BEAM EMITTANCE MEASUREMENT OF A POLARIZED ION SOURCE

A. A. Naqvi* and E. Huttel†

Energy Research Laboratory
King Fahd University of Petroleum and Minerals
Dhahran 31261, Saudi Arabia

الخلاصـة :

لقد تَـمَّ قياس انبعاث شعاع الديوترون المستقطب لمصدر الأيونات المستقطبة بجامعة الملك فهد للبترول والمعادن مستخدماً الجهاز ذا الفتحة الواحدة والماسح ذا السلك الواحد .

ولقد تم هذا القياس بعد قطاع مبادرة اللف الذاتي لمصدر الأيونات المستقطبة . وكانت نتائج القياس أنَّ الانبعاث كان ٩٠٪ من شعاع الديوترون المستقطب ويقع عند ١٥٠٠ مم . مللي راديان عند جهد الاستخلاص للمصدر = ١٢ كيلو الكترون فولت .

وهذه القيمة هي أعلى بحوالى ٥٠٪ من النتائج المنشورة لمصدر أيوني مماثل (في مختبر أبحاث الفيزياء النووية بكارلسروا بألمانيا) . وقد يعزى هذا الاختلاف إلى أن الانبعاث يعتمد بصورة قوية على كيفية وضع محـوِّل الأيونات ، وأن وضع محـوِّل الأيونات مختلف في المختبرين في السعودية وألمانيا .

*Address for correspondence:
KFUPM Box 1815
King Fahd University of Petroleum & Minerals
Dhahran 31261
Saudi Arabia

† Zyklotron Laboratory
IKIII, Kernforschungszentrum
Karlsruhe, Germany

ABSTRACT

The emittance of the polarized deuteron beam of the KFUPM polarized ion source has been measured using a single-slit and single-wire scanner set up. The measurement was carried out after the spin precessor section of the polarized source. The emittance of 90% of the polarized deuteron beam of the KFUPM source was measured to lie within 1500 mm.mrad at 12 keV extraction voltage of the source. This value is 50% larger than that of a similar source at Zyklotron Laboratory, Kernforschungzentrum, Karlsruhe,Germany. Since the emittance of an atomic beam polarized ion source strongly depends upon the setting of the ionizer,the difference in the beam emittance of the KFUPM source and the Karlsruhe source may be due to different settings of the ionizer of the two polarized ion sources.

BEAM EMITTANCE MEASUREMENT OF A POLARIZED ION SOURCE

1. INTRODUCTION

Emittance is an important property of an ion beam [1]. It is a typical characteristic of the ion source [2]. For a polarized ion source, the emittance deteriorates due to magnetic fields and charge-transfer process in the electron bombardment type ionizer [3]. Magnetic fields are always deleterious to the beam ion-optics quality, and for a typical atomic beam polarized ion source with an electron bombardment (EB)-type ionizer, the emittance of the beam depends upon the charge-transfer collision in the magnetic field of the solenoid of the EB ionizer [3]. Ohson *et al.* [3] have studied the effects of cylindrical and planar charge-transfer geometry on the beam emittance from a polarized ion source. They have found that the beam's emittance, which is proportional to R^2B, where R(mm) is the radius of the ionization column and B(kilogauss) is the solenoid magnetic field, is mainly determined by the EB ionizer settings. Table 1 shows the beam emittance of various atomic beam polarized ion sources taken from reference [4]. It is clear that from the Table that the beam emittance varies between 17–1500 mm mrad $\sqrt{\text{MeV}}$.

King Fahd University of Petroleum and Minerals, Dhahran has acquired an atomic beam polarized ion source from SENTECH, Zurich, Switzerland. The performance tests on this source were performed by measuring the intensity and polarization of deuteron beam [5, 6]. During the beam intensity measurements [5] it was found that out of a 41 μA beam produced at the end of the ionizer section, only 24 μA of polarized beam was measured at the end of spin precessor section. Out of that only 8 μA could be transported successfully to the target location. In order to investigate the polarized beam losses, the emittance measurement of the polarized beam was carried out utilizing a single-slit and single-wire scanner setup. The measurement was carried out at the end of the spin precessor section. In Sections 3 and 4 we describe the beam emittance measurements of the KFUPM atomic beam polarized ion source. For completeness, the KFUPM atomic beam polarized ion source will first be briefly described in Section 2.

