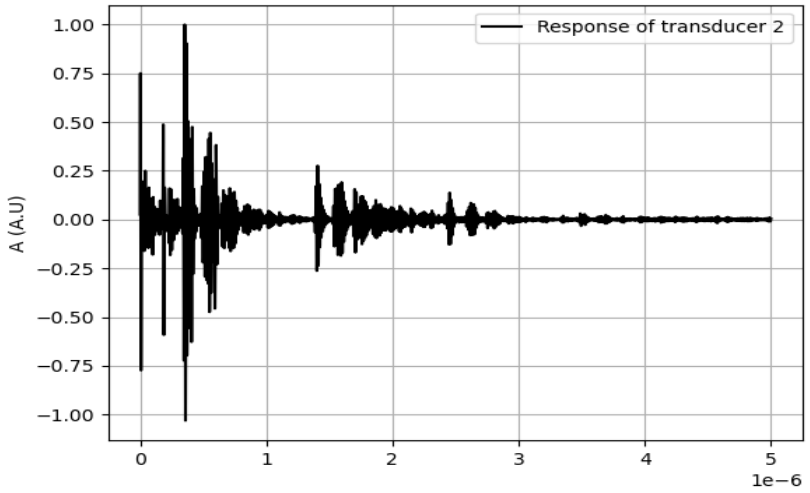
- T(y), T(z)

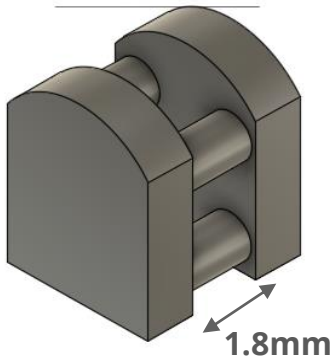


Response of transducer 1



Response of transducer 2

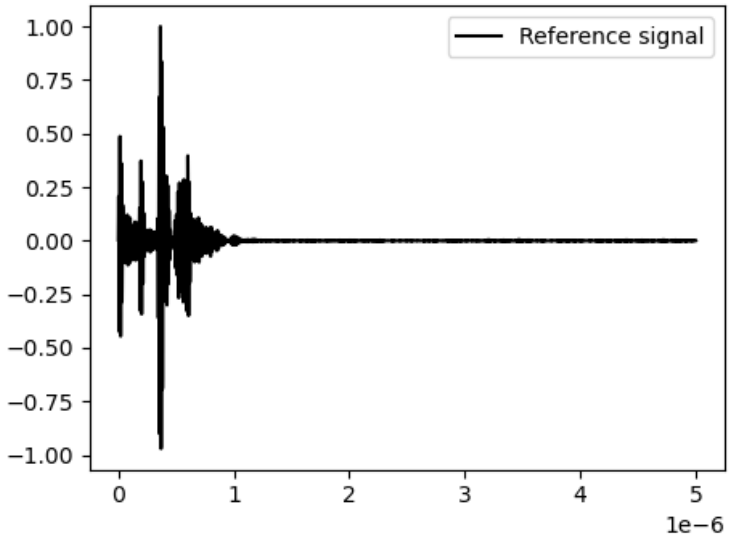




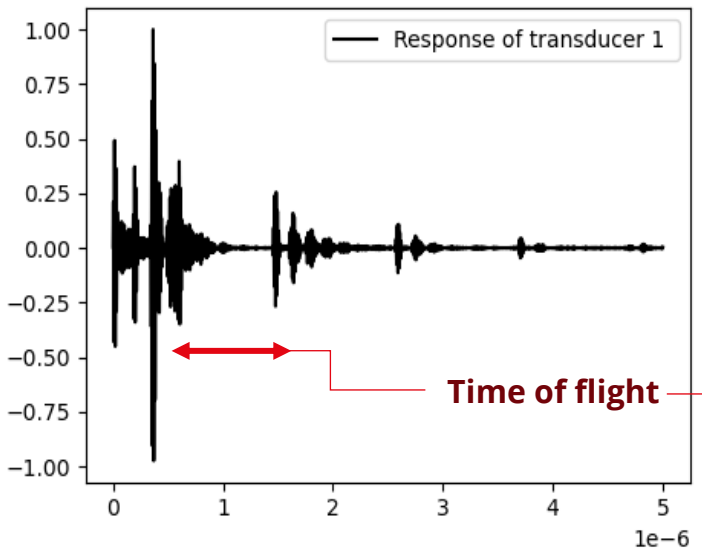
Acquired reflected ulrasonic signal comprising two series of echoes.

