# ACOUSTIC TIME REVERSAL IN GRANULAR MEDIA

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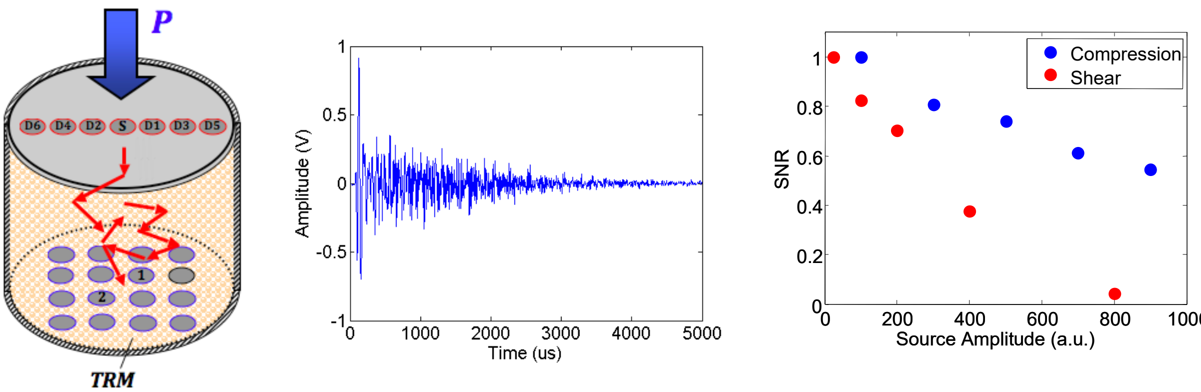
In a non-dissipative medium, the wave equation is symmetric in time. Therefore for every wave diverging from a pulsed source, there exists in theory a wave, the time-reversed wave, that precisely retraces all its original paths in a reverse order and converges in synchrony at the original source as if time were going backwards. In the early nineties, M. Fink proposed an original method for generating such a time-reversed wave from a surface named a Time Reversal Mirror (TRM) [1]. This method was first tested with ultrasound and then successfully extended to other types of waves such as microwaves, water waves, and even in optics. It has led to numerous applications including seismic source imaging [2]. Several studies have shown that time reversal wave focusing is very robust to disorder [3], including situations where perturbations occur between forward and back propagation steps [4,5]. Here we investigate time reversal (TR) of elastic waves propagating in fragile granular media consisting of glass beads under static compression. Pulsed elastic waves transmitted from a compression or a shear wave source are measured by a TRM (Fig. 1.a and Fig. 1.b), time reversed and back-propagated. The ability of the time-reversed wave to focus at the initial source is checked as a function of the source amplitude. We find that TR of the ballistic coherent wave is very robust to perturbations but provides poor resolution. By contrast, the short-wavelength scattered waves offer a finer TR focusing but are sensitive to rearrangements induced by the forward propagation wave itself: at large source amplitudes, time reversal focusing is broken (Fig. 1.c). Experimental results are confronted with predictions from a numerical model in which the propagation medium is modelled by a percolating network of spherical balls interacting via linear springs.




a) b) c)

**Figure 1.** (a) Experimental setup: 1.5mm diameter glass beads are placed between the source S and the 16-element TRM. Detectors D1 to D6 allow for spatial focusing measurements. (b) A typical ultrasonic waveform transmitted through the glass bead packing consists of a low-frequency coherent wave followed by high-frequency scattered waves (c) Ratio of the time-reversed peak amplitude to the RMS of the side lobes as a function of the source amplitude for a compression (blue dots) and a shear wave source (red dots).

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