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Intended for: seminar during colaboration



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## Acoustique Non-linéaire à Los Alamos

Pierre-Yves Le Bas



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Non linear acoustics at Los Alamos

## Los Alamos National Laboratory



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## Los Alamos National Laboratory



- >9000 ha
- 1200 bâtiments
- 10 000 employés
- 430 km de route
- 55 km de ligne électrique
- 100km de conduite de gaz
- 2.2 milliards de dollars par an

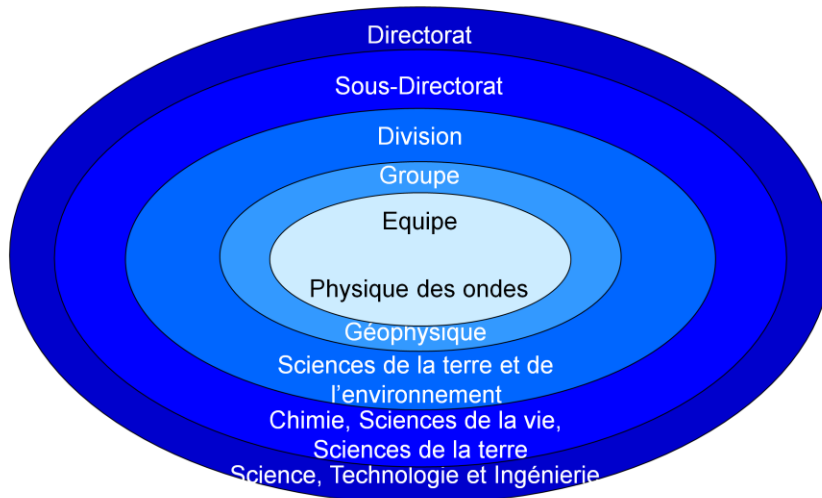


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over 9000 hectares  
1200 buildings  
10 000 employees  
430km of road  
55km of electrical lines  
100km of gas lines  
\$2.2 billion a year

## Acoustique Non Linéaire



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Directorate  
Associate Directorate  
Division  
Group  
Team

Wave Physics  
Geophysics  
Earth and environmental sciences  
Chemistry, Life, and Earth Sciences  
Science, Technology and Engineering

## Acoustique et Contrôle Non Destructif

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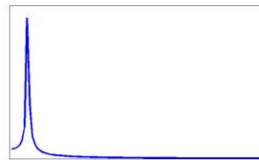
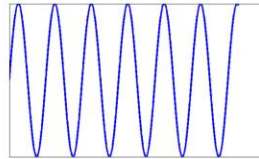
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Acoustics and non destructive testing

## Qu'entend-on par acoustique non linéaire ?

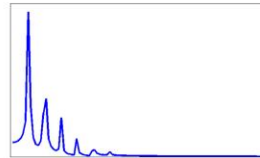
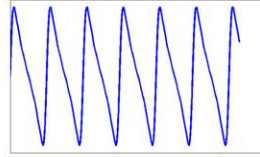


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What do we mean by nonlinear acoustics?

## Qu'entend-on par acoustique non linéaire ?



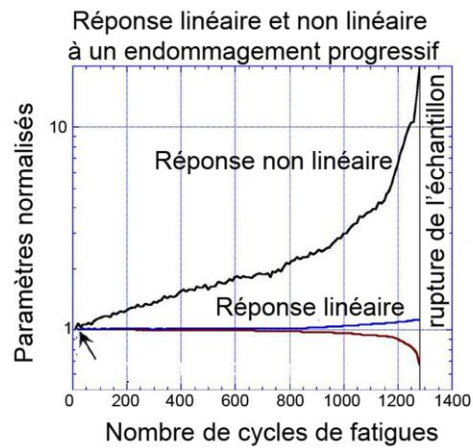
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What do we mean by nonlinear acoustics?



## Pourquoi l'acoustique non linéaire ?



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Why nonlinear acoustics?

