Nuclear Inst. and Methods in Physics Research, A 894 (2018) 81–86

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

# Electron beams scanning: A novel method

M. Askarbioki [a,b], M.B. Zarandi [a], S. Khakshournia [b,*], S.P. Shirmardi [b], M. Sharifian [a]

[a] Atomic & Molecular Group, Department of Science, Physics Factually, Yazd University, Yazd, Iran
[b] Nuclear Science and Technology Research Institute (NSTRI), Tehran, Iran

ARTICLE INFO

*Keywords:*
Electron beam scanning
Waist size
Knife edge technique
Wire scanner

ABSTRACT

In this research, a spatial electron beam scanning is reported. There are various methods for ion and electron beam scanning. The best known of these methods is the wire scanning wherein the parameters of beam are measured by one or more conductive wires. This article suggests a novel method for e-beam scanning without the previous errors of old wire scanning. In this method, the techniques of atomic physics are applied so that a knife edge has a scanner role and the wires have detector roles. It will determine the 2D e-beam profile readily when the positions of the scanner and detectors are specified.

## 1. Introduction

Nowadays, the use and promotion of accelerators are rapidly increasing [1–3]. Electron and ion accelerators are widely used in industry, medicine, agriculture and research projects [1]. One of the most important factors in this research is the type and shape of the beam profile being used. For instance, sometimes it is impossible to get the best results from dosimetry research without having optical parameters of the beam [4]. At LINAC and proton and ion accelerators their minimum transverse emittance is already defined by the source, therefore the measurement of the emittance near the source is important to optimize the beam parameters [5–7].

There are currently a variety of methods to scan the spatial profile of electron beams for industrial and laboratory uses. The most common method is Wire Scanning (WS) in which a conductive wire is moved through the electron beam. An electric current is than generated by the collision of electrons or charged particles with the wire (typically by secondary electron emission) and is measured in terms of the position of the wire [8–11]. Since scanning in one direction, provides only a transversal projection of the beam in one dimension, a group of researchers has used rotating wires [12] or a V shape orientation of the wires [13] to obtain a 2D profile of the beam with a single device. However, using the conventional methods of the WS, including Laser Wire Scans [5,14,15], two one-dimensional scans may not give a comprehensive overview of the beams distribution of particles in case of non-Gaussian beam profiles types [16]. The use of scraper scans is also a common method for measuring beam profiles in which the beam is scraped. However, some precautions must be taken to achieve accurate results [17,18].

In this report, the measurement of the complete 2D electron beam distribution is done by using thin wires in combination with a moving scraper close to the wires. In this method an attempt has been made to resolve the errors and shortcomings of the previous approaches. Although by establishing soft computing paradigms, the beam profile can be calculated [19]. The advantage of the proposed method compared to other methods such as laser wire scanning is that this method is also capable of accurately measuring the divergence angle of the electron beam.

## 2. Methodology

The new method combines two procedures of electron beam scanning, the WS in nuclear physics and the knife-edge technique in atomic and molecular physics [20]. In fact, in this method; the Wire Scanning with Knife-edge Technique (WSKT), the detector is a conductive wire and what sweeps the area is the edge of the blade. For better understanding, consider the following picture.

Fig. 1, illustrates a view of the cross-section of a transmission electron beam, the edge of the blade and a conductive wire located behind the edge of the blade. The conductive wire along $y$ and the edge of the blade along $x$ are replaced carefully. Imagine that, due to the displacement, the conductive wire is situated in $y_n$ and the edge of the blade is situated in $x_n$ (see Fig. 2).

Now, the amount of the current that the ammeter shows is recorded ($i_n$). Then without moving the wire, the edge of the blade is moved to the next position of $x_{n+1}$, as much as $\Delta x$ (see Fig. 3).

* Corresponding author.
*E-mail address:* skhakshour@aeoi.org.ir (S. Khakshournia).

https://doi.org/10.1016/j.nima.2018.03.062
Received 31 May 2017; Received in revised form 10 January 2018; Accepted 21 March 2018
Available online 28 March 2018
0168-9002/

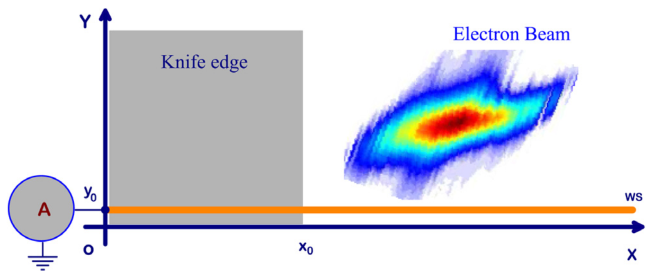


**Fig. 1.** A view of creation of WSKT method.

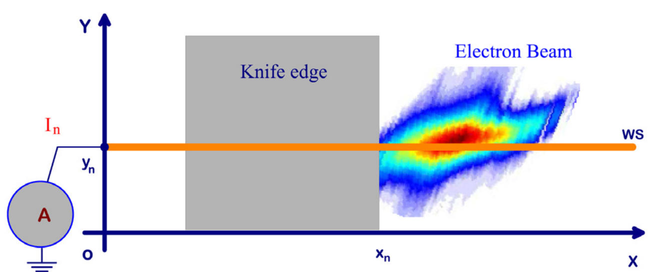


**Fig. 2.** Displacement of WS and the edge of blade in WSKT method.

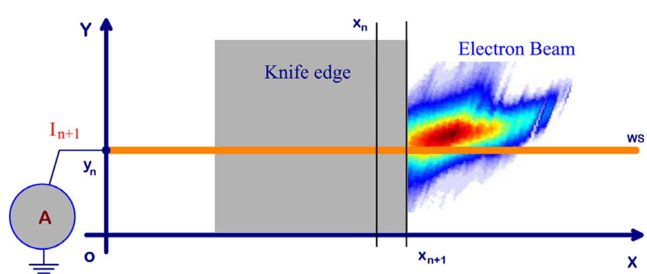


**Fig. 3.** Slight displacement of the edge of the blade and placing it in position. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

