Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/rpor

Preliminary communication

Status report: Nanodosimetry of carbon ion beam at HIL

Aliaksandr Bantsar[a], *Marcin Pietrzak*[b,*], *Marian Jaskóła*[a], *Andrzej Korman*[a], *Stanisław Pszona*[a], *Zygmunt Szefliński*[c]

[a] *National Centre for Nuclear Research, ul. Andrzeja Sołtana 7, 05-400 Otwock, Świerk, Poland*
[b] *Institute of Experimental Physics, University of Warsaw, ul. Hoża 69, 00-681 Warsaw, Poland*
[c] *Heavy Ion Laboratory, University of Warsaw, ul. Pasteura 5A, 02-093 Warsaw, Poland*

ARTICLE INFO

Article history:
Received 7 October 2013
Received in revised form
23 April 2014
Accepted 24 April 2014

Keywords:
Nanodosimetry
Ionization cluster size distribution
Carbon ion

ABSTRACT

We present preliminary data for measured distributions of ionization cluster size produced by carbon ions in tissue equivalent media. The experiments were carried out with a beam of 92 MeV carbon ions from the U200p cyclotron at the Heavy Ion Laboratory (HIL), University of Warsaw, and nitrogen targets using the so-called Jet Counter set-up.

1. Background

Great effort has gone into understanding the effects of ionizing radiation on living organisms. In particular in nanosites, such as DNA molecules, ionizing radiation induces elementary electric charges in the form of single or clustered charges. In living cells, radiation may cause reparable or irreparable DNA damage. This knowledge is nowadays used in photon beam radiotherapy.[1] However, with the progress of accelerator technology new methods, which use heavy charged particles forming a beam of radiation, are coming into use. One of the most interesting choices are carbon ions.[2] However, there is no way to perform an experiment showing single event effects in living tissue or water. The only way to gain this knowledge is to make a Monte Carlo simulation or an experimental model. A pioneer experimental work was done in 1976 by Pszona.[3] In some recent papers, this approach has been well applied to alpha particles[4–7] and low energy electrons.[8,9] The present paper presents first results of experimental modelling of the interaction of carbon ions with nanosites comparable in size to a short segment of a DNA molecule (unit density 1 g/cm^3). The main emphasis is placed on the formation of charge clusters induced by 53 and 73 MeV ions passing through the sensitive volume of nitrogen gas at low pressure. These energies are close to the Bragg peak, which are of the greatest interest in terms of biological effectiveness of charged particles in radiotherapy.

* *Corresponding author*. Tel.: +48 662601637.
E-mail address: Marcin.Pietrzak@fuw.edu.pl (M. Pietrzak).

http://dx.doi.org/10.1016/j.rpor.2014.04.017

2. Materials and methods

The main device used in the experiments was an ion counting nanodosimeter called a Jet Counter (JC), which has been developed and improved over the past two decades by a group from the National Centre for Nuclear Research, Poland.[4,7] The JC consists of an interaction chamber (IC) where a sensitive volume with nanometric dimensions is created by expansion of a gas (preferably nitrogen) jet from reservoir R injected by piezoelectric valve PZ (see Fig. 1). Nitrogen molecules are ionized by single carbon ions passing the sensitive volume by forming ionization clusters of different sizes. The frequency of formation for a given size cluster is stored on an event-by-event basis with a known total efficiency of about $\eta \approx 40\%$. This value is a product of efficiency of ion extraction, ion guiding to ion detector and ion detector itself.[7]

The method of determining the density of gas jet injected into the IC is based on measurements of electron transmission and has been described in detail in the following paper.[7] The electron transmission curves were determined for two sizes of the sensitive volume of nitrogen released to the IC in a single injection. The size ratio was set at 1:2, which should provide a similar ratio of mass-per-area of gas target.

As shown in Fig. 2, the duration and location of the maximum density (minimum transmission) hardly depend on the amount of gas injected. However, the minimum value is variable and is different in each case. For the calculation the period of 340 μs was chosen, wherein the density changes by no more than 5% around the mean value. Mean values appear in Fig. 2 as curve labels. Also, the period of 340 μs is the time window in which the JC is ready for measurement and waits for the arrival of a single ionizing particle.

