# ION SPECTRA IDENTIFICATION SOFTWARE FOR THE ECR ION SOURCE AT NAC

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## ABSTRACT

A microprocessor based software package to aid in ion identification has been developed at the NAC. The package automates the scanning process and aids species identification by displaying theoretical peak positions. The analysing magnet current is accurately controlled giving high resolution scans over any analysing magnet current range. Provision is made for automatic recording of beam stability. Complete ion source setup information as well as the graph is recorded. It uses a graphical user interface and runs on top of the OS/2 multitasking operating system. A description of the system is presented.


## 1. INTRODUCTION

The National Accelerator Centre (NAC) operates a 200 MeV separated sector cyclotron (Main Cyclotron) together with two injector cyclotrons (SPC1 and SPC2)[1]. The latter has two ion sources: an electron cyclotron resonance (ECR) ion source and an ion source for spin aligned ions (ISI) (see Fig. 1).

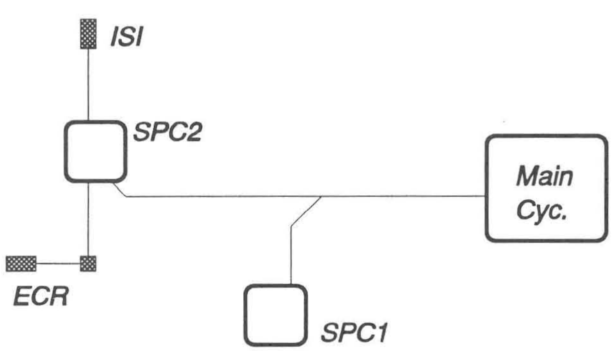


Fig. 1. Schematic Layout of NAC Cyclotrons.

Figure 2 illustrates the ECR ion source. The analysing magnet is used to select the ion with the required mass number and charge state.

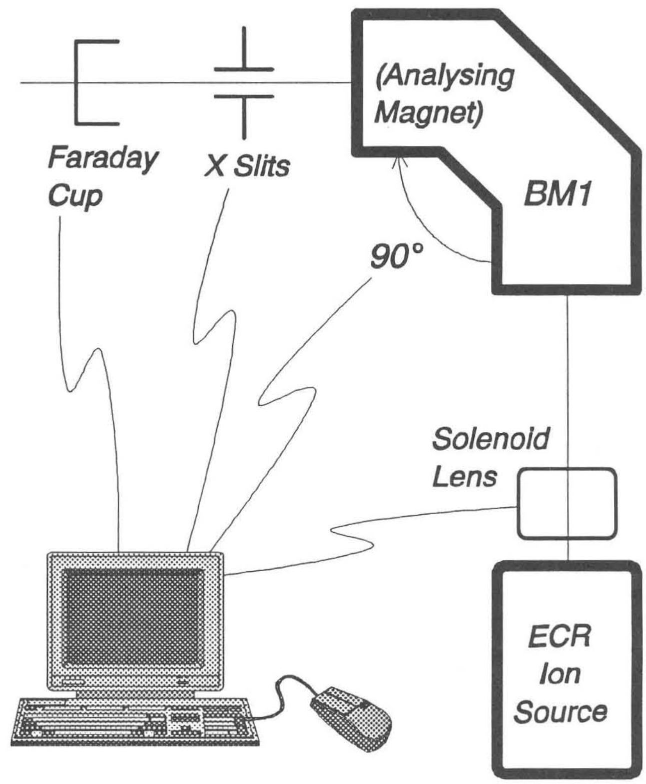


Fig. 2. Schematic Layout of the ECR Ion Source.

It was with a view to aiding the selection process that a program capable of controlling the analysing magnet and recording beam intensity on a Faraday cup was written.

## 2. ORIGINAL METHOD

Tests of the ECR Ion source were done with a 104° analysing magnet with its object focus point on the extractor and the image focus point on a Faraday cup. Currents measured on the cup were viewed on a storage oscilloscope. For a permanent record photographs of the ion spectrum were taken and ion source settings had to be tabled by hand.

