BEAM-PROFILE/-EMITTANCE MEASUREMENTS AT THE FRANKFURT ECRIS

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Abstract

The off -line analysis of the Frankfurt Emittance and Profile Monitor (FProM) has been improved to allow better (direct) access to the calibrated profile and emittance representations. With the new system profile and emittance scans can be performed and directly interpreted at measuring times of 2-3min per full scan. With this significantly improved working performance a series of measurements has been carried out, where we have pursued the issue of beam filamentation in the extraction region of the 14GHZ Frankfurt ECRIS. The new program development will be presented together with results from the measurements.

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INTRODUCTION

The determination of the beam parameters distinctly beyond the mere measurement of extracted beam currents has become an important issue for the development of new ion sources. In particular the development of newest generation ECRIS sources with their extremely high magnetic fields, extending far into the extraction area, have to be based on detailed measurements not only the beam emittance but also of the lateral beam profile, in order to carefully tailor the beam transport system. We have upgraded the “Frankfurt online scanning system”, which initially was developed as a simple and easy to install monitor to control position and integrated lateral profiles of the beam from the Frankfurt 14Ghz ECRIS. This system had already been turned into an emittance / and profile monitor by adding an automated moving-slit system [1]. For a better usability of this system, an offline data-analysis system has been supplemented, which allows direct access to the normalized and calibrated beam profiles and emittance distributions. For the determination of Twiss parameters a converter allows the use of the EAS code [2] for further processing of the measured data.

THE FProM-SYSTEM

A detailed description of the scanner hardware is given in Ref. 1. The idea behind the scanning system is to shadow the current, measured in a (in principle in any) Faraday cup in the beam line by moving a trapezoidal Aluminium screen, mounted on a wheel which rotates around the Faraday cup. In this way the primitive function of the beam profile is measured in two orthogonal directions. Derivation of these two profiles delivers the lateral density distributions of the beam profile (x/y-profiles). A typical online screen of FProM is displayed in Fig. 1. In the left upper corner the original profile (primitive function) is displayed, whereas in the bottom windows the derivatives of the two slopes (rising and falling) are plotted, allowing the online control of form and position of the beam in the two orthogonal scanning directions. The panels in the upper right of the screen are controls for the stepping motors of altogether 3 moving slit systems, which can be added to the hardware in order to transform the scanner into a high resolution profile and emittance monitor. In this way up to 3 systems can be controlled by the online program.

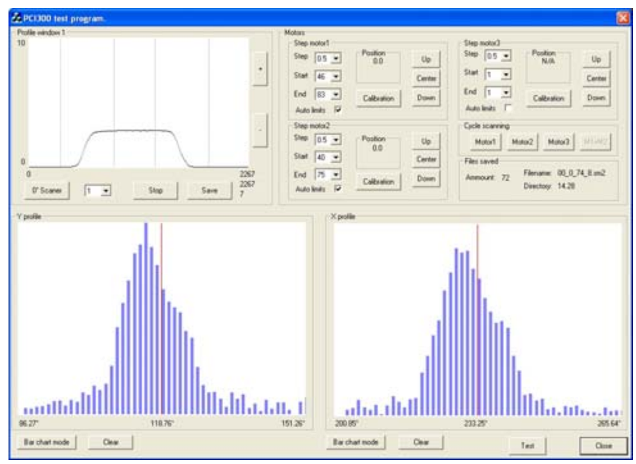

Figure 1: on line scree of the Franfurt Profile and Emittance Monitor (FProM)

Altogether three such systems have been installed in Frankfurt now, two in the ECRIS beam line (one at 0°; one at the injection into the RFQ). The third system has been installed in the injection line to the new Frankfurt Low Energy Storage Ring (FLSR) in order to match the injected beam to the ring acceptance. All systems are equipped with at least one slit system, the ECRIS 0° beam monitor has two slit systems allowing to measure emittances in both lateral directions (x-x´ and y-y´). Additionally, by controlling the joint movement of such a pair of orthogonal slits, the 4-dimensional information (x,x´,y, y´) can be measured like in a “pepper pot” measurement. Since the two orthogonal directions are scanned by only one rotating shadow, the scanning edges of the shadow have to be oriented at 45° to the axis of rotation. This implies that a mounting of the system e.g. into a spare port opposite to the mounting flange of the Faraday cup, which normally is mounted in a way that it is aligned to the accelerator based x or y direction, results in a scanning frame of reference which is rotated relative to the accelerator-fixed system by 45°. This can easily be compensated by mounting the diagnose box (with Faraday cup and Scanner) under 45° degrees relative to the accelerator frame of reference (see Fig. 2 of the FProM-system in the FLSR-injection line).

