PIXE MEXICO 2007

Proceedings of the XI International Conference on PIXE and its Analytical Applications
Puebla, Mexico, May 25-29,2007

New High Energy and High Resolution Lisbon PIXE Set-up

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Abstract. Nowadays the PIXE technique is a well established method and few improvements have been reported during the last years. Recent improvements are related with technical developments rather than the technique itself. Among these there can be found the use of microbeams, higher solid angle detectors, Si(Li) detectors which are closer to the physical ideal, some advances in data handling software and attempts to reach tomography analysis of inhomogeneous samples. Still, cross sections work has been nearly standing on the ECPSSR theory with small step improvements being made, as well as on the limitations of Si(Li) detectors, which lead to a limited exploitation of the electromagnetic spectra available. At ITN, a new approach was taken relative to this and a new PIXE set-up is being installed, which foresees important changes by extending the useful energy range of x-rays up to 120 keV and reducing the resolution at low and intermediate energies down to 1 and 0.5% respectively. This is achieved by making use of a CdTe detector that presents an energy efficiency platô up to roughly 70 keV, and a VeriCold Technologies GmbH POLARIS detector that presents a resolution better than 15 eV for the 1.486 keV of Al-K_{α} and better than 40 eV for the 10.550 keV of Pb-$L_{\alpha 1}$. In what concerns the first part of this two new approaches, the system is already working and applications are presented in other communications at this conference. Relative to the second part, natural delays have made that, at the time of the conference, the detector is still at the production site. Relative to this component, simulated PIXE spectra will be presented in this comunication which were produced by using the new DT2 code, also being presented in another comunication at this conference.

Keywords: High Resolution PIXE, High energy PIXE, CdTe, POLARIS

INTRODUCTION

In a General Ionex 3MV Tandentron accelerator was installed at ITN. Since then, a new beam line being already operational. In this second ITN PIXE line, new approaches to PIXE work will have the major time share, as a 1 to 0.5% X-ray EDS resolution setup will be used covering energies from below 3 keV up to nearly 120 keV. This new approach should in principle open up new frontiers to PIXE, or even allow for the establishing of new ion beam induced X-ray analytical techniques. In this communication we present the setup of this new line called HEHR-PIXE.

EXPERIMENTAL

In the new HEHR-PIXE setup, two different detectors, will be used simultaneously. Presently, an Amptek Peltier Cooled 3×3×1 mm CdTe detector is already operational and placed at 90º to beam direction. This detector has a 250 µm Beryllium window and a small size: 9.5×4.4×2.9 cm, thus it can be easily fit in to the PIXE chamber. This CdTe useful energy range covers from K-K_{α} (3.312 keV) up to more than 110 keV, the energy of one of the γ-rays from the $^{19}F(p,\alpha\gamma)^{16}O$ reaction.

The CdTe detector is coupled to the PIXE chamber by a Perspex sleeve, which fits in one of the flanges of the HEHR-PIXE chamber. The CdTe detector is coupled to the chamber, as near as possible to the target. X-ray collimators and absorber foils may be introduced outside the vaccum on the end of an insulator sleeve that assures both the electrical decoupling between the detector and the chamber and the fine positioning of the CdTe detector. The Polaris Microcalorimeter system will be the other detection system, in the HEHR-PIXE line, and is planned to be installed by the end of the year.

The chamber is a single block steel chamber, which interior is cylindrical in shape with an internal diameter of 309 mm and an internal height of 155mm. The main advantage of this chamber is the possibility to rearrange the chamber depending on a purpose of a particular experiment. The chamber has been equipped with 6 outlets, with inner diameter of 63mm (CF63), and with 2 outlets, with inner diameter of 100mm (CF100). At top has 4 outtlets with inner diameter of 40mm (CF40) and a center outlet with inner diameter of 63mm (CF63). At bottom there is a single outlet with inner diameter of 150 mm (CF150). In the irradiation chamber there is an electron gun that allows for the analysis of insulator targets or targets mounted in electrical insulating heavy elements free suports.

