A MULTIFUNCTIONAL PROFILE AND EMITTANCE MEASUREMENT SYSTEM*

G. Riehl, J. Pozimski, W. Barth, H. Klein
Institut für Angewandte Physik, Johann Wolfgang Goethe Universität
D-6000 Frankfurt a. Main 1, Robert-Mayer Str. 2-4, West Germany

Abstract

We present a microprocessor controlled profile and emittance measurement system, which can be easily applied to various applications. The system includes stepping motor driven slits and profile harps, multichannel profile current amplifier, a microprocessor system and software for measurement and data evaluation. Online profile measurements, 2-dimensional slit-to-slit and 3-dimensional point-to-slit emittance measurements are possible. Various slits and profile harps can be used to examine beams within a wide range of intensity, power and size. The device is used to develope ion sources and ion optical devices, to investigate influence of beam neutralization[1], to controll the beam injection into RFQ's and to examine the beam behind the accelerater[2]. The concept of the device and experimental results of the influence of a solenoidal lens and a gabor plasma lens on the ion beam phase space distribution will be presented.

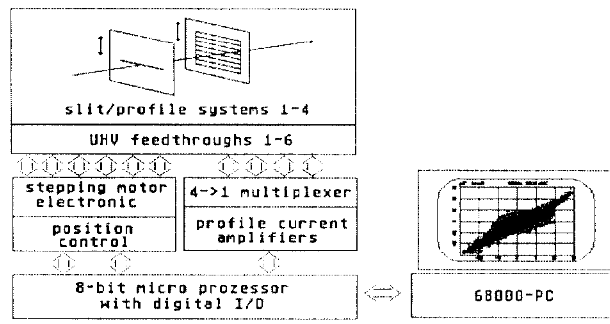

Fig.1: schematic drawing of the diagnostic device

Concept of the Device

Fig. 1 shows a schematic diagram of the measurement device. Up to 4 slit/profile harp combinations may installed to 6 stepping motor driven UHV feedthroughs. The profile currents of one harp are switched by a multiplexer to the 60-channel current amplifier. Motor and amplifier electronics are controlled by an 8-bit microprocessor system with digital I/O boards. This microprocessor is connected to a 68000-PC which handles interactive dialogs, data measurement and data evaluation. Slits are made of tantalum, molybdenum or stainless steel, cooled versions for mean beam powers up to 6 kWatt are available. An optional kicker in front of the emittance device may increase the measurable beam power up to 1 MWatt. The slit heights variies between 0.1 and 1mm, depending on the expected beam optics. The profile harps consist of 30- 60 tantalum or molybdenum wires or bars with a diameter of 0.1, 0.5 or 1 mm. Slit and profile harps are mounted either on one frame and one feedthrough or on two different feedthroughs to provide independent movements of slit and profile. We prefer the independent movement, because this makes online profile measurements, profile intermediate steps, profile offset and automatic positioning[3,4], high angle resolutions and also point-to-slit emittance measurements with crossed slits possible. Fig. 2 shows the measurement principle with crossed slits and profile harps. The slits filter a beam partition of the coordinates x,y. The profile harps determine the angles x' and y' of this partition, therefore obtaining the beams charge distributions I(x,y,x') and I(x,y,y'). Out of these 3-dimensional distributions calculation of all 2- and 1-dimensional subspaces of the beam distribution is possible. Fig. 3 gives an overview on all beam distributions which can be measured and calculated with our diagnostic device.

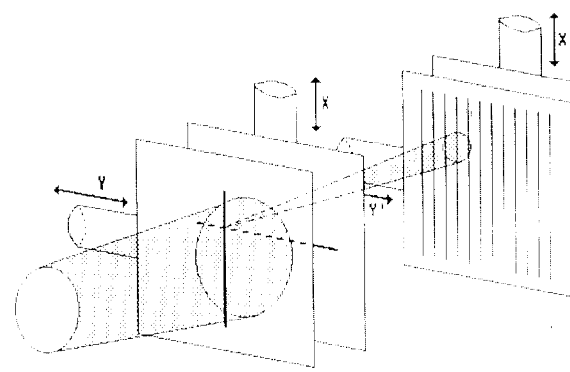

Fig. 2: crossed slits and crossed profile harps for measurements of the I(x,x',y) and the I(y,y',x) charge distributions

