ION ACCELERATORS FOR SPACE

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Abstract.

We have carried out studies of ion accelerators for space use, in particular for space stations. Two designs are presented, one suitable for treatment of large surfaces and the other for small sample irradiation.

I. INTRODUCTION

The main purpose of the accelerators is to allow ion implantation in space stations and their neighborhoods. There are several applications of interest immediately useful in such environment: as ion engines and thrusters, as implanters for material science and for hardening of surfaces (relevant to improve resistance to micrometeorite bombardment of exposed external components), production of man made alloys, etc. The microgravity environment of space stations allows the production of substances (crystalline and amorphous) under conditions unknown on earth, leading to special materials. Ion implantation "in situ" of those materials would thus lead uninterruptedly to new substances.

Accelerators for space require special design. On the one hand it is possible to forego vacuum systems simplifying the design and operation but, on the other hand, it is necessary to pay special attention to heat dissipation. Hence it is necessary to construct a simulator in vacuum to properly test prototypes under conditions prevailing in space.

II. DESIGN CRITERIA

We have set certain criteria and design parameters guided by the objectives enunciated above, for the two designs considered. Firstly, the voltage should be in the range of 100 kV. For sample irradiation a linear ion selector is to be preferred. Thus a Wien filter is indicated and should be placed between the ion source and acceleration system. The ion current should reach the mA range, thus space charge effects ought to be taken into account explicitely. There has to be a fully remotely controlled manipulation of the accelerator and/or samples. For the treatment of large surfaces a rather extended beam is preferable. The same is also true for ion propulsion, where in addition ion selection is not required. As for other equipment destined to space, the usual lithany applies: weight and energy economy, ruggedness and freedom from breakdown, high ion efficiency, fool proof operation, etc.

III. LARGE BEAM ACCELERATOR.

This design starts with an ECR (electron cyclotron resonance) ion source coupled to a short accele-

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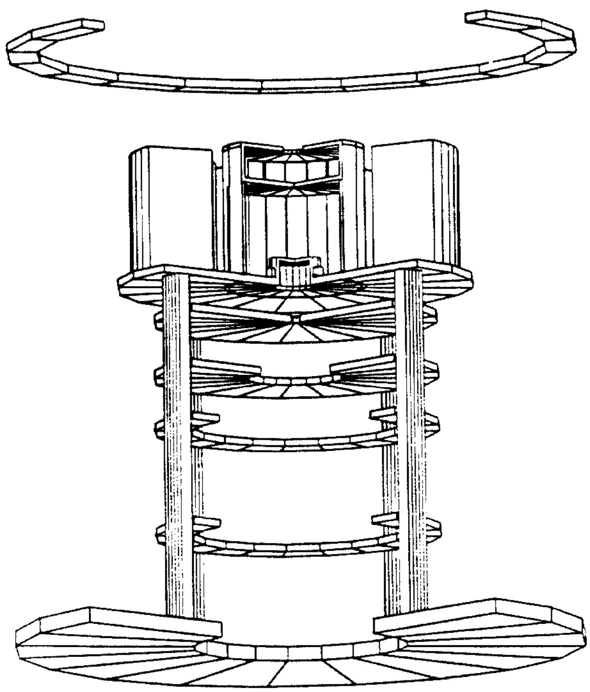

Figure 1. View of the large beam accelerator, 80 cm wide at the base plate, height: 86 cm. The ECR ion source is seen within an annular region for HV and RF supplies.

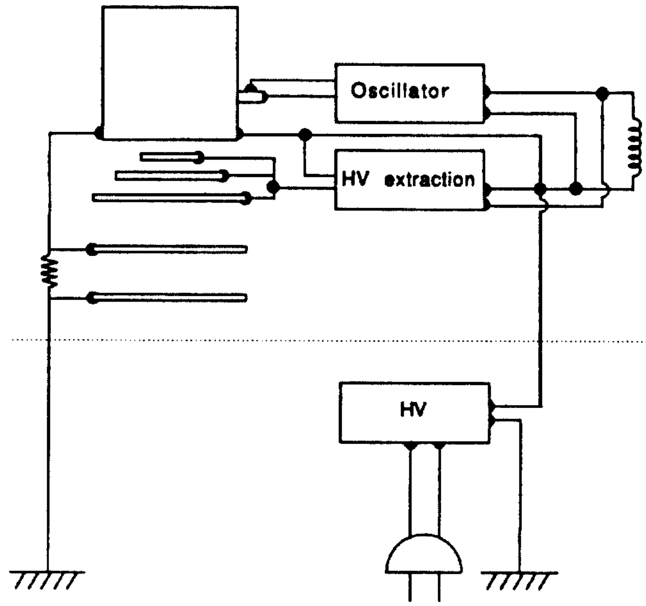

Figure 2. Electrical schematic of the accelerator of Fig. 1.

rating stage. Figure 1 shows a cut trough the machine. The ECR ion source would be similar to that of Mahoney et al. [1]. Their design should be modified with respect to refrigeration of certain parts on the side of the acceleration stage For beam extraction a gridded system as described by Septier [2] is adequate. With an extraction voltage in the range of 5 kV we have set the following dimensions: the iris at 2 cm in diameter, the distance between the plasma surface and the extraction electrode at 5 cm. The beam half angle would be 0.042 radian and the pencil half angle 0.045 radian. The electrostatic acceleration stage was designed following the method of Ref. [2]. The lens retained consists of three elements with 30 cm internal diameter and a 15 cm spacing, with a distance of the principal plane to the extraction electrode of 30 cm. the voltages on these elements would be in kV: +100, ion source ; +95, extractor, collimator and the first elements of the lens; +100 kV on the central element and the third element held at ground potential. This accelerating system, combined to the extractor should produce a fairly parallel beam of about 18 cm in diameter.

