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ERA RESEARCH IN JAPAN

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Summary

An overall view of ERA research plan in Japan is given. The system has a field emission electron gun producing several kA driven by a Marx and a Blumlein during some tens of nsec and a large vacuum chamber made of stainless steel into which the electron beam is injected and captured. The coils for compression are placed inside the chamber and produce a fast rising magnetic field. The electron ring has a final radius of about 2 cm and the energy of electrons should be about 10 Mev. Special attention is given to the theoretical and the experimental studies of the collective phenomena related to the ring stability just after the injection, the possibility and the efficiency of the acceleration of a charged bunch with an RF cavity, and other problems of the instabilities that may arise.

Introduction

The research of ERA in Japan has been continued over the last three years, especially at the Institute of Plasma Physics in Nagoya University as a co-operative work of the scientists belonging to many Japanese organizations concerned with plasma physics, nuclear fusion research and accelerator technology. The plan is progressing in the frame work of the study of plasma physics while great importance is being attached to the study of the character of the ring as a relativistic plasma and to the technical feature of the high current electron beam generation for fusion research more than to the research for a very promisive new accelerator.

The injection experiment of the electron beam of 600 keV into a static mirror field is just starting. The capture of the beam in the betatron orbit and related collective phenomena are now under investigation.

Co-axial Marx Generator

As a source for high intensity electron beam, the field emission type electron gun was chosen and driven by a simple Marx. To get a sufficiently large current the Marx is assembled in a completely co-axial construction. Fig. 1 shows its cross section and the rated values are given in Table 1. The internal inductance of the Marx is estimated to be about 100 nH. The field emission gun with multi-needles cathode can produce an electron pulse of 300 keV mean energy, 30 kA peak current, and a duration of 10 nsec when operating into a matched load (10 Ω). An example of the out put pulse is given in Fig. 2.

600 kV Blumlein

The Marx would charge the Blumlein, which is directly connected to it. The out put pulse should be shaped to get a better operation of the gun. Fig. 3 shows the geometry of the Blumlein. The circuit is now under test and will be applied soon.

Induction Linac as a Booster

As pointed out in the experiments at Dubna, Berkeley and Garching, the qualities of the injected beam have a large influence on the capture efficiency and the collective phenomena. They are supposed to be serious just after the injection into the compression field, such as negative mass instability.[1] We would improve the relatively large energy spread of the output beam as seen in the commercial Febetron accelerator by adding the induction linac as a booster. At present, the final energy of the electron beam is estimated to be 4 MeV. The detailed design of the linac is being investigated and it is intended to be constructed with the budget for 1973.

Vacuum Chamber and Inflection System

The vacuum chamber, in which the captured beam is compressed to form an electron ring, is large enough to contain the coils for compression, so that the pill box model would be well adopted to estimate the effect of the surrounding walls on the beam stability. The chamber is more similar to that in Dubna than to the compressor in IRL.[2,3] We will examine experimentally, the influences of various wall coatings on the negative mass instabilities expected at the injection period. The vessel is made of stainless steel and can be evacuated, with a combination of an ion pump and a turbo-molecular pump, to 10^{-10} torr if it is baked to a sufficiently high temperature, say 300°C.

The beams of 600 keV are injected into a static magnetic field through an iron snout in the chamber at the radius r=24 cm. The static field of 120 gauss is produced by a pair of coils set outside the chamber and the electrons are captured by the self-field of the beam and/or the work of the inflection pulse. The electrode plates of the electrostatic inflector are set along the two concentric circles in the vacuum chamber to which a rectangular pulse with very short rising and falling times is applied. The pulse has a length of 5 nsec and is applied to the four separated inflectors, charging

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them to 20 kV. Injection into a static field is expected to reduce the ambiguity accompanied with the phenomena appearing in the very short beam. The beam life will be over 10 μsec at least, and we will have enough time to analyse it. Multi-turn injection is also possible, but one turn injection scheme will be the most promising.

To generate the inflection pulse, a line type pulser is constructed. A set of co-axial conductors with outer diameters of 200 mm are installed inside. A matching load resistor of 5 Ω is also set into the co-axial system. The sketches of the vacuum chamber and the inflector system together with the pumping unit are shown in Fig. 4.

The coils producing the compression field would be placed in the chamber. The compressor is composed of a set of three one-turn coils of different radii. The timing and the intensity of the current flowing in them are programmed. The final energy of the electrons should be 10 MeV and the final magnetic field should be about 20,000 gauss on the axis, some modifications or reconstruction of the chamber will be necessary before we try the final compression. The schematic figure of the coils in the chamber is shown in Fig. 5.

Test Run of the Injection

Very recently, the whole system except the linac and the Blumlein was assembled and a preliminary injection experiment was carried out. Several hundred amperes of the electron beam were obtained at the energy of 550 keV at just in front of the gun; the injected current into the chamber, however, is measured to the order of 10 A due to the relatively poor focusing system. This is clearly far below the threshold over which some interesting collective phenomena will appear. Fig. 6 shows the injected beam as measured in front of the gun. The experiment has been continued and the intensity will be increased to confirm the capture of the beam.