The ECR ion source at the NAC has a solenoid lens located between the 90° analysing magnet and the ion source to focus the beam. The analysing magnet can be scanned from 0.0A to 10.0A. A set of slits in front of the Faraday cup can be adjusted to cut off unwanted beam or to obtain better definition of mass numbers of a certain charge state, for example $Kr^{9+}$.

The spectra of the first heavy ion beam were recorded on an X-Y plotter. Ion source settings once again had to be tabled by hand and corresponding plots attached, taking care not to mis-identify charge states.

The major disadvantages of this approach were:

- the difficulty in matching observed peaks with an ion;
- the possibility of making a mistaken identification, and
- identification was time consuming.

## 3. COMPUTER AIDED METHOD

### 3.1 Principle

As a PC was already in place for controlling the slits and the solenoid lens, it seemed reasonable to put it to work on the ion source as well. The idea was essentially simple: to store ion source settings along with the corresponding graphical spectra on disk and to be able to recall those settings and spectra for later reference. The computer must set the analysing magnet coil current (it should also read a return signal confirming the actual value) and read the beam current (on a Faraday cup).

In order to investigate the entire ion spectrum the software performs an automated scan by varying the magnet coil current between two user specified values (for example, from 0.0A to 10.0A) and plots the beam current *vs.* magnet current, which is displayed on the video screen.

Once the operator has identified at least two peaks of an element, for example helium, a constant $K$ for the system can be calculated; viz.:

$$\frac{q}{m} = K\frac{V}{I^2} \qquad (1)$$

where
$V$ is the extraction voltage,
$I$ is the magnet current,
$q$ is the charge on the ion, and
$m$ is the mass of the ion.

With this constant the program can calculate the positions of the charged states of any isotope and display these theoretical positions as an overlay on the graph. The analysing magnet current can then be set to the desired peak within 1mA and the operator can optimise the ion source. A rescan - usually over a much smaller range - will update the beam spectrum, and the graph and setup parameters of the ion source can be saved to disk.

Once $K$ has been found for each of the various extraction voltages it can be used thenceforward without recalculation.

### 3.2 Further Advantages

After installation of the software in its basic form as described above, it was apparent that the presence of the computer could help with a few other aspects.

#### 3.2.1 Beam stability analysis

While the scanned graph is displayed on the video screen, a free-moving 'dot' indicates the present magnet and beam currents being measured. This dot can leave 'high' and 'low' markers behind to indicate the peaks and troughs of beam current. These markers are made to persist for a while so the operator can get an idea of the stability of the beam and so that variations too fast for the eye to follow are nevertheless noticed.

To make this feature more useful the software keeps a record over time of these maxima and minima averaged over a user specified period. This is then displayed as a plot of maximum, minimum and average beam current *vs.* time (see Fig. 3). The plot is saved to disk along with the scan information and ion source parameters.

#### 3.2.2 Data storage/retrieval

Obviously being able to save data to disk is a tremendous advantage. Not only can previous graphs be called up for comparison, but all information pertaining to the ion source itself can be retrieved enabling the operator to quickly reproduce the same beam.

#### 3.2.3 Fine adjustment of magnet current

An unexpected advantage was the improvement in control over the analysing magnet coil current. The manual method relied on a rotary dial which provided good fine adjustment. Computer control via the DAC* is, however, much easier to use. With the mouse the operator can smoothly sweep the current through a range of values (using the dial the current tends to jump around) as well as directly set a specific value.

#### 3.2.4 Distributed control system

The NAC is in the process of converting its control system to a distributed set of microprocessors linked via

* Digital to analogue converter.

an Ethernet LAN[2]. The presence of this computer at the ECR ion source lends itself to connection to the new control system as an instrumentation node. It is conceivable that the graphical data could be displayed on the central graphics node and the entire source operated under remote control.

### 3.3 Results

Figure 3 is an example of a typical screen display after an automatic scan.