The source of carbon ions was the U200p cyclotron operated by the Heavy Ion Laboratory, University of Warsaw. The primary energy of the carbon ion beam was 92 MeV. The beam impinged on a thick gold foil and ions scattered at an angle of 45° entered the JC, as shown in Fig. 3. During dosimetric measurements the energy spectra of carbon ions leaving the IC were collected. A silicon detector was used to measure the energy spectrum of particles and trigger the acquisition system of the JC.

Due to the limited beam time that was available for the experiment, it was decided that the measurements would be carried out for four cases. Two beam energies of ions and two sizes of simulated nanosites (two target densities) were chosen.

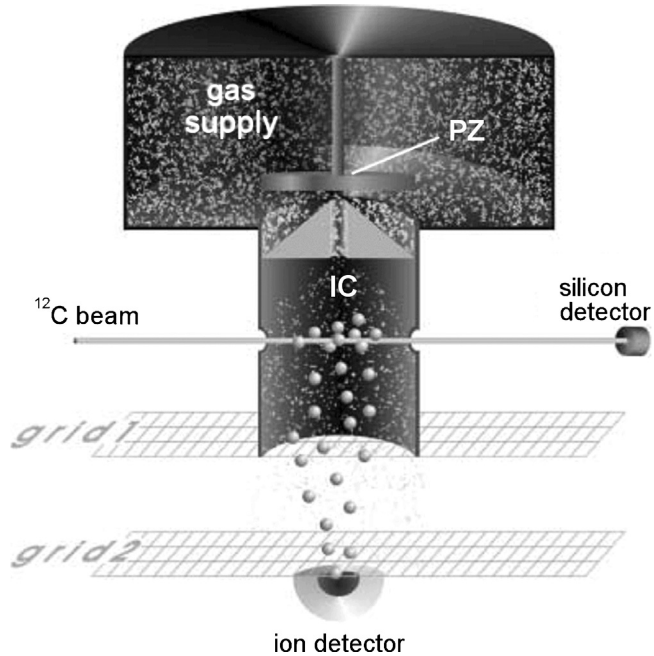

Fig. 1 – Schematic view of the Jet Counter.

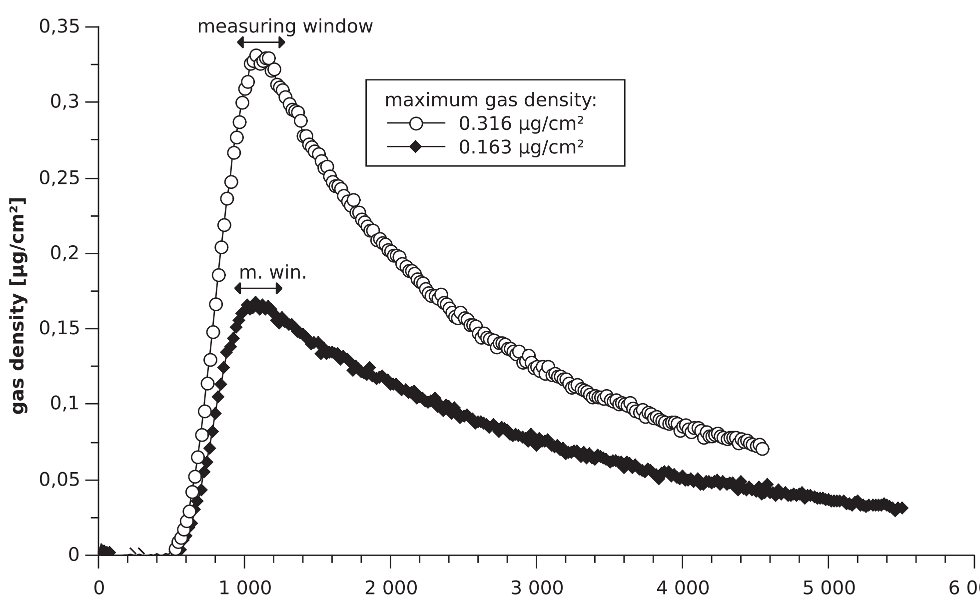

Fig. 2 – Time dependence of instantaneous mass-per-area of nitrogen jet released into the interaction chamber. Maximum gas density is the value of the actual nitrogen target.