IMPROVING THE ISIS EMITTANCE SCANNER SOFTWARE

S. R. Lawrie, D. C. Faircloth, A. P. Letchford, ISIS, Rutherford Appleton Laboratory, STFC

Abstract

The software to drive the slit-slit emittance scanners at ISIS has been re-written in C#. The scanner driver routine is enhanced to improve accuracy, and to allow real-time monitoring of the scanning procedure. A multiple document interface allows quick comparison with other measurements and with data from particle tracking codes. Integrated data processing and emittance calculation removes the need to transfer data between multiple software packages, making experimental work more efficient. A user-friendly and robust interface allows easy scanning and generates publication quality emittance plots for presentations.

INTRODUCTION

Emittance measurements are important tools for classifying the quality of a particle beam. With future projects requiring ever smaller emittances [1], it is important to be able to accurately record phase space data and subsequently calculate emittance values in a consistent and justifiable manner.

The Ion Source Development Rig (ISDR) [2] at ISIS allows thorough testing of new ion source components on a replica of the ISIS ion source without needing to disrupt the main ISIS beam.

Figure 1 shows the arrangement of the equipment on the ISDR. A Penning-type surface plasma ion source creates a 60 mA H^- beam with energy of 35 keV. Immediately after the ground plane of the system is a diagnostics vacuum chamber. Attached to the chamber is a scintillation detector which can travel along the axis of the beam to measure its downstream profile. An optional pepperpot emittance measurement device can be mounted in place of the profile detector.

Transverse to the beam axis are vertical and horizontal slit-slit emittance scanner arms. To avoid collisions, the scanning arms must be safely parked away from the beam when operating the profile monitor and vice versa. The upgrade to the slit-slit scanner driver software is the concern of this paper.

There is a sister pair of scanners on the ISIS beamline whose arms are displaced from the beam by different amounts than those on the ISDR. The scanning software must be able to position the slits correctly on both sets of apparatus, without the need to modify the code.

SCANNER DRIVER SOFTWARE

The slit-slit scanner hardware is driven by McLennan stepper motors which move to an accuracy of 1.25 μm per step. The process of sending commands to the motors and calculating the positions and timings to give a complete scan is unchanged from the previous software [3], but the scanning code has been further optimised.
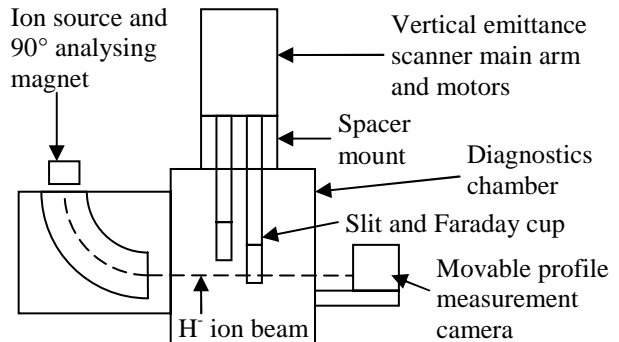

Figure 1: Side view of the ISDR apparatus. Horizontal emittance scanner omitted for clarity.

Justification for Re-writing the Software

The previous scanner software was written in C and C++. Whilst powerful and widely known languages, they make implementing any visual aspects to a Graphical User Interface (GUI) cumbersome. The new software is written in C# using the Microsoft Developer Studio .NET. C# uses the same coding style and memory management control as C++, but enables much simpler implementation of powerful Windows-based GUIs.

Unfinished sections of the program (e.g. missing axis scales; the facility to perform successive horizontal then vertical scans; importing of saved data) have been completed in the new code. However, more importantly, a whole suite of data analysis tools have been implemented.

NEW FEATURES ADDED

Multiple Document Interface

The new software is an entirely self contained, Windows-based system. This being the case, the overall main (parent) screen contains all the standard menus such as File, Edit and Window, as well as a set of toolbar buttons. Inside the parent screen are smaller (child) windows, in which the data is displayed, stored and analysed. The child windows are independent of each other so the user can, for example, be taking a new set of data from the slit-slit arms in one window whilst analysing data from several other previous scans, each in their own window. Windows are automatically arranged for tidy viewing. A typical view of the system is shown in Figure 2.

Multi-threading

Some of the features in the program require intense and sustained computer processing time; for example when a scan is being taken. In most programs, processes are completed in a single, linear chain. Any attempt to interrupt a process that takes a long time to complete generally leads to a system crash. However the emittance scanners *must* be reliably interruptible in case the user wants to abort a scan for some reason.