2. KFUPM ATOMIC BEAM POLARIZED ION SOURCE

The KFUPM source is a vertical atomic beam polarized ion source with the dissociator nozzle of the atomic beam system operating at 32 degrees Kelvin. The details of the KFUPM atomic beam polarized ion source are given elsewhere [5, 6]. The ion source has four major sections, namely: atomic beam section, ionizer, electrostatic inflector, and spin precessor. The atomic beam section converts the molecular gas into a polarized neutral atomic beam which is focused at the ionizer. On its way to the ionizer, the atomic beam passes through radio frequency electromagnetic fields, where the nuclear polarization is enhanced. The nuclear polarized atomic beam is then ionized in a strong-field electron bombardment type ionizer, whose field direction also defines the quantization axis of the polarized beam. The positively charged beam, which is then extracted from the ionizer at 10–12 keV energy, is focussed into the electrostatic inflector. The inflector converts the vertical motion of the beam into a horizontal motion without disturbing the beam polarization. The horizontally moving polarized beam is then focused by an einzel lens into the spin precessor which allows one to rotate the orientation of spin quantization axis

Table 1. Emittance of Various Polarized Ion Sources.

Lab.	Ions	Ionizer type	Emittance (mm mrad)
ETH	H^+	EB	60 $\sqrt{\text{MeV}}$
Pfeiffer	H^+, D^+	ECR	600@10 keV
PSI	H^+	ECR	600
KfK-NTG	H^+	EB	90 $\sqrt{\text{MeV}}$
LNS	H^+, D^+	EB	17
KFUPM	H^+	EB	1500@12 keV