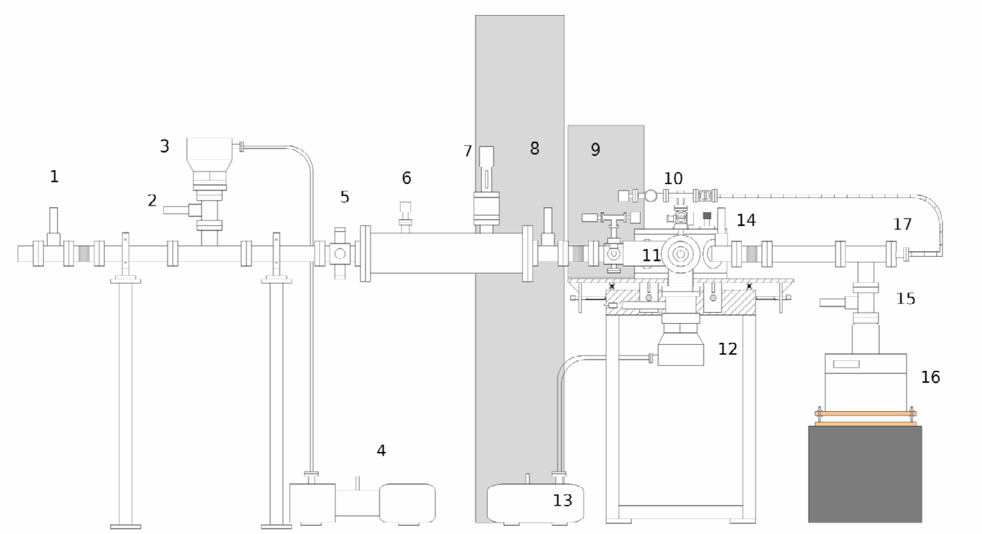

FIGURE 1: Lateral view of HE&HRPIXE line at the Tandentron accelerator. 1-Gate valve CF63, 2-Gate valve CF63, 3-Turbomolecular Varian Pump with 200l/s pumping speed, 4-Primary pump, 5- Slits, 6-Quartz, 7-Faraday cup, 8- Cooling column of thePolaris microcalorimeter system, 9-Polaris Microcalorimeter system detection, 10-Penning and Piranni sensor, 11-Gate valve CF100, 12-Turbomolecular Varian Pump with 200l/s pumping speed, 13- Variant Dryscroll turbo pumping, 14- Gate valve CF63, 15-Gate valve CF63, 16- Variant Dryscroll turbo pumping 60l/s, 17-Future entrance of aerosol samples.

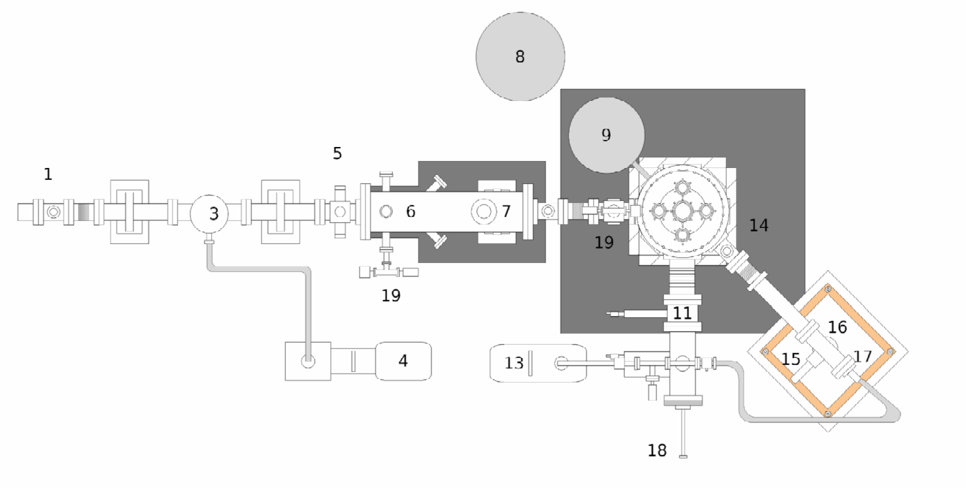

FIGURE 2. Top view of HE&HRPIXE line at the Tandentron accelerator. 1-Gate valve CF63, 3-Turbomolecular Varian Pump with 200l/s pumping speed, 4-Primary pump, 5- Slits, 6-Quartz, 7-Faraday cup, 8- Cooling column of the Polaris microcalorimeter system, 9-Polaris Microcalorimeter system detection, 11- Gate valve CF100, 13- Variant Dryscroll turbo pumping, 14- Gate valve CF63, 15-Gate valve CF63, 16- High vacuum backing unit, 17-Future entrance of aerosol automatic loader, 18- Future entrance of non aerosol samples, 19- Entrance collimators.

The ion beam is collimated by a tantalum collimator placed outside the chamber entrance. In figure 1 and 2 we presents the schematics of the HEHR-PIXE LINE Presently samples are introduce in the chamber by the top center outlet, although in future this will be made as presented in the figure 1 and 2, thus entrances of samples will exist,a general one and another for aerosol samples. In both cases, a pumping system is connected to the entrance region.

FIRST RESULTS

The first experinence with this new HE&HRPIXE line, a single sample was used namely an ultrapure Gd_2O_3 thick sample with 99.99% of purity. In the whole experiment, spectra were collected for proton beams having energies between, 1.6 MeV and 3.5 MeV, and for each ion beam energy value a spectrum having roughly $5x10^3$ counts on the Gd-$K_{\alpha 1}$ was acquired. In total 9 spectra were collected using H+ beam irradiation. The proton incidence and X-ray emission angle relative to the target surface was 45º. Once obtained, the Gd_2O_3 spectra were simply unfolded by using a Lorentzian function and the commercial general data handling software package ORIGIN®. In figure 3, the K spectra of Gd_2O_3 collected with CdTe detector at 3.5 MeV is shown.

