Review

The Role of PIXE and XRF in Heritage Science: The INFN-CHNet LABEC Experience

Leandro Sottili [1,2], Lorenzo Giuntini [3,4,*], Anna Mazzinghi [3,4,*], Mirko Massi [4], Luca Carraresi [3,4], Lisa Castelli [4], Caroline Czelusniak [4], Francesca Giambi [4], Pier Andrea Mandò [3,4], Marco Manetti [4], Chiara Ruberto [3,4], Laura Guidorzi [2], Alessandro Re [1,2], Alessandro Lo Giudice [1,2], Rodrigo Torres [5], Francesco Arneodo [5], Simi Maria Emilia Mangani [6], Silvia Calusi [7] and Francesco Taccetti [4]

1. Dipartimento di Fisica, Università degli Studi di Torino, Via Pietro Giuria 1, 10125 Torino, Italy; leandro.sottili@unito.it (L.S.); alessandro.re@unito.it (A.R.); alessandro.logiudice@unito.it (A.L.G.)
2. Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino, Via Pietro Giuria 1, 10125 Torino, Italy; guidorzi@to.infn.it
3. Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Via Giovanni Sansone 1, Sesto Fiorentino, 50019 Firenze, Italy; carraresi@fi.infn.it (L.C.); mando@fi.infn.it (P.A.M.); ruberto@fi.infn.it (C.R.)
4. Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Firenze, Via Giovanni Sansone 1, Sesto Fiorentino, 50019 Firenze, Italy; massi@fi.infn.it (M.M.); castelli@fi.infn.it (L.C.); czelusniak@fi.infn.it (C.C.); giambi@fi.infn.it (F.G.); manetti@fi.infn.it (M.M.); taccetti@fi.infn.it (F.T.)
5. Division of Science, New York University Abu Dhabi, Saadiyat Island, Abu Dhabi 129188, United Arab Emirates; rodrigo.torres@nyu.edu (R.T.); francesco.arneodo@nyu.edu (F.A.)
6. Dipartimento di Chimica "Ugo Schiff", Università degli Studi di Firenze, Via della Lastruccia, 3, Sesto Fiorentino, 50019 Firenze, Italy; simimariaemilia.mangani@unifi.it
7. Dipartimento di Scienze Biomediche Sperimentali e Cliniche "Mario Serio", Università degli Studi di Firenze, Viale Pieraccini 6, 50139 Firenze, Italy; silvia.calusi@unifi.it
* Correspondence: giuntini@fi.infn.it (L.G.); mazzinghi@fi.infn.it (A.M.)

Abstract: Analytical techniques play a fundamental role in heritage science. Among them, Particle Induced X-ray Emission (PIXE) and X-ray Fluorescence (XRF) techniques are widely used in many laboratories for elemental composition analysis. Although they are well-established, a strong effort is put on their upgrade, making them suitable for more and more applications. Over the years, at the INFN-LABEC (the laboratory of nuclear techniques for the environment and cultural heritage of the Italian National Institute of Nuclear Physics), the INFN-CHNet group, the network devoted to cultural heritage, has carried out many technological improvements to the PIXE and XRF set-ups for the analysis of works of art and archaeological finds. Among the many, we recall here the scanning external microbeam facility at the TANDEM accelerator and the MA-XRF scanner. The two instruments have shown complementary features: the former permits quantitative analysis of elements heavier than sodium, which is not possible with the latter in most of the case studies. On the contrary, the scanner has the undeniable advantage of portability, allowing it to work in situ. In this framework of technological developments in heritage science, INFN, CERN, and OPD are jointly carrying on the MACHINA (Movable Accelerator for Cultural Heritage In-situ Non-destructive Analysis) project for on-site Ion Beam Analysis (IBA) studies on cultural heritage.

Keywords: PIXE; MA-XRF; IBA; material analysis; heritage science

1. Introduction

IBA activities related to fundamental physics and other disciplines have been carried out at the INFN-LABEC since its foundation in 2004. Tests of detectors for nuclear and particle physics [1–3], studies of ion-matter interaction for solid state physics [4] and compositional measurements for heritage science (HS) [5], and environmental aerosol science [6] are just some examples of the diverse applications. Those activities have been conducted