

DIAM, A BIOMOLECULAR CLUSTER IRRADIATION SYSTEM*

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Abstract

DIAM is a new experimental system devoted to irradiation of biomolecular nanosystems by protons in the Bragg peak energy range [3]. This energy range corresponds to the maximum of ionization and also to the maximum of biological damage. The scientific objective is the study of the processes induced by ionization in an irradiated biomolecular system: fragmentation, reactivity. This work is a part of MIRRAMO project [1] (MIRRAMO: irradiation mechanisms of biomolecular cluster).

DIAM AND ANAFIRE PLATFORM

Biomolecular cluster irradiation system DIAM (in french : Dispositif d'Irradiation d'Agrégats Moléculaires) is one of the six key elements of technological platform ANAFIRE (Analysis and ion beams for radiobiology and environment, in french : ANALyses et Faisceaux d'Ions pour la Radiobiologie et l'Environnement) [2]. The scientific fields studied in the frame of this platform are several and related to radiobiology, sustainable development and environment but also development of future nuclear fuels of the 4th generation or doping semiconductor. We dispose of several tools such as ion beam analysis with two Van de Graaff and an ionic implanter 400 kV.

SCIENTIFIC AIM AND MOTIVATION

Irradiation of biomolecular nanosystems isolated in the gas phase opens new perspectives to elucidate irradiation mechanisms. DIAM will allow the proton irradiation of model systems such as protonated water clusters as well as more realistic biomacromolecules.

This new experimental challenge is related to fundamental questions on dynamics of non-equilibrium systems, to the description of the irradiation dose at the nanoscale as well as applications to mass spectrometry techniques.

EXPERIMENTAL SET UP

The DIAM irradiation set up (see figure 1) is a proton beam (160 keV and 1 mA) crossed with a mass selected molecular cluster beam. Proton source and cluster source are both installed on high voltage platform (respectively 160 and 30 kV). These platforms are supervised by a control/command system using *Labview* environment and optic fiber electronic modules. After focalization with series of quadrupoles and electrostatic deflectors (especially to keep the required intensity), proton and

cluster beams cross inside a detection chamber where the cluster fragments resulting from this interaction are analyzed by time of flight technique.

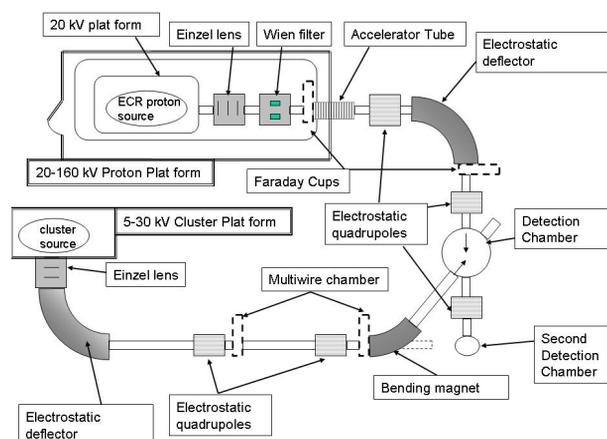


Figure 1: General layout of DIAM irradiation set up.

Proton Source

To produce proton beam we use an ECR (Electron Cyclotron Resonance) ion source at 2.45 GHz. This source has been designed in collaboration with the Ion Source Service of LPSC (Laboratoire de Physique Subatomique et de Cosmologie, Grenoble, France). Created beam is pre-accelerated at 20 keV and focused with an Einzel lens. The beam passes through a velocity filter to eliminate others ions created like H_2^+ .

Molecular Cluster Source

Its principle is based on condensation during the fast expansion under vacuum of an inert gas with intermixed vaporized molecules of biological interest such as DNA bases and water. While electrons (energy above 100 eV) are produced by a filament, condensation occurs and protonated molecular clusters are produced. This source is set on a high voltage platform (2 to 30 keV) and the beam is focused by an Einzel lens before entering a mass spectrometer to achieve a beam of mass selected clusters.

Detection Chamber

Proton and cluster beam are deflected and focused by series of quadrupoles and steerers to cross inside this chamber. The detection system associated to this chamber is able to detect products due to proton-cluster interaction such as ionic but also neutral fragments of the biomolecular cluster. Cross area is placed under a deflecting electric field so that mass of the produced

*Work supported by the French national research agency (ANR).

fragments is deduced from time of their arrival at the detector surface (time of flight technique).

Second Detection Chamber

The last chamber is mainly dedicated to biomolecular clusters of relative small size (from two to thirty molecules) which are model systems where comparison with theory is possible. However, DIAM allows to have a second point of interaction with a second detection system for irradiation of macrobiomolecules such as oligonucleotides (DNA and RNA) and large peptides (proteins).

PRELIMINARY RESULTS

- Protons source : ECR protons source has been tested successfully with a beam of 20 keV and 0.6 μ A of protons after Wien filter;
- 150 kV proton platform : it has been tested successfully at 150 kV;
- Proton beam line has been calculated and designed with "Transport" code [4] and is under construction;

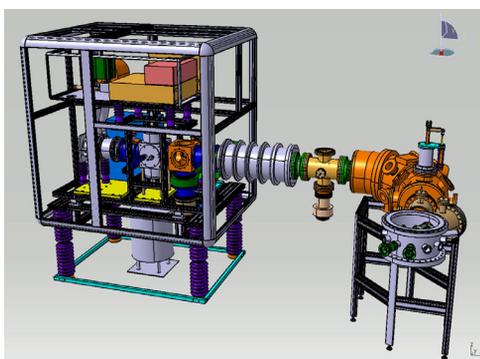


Figure 2: Scheme of proton beam line.



Figure 3: View of cluster beam line.

- Cluster source and cluster beam line : The cluster system is operational and beams of pure protonated water clusters $H+(H_2O)_n$ (n from 1 to 39) are currently used for preliminary experiments devoted to the tests of the multidetection system.

EXPECTED RESULTS AND PERSPECTIVES

Proton beams will be available at the two irradiation points in July 2009. Further tests will be achieved to insure beam stability, to measure the proton energy definition and to optimize the intensity. High intensity proton beams in the Bragg peak energy range will allow irradiation of a number and various biomolecular systems from single organic functions solvated in a water cluster to large macromolecules.

The scientific strategy is defined in consultation with the theoretical developments (LPT, Université Paul Sabatier, Toulouse, France) [5, 6] and with the measurements performed with monokinetics electrons (Institut für Ionenphysik, Innsbruck, Austria). This work is developed in the frame of the RADAM scientific community (initiated by the RADAM P9 COST Action, Radiation damage on biomolecular systems).

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