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Non-invasive studies of objects from cultural heritage

Eberhard H. Lehmann[a,*], Peter Vontobel[a], Eckhard Deschler-Erb[b], Marie Soares[c]

[a]Paul Scherrer Institute, WHGA/349, CH-5232 Villigen PSI, Switzerland
[b]University Zurich, Switzerland
[c]Swiss National Museum, CH-8005 Zurich, Switzerland

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Abstract

In order to preserve the objects from European cultural heritage in its structure and shape for our future generations, there is a need to perform all investigations on important samples non-destructively or with very limited amounts of material. Among the non-destructive testing (NDT) methods available for this purpose there are those that need large installations such as accelerators and reactors to provide different kinds of radiation (X-ray, protons, neutrons, gamma, etc.). Therefore, a link between the specialists working at such facilities with scientists from museums and archaeological institutes is necessary. This paper describes the status of a European network dedicated to the NDT of museum objects (COST-G8) as an overview. In more detail, the activities in Switzerland will be presented where PSI plays a role for the study with neutrons and X-rays. Most of the investigated samples of Swiss collections are from Celtic or Roman origin. The superposition of both applied methods gives the opportunity to decide about the structure of objects and artefacts from restoration work applied later to the virgin excavation status. The presented examples will give an overview about opportunities of the applied methods and their limitations in some cases. This should be motivating to adapt the demonstrated methods to other similar objects of historical relevance.

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1. Introduction

Museum objects and those considered as cultural heritage are very often unique, aged, degraded and contain unknown contents, which can deliver information about the period of origin, the process of manufacturing and their application and use. Although many techniques are available to investigate content and structure of these objects, non-destructive methods are preferred. In this way, the objects can survive and forwarded unscathed for future generations.

The aim of this paper is to describe how neutron imaging techniques can contribute to the

*Corresponding author. Tel.: +41 56 310 2963; fax: +41 56 310 3131.
E-mail address: eberhard.lehmann@psi.ch (E.H. Lehmann).

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investigation of museum objects. However, in most of the examples described here, X-ray imaging was applied too. In this way, the information of both methods is obtained complementary and can be superimposed and combined.

Some of the work that was performed is related to a European network—COST action G8—which was initiated 3 years ago to link the modern methods from natural scientists with the needs and problems from archaeologists and museum experts [1]. One of the contributions of Swiss experts is a project for the completion of a collection of Roman bronze sculptures and the non-destructive investigation of most of these objects. It will be the first time that a standard volume of this series will also contain results from non-destructive analyses.

2. The European network COST-G8

Several networks have been initiated under the auspices of the European Community (EC) in order to optimize the interaction between the partners within the member countries working on similar topics. COST is a "bottom up" initiative, which is organized via regular meetings between experts from the participating counties, topical workshops and missions to prominent sites for performing dedicated investigations. Members of the European neutron radiography community remember well the action 524, which finished successfully with the 7th World Conference in Rome 2002.

The COST-action G8 has the aim to contact and to join specialists from the museums and archaeological science with experts from the natural scientific departments and their methods and facilities to investigate museum objects with useful and relevant non-destructive methods. This network can help to bring unique objects into contact with best-suited techniques for their analysis.

3. Neutron versus X-ray

X-ray radiography is a very common procedure in medical diagnostics, because the human body is more or less transparent due to the high content of hydrogen and other light elements. Bones or even metals have much higher attenuation coefficient for X-rays and can easily be distinguished from the soft tissue. It is well known that the attenuation of X-rays is strongly increasing with higher mass numbers of the investigated material. One free parameter is the energy of the radiation, which can be from few keV up to about 500 keV with standard equipment.

In material testing of samples of technical or technological relevance (search for defects and material changes), where mostly metals are involved, the penetration of X-rays is limited. If heavy metals are to be investigated, few mm are sufficient to shield the X-ray beam completely.

At this point, neutrons become valuable due to higher penetration for most of the relevant metals. On the other hand, the attenuation of thermal neutrons by hydrogen is much larger than for X-rays and very small layers of hydrogenous materials deliver high contrast.

Whereas contrast and transmission can be influenced in certain limits with X-rays by changing the energy (due to the variable operational voltage of the tube), neutrons for imaging purposes are either thermal or cold ones. To use fast neutrons is more exotic due to the limited amount of facilities and the low detection probability.

To use both thermal neutrons and X-rays (with suited energy) for the investigation of a variety of museum objects, it is clear from the beginning that metals are more transparent for neutrons than for X-rays. On the other hand, the study of materials with organic origin like leather, wood, wax or textiles gives much higher contrasts with neutrons than with X-rays. Because the composition and the inner structure of newly discovered archaeological objects are often unknown, the availability of two complementary images of the same sample is a very useful for initial evaluations of artefacts.

Most of the here described examples take profit from the two methods and their individual results. In some cases, the X-ray investigation seems to be impossible due to the thickness of the material layers and the involved materials.