The physical layout can be seen on Fig. 1, the upper and lower platforms are attached to insulating rods which bear the different elements of the accelerator. A double wall should shield the microwaves of the ECR source from the station. Additional shielding against micrometeorites should be required for use outside the station.

The electrical diagram is shown on figure 2, the dotted line separates componentes inside the station from those outside (lower section). One of the strigent requirements is the need to maintain the power to a strict minimum. We arrive at 1.7 kW for a 1 kW beam power (10 mA at 100 kV). Heat dissipation of 650 W outside the station is to be foreseen. Control systems via transmission of optical digital codes and servo-circuits are envisaged. The treatment of exter-surfaces of a station would require a robotized operation.

IV. ACCELERATOR FOR SMALL SAMPLE BOMBARDMENT.

This design is primarily geared towards beams destined to the ion implantation of small samples and backscattering analyses of surfa - ces. Thus it is a case of much hi- gher beam densities and it is ad - visable to calculate the ion tra - jectories taking into account spa- ce charge effects. An ion source of the type Danfysik 910 should be adequate for this accelerator. It is a universal source producing an ion beam of up to 1 mA to be fol - lowed by a Wien filter (crossed B and E fields) in order to select the ions.

The accelerator system is shown on Fig. 3. We have written seve- ral computer programs for the cal- culation of focussing elements and acceleration gaps. In particular, for the design of Fig. 3 a combi - nation of a three element lens and a two gap accelerating system was used.

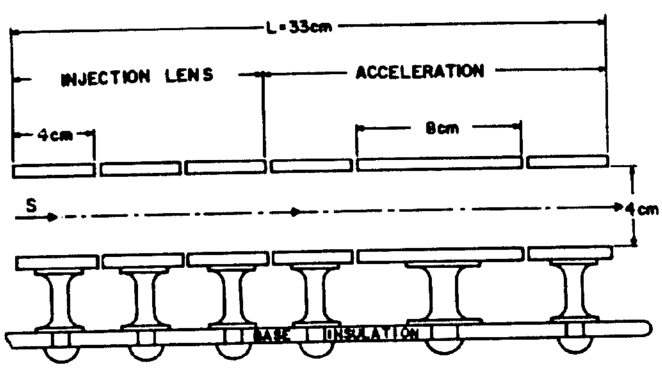

Figure 3. Schematic of the acce- lerator and injection lens.

We have constructed our pro- grams using non-relativistic dyna- mics and the geometric properties of equipotential surfaces and li - nes of force with cylindrical sym- metry. Without space charge effect results were compared with calcu - lations available in the literatu- ture, based on the solution of La- place's equation, the agreement was within 3 %. Figure 4 shows two ex-

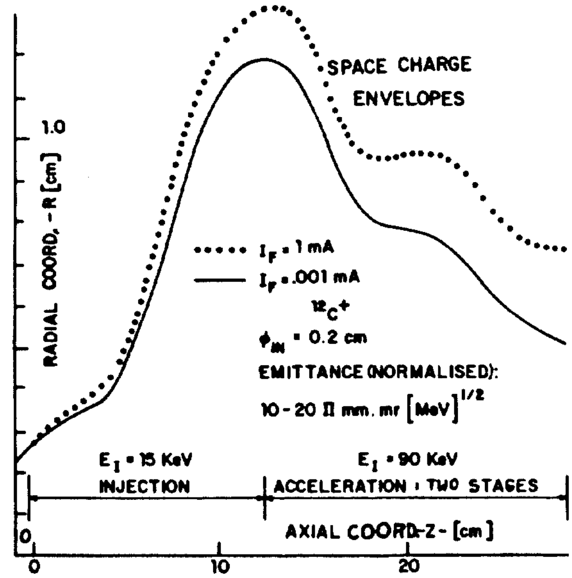

Figure 4. Beam envelopes calcula- ted with space charge effects.

amples of calculated beam optics for beam envelopes. Beams of 1 cm radius are obtained easily for 1 mA currents. For the injection a 25 kV source is sufficient and for accelerator a voltage doubler sys- tem for 100 kV is convenient. The power consumption is below 1 kW.

This accelerator can be built to wards the outside of the station with proper protection against spa ce dust and micrometeorites. Sam- ples would be manipulated inside and the whole system would be sta- tionary, not requiring robotized operation. The main construction materials for electrodes and sup - ports could be stainless steel and lightweight ceramics. Electrodes can be carved hollow to reduce the mass. Additional details of the de sign are available from the autors

The support under contract of the Canadian Space Agency is gra- tefully acknowledged.

V. REFERENCES

[1] L.Mahoney et al.MSUCP 47(1987)

[2] A.Septier, Focussing of Char- ged Particles,(Academic Press, N.Y. 1967) and Refs. therein.