5.5. Mr Ivan Padron (Cuba)

Introduction

In the past, some cultural heritage research works have been carried out by the CEADEN, in collaboration with the Arqueology Laboratory of the Cultural Heritage Department, employing techniques as EDXRF, X-ray Difraction, INAA and SEM-EDS for the analysis of Cuban pre-Columbian pottery, painting pigments characterization. Recently, with a modified portable X-ray fluorescence spectrometer were evaluated paintings in restoration process.

Wood is the material that has accompanied the whole development of mankind in various applications, for manufacturing tools and weapons, for buildings and constructions and also as fuel. It has various appearances and is subjected to decomposing changes, so there are sufficient arguments for non-destructive testing of wooden objects in the same way as is common practice with other technologically used materials. However, even today wood is rarely tested. Moreover, artifacts of cultural heritage containing wood are rare and delicate, so dismantling these for studying purposes is undesirable.

Neutrons behave complementarily; they are avidly absorbed by light elements such as hydrogen on the one hand and yet are capable of easily penetrating heavy metals on the other. This provides an alternative for X-ray radiography and tomography when material characteristics are of primary interest rather than structural details, or when shielding with plates or sleeves of heavy metal severely impedes inspections with X-ray or gamma radiation technologies. However, due to the moderating effect of wooden samples it is essential to use fast neutrons for radiography and tomography of voluminous objects. Some typical examples described here will show the difference between neutron and X-ray photon-based radiographic technologies.

Experimental facility:

A novel position sensitive fast neutron detector based on plastic micro-channel plate with a delay-line read-out will be developed for Neutron Resonance Transmission (NRT) application on cultural heritage studies with focus on objects made of wood and metals. That combination was very common on the objects conserved from Spanish colonization of the Americas.

Neutron Resonance Transmission (NRT) reveals the elemental composition of samples by measuring neutron absorption resonances in the transmitted neutron beam. For energy selectivity, needed in NRT analysis we will apply the Time-of-Flight (TOF) method and the associated particle technique (APT).

In order to have an associated helium particle unambiguous identification when D(d, n)3He or 3H(d, n)4He reactions are used for providing mono-energetic neutron beams of know flux and energy, an organic plastic scintillator (NE102A) can be used as associated particle (AP) detector. The neutron cone aperture is determined by the frontal slits which define the solid angle subtended by the AP detector, and in the horizontal plane by the kinematics of the reaction involved. A variable quasi mono-energetic neutron beam is obtained by angular variation using the D(d, n)3He reaction.

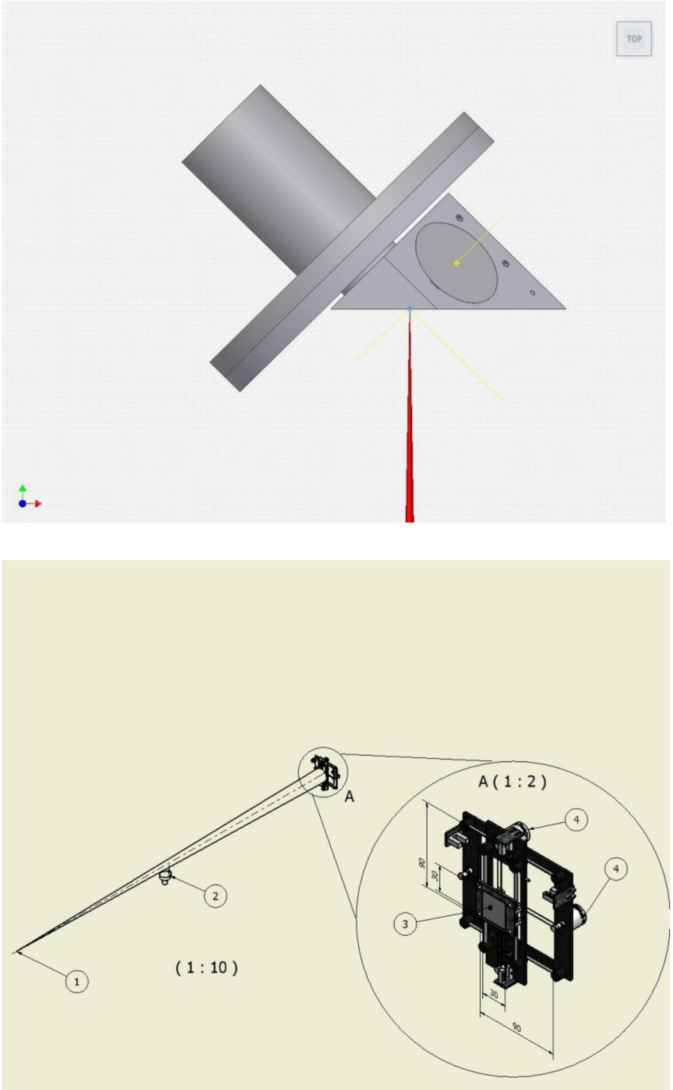

Figure 1 - Geometrical setup designed for Monte Carlo simulations.

