

RECENT MEASUREMENTS ON THE DUOPLASMATRON SOURCE

L. W. Oleksiuk^{*}
Brookhaven National Laboratory

At Brookhaven interest has been expressed in determining the phase space densities for the conventional duoplasmatron ion source beam as well as studying the effects of extracting the duoplasmatron ion beam from an expanded plasma.

It was hoped that measurements of the beam brightness in the ion source extraction region would indicate the maximum attainable beam that could be injected into the linac and that by varying the plasma surface from which the beam is extracted some insight could be gained into the factors controlling ion source brightness.

Figure 1 shows a typical brightness profile for the BNL conventional (Mark I) duoplasmatron beam after acceleration to 750 kV. The measurements were performed by A. Van Steenbergen using a 4-slit method. It can be seen that the filling of four-dimensional transverse phase space is poor, and much of the linac acceptance is populated only by the tail of the brightness profile. The brightness " B_{MI} " could theoretically put in about 1000 mA in the present linac acceptance if all the transverse phase space were filled at this brightness.

Emittance measurements were performed on the conventional (Mark I) duoplasmatron as shown schematically in Fig. 2. Measurements were also performed using photocopying paper. The slit width of 0.010 inches produced beam images on the fluorescent screen, and these were photographed and measured to yield emittance values for the beam. Current measurements were performed by collecting current from the slit plate and from the current transformer. Corrections were made for secondary electron emission, these corrections yielding an uncertainty of $\pm 20\%$ in the current measurements. Slit images for a 25 kV 200 mA (40 microsecond pulse width) beam are shown in Fig. 3, and the resulting phase space plot is shown in Fig. 4.

Preliminary measurements (see Fig. 5) for a range of extracted currents from the Mark I duoplasmatron from 30 mA to 400 mA indicate that the brightness of the Mark I, as measured by our techniques is

^{*}Now at the University of Toronto, Toronto, Ontario, Canada.