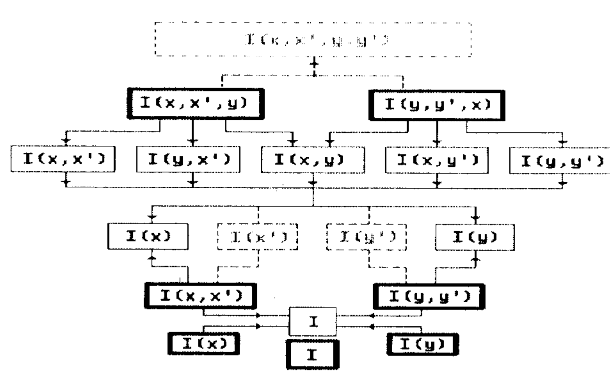

Fig.3: survey on the charge phase space distributions which may be measured (fat rect.) or calculated

* work supported by the BMFT under contract number 06 OF1861

Emittance Measurements behind a Gabor Plasma Lens

For a second measurement series we replaced the solenoid by a Gabor plasma lens[8]. The figures show the phase space distributions of a 10 keV/ 125 μA Ar^+ beam behind the lens. Again the beam occupied a large fraction of the aperture. Fig . 8 shows the xx'- emittance of the beam measured with slit and profile harp, composed of an extreme high intense convergent 'butterfly', a second low intense convergent 'butterfly' and a divergent neutral beam. The 3-dimensional distributions I(x,x',y) (Fig .9) give an explanation of the structure of the 2-dimensional emittance:

The Ar^+ beam is divided by the lens in a high intense central part and a low intense outer part, both showing the contour of a negative 'S'. Compared with the shape obtained from solenoid measurements, the focusing strength inside the solenoid increases with radius, the Gabor lens shows a decreasing with radius.

At the beam center decreasing charge intensities can be observed. The 2-dimensional beam profile in space (Fig. 10,11) show, that we get a hollow beam. This may be explained by the incomplete filling of the lens by electrons occupiing only the region near the axis.

Conclusion

The diagnostic device is a powerful tool to investigate 1-,2- and 3-dimensional phase space distributions of ion beams. The analysis of the 3-dimensional distribution I(x,x',y) and I(y,y',x) gives important information about the genesis of beam halo, emittance aberrations and emittance growth. Further development of the device will include reconstruction of the 4-dimensional phase space distribution I(x,x',y,y').

Reference

1. T.Weis et. al. "Evaluation of space charge ... ", this conference
2. A.Schempp, "The CRYRING RFQ", this conference
3. G.Riehl, Interner Report 89-14, Institut für Angewandte Physik D-6000 Frankfurt/M. , Pstf. 111932, FRG
4. G.Riehl, Interner Report 89-16 , mailing adress see[3]
5. K.Langbein, IEEE Catalog No. 87CH2387-9 1987, Vol.1, p.379
6. A. Müller-Rentz, Diplom Arbeit 1985, mailing adress see[3]
7. G. Riehl, J. Pozimski, W. Barth, Interner Report 90-14, mailing adress see[3]
8. J. Pozimski, private communications, mailing adress see[3]

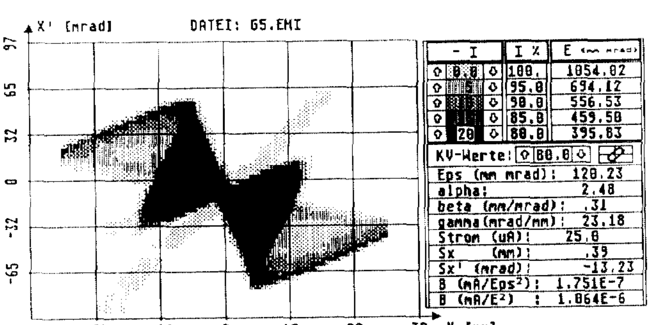

Fig.8: Distribution I(x,x') of a 10 keV/125 μA Ar^+ beam, measured with slit and profile harp behind a Gabor plasma lens