Linear and nonlinear response with progressive damage

Normalized parameters

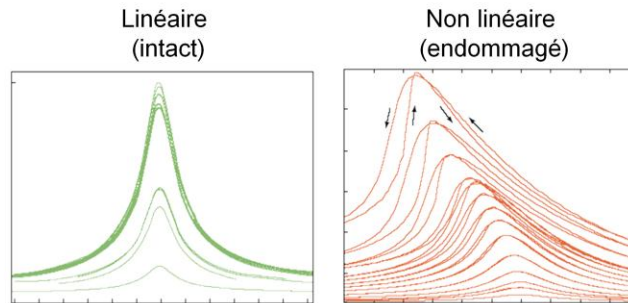
nonlinear response

sample fails

linear response

Number of damage cycles

## Effet non linéaire sur les résonances



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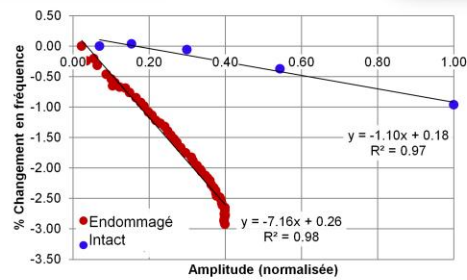
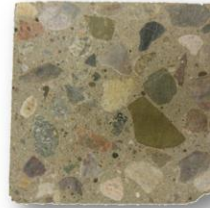
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Nonlinear effect on resonances

Linear  
(intact)

Nonlinear  
(damage)

## Exemple sur des échantillons en béton après endommagement thermique



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Example on concrete sample after thermal damage

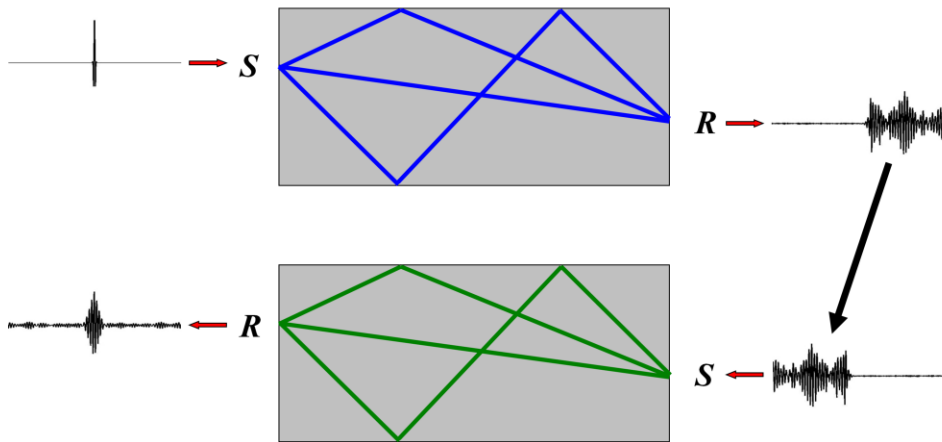
% frequency changes

Damaged

Undamaged

amplitude (normalized)

## L'acoustique non linéaire requiers de fortes amplitudes: Retournement temporel



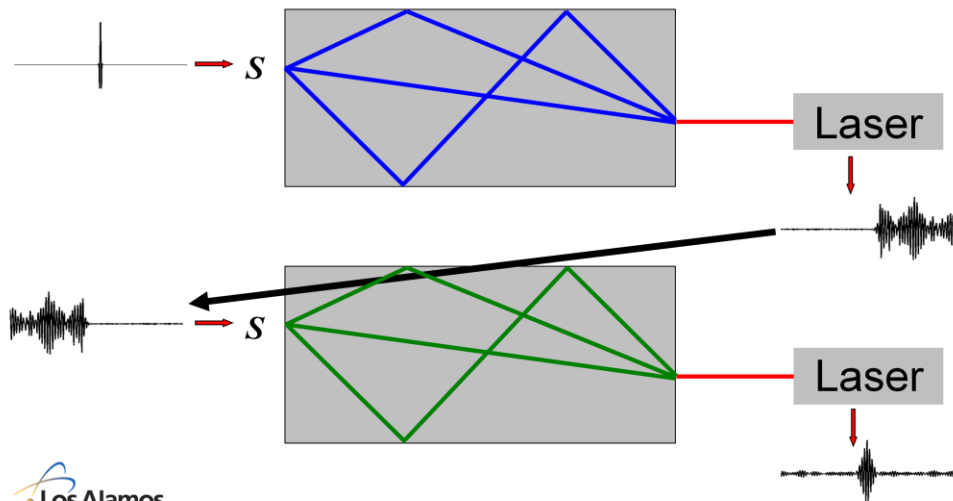
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Non linear acoustics requires large amplitudes:  
Time reversal