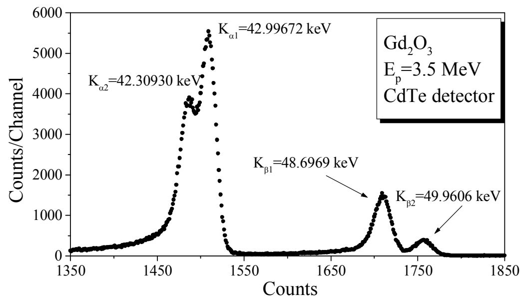

FIGURE 3: PIXE spectra of Gd_2O_3 pure thick sample collected by the CdTe detector at 45º with ion beam. The good efficiency and resolution at 40-50 keV is clear from the details of the Gd_2O_3 spectra.

In figure 4 the $K_{\beta 1,3}/K_\alpha$, $K_{\beta 2}/K_\alpha$ and $K_{\beta 2}/K_{\beta 1}$ intensity ratios are present for all values of beam energy. We observed that for values of ion beam energy bellows 2.0 MeV there is an increase in the values of ratios. This effect was already seen in previous works [1-3].

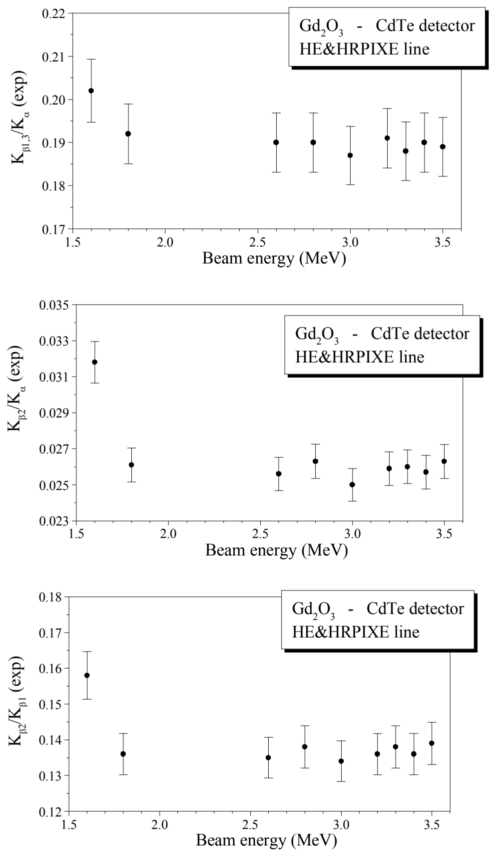

FIGURE 4: $K_{\beta 1,3}/K_\alpha$, $K_{\beta 2}/K_\alpha$ and $K_{\beta 2}/K_{\beta 1}$ intensity ratios for Gd_2O_3 thick sample, obtained in the new HE&HRPIXE line, using ion beam energies between 1.4 and 3.5 MeV.

In figure 5, we present the spectrum of a Mo foil sample, collected with a Si(Li) detector using a beam energy of 1.52 MeV irradiated at ITN 2.5MV Van de Graaff accelerator. In a set-up described in other work, and compare it to a simulation of the same spectra with a 10 times better resolution, which is expected to be comparable to the Polaris microcalorimeter EDS detector resolution. This simulation has been done using the core of the new DT2 program, which is presented in another communication at this conference [4].

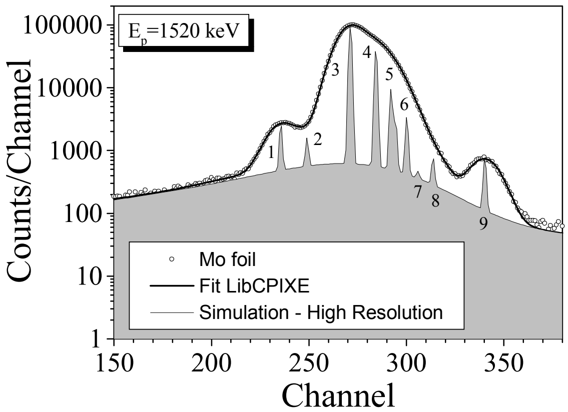

FIGURE 5. Spectrum of Mo foil irradiated using a proton beam of 1.52 MeV and collected using a 150 eV resolution Si(Li) detector (Gresham Scirus detector) placed at 110º relative to beam direction. In gray simulated Polaris high resolution spectra corresponding to the fit values normalized to the original spectrum height. Spectra were fitted using Bayesian inference algorithm recently introduced by Barradas and used in the new DT2 code. 1-L_l, 2-L_η, 3-$L_{\alpha1,2}$, 4-$L_{\beta1}$ 5-$L_{\beta3,4}$, 6-$L_{\beta2,15}$, 7-$L_{\gamma5}$, 8-$L_{\gamma1}$, 9-$L_{\gamma2,3}$.

ACKNOWLEDGMENTS

This work was partially supported by the Portuguese Foundation for Science and Technology, FCT, through a PhD fellowship with the following reference SFRH/BD/27557/2006.

This work is also funded in the framework of project REEQ/377/FIS/2005 of the Portuguese Foundation for Science and Technology, FCT.

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