Data Transfer Function Technique in Conjunction with Synchrotron X-Ray Radiography and Diffraction

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All the detailed knowledge we achieved about Earth's great depths structures and dynamics during the last decade is based on highly resolved seismic data, in particular seismic tomography. That means it is a three-dimensional distribution of elastic and inelastic data with the maximum resolution of the seismic wave length, i.e. at great depth several kilometres in principle. Any material information is a matter of interpretation. The recent tools for doing that are geophysical relevant high pressure research and using these data by numerical modelling. Measuring the high pressure elastic properties at a light source is to some degree the inversion of the outdoor seismic experiment and the logical second step to accomplish the evaluation. The scientific value of the indoor measurements is the higher the more similar the experimental conditions are to nature, i.e. pressure, temperature, sample material, size, structure, texture, wave length and so on.

The approved techniques for measuring the elastic properties under high pressure conditions are ultrasonic interferometry, Brillouin scattering and nuclear resonant inelastic scattering. The physical mechanisms of these techniques are total different from each other. For polycrystalline complex samples in large volume presses only ultrasonic interferometry is useful. At the same time this is the only technique using macroscopic elastic waves integrating the heterogeneity of complex samples, i.e. it is similar to outdoor seismic waves.

The data transfer function technique is the latest and highest developed version of ultrasonic interferometry. It was first published by Li [1]. A special version was independently developed and extensively used in geophysical high pressure research at GFZ by Mueller et al. [2, 3, 4, 5, 6, 7, 8]. Contrary to any other technique using triple-mode transducers it is able to perform simultaneous compressional and shear wave velocity, v_p and v_s, measurements in a time of few seconds to a minute, i.e. transient measurements of the elastic properties of a sample during ongoing processes as phase transitions, partial melting, crack propagation etc. are possible. The piezoelectric transducer is excited by an optimized function representing the whole frequency spectrum of the interferometric passband. The received signal contains the whole interferometric reply of the sample. During the experiment only this reply function is saved with the required high resolution.

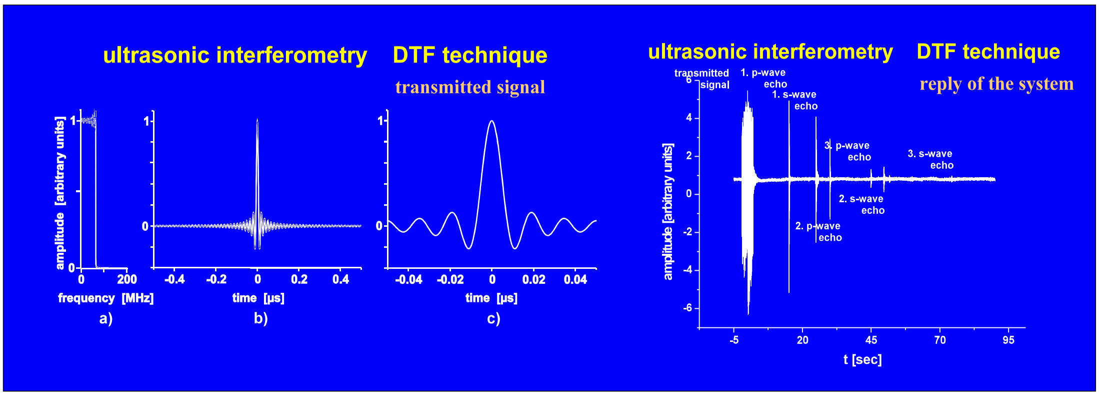

Figure 1: Ultrasonic DTF-technique - excitation function and response of the system.

After termination of the actual high pressure experiment the raw data are processed by convolution bringing back the reply of the system for each frequency inside the pass band followed by the classical interferometric evaluation. The result is a sequence of constructive and destructive interferences. Its periodic distance is a measure for the mean elastic wave travel time inside the

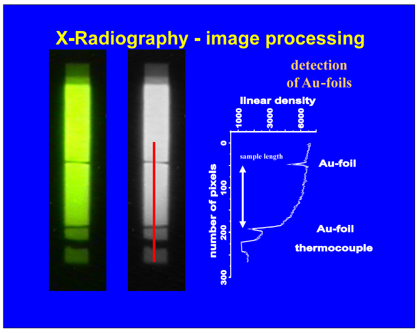

Figure 2: X-Radiography and image processing.

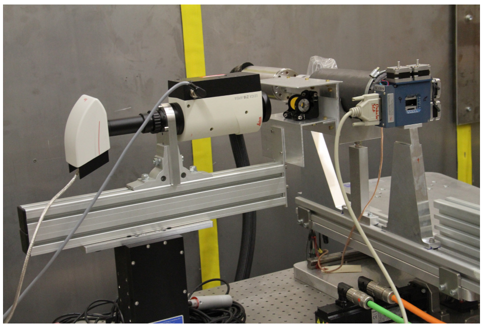

Figure 3: X-Radiography installation, slits and XRD-detector at MAX200x.

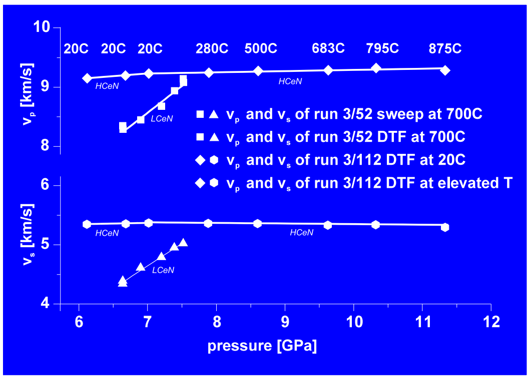

Figure 4: Elastic wave velocities v_p and v_s in high- (HCeN) and low-density (LCeN) clinoenstatite at various pressure and temperature conditions.

Figure 5: MAX200x - equipment for DTF-ultrasonic interferometry in front of the hutch.

sample. Measuring the desired elastic wave velocity requires a highly precise deformation measurement under in situ conditions performed by X-radiography. In favour of this a monochromatic X-ray beam is needed with a diameter of more than the sample size, recently from about 3 to 15 mm. Using white X-rays results in blurred radiographs and in problems to limit the scattered radiation inside the hutch. The X-ray shadow graph of the sample inside the high pressure set up is converted to a visible spectrum range image by a YAG-crystal. Finally this image is captured by a CCD-camera and evaluated by image processing. At the same time X-radiography is indispensable for the state of the art high pressure deformation technique enabling measurements of the elastic and inelastic properties in the seismic frequency band - a geophysisist's dream as long as global seismology exists. Last not least an extreme fine and highly brilliant white X-ray beam is needed to investigate semi-simultaneously the substructures of the 3-dimensional complex sample system under in situ conditions.

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