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Real time observation of granular analogue rock material deformation in response to shocks via nonlinear laser interferometry

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Inelastic strain analysis of rock under stress is of first importance to build up adequate theory of inelastic deformation and failure of geomaterials. The latter is crucial to have a better understanding of natural processes such as landsliding or seismic fault activity. In laboratory experiments, a rock sample can be easily stressed and different methods are used to study the deformation as for exemple X-ray tomography, or digital image correlation. But during the compression process of the sample, these technique don't allow to access the 3-D strain tensor.

We present a laboratory experiment in which we investigate the real time deformation of a granular rock material subjected to different mechanical perturbations. Our work provides a novel optical technique in the geoscientific context for studying the wave propagation and the fracture phenomenon.

The experimental measurement of the sample deformation is performed by nonlinear laser interferometry. The principle is based on the so-called self-mixing technique : a beam emitted by a semiconductor laser diode is reinjected into the emitter after reflection on the sample surface. The self-mixing signal in the laser diode can be measured on an integrated photodiode or even more simply by measuring the voltage across the laser diode. In both cases, we have a compact device allowing to observe in real time the direction and amplitude of the motion of the sample surface with a resolution of the half-wavelength of the laser (1.3 micrometers) at microsecond time scales.

In the experiment, our rock like sample which is actually made from a finely ground powder of TiO_2 is submitted to a constant load. Then we have performed two different experiments in which we have applied either a uniaxial or a transversal mechanical perturbation. The surface displacement is measured by two self-mixing interferometers localized to each side of the sample. In the case of uniaxial perturbation, we have observed nonlinear compression waves corresponding to fast oscillations of the rock sample surface. In the opposite case of transversal perturbation, the oscillation of the sample surface suggest a mixed-mode oscillation between S-waves and P-waves.

Due to its operational simplicity, compactness, high resolution and real-time capabilities, we believe that this technique opens a new and broad window for the analysis of the deformations of rock samples both in the elastic regime and beyond.