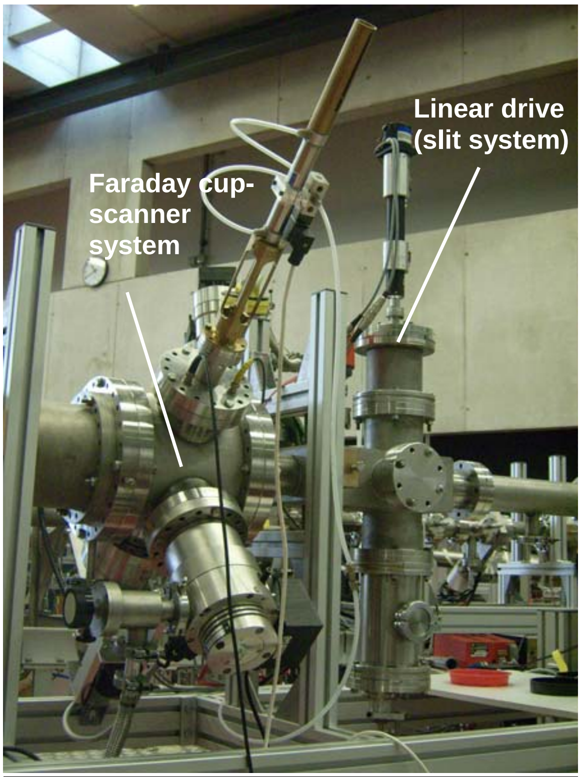

Figure 2: One of three systems installed at the IKF accelerator centre (Injection line to the Frankfurt low energy storage ring FLSR)

DATA PROCESSING AT FProM

The principle of an FProM emittance measurement is essentially a slit-grid measurement, however, in contrast to a slit-grid system, where the grid's zero position is usually moved together with the slit, in FProM the scanning system is fixed and the measured emittance profiles are rotated by 45° relative to the x´/y´= 0 axis. Additionally it may be skewed due to the constructive details of the respective scanner. Hence the interpretation of online data is aggravated and a further processing of the data is necessary. In order to keep the speed and universality of the online processing, this analysis in done in an offline program, containing all calibration parameters and constructive details of the scanner. This is not really a drawback since the program scans with a speed of 1Hz (data taking, online display and data storage).

It is an advantage of FProM that it always performs two scans in orthogonal direction. Therefore any profile scan perpendicular to the slit (emittance) is supplemented by a profile scan along the slit (high-resolution scan of the lateral density distribution). In Fig. 3 a screen of the offline analysis system for a very wide (divergent) beam in the 0° Faraday cup of the ECRIS beam line is displayed. This system calibrates and displays the online data in the accelerator based coordinate system (Profile, lower left screen) and in the normal emittance representation (lower right screen). The vertical lines on the profile are regions shadowed by the wires from the electron suppression grid (see the description in Ref 1). These are wires of 1mm thickness with 6 mm spacing. Due to the limited length of the active slit motor drive, only a total length of 35mm could be scanned, resulting in a range on the x and y axes of 49mm, not sufficient to show the full beam. The emittance profile is truncate as well but clearly points to a divergent beam.

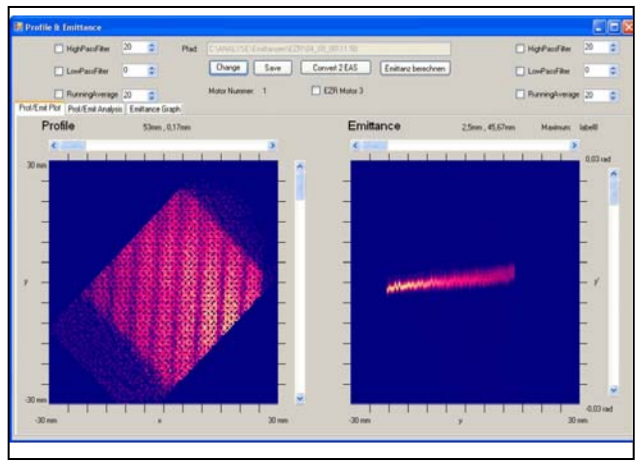

Figure 3: screen of the offline program for FProM

In order to suppress noise and to cut spurious signals, different filters in the offline program (upper part of the panel) allow modification of the data. Finally the data can be stored in a format directly compatible with the input of the emittance analysis software EAS [2] for further processing (e.g. determination of the Twiss parameters).

