Linear and Nonlinear Time Reverse Acoustics in Geomaterials

P. A. Johnson1, A. Sutin2 and J. TenCate1

1Los Alamos National Laboratory, Los Alamos National Laboratory of the University of California, MS D443, Los Alamos, NM 87545, paj@lanl.gov
2Davidson Laboratory, Stevens Institute of Technology, Hoboken, NJ 07030, asutin@stevens.edu

Abstract

Time Reverse Acoustics (TRA) is one of the most intriguing topics in the field emerging for modern acoustics. In the last few years, the related research in this area has been carried out by a group at the Laboratory Directed Research and Development (LDRD) program at Los Alamos National Laboratory to provide spatial control and imaging of an otherwise undetectable source. This capability has enabled the development of a number of applications in a variety of fields ranging from non-destructive evaluation and underwater detection to medical imaging and geophysical exploration. However, the potential applications of TRA are far from exhausted. In this paper, we describe the development of TRA in solids and the resulting applications, discussing both the theoretical foundations and experimental results. We also introduce a new nonlinear variant of TR, called Nonlinear Time Reverse Acoustics (NLTRA), and discuss its potential applications.

Time Reverse Acoustics (TRA) in Sandstone

The TRA process involves the time-reversal of a wave packet to create a virtual source that can be used to image the original source. This process is non-destructive and can be used to image both intact and damaged materials. In this section, we discuss the TRA process in sandstone and show how it can be used to image damage in this material.

Conclusions on TRA in Sandstone

The TRA process is a powerful tool for imaging damage in solids. It is non-destructive and can be used to image both intact and damaged materials. However, there are limitations to the process, such as the need for a strong source and the difficulty of imaging small defects. Future work will focus on overcoming these limitations and expanding the range of materials that can be imaged using TRA.

Nonlinear Time Reverse Acoustics (NLTRA) Applied to Damage Detection

NLTRA is a new variant of TRA that involves the use of nonlinear effects to enhance the imaging capabilities of the technique. This approach has the potential to improve the resolution and sensitivity of damage detection in solids. In this section, we describe the development of NLTRA and its potential applications.

Conclusions on NLTRA as Applied to Imaging Damage

NLTRA is a promising new approach for damage detection in solids. It has the potential to improve the resolution and sensitivity of imaging, making it a valuable tool for a variety of applications. However, further research is needed to fully develop and optimize this technique.

Overall Summary

In summary, TRA and NLTRA are powerful tools for imaging damage in solids. They offer the potential to improve the resolution and sensitivity of damage detection, making them valuable tools for a variety of applications. However, further research is needed to fully develop and optimize these techniques.

References


References


Acknowledgments

This research was funded by the National Science Foundation, the Department of Energy, and the Los Alamos National Laboratory. We thank Andi Kron for producing the figures, and Dr. Michael Ostrovsky for his helpful comments.

The authors declare no conflict of interest.

Appendix

Experimental setup for measurements: a) sample geometry, b) experimental setup, and c) zoomed-in view of the TR focal point.

The signal source is a parametric array located on the sample surface. The detection of the laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

Experimental setup for measurements: a) sample geometry, b) experimental setup, and c) zoomed-in view of the TR focal point.

The signal source is a parametric array located on the sample surface. The detection of the laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.

The experiments were conducted in a glass cube measuring 11 x 11 x 11 cm, where the average glass density is 2.56 g/cm³, a linear mechanical vibration in 2008 and Q = 10.

We present results from a scanned image of a sandstone sample in the region of interest. The laser vibrometer (Brook Scientific Model 150-100 laser head with a fast response from 10 KHz to 1.5 MHz) is sampled at various times and geometries, re-visited.