5.17. Mr David Mannes (Switzerland)

Introduction
Historical bronze objects play an important rule in cultural heritage research as this material was used for a broad variety of different purposes (tools, weapons, jewellery, cult objects,…) since more than 5000 years in most parts of the world (Africa, Asia, Europe). Furthermore this group of copper alloys shows high durability and has low susceptibility for corrosion, which explains the large number of objects, which have stand the test of time and wait to be studied. For the study of cultural heritage objects non-destructive testing methods are in many cases required and generally preferred. Neutron imaging provides a unique opportunity to thoroughly characterize bronze objects and to provide information on the inner structure also from larger objects while other conventional methods such as X-ray methods are restricted to surface regions of such metal objects.

In the scope of this CRP we propose an interdisciplinary platform for non-destructive investigations of historical bronze objects using neutrons. The platform will provide a forum and link users from the cultural heritage area with partners from the neutron imaging community. As outcome we anticipate a document listing the possibilities and limitations of neutron imaging (such as neutron-radiography, -tomography, energy selective imaging,…) and other neutron based techniques (e.g. diffraction, PGAA,...) to investigate certain questions and problems from the cultural heritage area regarding bronze objects. The document should also contain possible methodical approaches (i.e. how to perform certain investigations) and list partners from the neutron imaging community, which could help in the planning and realization of investigations.

The platform will intensify the collaboration and strengthen the connections between the involved research institutes from both areas neutron physics and cultural heritage and result in a long-lasting synergetic effect.

Experimental facilities
The neutron imaging facilities at the Paul Scherrer Institut include two beam-lines, NEUTRA and ICON, the first with neutrons in the thermal spectrum the latter with a cold neutron spectrum, which are both fed by the spallation neutron source SINQ. Both beamlines dispose over a variety of different detector systems (mostly scintillator-CCD camera systems), which can be chosen accordingly to the requirements of the respective investigation (object size, spatial resolution, sensitivity, temporal resolution,…). Large samples (up to 500 kg) can be scanned with a maximum field of view of 30 cm x 30 cm; the highest spatial resolution can be reached for small samples resulting in a pixel size of 13.5µm/px. The NEUTRA beamline is equipped with an optional X-ray tube allowing reference measurements with similar beam geometries and thus direct pixelwise comparison of the resulting images. ICON is equipped with devices for energy selective imaging and differential phase contrast imaging.

Table 1 – Basic specification of available neutron imaging instruments

NEUTRA specification (neutron energy: 25 meV thermal Maxwellian spectrum)

Position for experiments	**2**	**3**
Distance from the n-aperture L [mm]	7292	10547
Neutron flux / cm^2 / sec / mA	$9.8\ 10^6$	$5.1\ 10^6$
Collimation ratio L/D	350	550

ICON (Mean neutron energy 8.53 meV / 3.1Å)

Position for experiments	**2**	**3**
Distance from the n-aperture L [mm]	6864	12083
Neutron flux / cm^2 / sec / mA	$1.3\ 10^7$	$3.9\ 10^6$
Collimation ratio L/D	343	604

Table 2 – Typical CCD imaging parameters

Position	**Lens**	**Field of view [mm]**	**Nominal pixe size [mm]**	**Exposure time [sec]**
NEUTRA 2	Macro	65 x 65	0.032	60
NEUTRA 2	Normal	150 x 150	0.104	12
NEUTRA 3	Macro	131 x 131	0.064	50
NEUTRA 3	Normal	306 x 306	0.15	8
ICON 2 (Midi)	Normal	150 x 150	0.104	12
ICON 2 (Micro)	Normal	27	13.5	90
ICON 3	Normal	306 x 306	0.15	8

Instrument References:

– NEUTRA: E. Lehmann et al, Nondestr. Test Eval. 16, 191-202 (2001), doi:10.1080/10589750108953075
– ICON: Kaestner et al., NIMA , 659(1), pp 387-393, doi:10.1016/j.nima.2011.08.022

Cooperation:

- Swiss national Museum
- Ethnographic museum Geneva
- Rietberg Museum Zurich
- University Zurich, Institute for Archaeology

Workplan year 1:

The project will be embedded in the regular operational plan of the neutron imaging beamlines at PSI. Two PhD-projects will partially be integrated in the project, one dealing with the evaluation of the manufacturing processes of bronze age knives (University of Zurich) and the other one dealing with energy selective neutron imaging (PSI & EPFL). The scope of the second thesis will be to optimise and improve the method with regards to the topic for example by developing a double-detector setup allowing for simultaneous acquisition of transmission and diffraction images.

Beside the already existing project it is planned to actively identify and invite possible partners from the cultural heritage area and to expand the number of evaluated applications within the project.It is envisaged to present and publish results at relevant scientific and/or conservation conferences, for example at future IAEA coordinated research project meetings. Other events, which will be used to further promote the platform idea of the project are the International conference for experimental archaeology EXAR 2012 in Brugg, Switzerland and the 18th International Congress on Antique Bronzes, to be held in Zurich in 2013 and will be co-organised by PSI.

Main objective	Sub objectives	Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Demonstrate / Scrutinize possible application of neutron imaging for historical bronze objects	Bronze age knives → structures / textures	X	X	X	X								
	Historical bronze objects	X	X	X	X	X	X	X	X	X	X	X	X
Publications	Publications / conferences	X	X	X	X	X	X	X	X	X	X	X	X
Improvement of imaging methods (e.g. → double detector setup)	planning	X	X	X									
	Testing / measurements		X	X	X	X	X						
	Results and publication				X	X	X	X	X	X	X		
Document listing possibilities / limitations of neutron imaging for CH objects (bronze)	Gather info	X	X	X	X	X	X	X	X	X	X	X	X
	Compile methods	X	X	X	X	X	X	X	X	X	X	X	X
	Compile contact lists (CH partners)	X	X	X	X	X	X	X	X	X	X	X	X
	Report									X	X	X	X