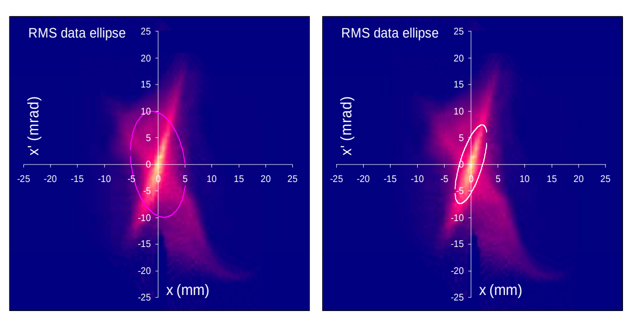

Figure 4: RMS emittance of a profile measured at the 0°-Faraday cup using EAS. **left picture:** no filters applied**;** **right picture:** a data-filter ellipse(EAS) was used to discard the aberrations.

An example of the data analysis with EAS is displayed in Fig. 4 for a measurement of the ECRIS -0° beam where substantial aberrations are present. The 85% area emittance (15%cut off level) determines to 392 mm mrad (EAS) and 287 mm mrad (offline program) respectively

MEASUREMENTS AT THE ECRIS

One motivation to upgrade the scanner system was to investigate the obvious losses of beam in the low energy bam transport system (LEBT) of the Frankfurt ECRIS. If the beam is well focussed onto the Faraday cup directly after the analysing magnet only a very small fraction of this beam could be detected in the next Faraday cup (3m downstream at the entrance of the RFQ post accelerator. On the other hand if focussing was optimized on the second Faraday cup, substantially larger beam currents could be measured there the same intensity was measured in FC90-1 also. One explanation of this unexpected behaviour could be the extraction of filament beams as a consequence e.g. of the radial magnetic confinement by means of the hexapole field inside the source. In fig. 5 a preliminary result of a scan at the 90° beam line scanner is displayed. The source was optimized for the production of Ar 8+ the beam transport was optimized in FC90-2. Clearly two centres can be isolated in the 90° profile as well as in the emittance distribution (upper panel of fig.5). The distributions measured for the same beam tuning in the 0°beam line show a well focussed beam without inner structures (no voltage was applied to the 0°-Quadrupole triplet for this particular tuning).

It is obvious that in particular the unfavourable positioning of the 0° scanner does not allow really deciding on this question. It is a long standing plan to redesign the LEBT of the Frankfurt ECRIS installation. Before doing so, it was meaningful to have the full performance of the FProM systems available. In particular, the position of the 0° scanner will be shifted upstream, to allow mounting of a new 0°-electrostatic quadrupol triplet with larger aperture (100mm) downstream from the Scanner (the presently used system has an aperture of 60mm and is installed between slit- and scanner system. It has to be switched off for FProM scans).

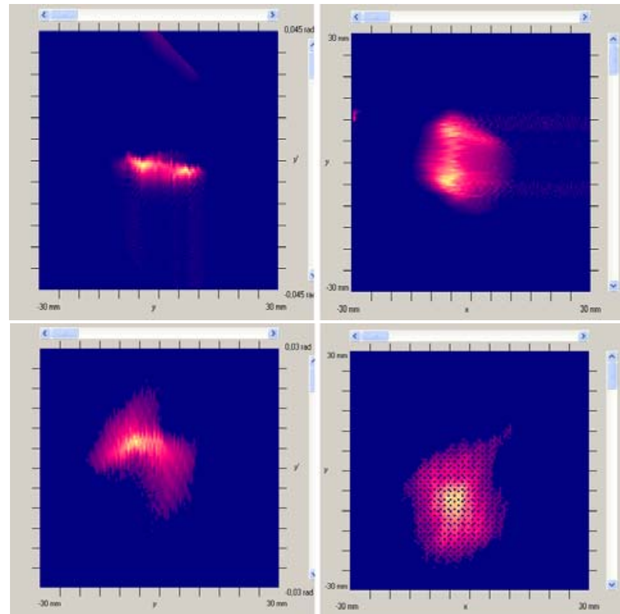

Figure 5: Ar^{8+} optimized in the Faraday cup of the 90°-ECRIS FProM); **upper panel:** emittance scan (left) and Profile scan (right) in the 90°-FProM; **lower panel:** emittance scan (left) and Profile scan (right) of the identical beam tuning in the 0°-beam scanner

The 90° degree scanner will be equipped with a larger-area Faraday cup to allow a wider scanning area. After upgrade the system is ready for systematic measurements of beam parameters as a function of different source tunings and manipulations.

REFERENCES

[1] K. E. Stiebing, M. S. Kaiser, J. D. Meyer, L. Schmidt, H.Schmidt-Böcking, O.Strekalovskij, V. Alexandrov, A. Kayukov, M. Koryevkina, G. Shirkov Rev. Sci. Instrum., Vol. 75, No. 5, May 2004;

[2] Emittance Analysis System (EAS), Accelerator PhysicsGroup Codes Spallation Neutron Source (SNS) ; <www.sns.gov/APGroup/Codes/Codes.htm >