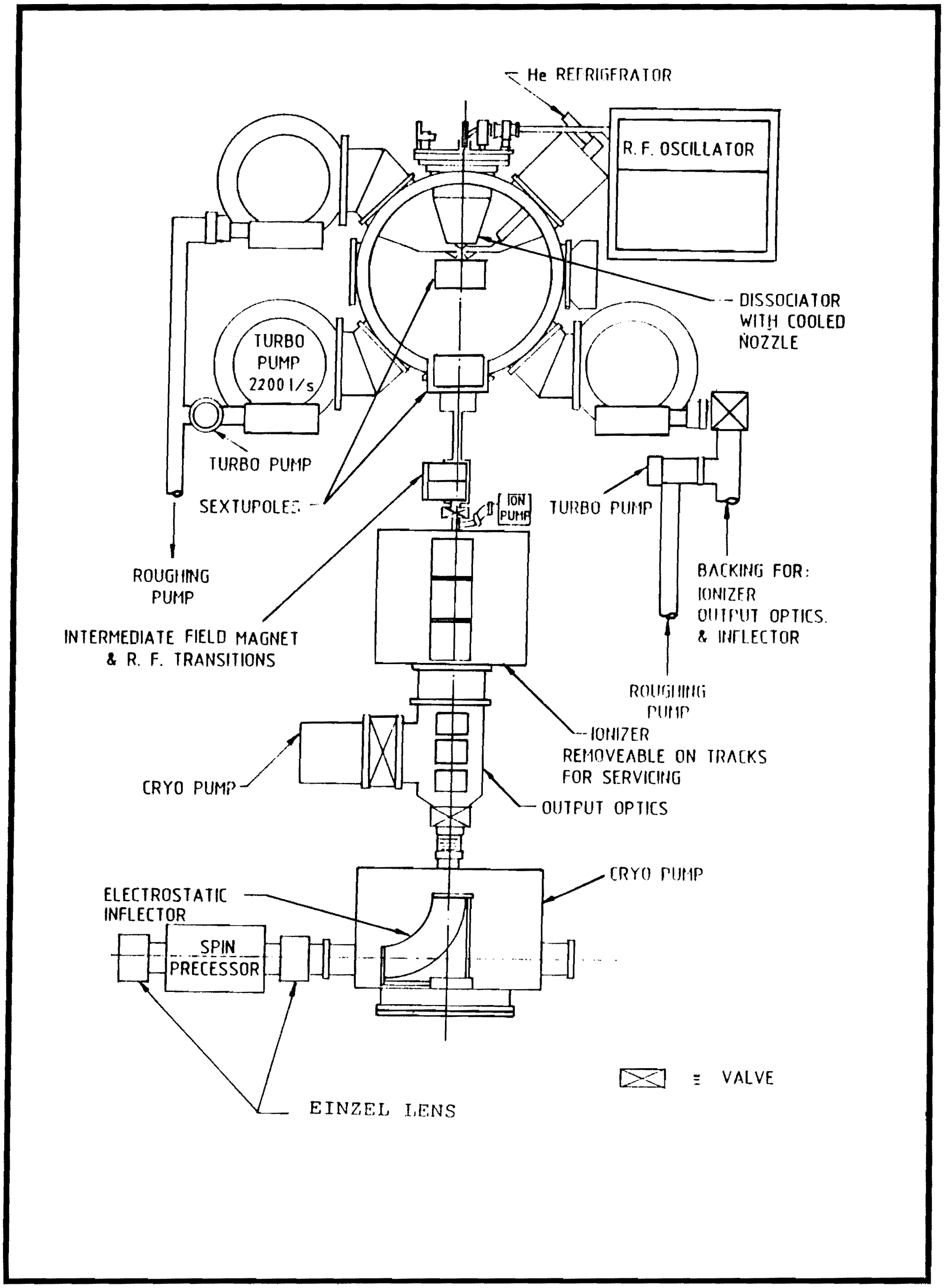

Figure 1. Schematic View of the KFUPM Vertical Atomic Beam Polarized Ion Source.

of the polarized beam as required. The beam emerging from the spin processor is further focused by a second einzel lens into the terminal of the 350 kV accelerator of KFUPM [7] for further beam transportation to the target location. Figure 1 shows the schematic of the vertical polarized ion source at KFUPM.

3. PRINCIPLE OF THE MEASUREMENT

In a particle beam, each particle is defined by two parameters- namely its distance and its angle with respect to the optical axis of the beam. When the divergence (mrad) is plotted against distance from the beam axis (mm), for all beam particles, the resulting distribution is called an emittance diagram. The emittance diagram has a shape of an ellipse whose area defines the beam emittance in units of mm mrad at the given beam energy or extraction potential. In the beam emittance measurement using a single slit–single wire scanner combination, the beam is collimated through a slit aperture. The width of the slit is chosen much smaller than the beam diameter. It is assumed that over the entire slit length the angle is constant. Ideally the slit width should be minimum, because there is a lower limit to the beam required for accurate measurements beyond the slit, the slit width in this case was chosen to be 1 mm. The beam emerging from the slit is detected by a wire scanner placed at a known distance from the slit. The slit is moved diagonally across the beam diameter. At any instant the position of the slit defines the distance of the beam particle from the beam optical axis, while the beam divergence, after the known drift length, is determined from the trace of the beam scanner signal.