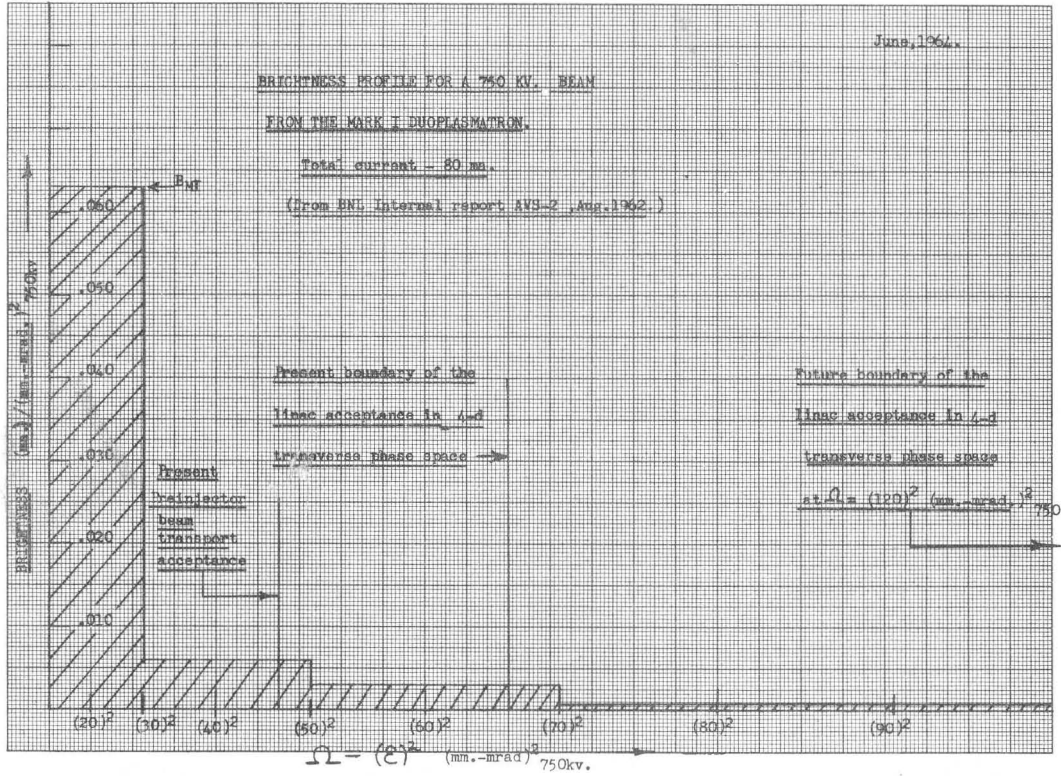


Fig. 1

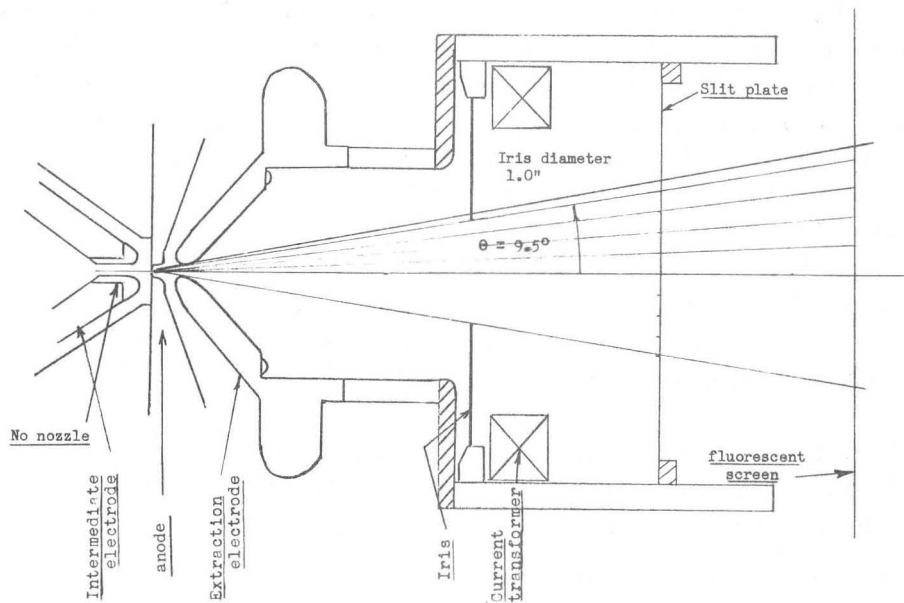


Fig. 2 Mark I duoplasmatron beam study geometry.

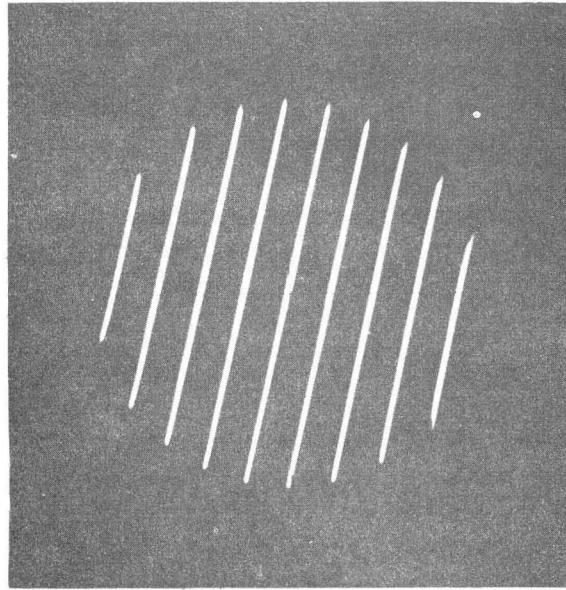


Fig. 3 Mark I duoplasmatron beam: slit images for a 200 mA. beam.