After this displacement, the amount of the current passing through the ammeter, ($i_{n+1}$), is read. Clearly, the new current is smaller than the previous one ($i_{n+1} < i_n$); as in the new case (Fig. 3) the greater amount of the beam, though slight, is covered. Obviously, the area of the edge of the blade must be larger than the approximate size of the cross-section of the electron beam, and its thickness and component must be designed in a way that the electron beam with 10 MeV energy does not pass through it.

It is logical to attribute the difference between these two currents ($i_n - i_{n+1}$) to the current passing through a small insulated piece of wire having the length of ($x_{n+1} - x_n$). This small piece is shown in Fig. 3 as a blue element. So it can be argued that the low electric current passing through the wire with the length of ($x_{n+1} - x_n$) at the coordinate ($\frac{x_{n+1}+x_n}{2}, y_n$) has been measured.

If this procedure is repeated, the electric current passing through the small element of wire can be measured in all parts of the plane. In other words, the current passing through the xy plane can be examined point by point and the plane can be divided into small hypothetical pixels.

As seen in Fig. 4, the use of the WSKT is dividing the swept plane into small elements and measuring the electric current passing through each one. Finally, the two-dimensional scan or the topography picture of electron beam profile is achieved. If one uses the WSKT to scan the electron beam, it will take a long time, about several ten minutes, but the suggested method requires less time. To achieve this purpose, several conductive wires can be applied simultaneously.

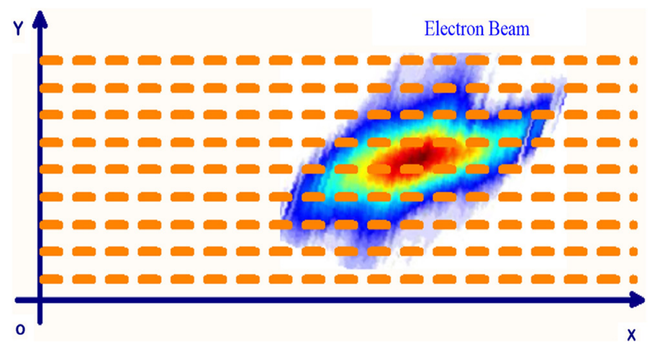


**Fig. 4.** A hypothetical view of plane using WSKT.

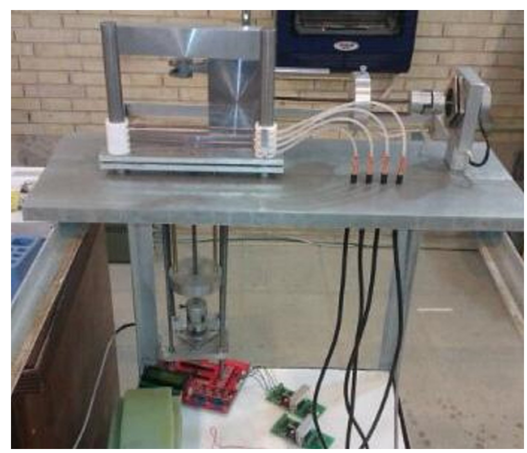

**Fig. 5a.** Design and construction of beam scanner setup.

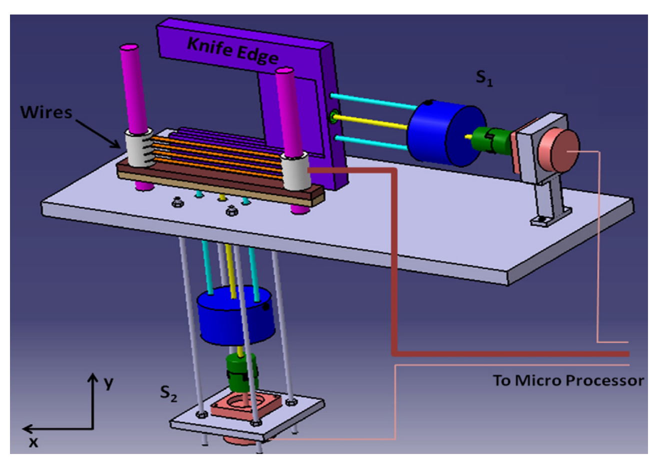


**Fig. 5b.** Schematic view of the experimental WSKT.

As shown in Figs. 5a and 5b, the number of the steps of conductive wire procedure will increase as their number decreases because the steps of each of these wires are up to the position of the next wire. In addition, the amount of current passing through each of the wires according to their own position and the edge of blade at each stage of the motion of the stepper motors will be recorded by an electronic microprocessor. The microprocessor stores the received data according to the algorithm described above.