Future Plan

Our future plan is divided into three topics:

1) generation of much more high intensity and high energy electron beams. A new induction linac will be prepared within a year and a new 2 MV co-axial Marx is also under construction. These improvements of the technical features will make possible the clear understandings of the injection and the related phenomena.

2) We will proceed with the theoretical study on some instabilities which may be found as the electron intensity increases from the point of view of the plasma physics with the co-operation of theoreticians dealing with this field. In regard to the theoretical research, the spiral injection - radial or axial - experiment is also planned in order to get large ΔE/E value to improve the ring stability.[4]

3) We will check the possibility of acceleration of a high intensity relativistic electron bunch by a single unit or a series of cavities. Many theoretical works have been done to calculate the energy loss of the charged bunch of particles passing a cylindrical cavity or its infinitely large periodic sequence.[5,6] So far as we know no complete experimental demonstration for the radiation loss has been given. We will carry on research in our laboratory with an experimental as well as a theoretical approach, where an intense electron beam will be studied by analysing its energy spectrum before and after passing through a single RF cavity.[7] We easily come to the conclusion that the geometrical dimension should be very large, to deduce some knowledge about the radiation from the beam streaming into the cavity, by comparing the two energy distributions. Two alminium plates of 3m × 3m are combined to make a capacitor and an electron beam of 300 keV and 5 kA lasting 10 nsec passes the capacitor perpendiculary through the hole of 10 cm in diameter at the center of the plates. The experiments are now progressing and the preliminary results will be given in the near future.

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Table 1. Parameters of the 600 kV co-axial Marx generator.

OUTPUT VOLTAGE	600 kV
CHARGING VOLTAGE	60 kV
NUMBER OF GAPS	10
CAPACITOR	CERAMIC 30 kV 2000 pF
NUMBER OF CAPACITORS	160
STORED ENERGY	160 J
RESULTANT CAPACITANCE	800 pF
OUTPUT IMPEDANCE	10 Ω
SIZE	350φ×1500 mm

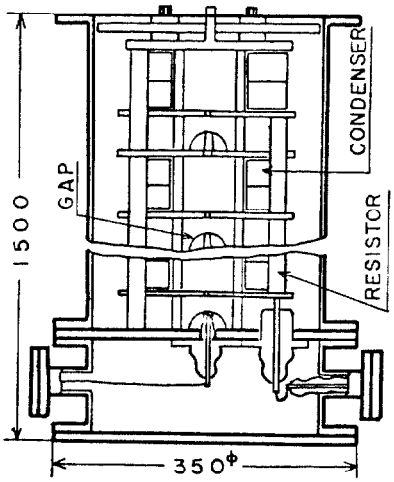


Fig. 1. Cross sectional view of the 600 keV co-axial Marx generator.

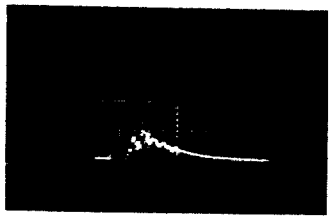


Fig. 2. Out put pulse of the Marx generator. (Load resistance = 50 Ω)

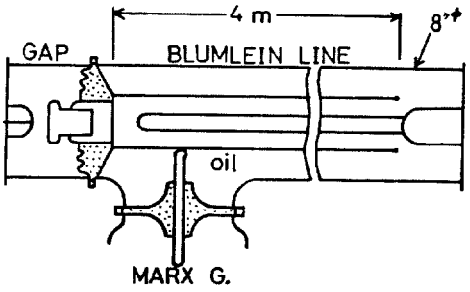


Fig. 3. Geometry of the 600 kV Blumlein.

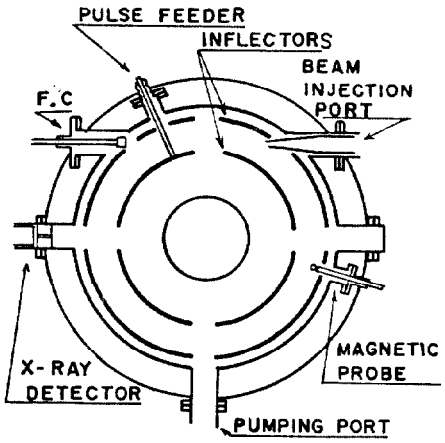


Fig. 4. Vacuum chamber with inflector system.

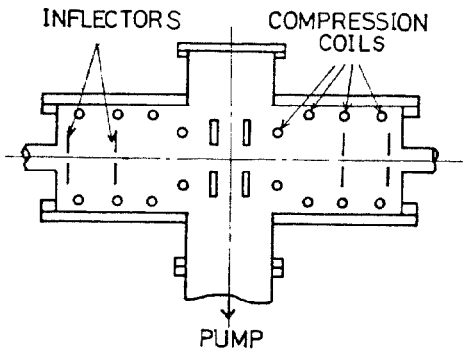


Fig. 5. Schematic figure of the compression coils.

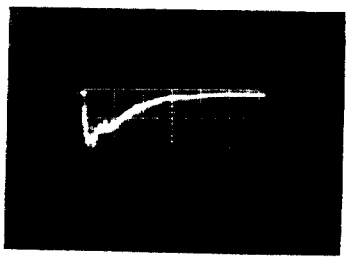


Fig. 6. Oscilloscope pattern of the injected beam in front of gun.