

DEVELOPMENT OF EMITTANCE SCANNER SOFTWARE FOR ISIS

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Abstract

The ISIS facility, based at Rutherford Appleton Labs in the UK, provides an intense source of neutrons and muons for condensed matter research. The proton accelerator delivers an 800MeV beam, pulsed at 50Hz to the target station. The development of new software to control the emittance scanners on ISIS and the proposed Front End Test Stand (FETS) system is discussed. The software has been tested using the emittance scanners on the Ion Source Development Rig (ISDR) [1] at ISIS. Written mainly in C and C++, the software has major benefits over the previous software written in Labview. A full scan of the phase space can be completed in one operation; a key improvement over the old system. The modern code also allows alterations to be made quickly and easily.

INTRODUCTION

Emittance

For ISIS and all other accelerators, it is important to keep the beam emittance as low as possible so as to transport and accelerate the beam effectively with minimal beam loss. Emittance growth around the accelerator is inevitable, so minimising the emittance is important to maximise transmission. Having the ability to measure beam emittance accurately is necessary both on ISIS and when doing research and development on apparatus such as the ISDR. [1].

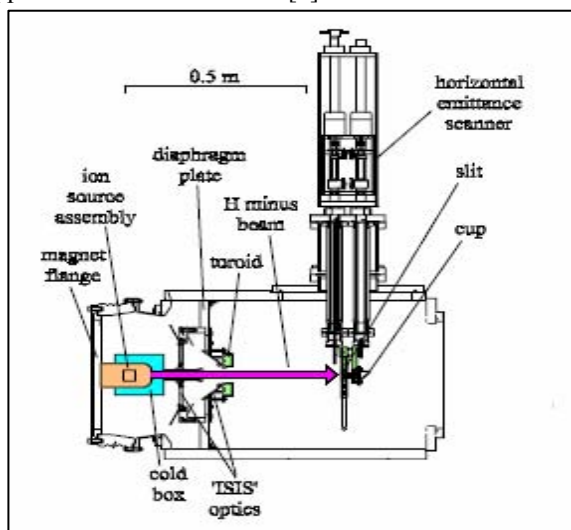


Figure 1: Plan view of the ISDR setup at RAL

ISDR

The ISDR was initially set up at RAL to fully characterise the ISIS Penning ion source and research possible improvements to the ion source for ISIS and future accelerators. Emittance readings have been, and will continue to be, vital in highlighting the improvements or any worsening effects on the beam through making a change to the ion source or running parameters. Figure 1 shows a plan view of the ISDR setup and the location of the horizontal emittance scanner with respect to the ion source. The vertical scanner is positioned at the same distance from the ion source, only rotated by 90 degrees around the beam axis.

Emittance Scanner Hardware

The emittance scanners were originally set up at ISIS in 2002 [2]. They are of a Faraday cup and slit arrangement, controlled by McLennan stepper motors.

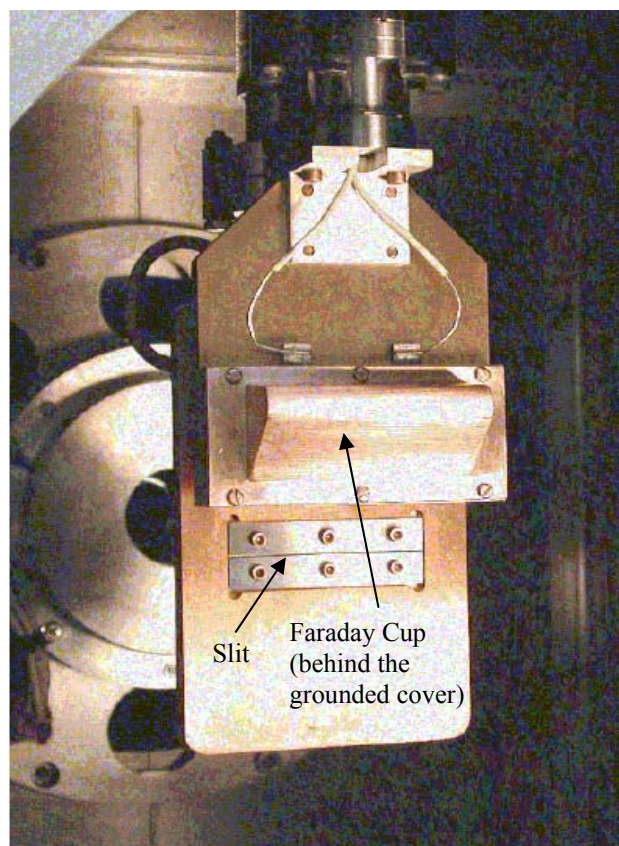


Figure 2: Vertical cup and slit scanners

The H⁻ ion beam first passes through the slit and is then collected in the faraday cup positioned directly behind. The slit and faraday cup can be identified in figure 2. There are two scanners; horizontal (of which a plan view is shown in figure 1) and vertical (shown in figure 2). Each has three axes controlled by stepper motors. For the horizontal scanner, axis 1 controls the main arm which moves the whole slit and cup assembly. Axes 2 and 3 allow adjustment of cup and slit position. The stepper motors controlling the axes can accurately move in 1.25 μ m steps and can therefore capture high resolution emittance measurements.