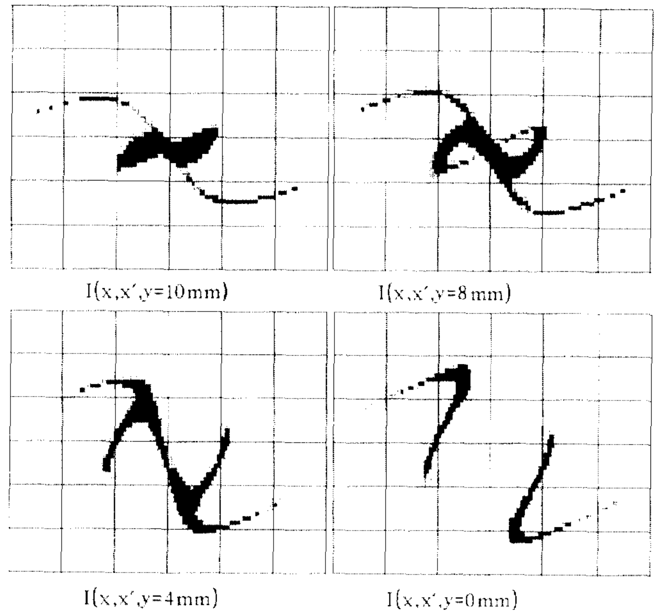

Fig.9: Ar^+ beam distributions I(x,x',y) at different positions y, measured with two crossed slits and profile harp

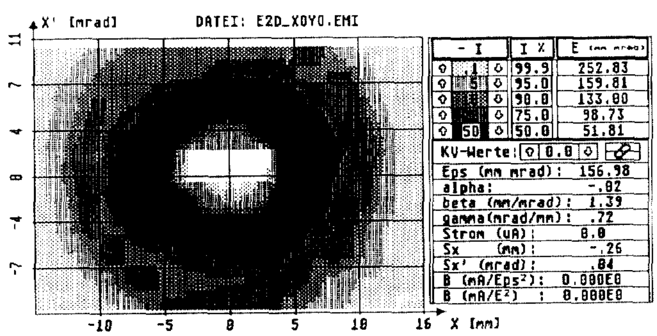

Fig. 10: Ar^+ beam distribution I(x,y), calculated from the measured distribution I(x,x',y)

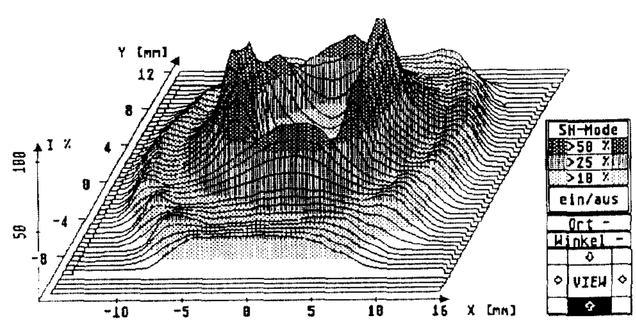

Fig. 11: perspective view to the Ar^+ beam distribution I(x,y)

Emittance Measurements behind a Solenoidal Lens

We used a plasma beam ion source[5] with a successive selenoidal lens[6] and extracted a 10 keV/3.6 mA He^+ beam. The ion beam occupies at least 75% of the lens aperture, causing aberrations of the beam phase space distribution. Fig.4 shows the measured x-emittance, the I(x,x′) distribution of the beam, measured with slit and profile harp. The convergent He^+ beam and a divergent neutral beam can be clearly distinguished. The dark 80% partition of the He^+ beam shows a 'S' shaped contour. This is the effect of the nonlinear solenoidal field. In addition the phase space distribution has a 'butterfly' shape.. This is caused by the nonlinear field with radial symmetry, which twists different beam partitions I(x,x′,y) dependent on their position y. More clearly this can be seen from the results of the point to slit measurements. Fig.5 shows the beam profile, calculated from the beam emittance (Fig.4). The distribution is sharply peaked containing a broad halo caused by the lens aberration. We measured the beam distribution I(x,x′,y) with the point to slit method for the same beam parameters. Fig.6 shows different parts $I(x,x',y_i)$ of this measurement, with y=-14, -12, -10 and 0 mm. At the edge (y=-14mm) a small xx′ distribution can be seen, showing less aberrations. The I(x,x′,y=-12mm) distribution is characterized by a '8' shaped contour, which is caused by the nonlinear field and the drift space inside the solenoid. The I(x,x′,y=-10mm) distribution shows the same contour, but the '8' becomes wider. In the center of the beam (y=0mm) the '8' is very wide, but no more closed. This may be explained by the resolution of the current amplifiers, which suppress the low intensity part of the distribution in the neighbourhood of the intens beam core. Therefore the 'butterfly' shape of the emittance, the I(x,x′) distribution and also the beam halo is composed out of different '8' shaped I(x,x′,y) distributions. From this distribution we calculate the distribution I(x,y), the 2-dimensional beam profile, Fig.7. Again we distinguish a high intens beam core, a homogenous middle part and increasing intensities at the edge of the beam. This 2-dimensional profile has a 'sombrero' like shape. The rim of this distribution is caused by strongly focused beam particles with shorter focal lengths than the inner beam part. Additional measurements with different beam and solenoid parameters gave the same results[7].

