The University of Oxford Department of Earth Sciences

EARTHSCIENCES

UNIVERSITY OF OXFORD

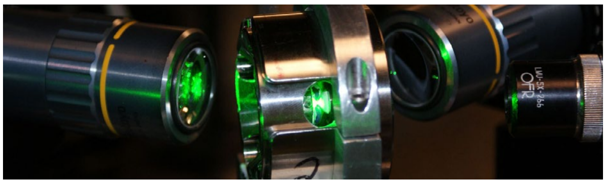
Rapid Multi-dimensional Seismic Property Mapping of Earth Materials

Supervisory Team	Prof. Hauke Marquardt (Earth Sciences) (https://www.earth.ox.ac.uk/people/hauke-marquardt/) Prof. Felix Hofmann (Engineering) (http://www2.eng.ox.ac.uk/solidmech/people/professor-felix-hofmann)

Key Words	Mineral physics, planetary interiors, novel methodology, spectroscopy

Overview

Our planet's inner dynamics and surface plate tectonics are governed by the properties of and processes in the Earth's lower mantle. A quantitative understanding of the physical and chemical properties of the lower mantle is key to modelling Earth's dynamic evolution, including the long-term chemical interactions between mantle and atmosphere that are vital to habitability of Earth. The main approach to determining the structure, composition and dynamics of Earth's inaccessible interior is to compare seismic interior maps of compressional Vp and shear Vs velocities, constructed from the analysis of Earthquake waves, to mineral physics predictions derived from deep Earth models. Unfortunately, this approach has led to highly ambiguous results on the state and composition of the lower mantle. The reason is that a unique interpretation of deep Earth seismic data critically relies on quantitative knowledge of the elastic (seismic) properties of Earth materials at extreme pressures and temperatures characteristic of the Earth's deep interior. This information is largely incomplete, as existing methods for probing seismic properties are far too slow to provide the required detailed information.



The aim of this project is to develop a new experimental capability, using rapid transient grating spectroscopy (TGS) measurements to probe the elastic, i.e. seismic, properties of Earth materials in a Diamond Anvil Cell (DAC). TGS has the potential to allow measurements up to 4 orders of magnitude faster than currently-used Brillouin scattering methods. To fully exploit this speedup, automated experimental routines must be developed for TGS data collection for multiple sample orientations and changing pressures. This new capability would allow a very high resolution mapping of seismic properties as a function of pressure. By integrating a heating capability into the DAC, this could be further expanded to also allow the mapping of temperature dependence of elastic properties.

This new tool will then be deployed to map out the pressure and temperature dependent properties of ferropericlase and optionally bridgmanite, the two main constituents of Earth's lower mantle.

Methodology

This project will concentrate on the use of transient grating spectroscopy, a laser-based method for probing micro-scale elastic and thermal transport properties of transparent and opaque media. FH has developed a TGS setup that uniquely allows the rapid mapping of material properties in extended samples. This setup will be further developed to allow measurements of Earth materials in a diamond anvil cell. Material for this project can either be synthesised in Oxford, produced by collaborators or purchased commercially. Preparation of samples can be carried out in Oxford. HM's group specialises in the use of DACs for the study of Earth materials at high pressures. Analysis of the experimental data will be performed using Matlab, building on pre-existing analysis codes.

Timeline

Year 1: Doctoral training courses, literature review, planning of experimental developments and campaigns, and laboratory training.

Years 2 and 3: Implementation of TGS, preparation of diamond-anvil cells, high-pressure measurements, presentation of research at national conferences.

Year 4: Data integration, thesis completion, papers for international journals, presentation of research at an international conference.

Training & Skills

The supervisory team are leaders in high-pressure mineral physics, optical spectroscopy, and its application to the understanding of planetary interiors (Marquardt and Thomson 2020).

As part of this project you will learn how to prepare diamond-anvil cells and conduct high-pressure experiments using optical spectroscopy (TGS and Brillouin spectroscopy). You will further be trained in how to plan and carry out laboratory experiments, using world-leading research facilities. You will also receive training and guidance in how to model and interpret data, how to present scientific results, and how to write scientific papers for publication.

References & Further Reading

Marquardt, H. and A. R. Thomson (2020). Experimental elasticity of Earth's deep mantle. Nature Reviews Earth & Environment **1**(9): 455-469.

Further Information

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