

THE ISIS RFQ EMITTANCE SYSTEM

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Abstract

The hardware and software developed for emittance measurement on the ISIS RFQ is described. The Hardware has sufficient power handling capacity to measure the 665KeV beam at 50 mA and 10% duty cycle. It is capable of measuring the emittance with spatial resolutions of 0.25 mm and 4 mrad, and giving the time variation at better than 10 microsecond resolution. This is a slit and cup system with individual motion but mounted on the same arm, mechanically separate systems are used for each axis. The control is through a McLennan stepper motor interface, data collection is performed using a Microstar Dap system and the overall control and display programs are written in Labview.

1 PHILOSOPHY

The emittance scanners are designed to cover the phase area by using two separate motions and slits one defining the position of the sample and the other its angle. Each location is sampled on a separate beam pulse. The sample rate is sufficient that many samples can be taken within each pulse enabling examination of the time dependence of the beam. The fastest acquisition mode uses a continuous motion of the angle arm. This does give a very slight skew to the position of the end of the pulse. However, the displacement as a fraction of step width is the same as the duty cycle, and so, only gives a significant change if a very coarse resolution is being used. In this mode of operation, the position of the cup is sensed by the shaft encoders. This output is copied to the analysis program so the position of the cup at the start of each pulse is recorded. If the required speed is close to the minimum speed of the motors, a slower acquisition mode is used in which the cup is stopped for every sample.

2 HARDWARE

To enable the scanners to be used at 50 Hz in a 50 mA 665 keV beam from the RFQ, there are water cooling channels in the forward slit plate, which are designed to dissipate 5 W/mm². This is more than the power density at the centre of the beam. The mechanisms consist of independent slit and faraday cup arrangements mounted on a common actuating arm, fig 1,2. This arm moves the scanner into the beampipe or sufficiently far out to clear any other devices inserted into the diagnostic vessel.

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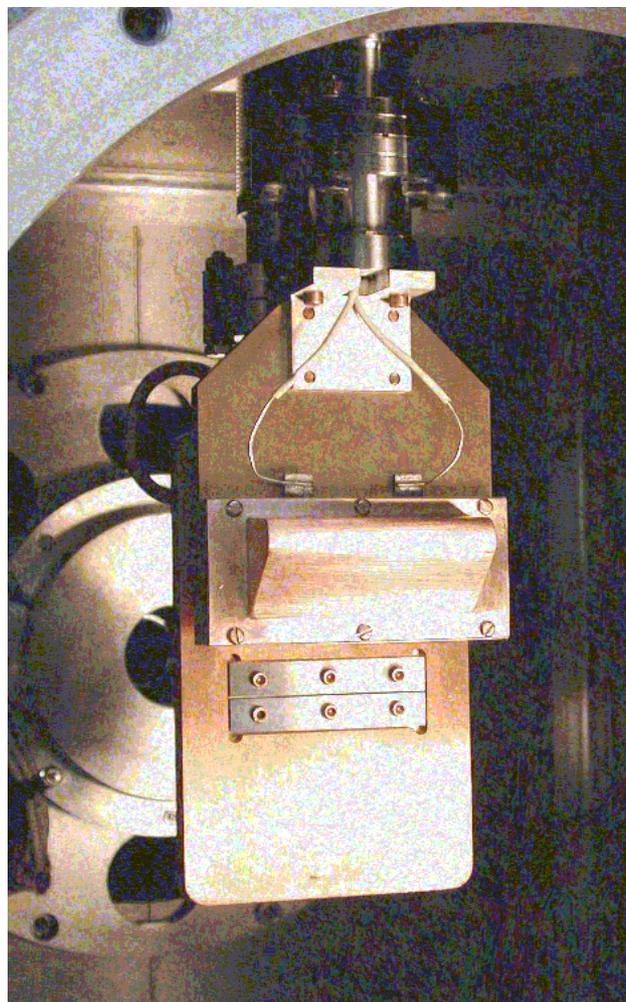


Fig 1 Close up of slit and cup.

The signal current collected at the faraday cup is transferred to the Microstar DAP, data acquisition processor via a Stanford Instruments current amplifier. The amplifier is in the control room so the unamplified current is carried on a shielded twin core cable for noise immunity. The faraday cup has a 500 V suppressor to prevent secondary emission causing problems. Each beam pulse can be sampled many times, with a minimum sampling interval of 9 μ S, over its duration giving a time profile of the beam. The motion of the scanners is driven by CoSm permanent magnet stepper motors controlled by McLennan [1] programmable stepper motor controllers and drivers. A 0.5 mm pitch lead screw gives a 1.25 μ m step size resulting in 16 steps per mrad. During use, pickup outside the expected beam has been quite strong and hence the cup design has had to be modified to include a grounded screen around the back of the cup. As

a temporary measure this has been implemented at the expense of the suppression plate, which has reduced but not eliminated the problem. The scanners were manufactured by Bird and Tole [2].

