BEAM STEERING WITH IMAGE PROCESSING IN THE CRYRING INJECTION BEAMLINE

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Abstract

By varying six quadrupoles and observing how the beam spot moves on three fluorescent screens the beam is aligned in the injection beamline. The method is now automated and upgraded by using image processing of the picture to get the position of the beam.

1 CRYRING

CRYRING is a 52-m circumference storage ring for atomic and molecular ions [1]. In the injection line an RFQ pre-accelerates ions with q/m>0.22. Thus, in the injection line right before injection, where the system below is used, the beam can be of two types: "Fast", 290 keV/u and q/m>0.22, or "slow" with 40q keV total energy. Examples of ions are Pb^{54+}, HCN^{+}, and Sr^{+}. The beam current varies from 20 µA down to below 50 nA. For the fast beam the pulse length is 0.1 ms and the repetition rate is 3 Hz.

2 THE OLD SYSTEM

For several years a Pascal program running on the PDP-11 computer has been used which aligns the beam horizontally in three focusing quadrupoles and vertically in three defocusing quadrupoles. The magnets are varied approximately 15% up and down while the operator looks at a monitor showing the beam spot on a fluorescent screen.

Changing the focusing naturally changes the shape of the beam, but when the centre of the beam moves the beam doesn't go through the centre of the quadrupole and the preceding steering element should be adjusted.

Figure 1. Grey-scale picture of the beam spot.

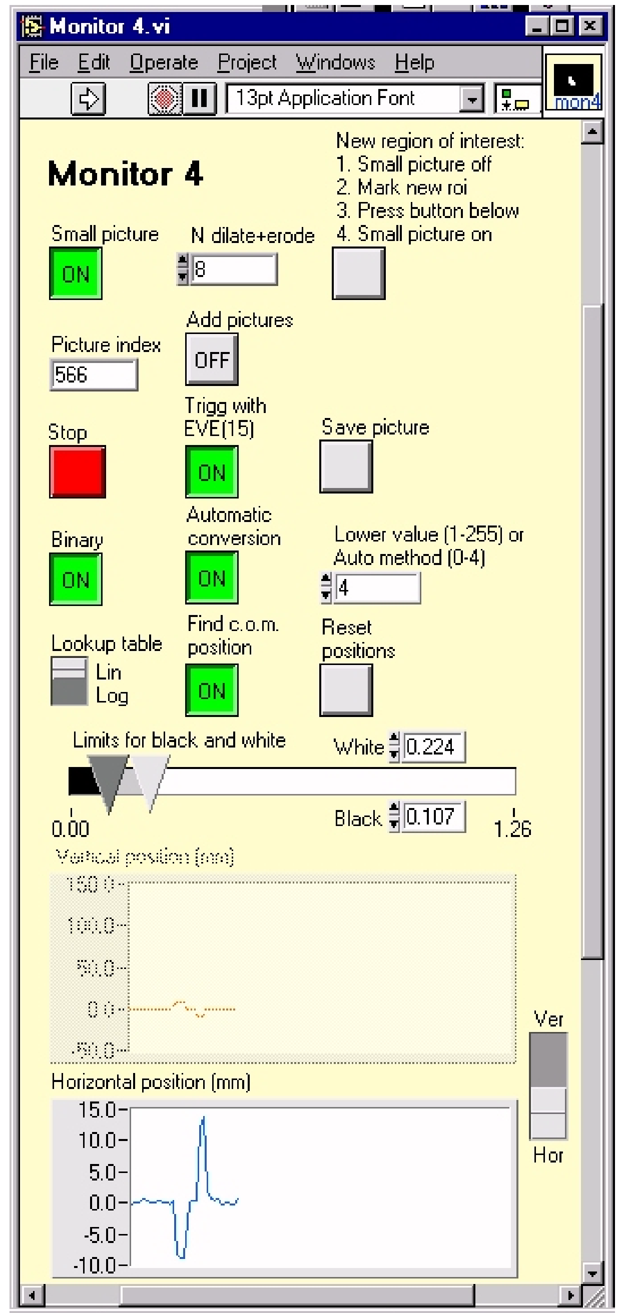

Figure 2. The front panel of the LabVIEW program shows the image processing options. The diagram at the bottom shows large movements of the horizontal beam position when a focusing quadrupole is varied.

Next a new setting of the steering element is calculated from the change of the beam position.

This method is also much used in electron machines where one can view the synchrotron radiation and measure changes of the beam position with high precision.

In order to cope with varying beam intensities the pulse length can be varied, from one μs up to several ms.