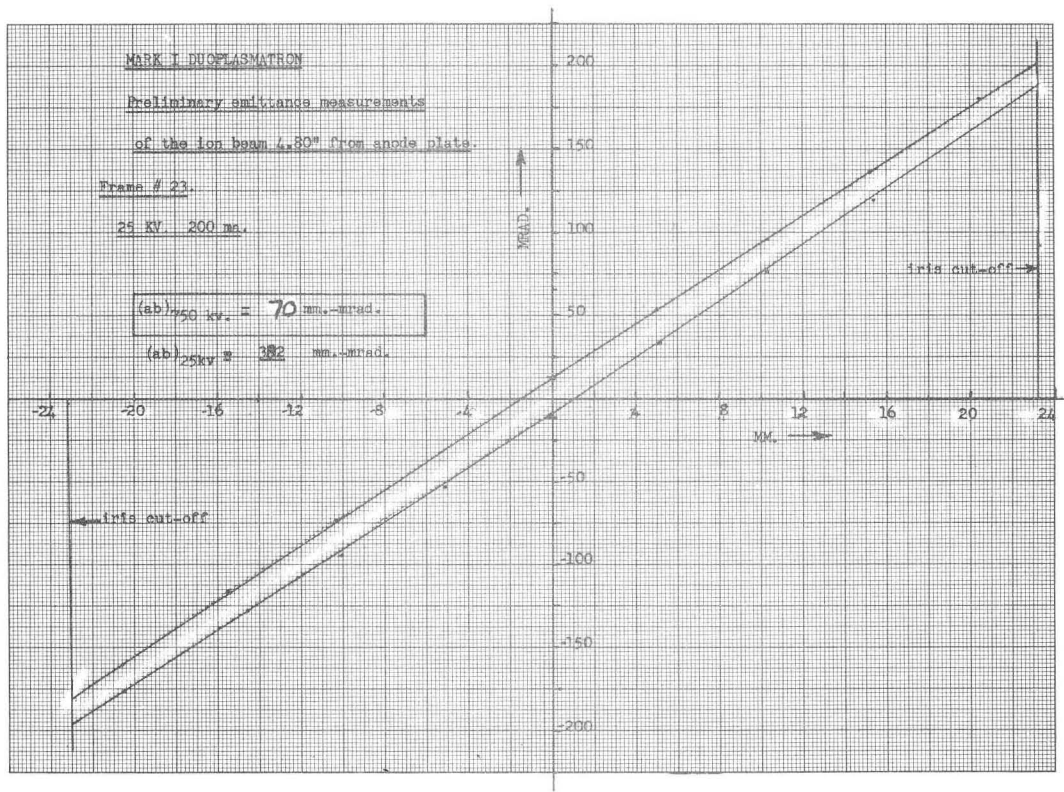


Fig. 4

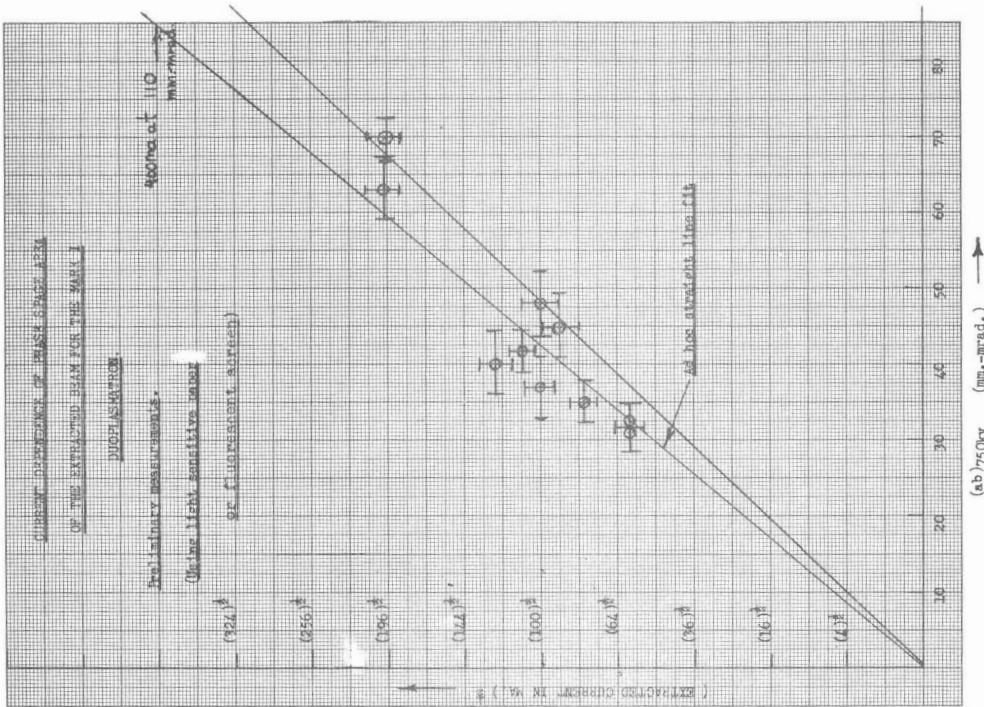


Fig. 5

MARK II DUOPLASMATRON MEASUREMENTS.
Typical beam optics for 50 nV. beam

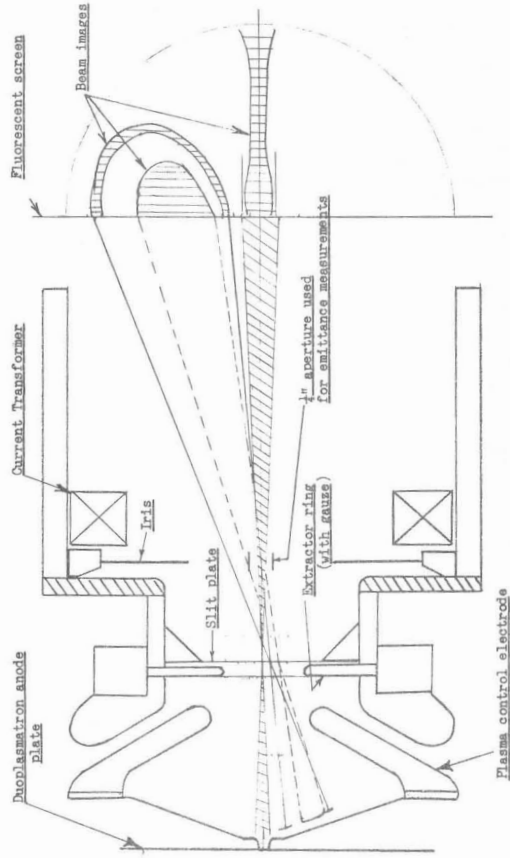


Fig. 6 Mark II duoplasmatron beam extraction geometry using the plasma expansion cup.

between 0.04 and 0.06 mA/(mm-mrad)² 750 kV which corresponds approximately to the region B_{MI} in Fig. 1. Since the uncertainties in defining the cut-off point on the brightness profile are large for this kind of measurement, it can be assumed that the measurements described here represent only the highly dense portion of the brightness profile.

The duoplasmatron extraction region was modified to incorporate an area for the expansion of the arc plasma through the anode aperture. This modification has been shown to be potentially capable of giving larger extracted beams of high brightness from a hot cathode arc discharge. The first model of this method of beam extraction at Brookhaven was the Mark II duoplasmatron, consisting of a Mark I ion source with a modified extraction geometry shown in Fig. 6. The beam optics for a 50 kV beam are also shown, indicating the existence of a beam cross-over just upstream from the iris position. The plasma control electrode was biased approximately 20 - 30 volts positive from the anode plate to prevent the plasma from expanding too close to this electrode. This bias had a significant effect on the intensity of extracted beam and in some modes of operation it could increase the extracted beam intensity by a factor of 3 over the beam intensity without bias. The extraction electrode had a fine tungsten wire gauze across its aperture to increase the focusing at the extractor electrode.

A set of emittance measurements were performed for the Mark II extractor geometry using slits placed near the extractor ring and 1.25 inches from the end of the Faraday cup. By narrowing the intermediate electrode channel to 0.10 inches diameter it was found possible to expand the anode aperture to 0.060 inches and get large extracted beams of the order 600-700 mA.