06 Instrumentation, Controls, Feedback & Operational Aspects　　　　　　　T03 Beam Diagnostics and Instrumentation
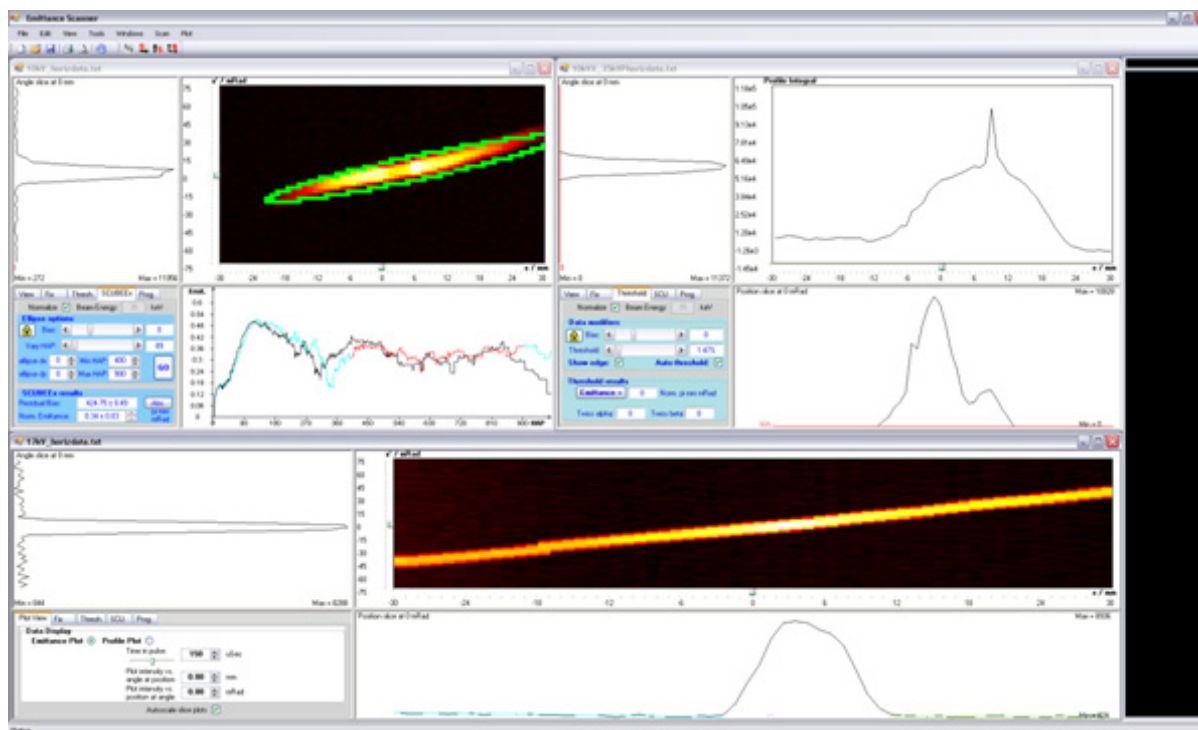
Figure 2: A typical screenshot from the emittance scanner software. Three child windows displaying different data are open. The black section on the right is the command interface to the scanning arm motors.

Additionally, the display must be continually updated to show newly acquired data and hence indicate the progress of the scan. Moreover, if the user wishes to analyse previously saved data whilst a new scan is in progress, the system must be able to complete both tasks concurrently. For these reasons, the emittance scanner software is multi-threaded throughout, enabling multiple processes to be completed at the same time and the user to have full control at all times.

Scanner Command Input and Real-Time Information

Using the previous software, if the scanning arms were motionless during a scan, the user was often unsure of whether the system was merely "thinking" temporarily or was completely stuck. This led to either force-quitting a scan unnecessarily and losing any data already captured, or frustrating periods trying to coax the motors into motion again. Windows Hyperterminal needed to be opened to communicate with the arms in the latter case.

The new software has a region of the screen where all commands sent and received to/from the stepper motors are displayed real-time. This allows the user to see exactly what the motors are "thinking" at all times. It turns out that periods of no motion are often simply the motors ensuring that they are safely parked and ready to move.

Additionally, a mock-up of Hyperterminal is implemented to allow the user to send commands to the motors and see the response from within the emittance scanner interface.

Config Files

No data referring to the set-up of the emittance scanner arms are hard-coded into the software. Instead, data such

as the maximum travel distance of the slit and cup are imported from a config file associated with each emittance scanner apparatus. Therefore, the software works on both the ISDR and on the ISIS scanners without having to modify the code, ensuring maintainability.

Previous Version Compatibility

To ensure compatibility with old data, headers are used at the start of stored files. This allows the program to deal equally well with both old and new files which may include emittance analysis results along with the raw data. Any future software updates would simply add extra file headers which the code will be able to handle just as well.

Data Display

The dominant feature of each child window is a histogram plot of the 2D phase space data at a certain time interval in the beam pulse. The histogram's colour map can be changed to a variety of styles (for example 'Hot' or 'Jet') from the parent menu. This function allows data displays to be compared with Matlab analyses. The time in the beam pulse is easily changed via a slider. The 2D histogram can be replaced by a 1D integrated profile of the beam to give a feel for the beam's real-space shape.

There is the facility to enhance the contrast of low intensity portions of the beam so that, for example, otherwise unnoticed faint "wings" stand out much more from background noise.