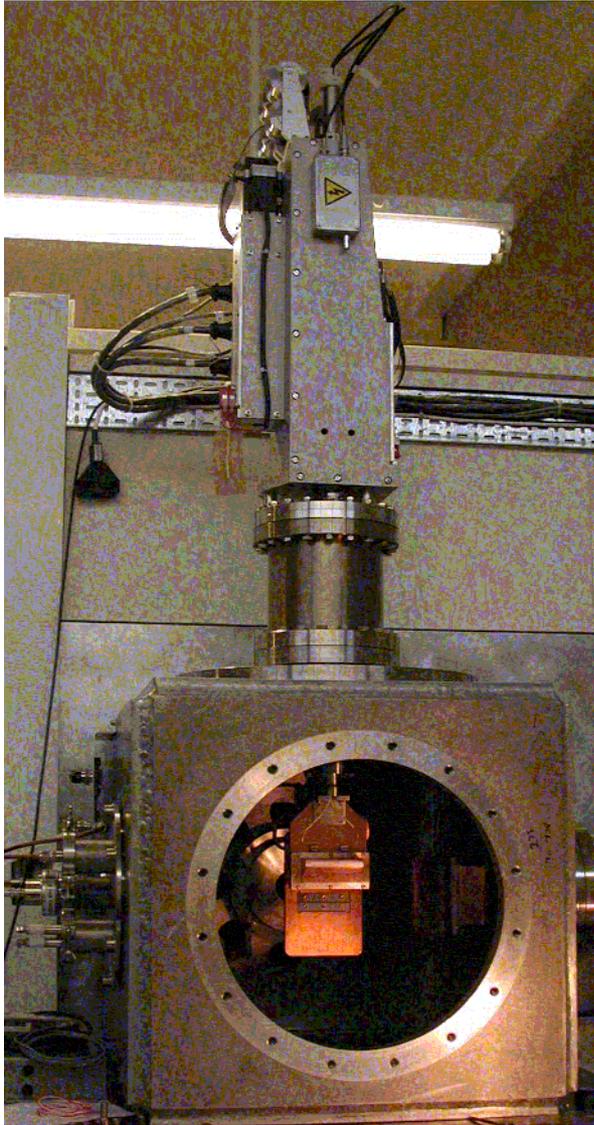


Fig 2 Scanner mounted in ion source test stand.

3 SOFTWARE

The whole system is controlled by 2 LabView programs running on the control PC one handling user interactions with the data and the second controlling the process of taking a measurement. The first presents the user with a front panel, fig 3, which enables them to set the axis and ranges to be scanned, it also provides for saving the collected data and viewing previously saved data. Some initial analysis of this data is provided, the beam centre, RMS emittance and twiss parameters are calculated for a selected time slice of the data. This time slice can also be saved for analysis by further programs. There is also a display of the pulse profile; this can be for an individual sample, the sum over position, angle or the whole beam.

