

# MEASUREMENTS OF BEAM CURRENT AND ENERGY-DISPERSION FOR ION BEAM WITH MULTI-COMPONENTS\*

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## Abstract

The multi-component ion beam is very common in nuclear physics, materials physics and most kind of ion source. But the diagnosis of multi-component ion beam [1] can be difficult because of its complex composition and irregular energy-dispersion. We need an effective way to analyze the multi-component ion beam. There is a multi-component ion beam whose total beam current varies from 1 mA to 50mA and the beam energy can be 20keV to 150keV. In this paper, four methods to analyzing this multi-component ion beam are described, which are Faraday cup array, fluorescent screen with Faraday cup, movable aperture with conductive fluorescent screen, and current calibration method, respectively. The distributions and currents of the separated ion beams are obtained by means of the four methods, and the current and energy-dispersion of each component might be measured at the same time. This is of special interest for beams with multi-components. Detailed description and comparison of the four methods are discussed in this paper.

## INTRODUCTION

The multi-ion beam is widely used in nuclear physics experiments and material modification. In most of cases, the beams extracted from the ion source are multi-component because there always have some impurities and different ionization state. The composition and energy-dispersion of the beam extracted from the ion source are kernel parameter of an ion source, and it also has a great influence on the beam transportation. It's necessary to develop an effective way to analyzing the multi-component ion beam. Not just for nuclear physics and materials physics, this might have special interest for all kind of ion source.

There is a multi-component beam coming from ion source whose total current varies from 1mA to 50mA and the beam energy can be 20keV to 150keV. The beam contains more or less six kinds of particles and the energy can be 20keV to 150keV. In order to research the composition of the multi-component ion beam, an orthogonal magnetic and electric fields is used to separating the ions with different charge-mass ratio. With numerical simulation, we expect that after the beam

crossed the orthogonal magnetic and electric fields the separated ions may have five groups of distribution which was showed in figure 1.

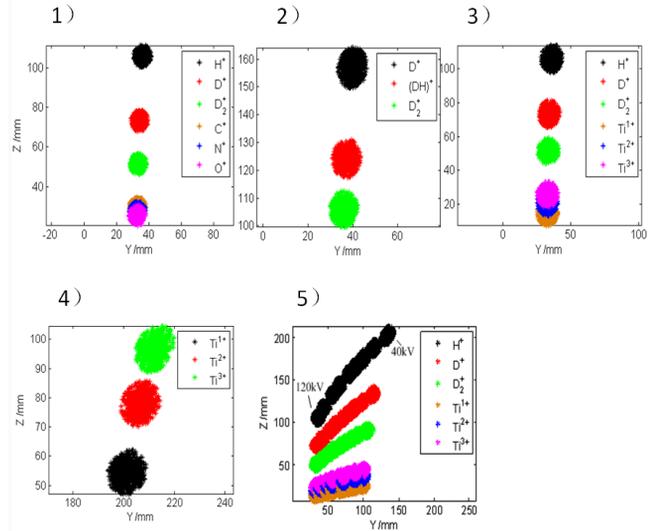


Figure 1: 5 possible distributions of the separated ions

## FOUR METHODS TO ANALYZING THE MUTI-ION BEAM

In order to research the composition of this multi-ion beam, four methods are presented in this paper

### Method 1: Faraday Cup Array

We use independent faraday cups to install in array and use appropriate acquisition circuit connect each faraday cup to the computer [2]. The faraday cups must to be isolated with each other. It difficult to make the faraday cups smaller than 3mm because of the Install difficulty. The sketch of this device is showed in figure2. In this way we can get the distribution and the current in the same time.

This may be very simple for the operating and we can complete the measurement in just one pulse. Each of the independent faraday cups needs an amplifying circuit. The smaller of the faraday cups the higher of the measurement accuracy. But the smaller of faraday cups result in each faraday cup got smaller current, which means needs more and better amplifying circuit, means higher cost. On the other hand, it's very difficult to install small faraday cups as a detect matrix and isolated with each other. So the accuracy of the distribution measurement can be hardly smaller than 3mm.

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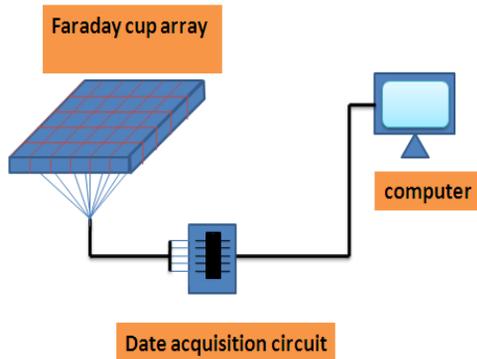


Figure 2: Faraday cup array

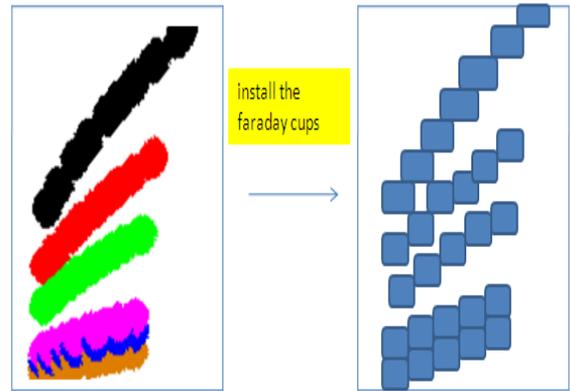


Figure 4: Second step: install the faraday cups

*Method 2: Fluorescent Screen and Faraday Cup*

Fluorescent screen [3] is a sheet of material coated with a fluorescent substance so as to emit visible light when struck by ionizing radiation. Using fluorescent screen may solve the problem of amplifying circuits in the first method. We need two steps to complete the measurement. First, we use the fluorescent screen to get the distribution of the separated ion beam which may be like figure 3. A CCD camera is needed to get the picture and transmitted it to the computer. Then, we install the faraday cups in the necessary place according to the first step.