The position sensitive fast neutron detector for TOF measurements that we are designing is based on plastic Micro-channel plates (MCP) + two stage stack of lead MCP with a delay-line anode. These novel devices combine the low-noise and high temporal and spatial resolution of MCP with the neutron stopping power of hydrogen rich plastic substrates. Arradiance Inc. of Sudbury is using the atomic layer deposition to add emissive and resistive thin films to the plastic substrates. When a neutron hits a plastic microchannel plate, it interacts with hydrogen, resulting in a recoil proton entering one of its adjacent pores. The proton then hits the walls of the pore, causing a cascade of secondary electrons. The advantage of this technology over the existing fast neutron detectors is the direct conversion of fast neutron into measurable electrical signal and low sensitivity to gammas. Our MCP stack composed of one plastic and two lead MCPs will convert the incoming fast neutrons on 10^3 – 10^6 electrons, providing neutron detection efficiency better than 1%.

Monte-Carlo simulations using the GEANT-4 and MCNP-4C codes will be performed in order to study:

- The performance of a direct neutron conversion in plastic MCP, comparing its resolution and efficiency for fast neutron detection with the silicon MCP.
- The parameters affecting detector performance for its optimization.
- To characterize the intrinsic spatial resolution of MCP neutron detector, a neutron transmission image of archeological object reproductions containing a series of materials like wood, ceramics and different metals will be simulated.

The read-out concept needs to be specially designed to presume that an MCP stack will respond to multiple hits, i.e. it will deliver spatially and timely well defined charge clouds for each particle. However, all common techniques based on phosphor screen read-out can not be applied here as the read-out scheme is much to slow. Pixel anodes with fast and independent read-out electronic channels can handle high rates and multi-hits, but with increasing position resolution demands, such techniques become inefficient as the number of electronic channels increases at least linearly with the position resolution dynamics in each dimension. Also charge integrating read-out schemes as used by the wedge-and-strip or the resistive anodes fail to detect multiple hits as their read-out electronic’s shaping times must be in the order of one microsecond to ensure sufficient position resolution.

A promising approach combining most desired features of an MCP read-out scheme, good position and timing resolution at high particle flux, including the ability to analyze multiple-hit events is the delay-line technique.

For reducing the multi-hit dead-time we will investigate the possibility to analyze the pulse shapes of the analogue signals from the delay-line with fast sample-ADCs. The discrimination between single or multiple signals and the generation of the “timing” is than performed by pulse shape analyzing software codes. Thus it should be possible to identify and analyze even double hit events with a pulse pair distance smaller than the individual signal lengths. Such a “digital timing discriminator” in combination with a delay-line anode could improve the multi-hit performance significantly.

Workplan year 1:

– Design of the fast neutron detector based on one plastic MCP and two stage chevron configuration lead MCP with a delay-line position sensitive anode.
– Design and characterization of read-out scheme.
– Design of sample holder and optimization of physical parameters for NRT applications.
– Monte-Carlo simulation and analysis, comparison with GEANT-4 code for detector design and feasibility study for application in cultural heritage research by NRT.
– Investigation of possible discrimination between single and multiple signals and the generation of the "timing" by pulse shape analysis.
– MCP stack acquisition.

Main objective	Sub objectives	Year 1				Year 2				Year 3			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Designing of MCP detector	Get information about commercial MCPs	X	X										
	Designing of MCP detector		X	X									
	Designing of readout system				X	X							
Exper. setup optimization	Designing of geometrical setup		X	X									
	Monte Carlo modeling of experimental setup			X	X	X	X						
Detection system optimization	Simulation of direct fast neutron detection on plastic MCP		X	X									
	Estimation of temporal and spatial resolutions			X	X								
1st year Report	Analysis of results				X								
	Writing the report				X								
Exper. setup development	Fabrication of sample holder					X	X						
	Fabrication of detector holder						X	X					
	MCP stack acquisition						X						
	MCP detector fixing							X					
Readout system development	XDL anode acquisition						X						
	XDL anode fixing							X					
	Testing of MCP detector								X				
2nd year Report	Analysis of results								X				
	Writing the report								X				
Software assimilation	Imaging software installation									X	X	X	
Facility testing	Imaging different artifacts										X	X	
	Data analysis										X	X	
	Comparison with X-ray radiography											X	X
3rd year Report	Analysis of results												X
	Writing the final report												X