CONCEPTUAL STUDY OF HIGH POWER PROTON LINAC FOR CLEAN NUCLEAR POWER SYSTEM

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Abstract

The conceptual study of clean nuclear power system is underway in China. Many different designs of high power proton linac are discussed. A research and development plan for this linac is considered. Its task are: (1) to build a 150MeV high power proton beam test facility with a pulsed current 60 mA, (2) to develop the superconducting accelerating cavities and (3) to develop high power CW klystrons and RF systems.

1 INTRODUCTION

The rapid development of the national economy asks for a sufficient supply of energy, but the store of coal and petroleum is very limited. So it is the fundamental way of resolving the shortage of energy for human being to make use of the nuclear energy. It is generally regarded that the applications of nuclear fusion energy to industry still needs fifty years. Therefore, it is important issue faced at present to develop clean nuclear fission energy.

The proton linear accelerators with a current of tens of mA at an energy of about 1GeV can be used to drive a sub-critical nuclear reactor, for the proton beams generated by this kind of accelerators may react with a target of heavy nuclei such as lead and tungsten and produce a large quantity of spallation neutrons. There is very little nuclear waste generated in the process of producing nuclear energy with such facilities. Because the reactor is in a sub-critical state and stops immediately after the accelerator stopped. It is of intrinsic safety. At present, the nuclear scientists from many countries have paid attentions to this idea and suggested many different designs and plans.

Up to now, the proton linear accelerator LAMPF in LANL located in Los Alamos , USA has the largest beam power in the world. It is of an energy of 800MeV , an average current of 1mA and a average beam power of 0.8MW. Based on the calculations of C. Rubbia and other scientists, as a stable and reliable industrial energy system , the power of proton beams can not be less than 2530MeV[1], which is tens of times larger than that of the accelerators now available. Obviously, this is a great challenge to accelerator physics and technology. To achieve this object, people still have much to do in decreasing beam loss, increasing the efficiency of accelerators and raising the ratio of operation time.

China is a developing country. The need of the energy increases very quickly as the results of the rapid development of economy. It is quite necessary to develop the nuclear energy industry. At the advocacy of some famous scientists, the studies on the clean nuclear energy system have began in Institute of Chinese Atomic Energy , Institute of High Energy Physics, Beijing University and Tsinghua University.

2 HIGH POWER PROTON LINEAR ACCELERATORS

In order to satisfy the requirements of the clean nuclear system, we suggest using a CW proton linear accelerator with a current 30mA at an energy 1GeV. We have once proposed several plans of different types of accelerators. The first plan is very near to that of APT in LASL[2]. It consists of an ion source, a radio-frequency quadruple(RFQ), a coupled cavity drift tube linac(CCDTL) and superconducting accelerating cavities(SCC). The parameters of different parts are listed in the following.

Ion source	
type	ECR source
energy	50keV
current	35mA
emittance	0.2 mm-mrad
RFQ	
type	four-vane type
energy	7MeV
current	30mA
work frequency	350MHz
length	8m
average bore radius	23.5mm
average accelerating gradient	1.4MV/m
cavity power losses	1.3MW
beam power	0.2MW
CCDTL	
energy	100MeV
current	30mA
work frequency	700MHz
length	100m
bore radius	11.7cm
structure accelerating gradient	11.6MV/m
cavity power losses	5.0MW
beam power	2.8MW

SCC

energy	1000MeV
current	30mA
work frequency	700MHz
length	500m
bore radius	58cm
structure accelerating gradient	46MV/m
design (proton velocity/light velocity)	
	0.47(100-210MeV)
	0.64(210-470MeV)
	0.8(470-1000MeV)
cavity power losses	0.3MW
beam power	27.0MW

The second plan is to use drift tube linac(DTL) or radio-frequency focused drift tube linac (RFD)[3] instead of RFQ and CCDTL in the energy range of 2.5 to 100MeV.

The third plan is to accelerate the positive and negative ion simultaneously. That is to say, the positive ion beams are accelerated during positive half period of high frequency field, the negative ion beams are accelerated during the negative half period of high frequency field. The advantage of this method is that the beam current can be almost doubled.

3 RESEARCH AND DEVELOPMENT PLAN

In order to pursue the studies on the clean nuclear energy system, a R&D plan is laying for developing high power proton linear accelerators. Its tasks are (1) to build a high power proton beam test facility, which can provides proton beams for the tests of sub-critical reactor and the related nuclear physical experiments. (2) to develop the superconducting accelerating cavities that can be used at the high energy(1001000MeV) range of high-intensity, CW proton linear accelerators. (3) to develop high power CW klystrons and RF systems.

The tasks of recent late years are (1) to complete the front end (including the ion source , LEBT and RFQ) of the proton beam test facility. (2) to complete the theoretical studies on the main body of the proton beam test facility, model tests and the preliminary design. (3) to build a superconducting accelerating cavity laboratory. (4) to build a high power klystron laboratory.

4 HIGH POWER PROTON BEAM TEST FACILITY

The technical specifications for the high power beam test facility planed to build are

energy	150MeV
pulsed current	60mA
pulse duration	1ms
pulse repetition rate	50Hz
duty factor	5%

This test facility consists of a 65keV ion source, a low energy beam transport section (LEBT), a RFQ(2.5MeV, 350MHz) , a medium energy beam transport section(MEBT), a DTL(20MeV, 350MHz), a CCDTL(96MeV, 700MHz) and a coupled-cavity linac (CCL 150MeV, 700MHz). The test facility can also provide nanosecond pulsed beams for some physical experiments. To this end, a chopper will be installed at the LEBT or MEBT section.

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6 REFERENCES

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