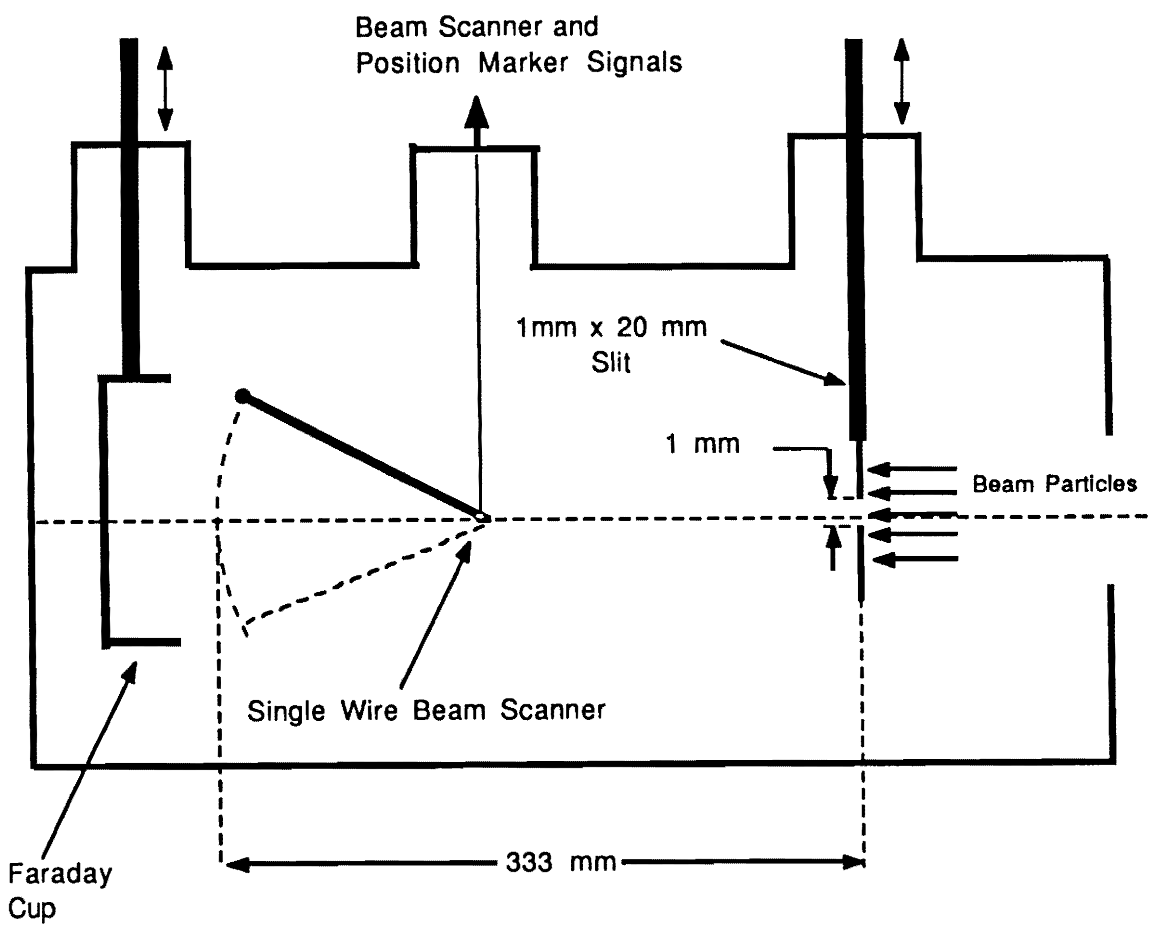

Figure 2. Schematic Diagram of Beam Emittance Measurement Setup.

4. EMITTANCE MEASUREMENT

The beam emittance measurements were carried out using an emittance chamber containing the slit-scanner setup and a Faraday cup. The emittance chamber was designed and fabricated at the External Ion Sources Lab., Zyklotron Laboratories, Kernforschungzentrum Karlsruhe, Germany. The chamber mainly consisted of a slit mounted at a distance of 333 mm from a single wire scanner of 516 P type manufactured by Danfysik. The slit opening was 20 mm long and 1 mm wide. The beam intensity was measured at a Faraday cup mounted behind the scanner. As the scanner consisted of a very thin wire, the beam attenuation by the scanner wire during the beam scanning was insignificant. Figure 2 shows the schematic diagram of the set up used in the beam emittance measurement. The emittance measurement for the KFUPM polarized ion source was carried out after the spin precessor section. The polarized deuteron was extracted from the source at 12 kV extraction voltage.