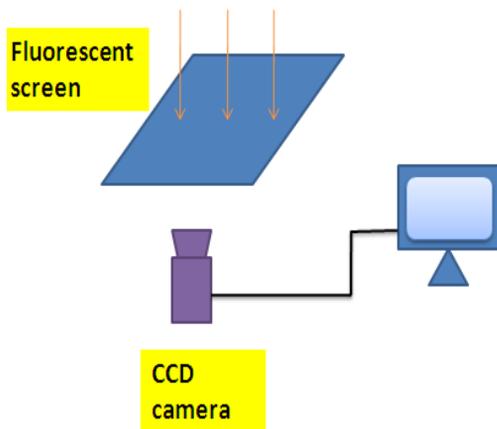


Figure 3: First step: use the fluorescent screen to get the distribution

By this way, we can greatly reduce the number of faraday cups and the amplifying circuits. But there are two step, we can't get the currents and distribution in the same time. Between the two steps there exist a broken of vacuum, which means that requires the beam have a good repeatability and waste a lot of time. The accuracy of the distribution measurement can be no more than 3mm because of the size of faraday cup.

*Method 4: A Movable Aperture and Conductive Fluorescent Screen*

The third way is using a movable and variable size aperture which made of four insulating barriers each connecting to stepper motor to select the target area but block out others (figure 5). We use a conductive fluorescent screen to get the total current and the distribution. The movement and the size changing of the aperture are guided by the picture from the fluorescent screen, because the fluorescent screen is a conductor so we can get the current of the target area (figure 6). Repeat this step we can get the currents of each kind of ion beam.

This method can avoid vacuum break up and complex circuits. It also has a high precision in position measurement upon the stepper motor. However, we would get a complicated mechanical structure and a long time measurement. This means a good repeatability is required to accomplish the measurement.

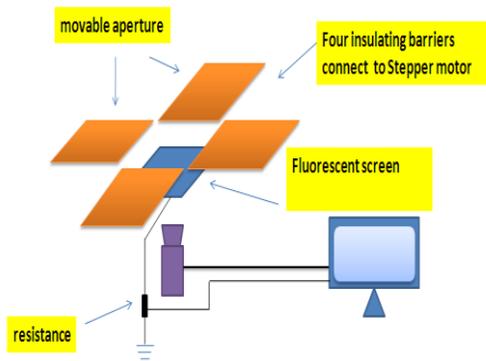


Figure 5: The structure of the third method

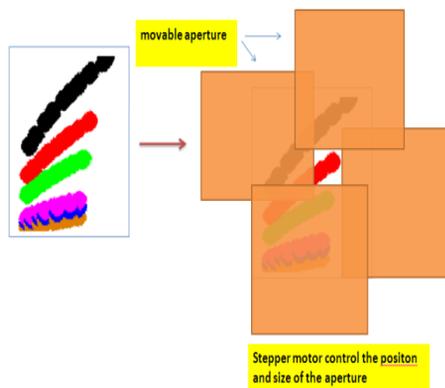


Figure 6: Stepper motor control the position and size of the aperture

*Method 4: Current Calibration Method*

The fluorescent screen gets the beam distribution of the ions from its luminance distribution. The current must have some connection to the luminance [4], too. We can use some faraday cups to define the connection between the luminance and the current for each kind ion. If we get the function relationship between the luminance and the current, we can get the current distribution easily from the picture of the fluorescent screen. The numerical simulation makes us have a rough idea of the distribution of each kind of ion. Move the faraday cup to the exactly position use the stepper motor ,only one small faraday cup is enough to get the function relationship between the current and the luminance. Computer can analysis the picture and get the current of each ion (figure 7). To get an ideal result demand the fluorescent screen can be never saturated and a stable function relationship between the luminance and the current is needed.

Once the calibration completed, no other calibration is needed in the same condition. We can get the distribution and the currents from the luminance distribution. That means there are no vacuum broken or complex circuits, and we can complete the measurement in just one pulse.

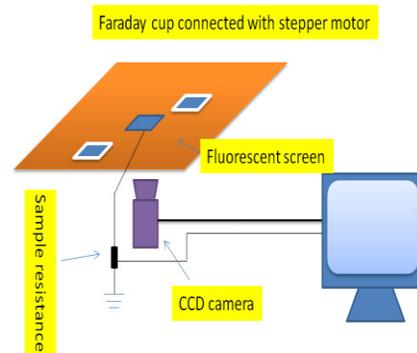


Figure 7: Faraday cups calibration method

It also has high accuracy in current and position measuring which are only limited by fluorescent screen and the calibration. But all those are based on the stable function relationship between the luminance and the current, and there must have no saturation.

**CONCLUSIONS**

Four methods have their advantages and disadvantages. Faraday cup array method is instantaneous measurement and has a simple structure and simple operating, but it has too many amplifying circuits and in low accuracy. Fluorescent screen and faraday cup method need fewer amplifying circuits but there is a vacuum broken during the measuring and also in low accuracy. A movable aperture and conductive fluorescent screen method can avoid vacuum broken and complex circuits, but it is very time consuming and need a good repeatability condition. All the 4 methods, the faraday cups calibration method maybe the most convenience and clever way. It has no vacuum broken and complex circuits, what is needed just a current calibration. But we are not sure whether there is a stable function relationship between the luminance and the current. After all, each method has its merit, further study should depend on experiment, measurement requirements and the beam quality will determine which one is the best.

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