A typical emittance measurement is shown in Fig. 7 for a 60 kV - 710 mA beam extracted from the Mark II setup. Evidence for the existence of two phase space areas is shown in which the smaller area has probably the higher current density. The ion source was pulsing for a 40 micro-second pulse width and a 55 A discharge current for this measurement.

A summary of recent emittance measurements for the duoplasmatron type of ion source is given in Fig. 8. It can be seen that in general higher extracted currents with better brightness qualities can be obtained with the plasma expansion mode of extraction. It is expected that future trends for high accelerator beam intensities will be satisfied by means of careful attention to the ion extraction mechanism in ion source plasmas.

VAN STEENBERGEN: More in terms of a remark, it seems possible to change the magnitude of the plasma cup and get the same plasma density for a lower discharge current.

OLEKSIUK: That is right. I think the density is really dependent on discharge current. I believe that discharge current tells you how many neutrals you have relative to ionized particles in the plasma and this is perhaps where the strong dependence arises. If you are trying to control an ion density, I believe that this is the place to do it. The control of the plasma area I think will be perhaps a control on the aperture of the anode. We did get larger extracted currents, of course, using larger apertures, but the increase in brightness appears to come from the discharge current.

VAN STEENBERGEN: I remember Solnyshkov's results whereby he used 150 A discharge current for typically a 10-cm diameter plasma cup. He got equivalent results at least in emittance when he used, say 50 A with a 3-cm cup. It was as though the plasma density in both those cases was similar but he did not expand the plasma as far in the latter case.