The method works rather well, although it is a bit cumbersome to use and it takes approximately half an hour to align the beam.

When the beam is very weak the beam spot is difficult to see, and since there is a large interest from the users in clusters and molecular ions that only can be produced in tiny quantities, an increased sensitivity is desired.

3 THE IMPROVED METHOD

With the help of a frame grabber board a PC calculates the position of the beam spot. At present the value is entered manually into the old program, but the goal is to get a more or less automatic system.

Firstly the grey-scale picture (fig 1) is transformed to a binary picture, and afterwards the centre of gravity of the beam spot in the binary picture is calculated.

One clear advantage is that one now uses a triggered picture with constant light conditions, while the running video used earlier have bright flashes every 0.35 s and then a fading after-glow.

4 HARDWARE AND SOFTWARE

The cameras are standard video cameras, i.e. Hamamatsu and Kappa. The PC program is written in LabVIEW with an IMAQ PCI-1408 frame grabber board and IMAQ Vision software for image processing.

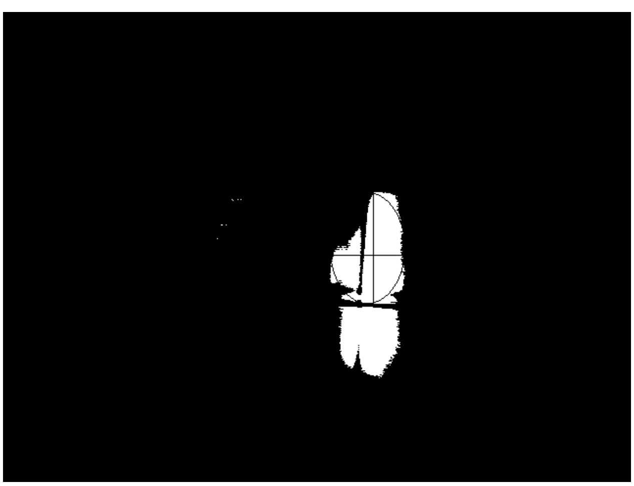

Figure 3. Binary picture where the beam spot is divided in two parts by a cross on the screen. The program chooses the upper half of the beam spot since it is the largest one. The thin cross shows the calculated centre of gravity.

5 SOME PROBLEMS AND IMAGE PROCESSING SOLUTIONS

5.1 Crosses on the screens disturb the measurements

To be able to get the absolute beam position there are crosses on the fluorescent screens, but these often divide the beam spot into two or four spots, and the program then selects the largest one as the beam spot (fig 3). When the beam moves, frequently another one becomes larger, and the change of position cannot be read. This problem is solved by dilation followed by erosion, 5-10 pixels dilation is needed (fig 4).

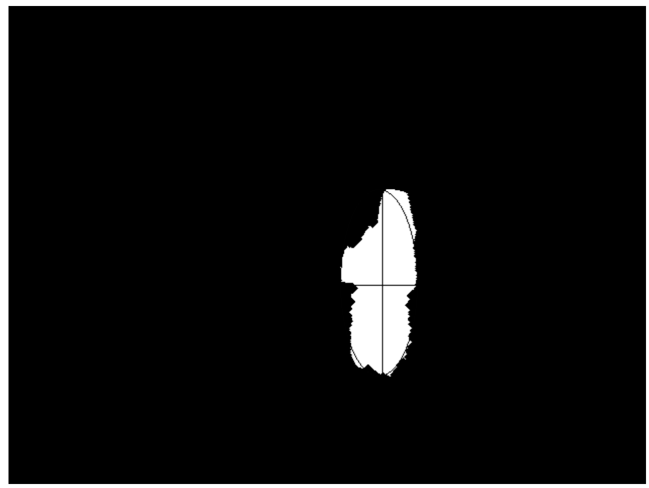

Figure 4. Beam spot after dilation and erosion. The cross in figure 3 is removed.

5.2 Weak beam

Three different methods are used to enhance weak pictures. Firstly stretching of the grey-scale, i.e. adjusting the thresholds for black and white. Secondly a logarithmic look-up table works better than a linear one for weak signals, and finally several consecutive pictures can be added.

5.3 Aperture limitations give false movements of the beam spot

When the shape of the beam is changed a part might fall either outside the aperture in the beam line or outside the fluorescent screen. Since such a cut is asymmetrical the apparent centre of gravity will change erronesly. This problem has not been addressed but one can e.g. decrease the quadrupole jumps or in some way check for this behaviour in the software.

REFERENCE

[1] G. Andler et al., “Progress Report for the CRYRING Facility”, EPAC’98, Stockholm, June 1998