1D slices through the phase space data giving intensity as a function of angle and position are shown the left and bottom of the histogram plot, respectively. Slider bars on the x and x' axes of the 2D plot allow the user to take these intensity slices at any position or angle.

06 Instrumentation, Controls, Feedback & Operational Aspects

T03 Beam Diagnostics and Instrumentation

Display Image Capture

A facility to save an image of the currently displayed emittance plot or 1D slice plot has been implemented, allowing insertion of pre-cropped, high resolution plots into publications.

Beam Current Monitor

By integrating the beam intensity and multiplying by the sensitivity setting on the current amplifier, the total beam current as a function of time can be plotted. An example plot is shown in figure 3. The beam pulse shape can thus be studied in a way complementary to using a current transformer and oscilloscope, with good accuracy.
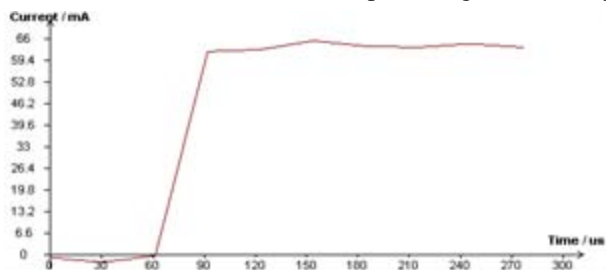

Figure 3: Beam pulse current as a function of time.

Data Manipulation

Some data sets contain features that affect emittance calculations. The new software has a suite of tools to remove such anomalies, all controlled from a tabbed panel to the bottom left of the child form.

For example the current amplifier can add a positive bias to incoming data, offsetting the background noise from zero. Additionally, some emittance calculations require thresholding of data to remove background noise altogether. The user can either adjust and/or remove any bias manually with slider bars, or have the software automatically deduce a suitable threshold.

A 'drift' of the background noise is sometimes apparent, caused by either capacitive charging in the current amplifier or anomalous secondary electron currents at one end of the Faraday cup. The drift tends to give a gradient to the background noise and, in turn, the captured phase space data (see Figure 4). Best fit lines are calculated from the background noise and displayed on the 1D slice plot. The user may then subtract the calculated gradients from the data to flatten out the noise.

Figure 4: Data before and after drift fixing procedure. The best fit lines are shown in blue and green.

Finally, some data points may become shifted relative to those either side. This happens, for example, if a high voltage discharge prematurely activates the timing trigger. The affected column can be selected and replaced by an average of the data points either side, thus removing the anomalous data, as shown in Figure 5.
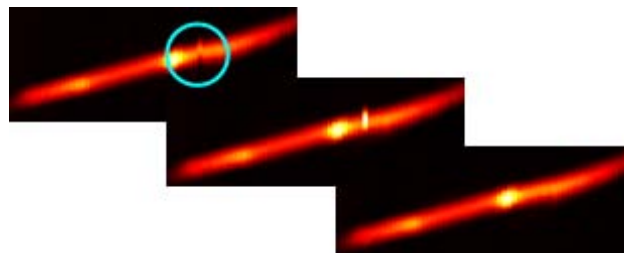

Figure 5: Procedure to fix shifted data points. From left: Broken data identified; Use controls to select the affected data; Data after being repaired.

EMITTANCE CALCULATIONS

The most significant addition to the emittance scanner software is the ability to perform sophisticated emittance calculations and analyses; all within same the user friendly interface used to capture the data. This feature removes the need to export captured emittance plots to different data analysis packages and hence saves time, effort and computer memory resources. It also ensures consistent, comparable results are given. Two emittance calculation routines have been implemented: the threshold and SCUBEEx methods.

Threshold Analysis

An emittance calculation using thresholding assumes that any data below a certain value is background noise. With a suitable threshold chosen, the background noise is eliminated and only true beam remains so the emittance is not affected by individual noise pixels far from the beam.

SCUBEEx Analysis

A different method of calculating emittance without having to lose some of the beam core data due to thresholding is the SCUBEEx analysis [4]. The graphs generated are output to a file and displayed at the bottom of the child form (see top left child form in Figure 2). This routine allows the comparison of ellipses with different Twiss parameters and half-axis products to generate a self consistent, un-biased emittance measurement with justified errors.

CONCLUSION

The new emittance scanner software is a major improvement over the previous code. Emittance scans are now simple and enjoyable to perform, in an intuitive environment. Various tools to post-process data result in less time wasted due to scans needing to be re-taken.

Powerful and complementary emittance calculation routines significantly enhance the usefulness of the software by removing the need to analyse data in a separate package to achieve reliable emittance results.

REFERENCES

[1] Letchford A. P. et al., These proceedings, THPP029.
[2] Thomason J. W. G. et al., *EPAC 02*, THPRI012.
[3] Thomas C. and Faircloth D., *EPAC 06*, TUPCH037.
[4] Stockli M. P. et al., *AIP Conf. Proc.* **639**, 135 (2002).

06 Instrumentation, Controls, Feedback & Operational Aspects

T03 Beam Diagnostics and Instrumentation