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The Ancient Charm Project: New neutron based imaging methods for cultural heritage studies

Ralf Schulze for the Ancient Charm collaboration[1]
Institute for Nuclear Physics, University of Cologne
ralf.schulze@ikp.uni-koeln.de

Abstract

In the last decade Neutrons became a valuable tool to investigate non-destructively the inside of objects with cultural heritage importance. In contrast to X-ray or proton methods, neutron based methods combine a high sensitivity and high penetration depth. The goal of the European ANCIENT CHARM[2] project [1] is the development of existing non-destructive methods for the bulk analysis of samples into imaging methods, as well as the investigation of new neutron based techniques for 3D elemental mapping. The results obtained with these novel methods should help answering questions about the manufacturing process of the investigated objects, as well as giving informations for choosing the best conservation and restoration techniques.
Here we will present an overview of the concepts of these new methods and first results.
Abstract
Neutron based methods for the bulk analysis of objects from multiple fields of research are well established and in common use. E.g. Prompt Gamma-ray Activation Analysis (PGAA) [2] is a method utilizing the immediate gamma-ray radiation that is produced when an object is placed into a cold neutron beam, whilst Neutron Resonant Capture Analysis (NRCA) [3] uses gamma radiation from resonances in the absorption spectra of epithermal, i.e. higher energetic, neutrons. For most valuable results it is desirable not only to have information of the bulk properties of the investigated objects but also to get informations about the spatial distribution of these properties. For this reason the European ANCIENT CHARM project was started in 2006 with the aim to extend these well established methods into 3D imaging methods. 10 institutions from Italy, Hungary, Germany, Belgium, the Netherlands and Great Britain covering the fields of Nuclear Physics, Radiochemistry, Archaeology, Conservation and Crystallography are working together to accomplish this challenging task.
For turning PGAA into the imaging method Prompt Gamma-ray Activation Imaging (PGAI) [4] the spatial information is obtained by collimating the neutron beam and the gamma detection system to areas of a few square-millimeters. Thus the volume that is

1 http://ancient-charm.neutron-eu.net/ach
2 **A**nalysis by **N**eutron **R**esonant **C**apture **I**maging and other **E**merging **N**eutron **T**echnologies: new **C**ultural **H**eritage and **A**rchaeological **R**esearch **M**ethods

irradiated by the neutron beam is locally confined to the desired measurement position. The intersection of this volume with the collimated field-of-view of the gamma detector defines the active measurement region, the so called “isocenter”, which can be placed into the desired measurement positions. This allows in principle a complete 3D scan of the investigated object. Nevertheless in most real cases it is sufficient to investigate only a few selected points. Most real samples are assembled out of some nearly homogeneous distinct parts. By confining the measurements to some positions at these different parts a considerable amount of measurement time can be saved. To assign sensible measurement positions PGAI is combined with the Neutron Tomography (NT) technique which gives the morphological structure of the sample.
A PGAI/NT setup was installed at the research reactor FRM II in Garching near Munich, Germany [5] in the middle of 2008. Several measurements of fake and real objects of cultural heritage interest were performed with promising results.
In parallel to the development of PGAI/NT, efforts have been made for turning NRCA into the position sensitive Neutron Resonant Capture Imaging (NRCI) method. Again the sample is irradiated with a collimated pencil beam of a few square-millimeters. The emitted gamma-rays are detected by a surrounding array of 28 scintillation detectors. Because of the use of higher energetic neutrons NRCI allows the analysis of larger and bulkier samples. This setup was installed at the ISIS spallation source in Didcot, Great Britain.
Instead of the gamma detector array a position sensitive neutron detector may be placed behind the sample to detect energy dependant absorption dips in the neutron transmission spectrum. This detector, having a resolution of 10x10 pixels, each being 2.5 mm x 2.5 mm large, delivers 2D elemental distributions. By turning the sample in front of the detector, tomography algorithms may be used to obtain the 3D information. This setup, called Neutron Resonant Transmission (NRT), has been tested in spring 2009 and produced impressive 2D “pictures” of the sample objects. A full tomography has been taken with this setup, but its analysis is still in progress.
For the analysis of the measured data the development of (semi-)automatic computer programs is essential, due to the huge amount of data. Methods for the correction of attenuation effects of neutrons and gamma-rays have to be developed to be able to get more quantitative results. This is a topic of current development. The combination of the data-sets obtained with the described methods was addressed by using some reference objects for the calibration of each facility. This has already been shown for PGAI and NT data-sets and should allow the combination with results from other experiments, like e.g. crystallographic properties from Neutron Diffraction experiments.
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