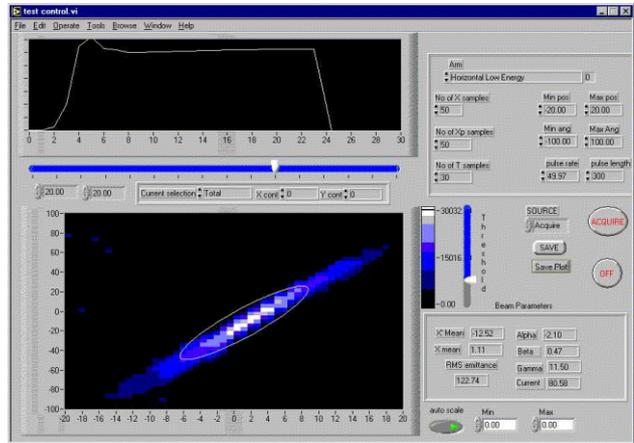


Fig 3 Screen shot of first program

Once a scan is initiated, the second LabView program takes over, fig 4. This loads and runs further programs on the DAP and McLennan drivers. Checks are made that all insertable diagnostic devices are parked. The repetition frequency is measured using a DAP program. The motion of the arms is controlled by a mixture of programming the motor controllers and providing instructions from the LabView program. Control sequences are programmed into the motor controller for the scans of angle. These wait for a signal from the DAP, move the cup a specified distance at a specified velocity, and then signal back to the DAP the move is complete. Control of all other movements is by instruction from the LabView program, which enables the system to be resilient to the motors stalling. The worst time for a stall to occur would be during an angle scan, which would cause the data in that scan to be incomplete, but the next move would be back to the correct positions. All other cases would have no effect on the data taken. A program is loaded into the DAP to synchronise data collection with the cup movements. This is triggered by an ion source timing pulse. The signal is sent to start the scan sequence in the motor controllers by using its IO ports. A data sequence of the requested length is acquired for successive angle samples after each trigger pulse until the motor controller signals its move is complete.

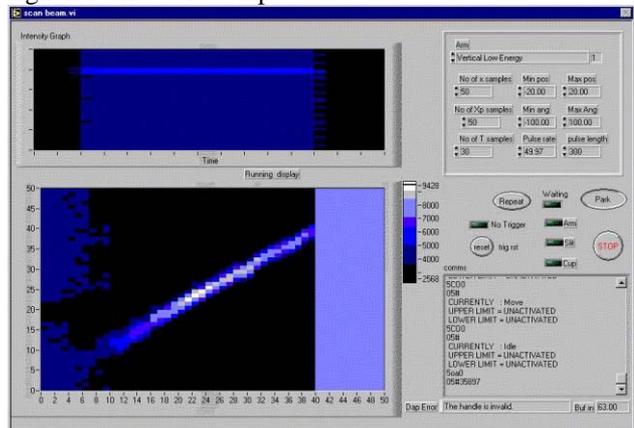


Fig 4 Screen shot of scanning program

This block of data, corresponding to one move i.e. a full set of angles at one position, is then passed back to the LabView program together with the encoder position value for each pulse. Each block is displayed as it is collected. When the full range of positions has been sampled, the choice is given to repeat the scan with changes to the range or resolution, or to keep the data and end the scan. If the scan is ended the scanner is parked and control is returned to the first program.

4 PERFORMANCE

The system uses a 0.25 mm position slit and a .08 mm angle slit separated by 20 mm, giving 4 mrad slit width. However, it is possible to oversample within this width, as the step length is 1.25 μm , fig 5. Typical step sizes are 0.8 mm and 2 mrad; in this case sampling is smoothed in the angle direction. The scanners take about 1 minute to move into scanning position or to park. At 50 Hz a 25 \times 25 scan takes around 2 minutes and a 50 \times 50 scan over the same area about 5 minutes. If the frequency is dropped to 25 Hz this increases to around 7 minutes. Analysing the movements of the scanners shows that there are still delays in the software that having nothing to do with the hardware limits or communications latencies.

The scanners have been operated for several months at both high and low energy locations and all evidence shows that there are no problems operating the system at 50 Hz and 665 keV, at the currents up to 35 mA.

5 PROBLEMS

The major outstanding problem is the background signal, of up to 10 μA . It is only present during the beam pulse and extends across the whole of the accessible phase space. It is significantly weaker in the 665 keV

diagnostics and its intensity is affected by the settings used in the LEBT, which suggests it is not entirely a function of the scanner. It is hoped that the shielding and suppresser voltage when used together will reduce this level significantly. There are also some intermittent communications problems between the DAP and LabView programs which have not been possible to isolate. These cause the system to fail to recognise the timing signal, which results in an incorrect measurement of the repetition frequency or collection of data that does not correspond to the beam pulse. This rarely happens twice in a row and so does not render the system unusable but needs correcting.

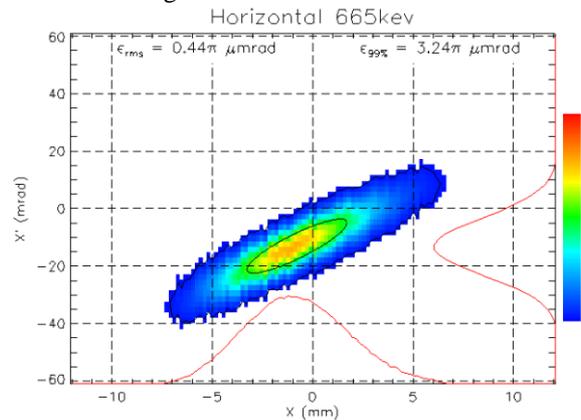


Fig 5 Typical emittance plot.

6 REFERENCES

- 1 www.mclennan.co.uk
- 2 www.birdtole.co.uk.