OLEKSIUK: Yes, that sounds reasonable. In fact this may be the other way of doing it, that is, keeping the plasma expansion down to a certain finite degree.

VAN STEENBERGEN: Yes. This, of course, might limit the total current. You might not get 700 mA then.

OLEKSIUK: This would be for the same brightness figures. The brightness figures would not change radically--that is a possibility. We used only the one extraction geometry at this stage and, of course, there is a lot more work to be done that way.

MORGAN: On the 700 mA emittance work at 50 kV, I believe you say you used only 600 to 900 V bias on the target. Did you actually check this current calorimetrically. With a beam like this, this field would probably be insufficient for containing the electrons.

OLEKSIUK: The two readings we had were the current transformer and the Faraday cup. No calorimetric readings were obtained. We see what is hitting the iris and what is being collected in the cup and what the current transformer reads. We are biased for secondaries and we have a small area that the back-streaming electrons see anyway to get out. So it seemed that we were fairly safe in the current measurements.

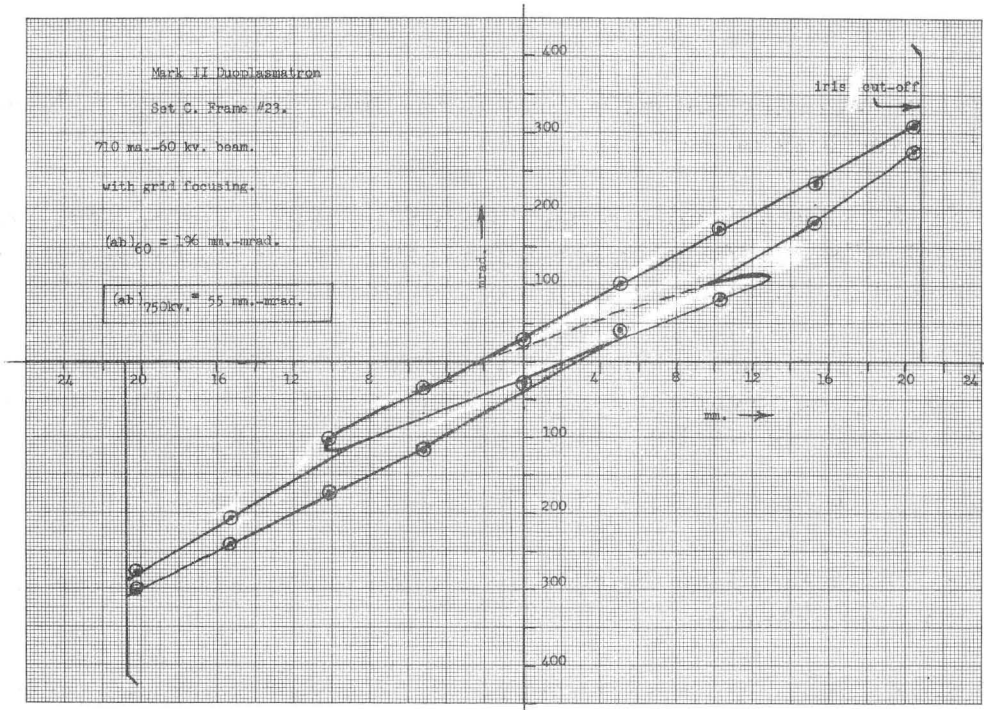


Fig. 7 Emittance of a 710 mA beam extracted from the Mark II configuration.