## L'acoustique non linéaire requiers de fortes amplitudes: Retournement temporel



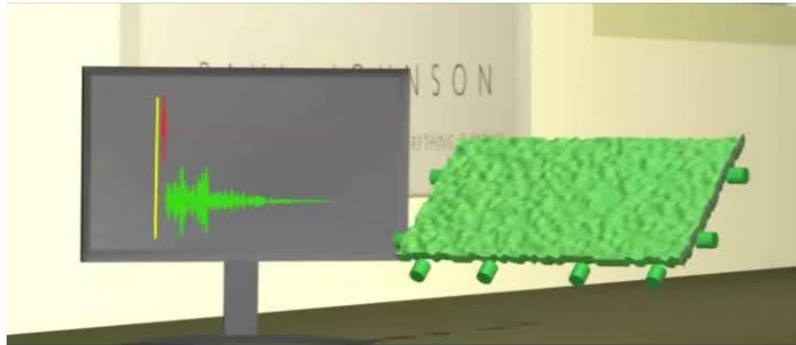
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Non linear acoustics requires large amplitudes:  
Time reversal

## Retournement temporel et acoustique non linéaire

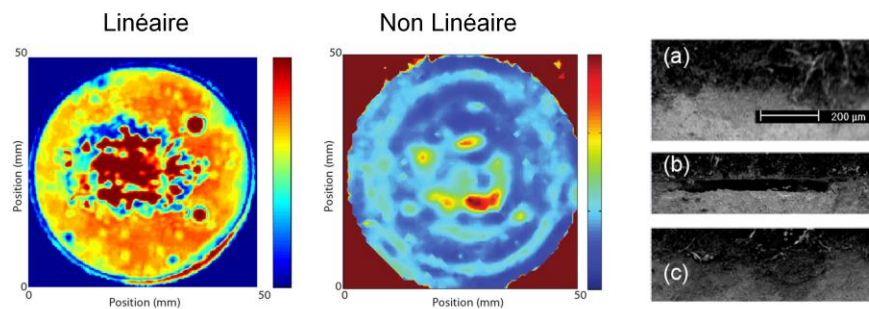


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Time reversal and non linear acoustics

## Retournement temporel et acoustique non linéaire



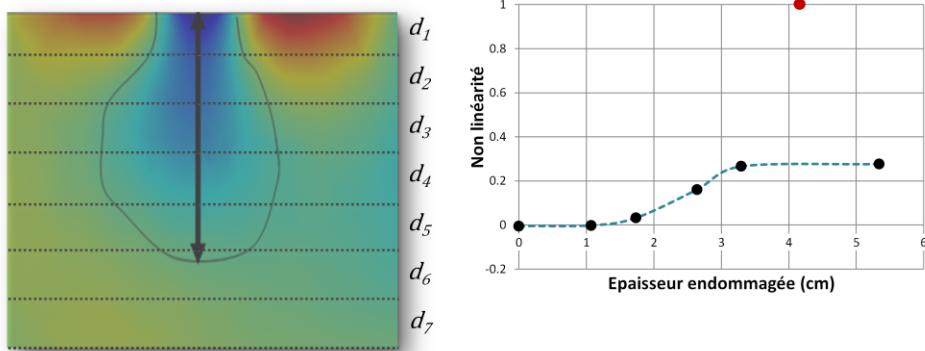
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Time reversal and non linear acoustics  
Linear Nonlinear

## Retournement temporel et acoustique non linéaire



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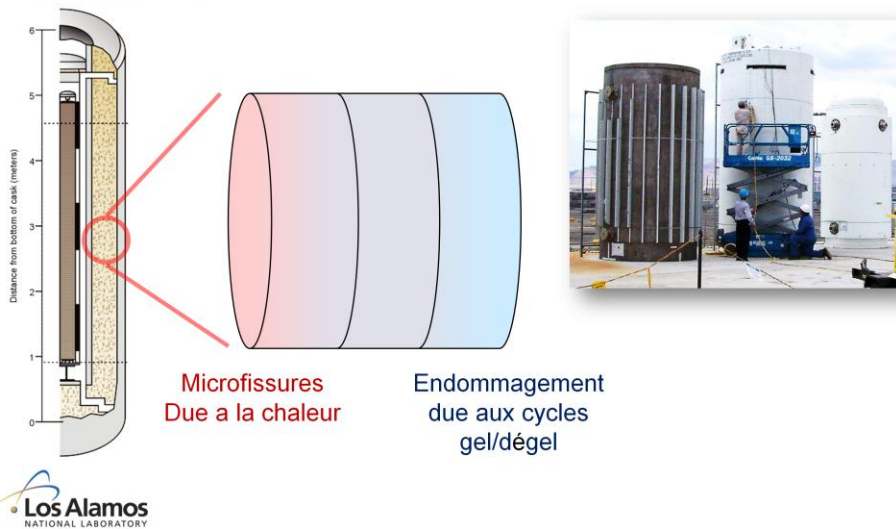
Time reversal and non linear acoustics

nonlinearity

damaged thickness



## Applications



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Applications.

Heat induced  
Microcracking

Freeze-thaw  
weathering