SOME CONSIDERATION ON THE APPLICATION OF LINEAR RESONANCE ACCELERATORS TO THE ION IMPLANTATION

A.N.Antropov, V.K.Baev, N.M.Gavrilov, R.K.Gavrilova, A.A.Kostjuhin, S.A.Minaev, A.V.Shalnov

Moscow Engineering Physics Institute, Kashirskoie shosse, 31, Moscow, USSR

Summary

Application possibilities of linear resonant accelerators in ion implantation technology and radiation defectoscopy of surface layers are discussed. As compared to those of electrostatic accelerators are small sizes and radiation safety. Versions of radio-frequency accelerating structure of boron ions and protons with output energy 1,2 MeV have been studied. Accelerating structure is based on resonator with drift tubes and ion beam being focused by accelerating field. We intend to use microwave ion sourse with potential 25kV that excludes necessity of radiation protection and produces no make failures in operation of control computers. Small RF power (about 40kw) required and effective cooling sistem allow c.w. operation. Problems of output energy variation in resonant accelerator and acceleration of different kinds of ion by single accelerating structure at fixed frequency are also discussed.

Introduction

High voltage Cocroft-Walton and Van-de--Gnaaf accelerators with energies up to 0.5MeV are used for technical applications in many cases. They have some convenient features such as energy variation, high beam stability, possible acceleration of various ion species. However highest voltages require much more space for accelerators and correspondingly radiation shielding etc. which made them less economical. The development of microfabrication technology follows the demands of higher energies (about several MeV at the moment).

In resent publications (1,2) attention has been paid to more acceptable linear resonance accelerators of the required energies. These accelerators have been well known instruments in atomic and nuclear physics for many years. Their main attractive features are the absence of high voltages and modest sizes. Nevertheless, some drawbacks of linacs should be mentioned. First of all they have a fixed energy of ions due to the principle of resonance acceleration. Second, their average current is incomparably less tnan the current of the accelerators mentioned above owning to a pulsed r.f. generation at a small duty factor. In addition the difficulties of ion focusing for non-relativistic ions are great. We'll give some considerations to these reasons taking into account the latest developments in the area.

There are two different implementations in the technology of microelectronics concerning ion implantation. The first one is intended for industrial applications on standart VLSI's which required ion implantors with central ions (B,P, as etc) of fixed energy simoultaneusly. The amount of wafers thus produced should be about a hundred elements per hour to be economically acceptable. For resonant accelerators to obtain such values is not a problem. There are some compact accelerating structures with many drift tubes and gaps developed for this purpose.

The second implementation is connected with research and development projects. In most of the cases it is necessary to have different ions with variable energies and currents. It is known that the valocity of travelling wave must be equal to the velocity of accelerated ions which means that the energy cannot be changed simply by r.f. power variation. The only way is to change the frequency but such an operation is possible for no accelerating structure. Hence a module structure of an accelerator can be used where a variation of energy is obtained by replacing or adding one or several resonators to the end side.

The mean current can be raised by shifting from a pulsed operation to continuous or quasy--continuous one with a high duty factor. Many accelerating structures with a hifh shunt impendance can operate with modest power supply, say 10-40 kW, to achieve the electric field of about 10-20 $kV.cm^{-1}$. The problem of cooling depends on the structure and may be easily solved. For a continuous operation resonance ion accelerator the focusiny problem is very complicated. Up to several MeV's a radiofrequency quadrupole focusing (RFQ) and the varied value of synchronous phase (VSP) are used. The accelerators with a RFQ can be used to get peak currents up to several hundred mA with the efficiency of the phase acceptance of about 2π. They are used in many cases and can be employed in continuous operation (4,5,6). For industrial applications their disadvantages are low energy gain (about 0.5 $MeV.m^{-1}$ at the input) with a high electric field inside the structure and complicated technology of accelerating structure. Therefore a possibility to implement USP accelerators with drift tubes in continuous operation is considered. The VSP accelerators are simple for construction, have a comparably big energy gain but their mean currents in continuous operation do not exeed some mA which might be acceptable in many cases.

Experiments and results

An experimental VSP accelerator was put into operation in 1981 at 1,2 MeV proton energy (7). The length of the accelerating structure was 75 cm, the diameter being 20cm. The accelerating structure is shown in Fig.1.