Since emittance needed to be defined for deuterium beam only, the measurements were carried out by selecting the deuterium ion through the spin precessor. During the measurements the beam scanner signal was displayed on a Tektronix oscilloscope. As a first step towards the measurement the oscilloscope was calibrated for the amplitude

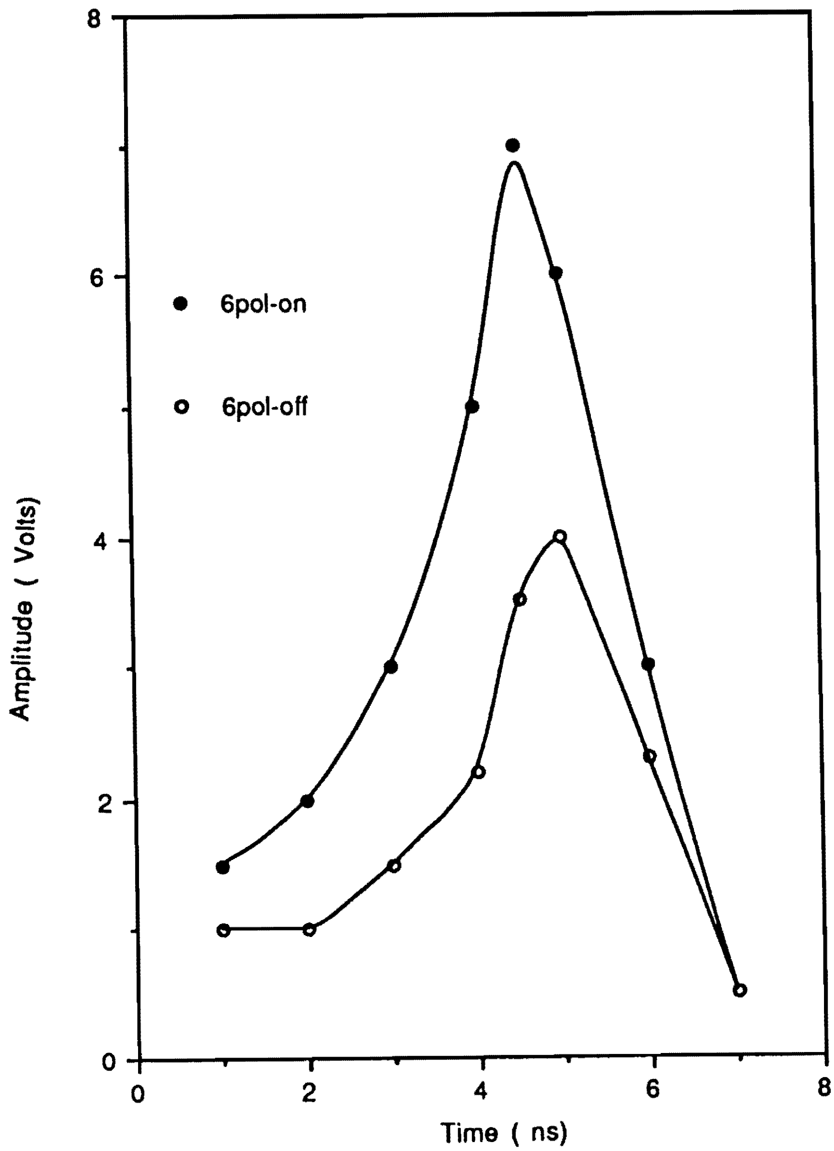

Figure 3. A Typical Beam Scanner Waveform Traced from an Oscilloscope with Sextupole ON and OFF Positions.

of the oscillation of the scanner using position markers signals. The Faraday cup signal was connected to a Keithly pico-ammeter for beam current measurements. The slit was then moved out of the beam and the scanner signal was displayed on the oscilloscope when the sextupole magnets were switched ON and OFF respectively. Figure 3 shows a typical waveform traced from the oscilloscope for sextupole ON and OFF positions. The beam intensity profile was then measured by recording the Faraday cup current when the slit was moved across the beam diameter in steps of 2.5 mm. Figure 4 shows the beam intensity profile over the beam diameter. It also shows that the beam