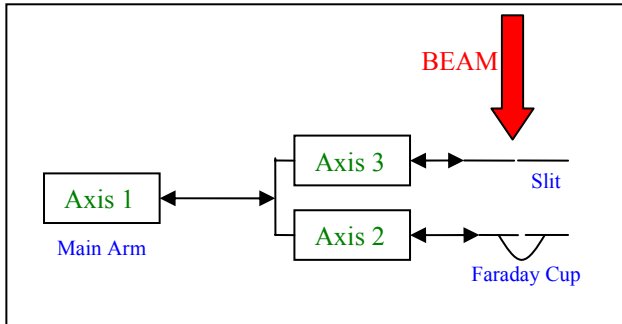


Figure 3: schematic diagram of horizontal scanner axes

The vertical scanner uses axes 4, 5 and 6 to control the main arm, cup and slit.

Using both horizontal and vertical scanners, the whole phase space can be covered and emittances calculated for both directions.

SOFTWARE

There are two main parts to the emittance scanner software: communicating with the stepper motors to control the movement of the slit and cup; and collection of data. These two processes are controlled through a graphical user interface (GUI).

Scanner Movement

To cover the whole of the phase space, the slit and cup must move in a specific manner where the slit moves into position and the cup scans over a range downstream from it. This is repeated for a number of regularly spaced slit positions until the whole of the beam has been scanned.

To move the main arm, slit and cup, command strings are sent to the stepper motors. The motors are controlled using commands sent from the computer via an RS232 connection. In addition to single command signals and manual jog signals, *sequences* of commands can be built up and sent to the motors.

Before commands can be sent between computer and motors, the port parameters must be initialised. These include the baudrate, parity, number of stopbits and number of databits. Third party serial port driver library code is used to send control strings to the stepper motors from the main C code. Figure 4 shows how a command can be sent to the stepper motors in the form of a string.

```
ParkCup()
{
    SioPutc (Port, n);
    LPSTR CmdPtr = "2MR800";
    CmdLen = strlen (CmdPtr);
    for (i=0; i<CmdLen; i++)
    {
        c = CmdPtr [i];
        if (c=='\r') c = '\n';
        SioPutc (Port, c);
    }
    SioPutc (Port, 13);
}
```

Figure 4: Sending a command to the stepper motor in the form of a string

This piece of code tells the motor controlling the axis 2 to move 800 steps (1mm) in the positive direction by sending the control string "2MR800" (Axis 2, Move Relative to current position, **800** steps) to the serial port.

The user can input a number of parameters to set up the emittance scan. These include the range over which the slit will scan and the number of slit positions to sample; the range over which to scan the cup and the number of angles to sample during this scan; and the number of time steps to sample over each pulse.

Once the user has entered the scanning parameters, a trajectory array is created with the positions (in number of steps) of the main arm, slit and cup. The movement of the axes is then controlled by the values in this array.

One of the main advantages of creating and using a trajectory array of positions is the ability to split the scan into two parts. This is often necessary because axis 3, which controls the slit position, has a finite range of movement of approximately 60mm. Therefore, if the user specifies a range of positions greater than this, the scanning must be split into two. Axis 1 will move to a new position so as to increase the available range of slit positions.

Axis1 (steps)	Axis2 (steps)	Axis3 (steps)	
.....			
80000	44000	43200	
80000	46000	45200	(Axis2 limit reached)
125000	3000	2200	(Axis1 moves)
125000	5000	4200	
.....			

Figure 5: part of a trajectory array, demonstrating the change in axis 1 position to allow a larger range of slit positions

The ability to split the scan into two sections was not possible with the previous software which made performing an emittance scan time-consuming and tedious.

Data Collection

The faraday cup on each scanner measures a current from the beam it collects. This current is converted into a voltage using a current amplifier set at $20\mu\text{A/V}$.

