TECHNOCALITIES FOR A NOVEL MEDIUM ENERGY ION ACCELERATOR

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Abstract

Transmutation of radioactive waste, high-intensity pulsed sources of fast neutrons, problem of inertially-confined fusion and a lot of different problems of science and technology put increased demands on the linear high power medium energy proton and heavy ion accelerators. But these accelerators are presently massive, huge and very expansive, which restrict now and in a near future their wide use and motivates the study of altenetive methods to achieve the design current, power and economic characteristics. This report decribes the present reseach on attaining high power medium energy ion beams, using novel idea for accelerator design. Theoretical proposal and preliminary conceptual design for the accelerator, based on a principle of free flying ion emitter("ballistic anode"),were discussed first a few years ago. The principle involves a high potencial difference generated only for a short time in the special vacuum chamber, but not steady-state conditions. Now, we would like to discuss next problems:

1. Technicalities of the ballistic anode design, both for proton and heavy ion beams generation.
2. Pulse power multiplication.
3. High current sources for charge pumping of the ballistic anode.
4. Experimental modelling.

ELECTROSTATIC SUSPENSION

A physical principle was proposed some years ago which provided for the first time a possibility in principle to arrange and perform laboratory experiments on generation of quasistationary electric fields in the gigavolt range [1, 2]. As a main physical process, this principle involves so-called "charge pumping". It consists in accumulating a positive charge on a body of relatively small size (a "ballistic anode") free flying in high vacuum at a sufficient distance from the walls of a grounded vacuum chamber. A positron beam whose energy must be linearly profiled in time was proposed as a carrier of positive charge for charge pumping.

The charge of more than one millicoulomb is necessary to generate the gigavolt potential on the ballistic anode constituting a solid body with a characteristic dimension of several centimeters. Let (as is done in [4, 5]) the time of charge pumping be a hundred microsecond. Then the positron beam current is about ten amperes. This is a rather great value. Positron sources presently used in accelerators provide much lower currents (of the order of one to ten microamperes) and represent complexes consisting of an electron accelerator of gigavolt energy and a positron target made of heavy elements (such as $W_{75}Re_{25}$).* These sources can be used for charge pumping. However, in this case of small positron currents it is necessary to suspend the ballistic anode at the centre of a vacuum chamber for a long time and maintain its motionless state throughout the whole time of irradiation. The vacuum chamber itself can be built-in in the accelerating section and have some common structural components with it.

There exist a number of non-contact suspensions using electromagnetic forces or interaction between magnets and superconductors [6, 7]. We think that an electrostatic suspension with a transverse dynamic stabilization is the simplest solution in our case. In contrast to other fields of technology, the suspension proposed by us for charge pumping must hold a small body ("ballistic anode") at a great distance (about one meter) from the walls of the vacuum chamber, which will require special theoretical, experimental and design efforts.

The long-term irradiation of the ballistic anode with the positron beam does not yet secure the accumulation of the positive charge up to the required level. The charge pumping is possible only in the event when the positron beam current (more precisely, that part of it which thermalize and annihilate in the substance of the ballistic anode) is greater than the sum of all parasitic currents decreasing the positive charge. The parasitic currents result mainly from the pressure of residual gases in the vacuum chamber, autoelectronic emission from the inner surface of the vacuum chamber and ion emission from the surface of the ballistic anode. For this reason, under conditions of stationary irradiation the heavy requirements are imposed on vacuum (10^{-10}-10^{-11} torr) and on smoothness of the inner surface of the vacuum chamber.

Let us demonstrate the aforesaid with qualitative estimates. Let the substance of the ballistic anode withstand an electric field strength of $3 \cdot 10^8$ V/cm. For the simplicity of calculations, assume that our purpose is to generate a potential of $3 \cdot 10^8$ V. Then the diameter of a spherical ballistic anode will be 2 cm, its charge being 1/3 mC.

If we assume (somewhat arbitrarily), that only a third of beam positrons annihilate in the substance of the ballistic

* It is technically possible to create a positron source capable of providing a current of up to a milliamp with the use of isotope $_{29}Cu^{69}$ [3]. However, this scheme is not sufficiently developed for practical purposes.

anode, then for a positron current of 1 μA the time of charge pumping will be about 1000 s.

Upon completion of the process of charge pumping the ballistic anode will obtain the specified value of positive potential that can be used for different purposes, for example, to accelerate protons or heavier ions. In this case the surface of the ballistic anode (more exactly, its small part) will act as a source of positrons or heavier ions, respectively. The design solutions can vary.

The gap between the ballistic anode and the wall of the vacuum chamber can be used for the production of a neutral beam. To do this a source of negative ions must be placed near the wall of the vacuum chamber. The ballistic anode per se must have a design feature allowing the electron stripping and the conversion of negative ions into neutrals. This can be easily attained by substituting a thin foil for the central part of the ballistic anode.

If the chosen foil is thicker than is required to realize the negative ion-to-neutral conversion, a tandem scheme of negative ion-to-positive ion conversion is feasible. In the tandem scheme the ions will receive the energy twice: in their motion from the negative ion source to the ballistic anode and, after charge exchange, from the ballistic anode to the opposite wall.

Above all, a ballistic anode suspended at the centre of a vacuum chamber by any noncontact suspension system is capable of acting as a source of constant ion current in contrast to the case considered in [4, 5]. For this purpose it is essential only to maintain the potential of the ballistic anode at the proper level by irradiating it continuously with a positron beam, that is to carry out the charge pumping.

References

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