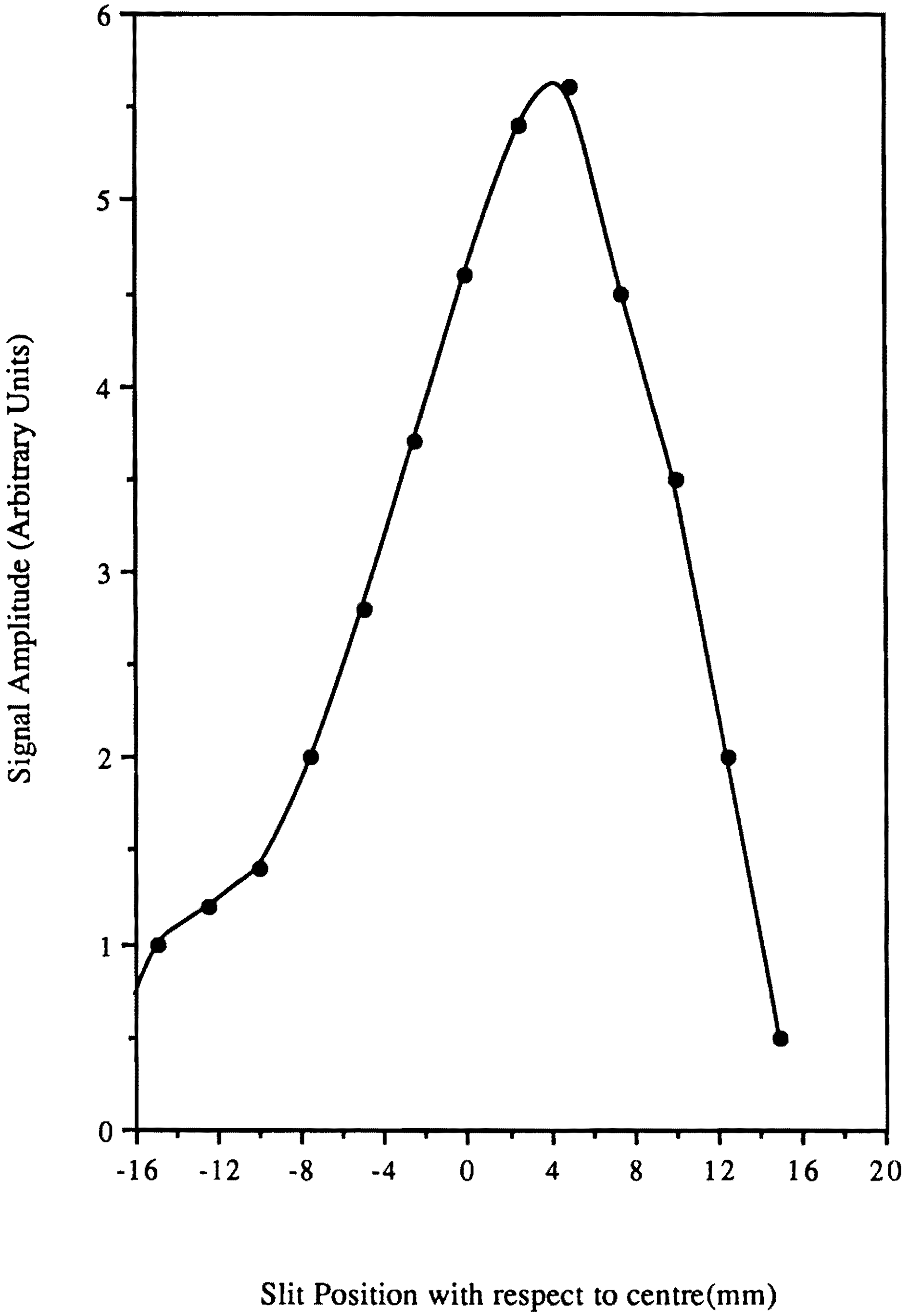

Figure 4. A Typical Beam Intensity Profile as a Function of Slit Distance from the Centre (Position with Maximum Signal Amplitude).

spot is shifted toward the right by 2–3 mm. This may be due to a misalignment of the inflector with respect to the spin precessor. The measurements were carried out with the maximum total beam intensity of 25.8 μA measured at a Faraday cup after the spin processor section.