In this case the analysing magnet was scanned from 3.20A to 4.30A in 200 steps. At the right side of the plot can be seen the value of the calibration constant, $K$ = 2.7235. Above the graph itself are displayed some overlays for He, O, N and C. It can immediately be seen how these overlays help in identifying the ion species present.

To the right of the graph the word *SLOW* indicates that the operator has chosen to use the slower and more accurate DAC which updates the screen only twice per second. A *FAST* setting uses a slightly lower accuracy DAC but updates ten times each second. The number below (e.g. *3.950*) indicates the actual setting of the analysing magnet current. This value is set via the mouse: a digit is selected by double-clicking and then is made to run up and down with the two mouse buttons. This proved to be a most satisfactory way of adjusting the current. Above this, *Im* and *Ib* refer to the actual magnet and beam current values.

When the mouse pointer is moved into the graph area a crosshair appears and the beam current and magnet current corresponding to the crosshair position are indicated (the cross-hair has been removed to prevent clutter in an illustration that has been much reduced in size). Also visible on the $^{14}N^{5+}$ peak (a bit below the maximum) is the 'dot' which indicates the present beam and magnet currents.

The broken lines running across the graph near the top are an example of a beam stability plot: in this case the minimum, maximum and average beam value were recorded from 13:58:25 to 14:08:33. When a beam stability plot is displayed the time corresponding to the crosshair position is also displayed.

Along the top of the screen are a number of menu options available to the operator. These are chosen by mouse (or with keyboard accelerator keys). For example, a scan will be started from a menu option.

Lastly, it should be pointed out that plots on the colour computer screen are naturally clearer and can show more information than can be reproduced here.

Figure 4 illustrates the ECR ion source parameters stored for each plot; this particular set pertains to the plot of Fig 3 (optimised for $^{14}N^{5+}$).

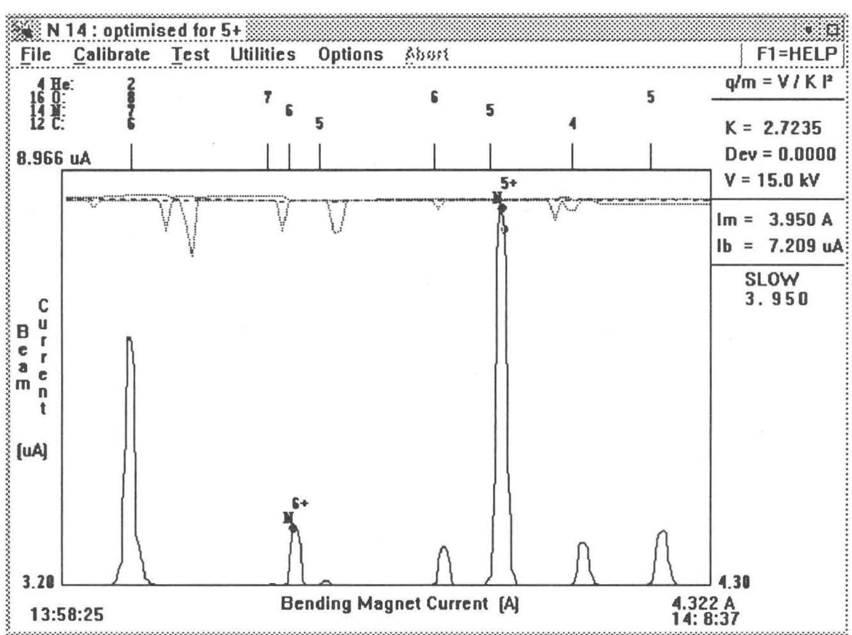


Figure 3. ECR ion source plot for a $^{14}N^{5+}$ beam.