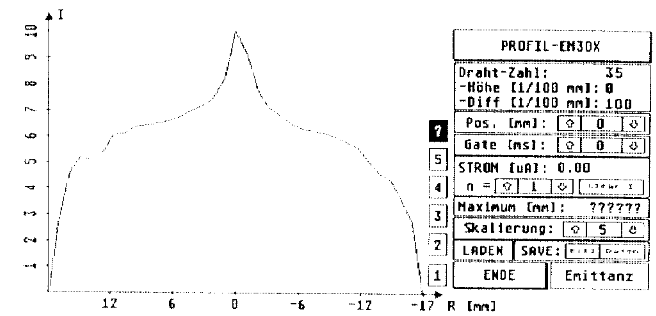

Fig.5: The beam distribution I(x), calculated from the distribution I(x,x′), Fig.4

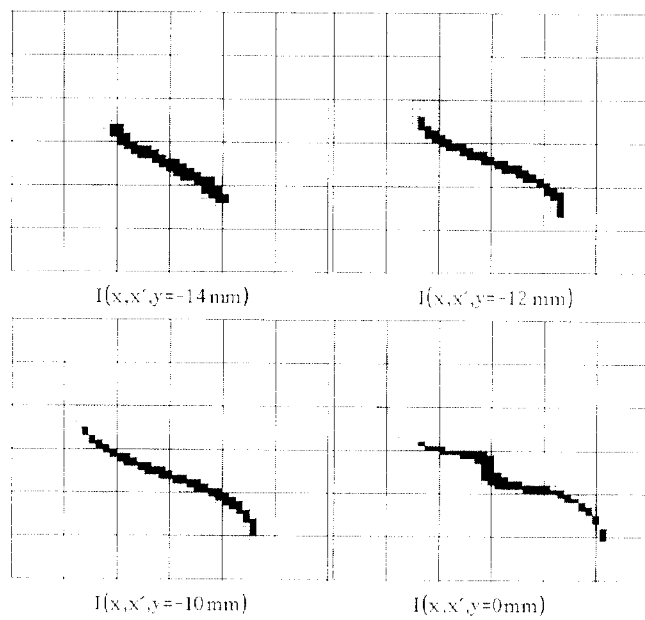

Fig.6: He^+ beam distributions I(x,x′,y) at different positions y, measured with two crossed slits and profile harp.

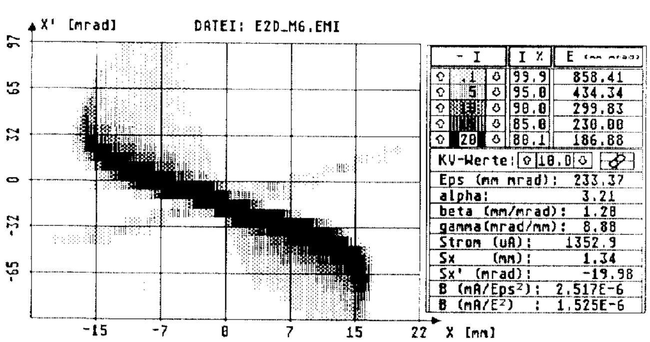

Fig.4: The distribution I(x,x′) of a 10keV/3.6 mA He^+ beam, measured with a slit/profile harp combination behind a solenoidal lens

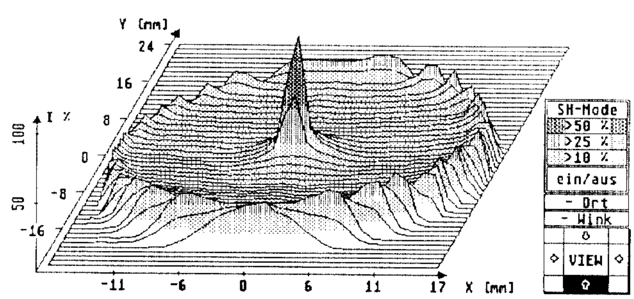

Fig. 7 : Distribution I(x,y) of the He^+ beam, calculated from the measured distribution I(x,x′,y)