Finally, the beam emittance measurements were carried out using the difference between the left and right side of the scanner signal with respect to central line on the oscilloscope. The central line on the oscilloscope was chosen where the scanner waveform had its maximum amplitude. The height of left and right side of the waveform was taken where the waveform dropped to 10% of the peak amplitude. The amplitude of the waveform was also recorded. The slit was moved in steps of 2.5 mm and the left and right position were recorded as a function of the slit position. The beam divergence for the centroid ray was calculated from the difference of the peak centroid position at the scanner, slit positions, and the slit-scanner distance. Later on, the range of divergence (in mrad) defined by the left and right positions was plotted as a function of slit position to get the emittance diagram. Figure 4 shows the measured emittance diagram for the KFUPM polarized ion source measured at the 90% level. The emittance of the KFUPM polarized ion source is 1477 mm mrad at 12 keV beam extraction energy. Compared with

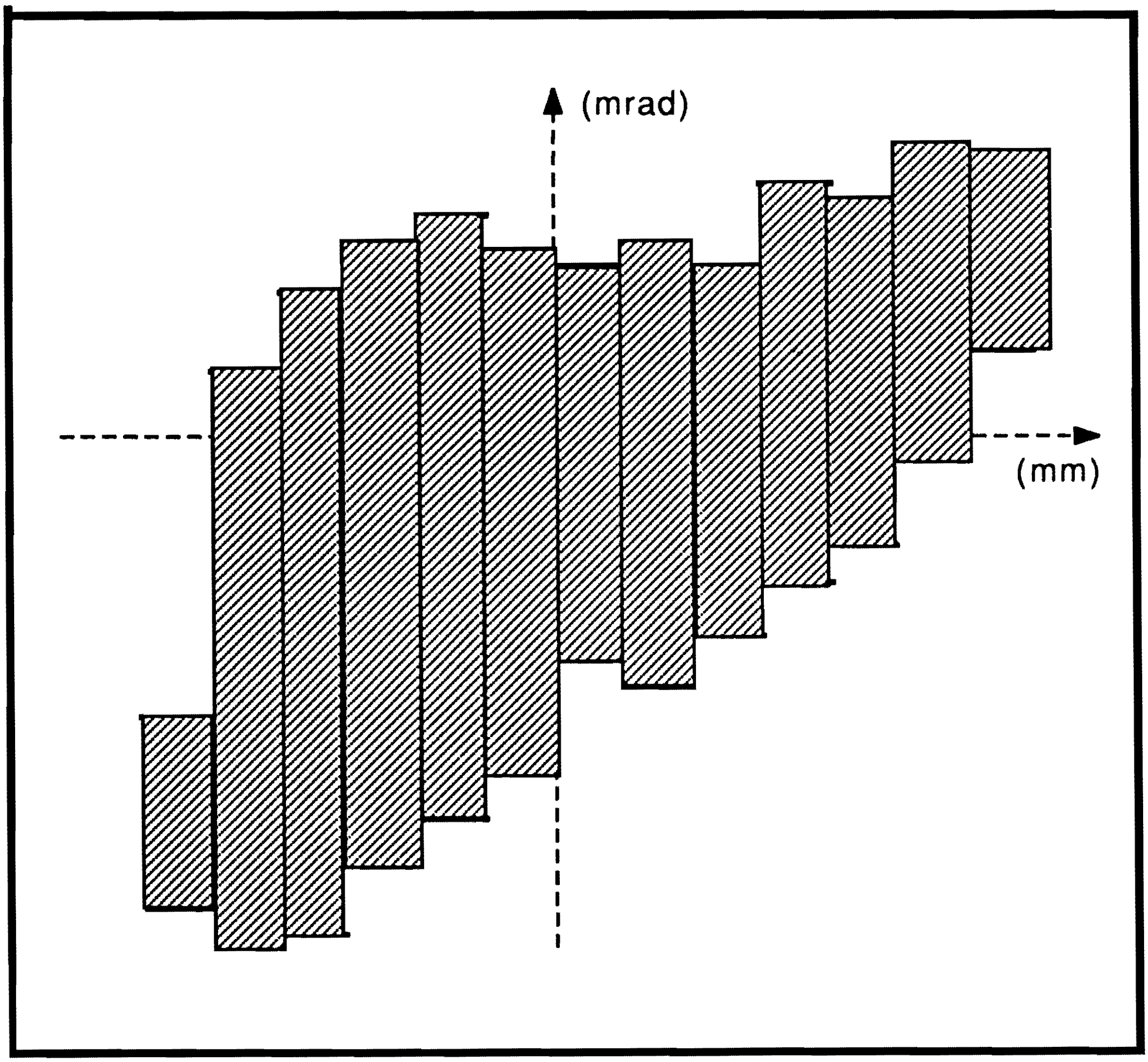

Figure 5 Emittance Diagram of the KFUPM Polarized Ion Source at 90% Level.

about 1000 mm mrad beam emittance of a similar source at Kernforschungzentrum, Karlsruhe, Germany, the emittance of KFUPM source is almost 50% larger than that of the Karlsruhe source. The difference in the beam emittance may be due to different tuning conditions of the electron bombardment type ionizer of the KFUPM polarized ion source as compared to Karlsruhe ionizer.

5. SUMMARY