Distance inter-plate measurement

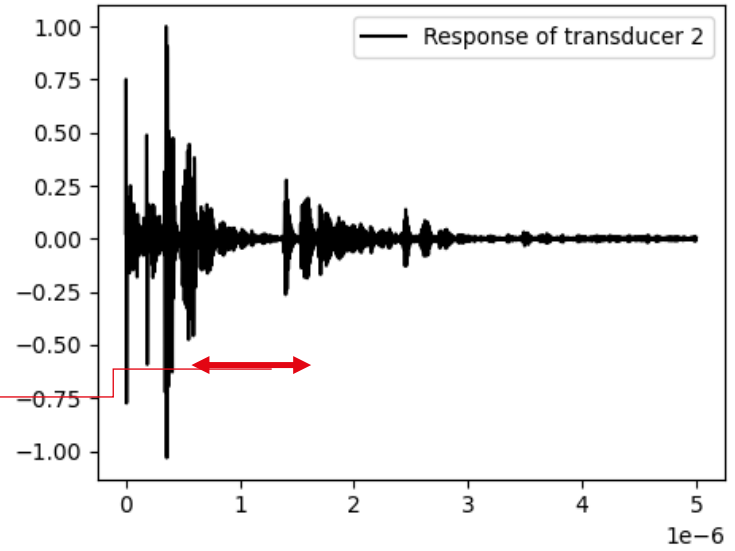
Signal with one echo serie



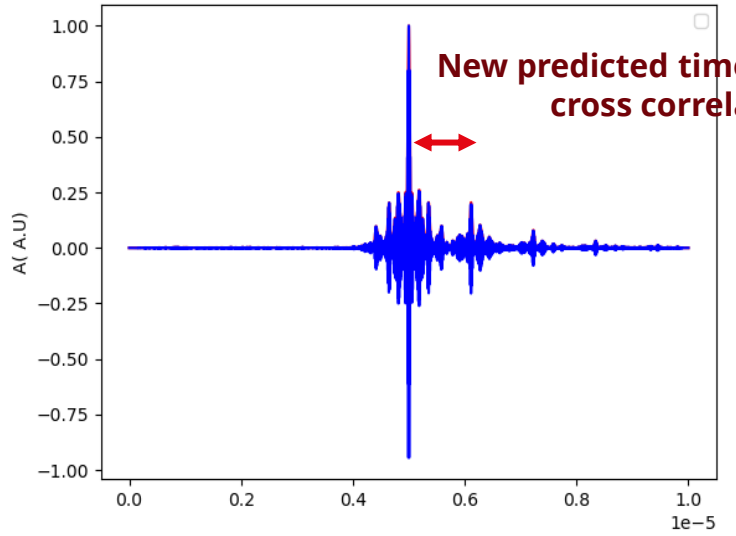
Signals with two echo series



Time of flight



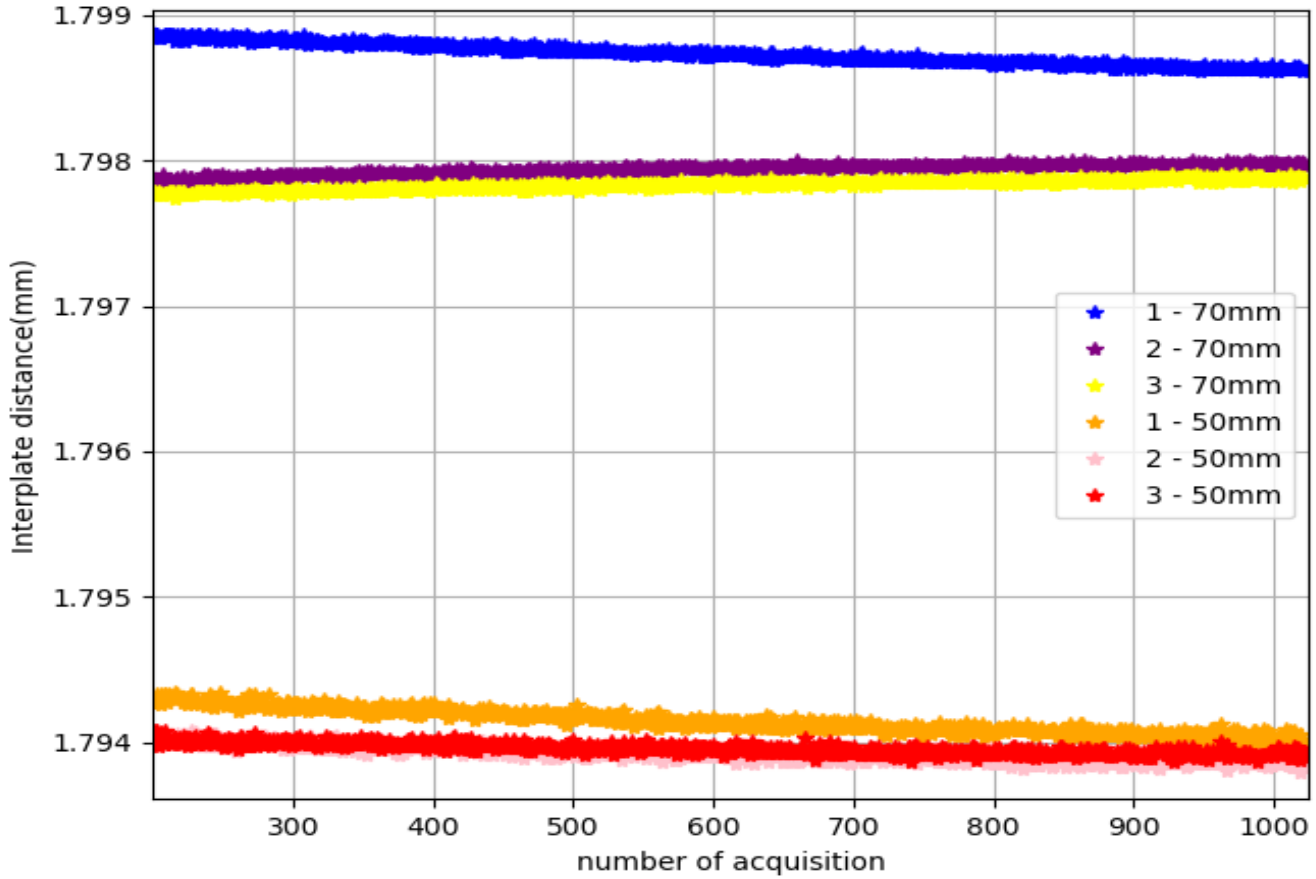
Cross-correlation between the two echo series