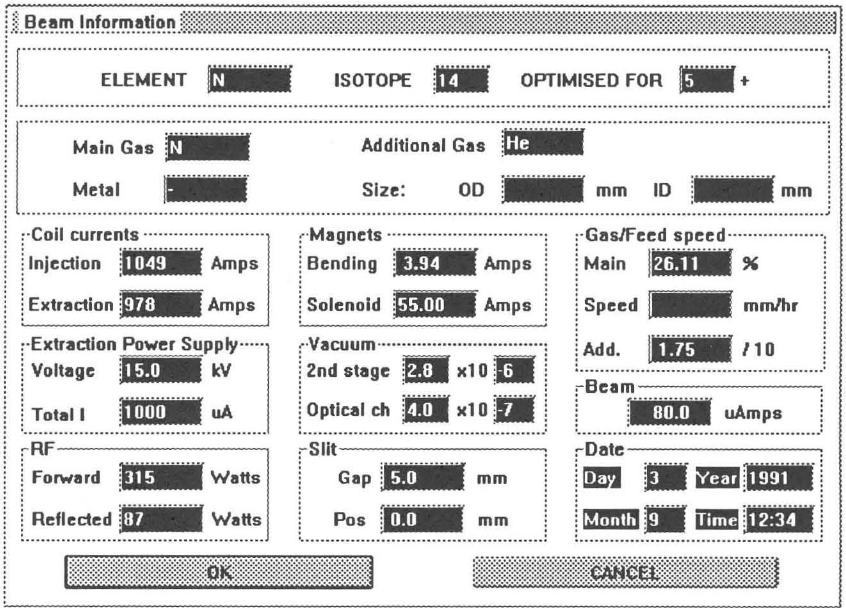


Fig. 4. ECR ion source information stored for each beam.

Figure 5 is included to illustrate a plot for Krypton in which each charge state has been resolved further showing the different mass numbers, namely $^{82}$Kr, $^{83}$Kr, $^{84}$Kr and $^{86}$Kr.

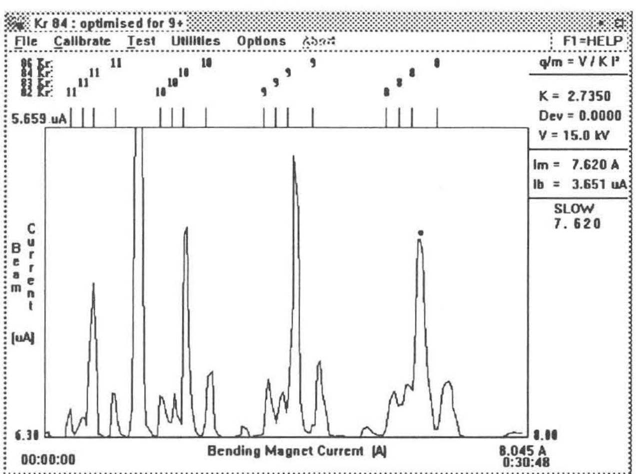


Figure 5. Plot illustrating different mass numbers.

### 3.5. Hardware

The microprocessor is a 25MHz Intel 80386DX with 8MB of RAM running the OS/2 v1.3 operating system. It has a 40MB hard disk drive and VGA screen. Input is via a mouse and keyboard.

Locally developed hardware is used for controlling the analysing magnet power supply as well as for reading the beam current. This hardware resides in a separate crate (SABUS crate) and communication from the crate to the PC is via locally developed differential drivers. Naturally the analysing magnet power supply must be electronically controllable.

## 4. CONCLUSIONS

The major initial objective of this software was to aid in the identification of ion species, the manual method of comparing plots with pre-prepared schematic graphs being cumbersome and prone to error. Not only was this objective achieved but a number of other advantages came to light; namely, improved control of the analysing magnet, automatic recording of beam stability, easy retrieval of past data (both graph and ion source parameters) and the possibility of remote control.

## 5. REFERENCES

1) du Toit, Z. B. et al, "Progress with the NAC Injector Cyclotron for Heavy and Polarised Ions", this conference.
2) Weehuizen, H.F. et al, "The New Distributed Control System of the NAC", this conference.