The beam emittance of the KFUPM atomic beam polarized ion source has been measured using a single slit–wire scanner combination. The measurements were carried out at the end of the spin precessor section of the source, using a polarized deuteron beam. A maximum of 25.8 μA polarized beam current (sextupole magnets ON–OFF difference), was measured after the beam scanner. It was found that 90% of this beam was included within a phase space area of 1500 mm mrad. This emittance is 50% larger than that for beams from a similar source at Zyklotron Laboratory, Kernforschungzentrum, Karlsruhe, Germany. The difference in the beam emittance may be due to different tuning conditions of the electron bombardment type ionizer of the KFUPM polarized ion source as compared to Karlsruhe ionizer.

ACKNOWLEDGEMENT

This work is part of KFUPM/RI project 'ERL' supported by the Research Institute of King Fahd University of Petroleum and Minerals.

REFERENCES

[1] P. H. Rose, A. B. Wittkower, R. P. Bastide, and A. Gale, *Nucl. Instr. & Meth.,* **14** (1961), p. 79.
[2] F. Bordoni, T. Letardi, and M. Placidi, *Nucl. Instr. & Meth.,* **65** (1968), p. 72.
[3] G. G. Ohlson, J. L. McKibben, and G. P. Lawrence, *Nucl. Instr. & Meth.,* **73** (1969), p. 45.
[4] T. O. Niinikoski, *Proceedings of 7th International Conference on Polarization in Nuclear Physics,* 9–13 July 1990, Paris, France, p. c6-191.
[5] A. A. Naqvi and G. Clausnitzer, *Nucl. Instr. & Meth.,* **A324** (1993), p. 429.
[6] A. A. Naqvi and M. Raashid, *Nucl. Instr. & Meth.,* **A320** (1992), p. 32.
[7] H. Al-Juwair, G. Blume, R. J. Jarasma, C. R. Meitzler, and K. H. Purser, *Nucl. Instr. & Meth.,* **B24/25** (1987), p. 810.

Paper Received 2 March 1993; Revised 1 June 1994; Accepted 3 July 1994.