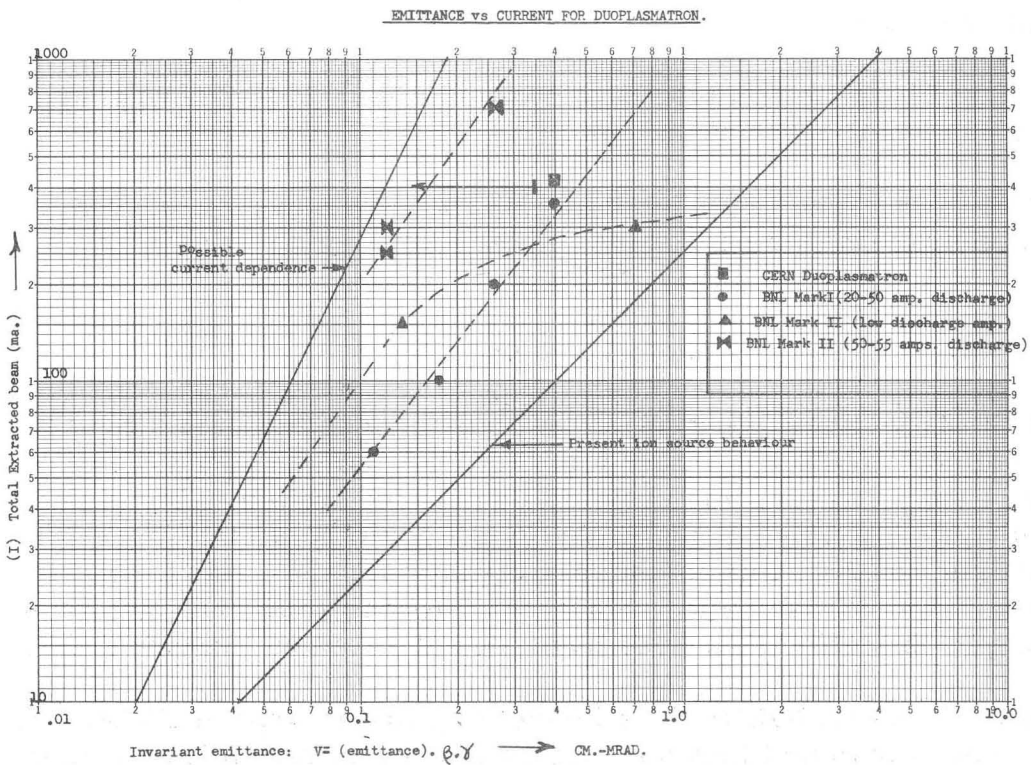


Fig. 8 Recent beam emittance values for the duoplasmatron type ion source.

MORGAN: Were the 700 mils through the iris or was that the total current, including the loss on the iris?

OLEKSIUK: The 700 mils were through the iris. There were possibly about 100 mils cutting in on the iris itself. So we measured the collected slit current and checked it with the transformer.

WROE: I just wanted to check on variation of emittance with arc current. Were you saying toward the end that the emittance you measure went down as the arc current went up?

OLEKSIUK: Yes.

WROE: This seems the wrong way around if you attribute the emittance to an ion temperature.

OLEKSIUK: Well, in fact, we do not know what the temperature does. One may be just changing ion density. Of course, I don't know how the plasma would see this. But, in fact, just looking qualitatively at the way this bright spot appears, I think we are introducing some sort of a new area in the plasma from the high discharge and this dense area is perhaps contributing to the large effects we are seeing in the brightness. Extraction from this new bright area may be giving us the high brightness numbers.

LAPOSTOLLE: You tested your source with and without grids. Could you say what you think is best?

OLEKSIUK: The grids tended to dilute the beam emittance a little bit. The emittance numbers were perhaps 20% higher for the same current extracted using the grids.

LAPOSTOLLE: Is it one or two grids?

OLEKSIUK: It is one grid. The grid changed the optics a bit as was expected. The other effect was that with the grid I could extract higher currents. That is, without grid I would be limited to perhaps 350 to 400 mA. Then by putting in the grid I could go up to 700 or 710 mA of beam under the same ion source conditions. So I think the grid is contributing secondaries which are neutralizing space charge, or something to this effect. It does have a good effect on the extraction.

VAN STEENBERGEN: It is interesting to note that at HVEC indications have been obtained that the various shapes in the emittance diagram

would be related to two kinds of beam shapes or beam profiles. The high intensity central core would come from a lower density plasma at the periphery of the plasma boundary and the rather wider beam of lower intensity, which constitutes the lower density filled distorted shape in the emittance diagram, would come from the central part. Thus there seem to be indications of an inhomogeneous density distribution at the plasma boundary. I don't know how this would tie in with the observation of a preponderance of heavy ions in the distorted shapes. Possibly beams from a lower density region with a lower plasma temperature might show a different proton percentage.

OLEKSIUK: I should really mention ion source oscillations; we get evidence of about a 10-12 Mc oscillation in the extracted beam and I believe this is due to ion sound-wave oscillations; one can estimate the frequency using the parameters in the discharge and get reasonable agreement with this range. I found it possible for the oscillation to disappear, due mainly to change in the aperture of the anode plate, that is, for large anode plate apertures the oscillation completely disappeared.