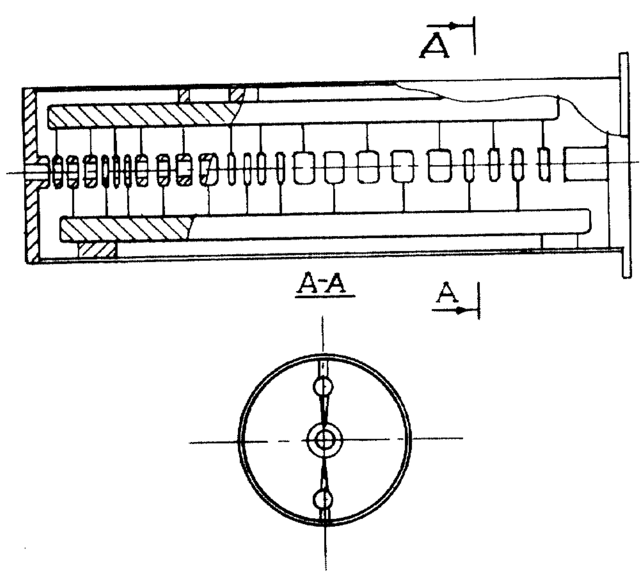

Fig.1: The accelerating structure of the proton linac.

Later the accelerator was modified for an operation without an r.f. power supply wher an electron beam was used for focusing as w as for r.f. generation (8).

The experimental results as well as th further dynamics calculations resulted in another modification of the VSP accelerator with a low injection energy and electric field and higher acceptance of injected bea The calculated figures are listed in the table.

Table

Typical parameters of accelerating structure with the drift tubes calculated on the basis of modelling

ion	Wi KeV	Wo MeV	λ m	$\Delta\varphi$ rad.	L m	Ra mm	Ec $MV.m^{-1}$	N
$^1H^+$	30	1,5	2	$\frac{4}{3}$	1,2	4-8	5	29
$^{11}B^+$	25	1,2	6	$\frac{11}{9}$	1,2	4-8	5	27

here W_i and W_o are initial and output ion energies;

λ is the radiofrequency wave length;

$\Delta\varphi$ is the phase acceptance;

L is the accelerator length;

N is the number of the gaps.

It can be seen that the phase acceptar is twice that published for the VSP accelerators (9,10) and the electron field in the gap is considerably less.

A low injection energy used made the accelerator advantafeous from the point of view of the radiation safety and size. It becomes possible because of combination of the VSP principle and additional focusing by the field of the fast wave (11,12).

A special structure of the drift tubes and gaps was developed to achive such a combination. The modification of the two-li resonator was utilized as shown in Fig.2. The resonator tuning is performed by disple cement of the line support. The uniformity of the electric field in the gaps is about 15 per cent within 1,2 m structure. The r.f can be tuned from 50 to 150 MHz which allov to accelerate not only protons but heavier ions as well.

The cooling system can provide the str ture temperature within 10°C limit. Evaluat ons show that the mean current of the accel rator is about 10mA.

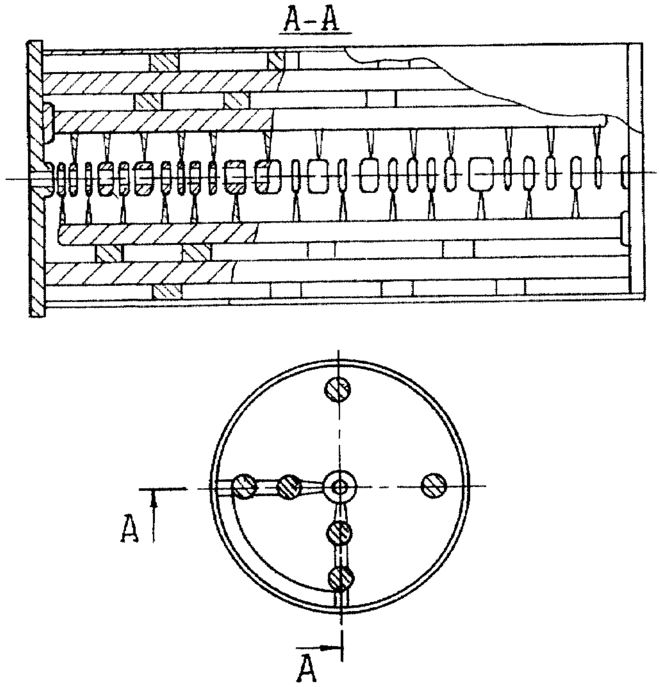

Fig.2. The modification of the two-line resonator.

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