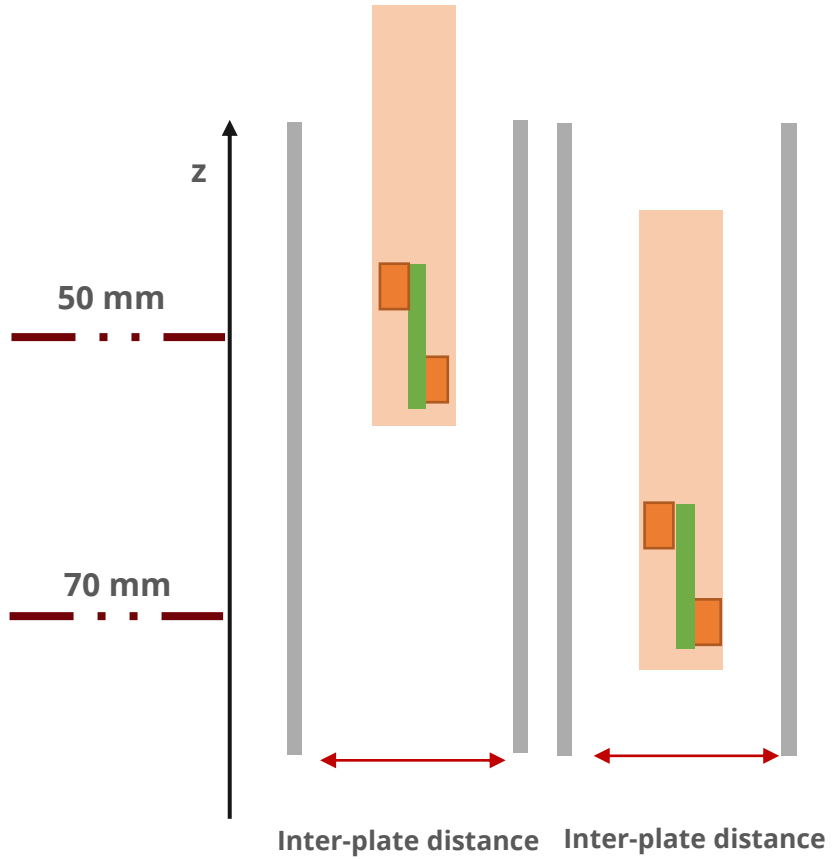


New predicted time of flight by cross correlation

Distance inter-plate measurement

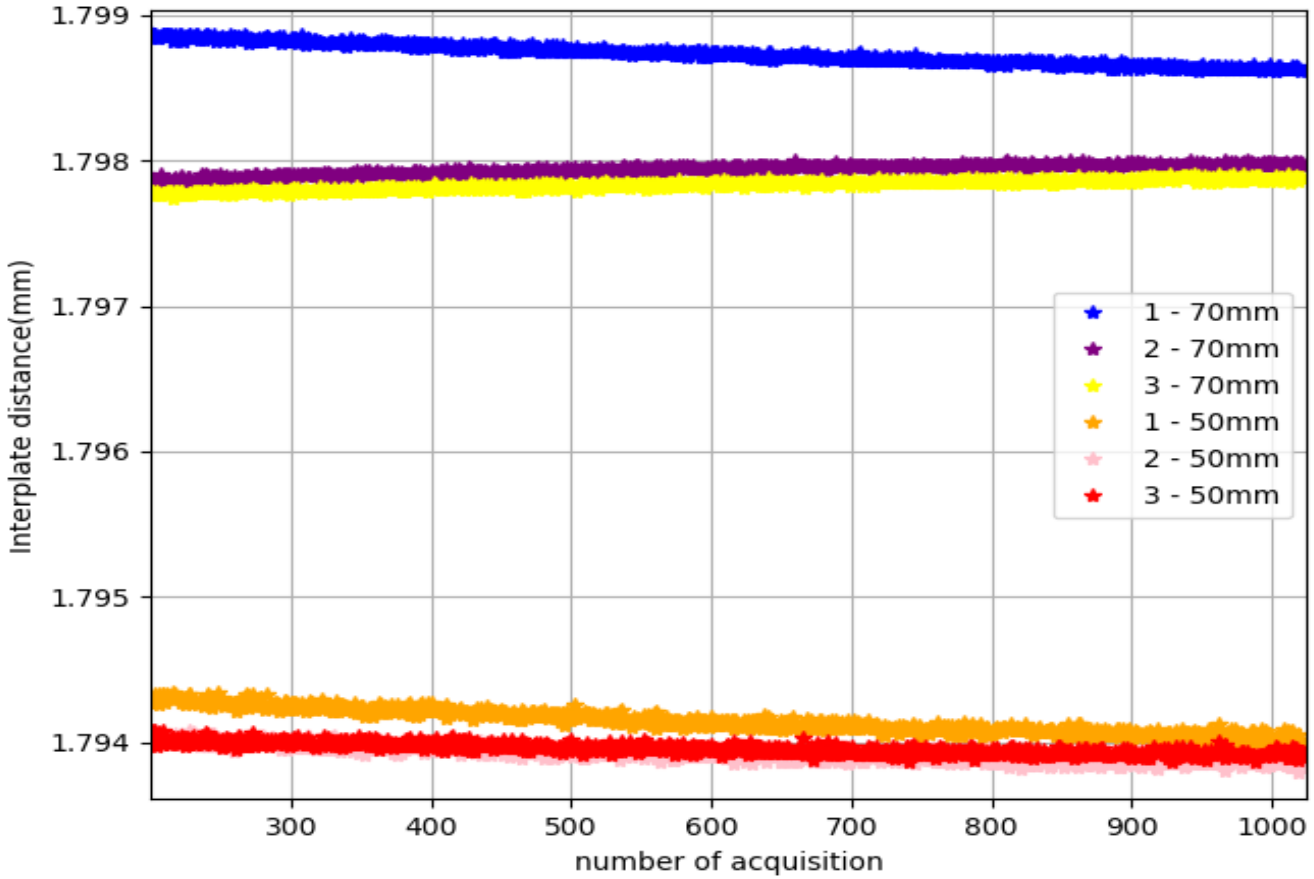
Distance measurement throught the evaluation of the time of flight between two series of echoes and the ultrasonic velocity





Distance inter-plate measurement

Distance measurement throught the evaluation of the time of flight between two series of echoes and the ultrasonic velocity



Position	Mean	Standard deviation
1_70 mm	1.7987 mm	0.09 µm
2_70 mm	1.7979 mm	0.07 µm
3_70 mm	1.7978 mm	0.05 µm
1_30 mm	1.7941 mm	0.12 µm
2_30 mm	1.7939 mm	0.09 µm
3_30 mm	1.7939 mm	0.06 µm

Conclusion

- Development of a high frequency ultrasonic device for the distance inter-plate measurement ;
- Modeling of the wave propagation within the model structure by the finite difference ;
- A high accuracy with the experimental signal.

Prospects

- Development of a guiding system for device control into the fuel element ;
- The next in situ measurement compaing inside the HFR through the new ultrasonic device and its measurement bench ;
- Inter-plate distance line scan experiments with high resolution.

Thanks for your attention