Collection of the voltage signal is realised using a Data Acquisition Processor (DAP). Signals are collected while the cup is scanning behind the slit. The beam from the ion source is pulsed at 50Hz. Therefore, if the cup scans and gathers data for 1 second, 50 pulses are collected. Providing the cup is moving at a constant velocity, each pulse will correspond to regularly spaced positions behind the slit. The speed of the motor, in steps/second, is altered depending on how many points the user wishes to sample. For example, if the user specifies sampling over 3mm with 60 points behind the slit, the speed of the motor is calculated as such:

$$3\text{mm} = 2400\text{steps};$$

$$\text{Time for scan} = 60/50 = 1.2\text{seconds.}$$

$$\text{This gives a velocity of } 2000\text{steps/second.}$$

Therefore, just before the scanning commences the command "6SV2000" (stepper motor number 6, Set Velocity 2000steps/s) is sent via the RS232 connection to the faraday cup stepper motor.

Synchronisation

Synchronisation between cup scanning and data acquisition is essential to calculate the correct emittance. The data collection must begin as soon as the cup starts scanning and end when the cup stops. For each slit position, Approximately 50 pulses should be captured (this can be altered by the user) to correspond with 50 angular positions behind the slit. Therefore the cup is scanning for approximately 1 second. To capture data from each beam pulse during this time, trigger signals are set up to trigger the DAP such that it collects data only when the cup is scanning and the when the beam is present. The first trigger is prepared by setting the read

port on axis 2 "low" as the cup begins its movement and setting it "high" once the scan has finished. The other trigger comes from the ISIS 50Hz timing pulse which occurs just before a beam pulse. As soon as the axis 2 read port is low, and a timing pulse is seen, the DAP is programmed to start reading in the pre-defined number of current readings. It will continue to acquire readings for each pulse until the read port returns to high (once the cup has stopped its scan).

Collision Avoidance

An important part of the software is ensuring that the scanners do not collide with each other, causing damage and misalignment. Before each scan takes place, all horizontal and vertical axes are parked. Then, while one scanner is in motion the other remains parked.

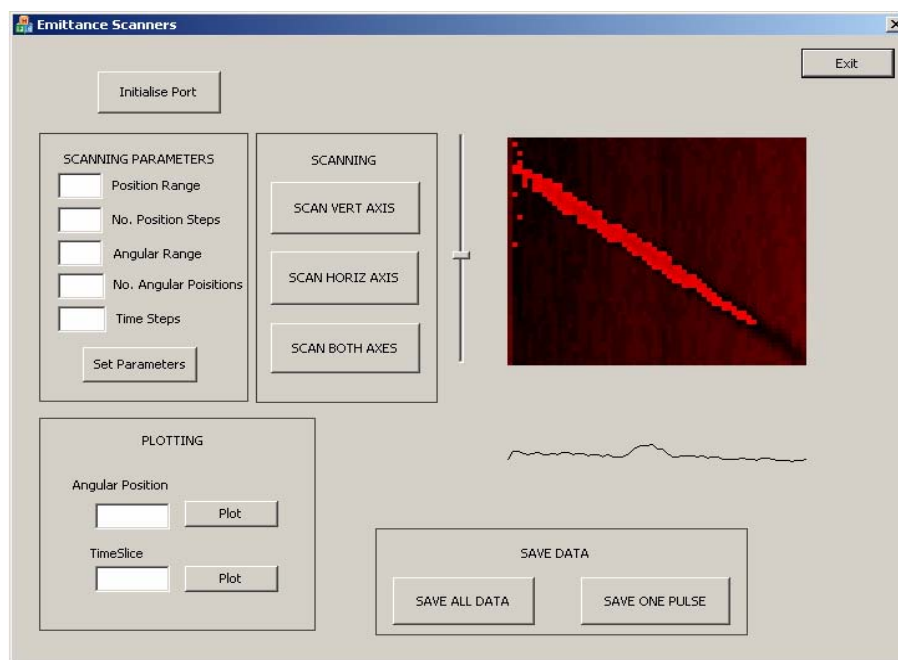


Figure 6: The Graphical User Interface showing an emittance plot from the new software and below it a cross-section through the centre of the emittance

CONCLUSION

The code is written in a modular style and can be easily modified, unlike the Labview code which had become large and unmanageable. This new software allows the user to complete scans effortlessly using a modern style GUI. It has the ability to scan both vertical and horizontal axes in one motion where the scan may be split into two sections if the position range is too large.

REFERENCES

- [1] J. W. G. Thomason *et al*, "Performance of the H- Ion Source Development Rig at RAL", EPAC'02
- [2] C. P. Bailey *et al*, "ISIS RFQ Emittance System", EPAC'02