# Exploiting Time Reversal Acoustics for the Development of New Ultrasound and Seismic Imaging Techniques in Complex Media

(i.e. how to take advantage of noisy multiple scattering)

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## Abstract

Time Reversal Acoustics (TRA) has been developing since '990s as a new intriguing field of Research in Elastic Wave Propagation in complex fluid and solid media. Typical TRA experiments are performed with arrays called Time Reversal Mirrors (TRMs) and are composed of two steps: the first step (forward propagation, FP), during which a source (or many) emits a pulse that travels throughout the specimen and is recovered by the TRM; the second step (backward propagation, BP), where each detected signal is digitally time-reversed then re-injected at the detection point (the detector acts as both receiver and source). As a consequence of the invariance of the Elastodynamics wave equations to time-reversal[2], it follows that the TR backward waves propagate throughout the specimen following the same ray-paths as the FP stage but with opposite direction (like in a movie played backward), so they focus on the location of the source(s). Scatterers in the medium (cracks, voids, inhomogeneities), acting as secondary sources, can be preferentially focused on as well, by using different signal processing techniques and iteration of the procedure itself.

Although complete TR invariance of (elastic) wave phenomena is limited to lossless media, it has been shown not only that TRMs are robust enough to obtain retro-focus elastic energy onto primary/secondary sources, but that they can take advantage of multiple (random) scattering in order to improve temporal and spatial resolution, also beyond the limits imposed by diffraction effects.

In this talk, I will show how new kinds of experiments, new signal processing approaches and numerical simulations can be used synergetically in order to exploit TRA techniques for the localization and characterization (in space and time) of both primary and secondary sources in complex media. Cross fertilization between Nonlinear Nonclassical Elasticity, NDE techniques, High Performance Scientific Computing and Seismology is at the basis of work under development at the Nonlinear Elasticity Group, EES-11, Los Alamos National Laboratory, in order to use such new techniques for solving long-standing problems as “How to selectively localizing in 3D distributions of micro-cracks embedded in composite structured solid specimens” or “How to localize in space Earthquake sources at faults with a complicated pattern of emission in time”.