THE "SALO" PROJECT

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Abstract

The NSC KIPT (Ukraine) and the Technische Universiteit Eindhoven (The Netherlands) are now considering the possibility of creating the electron accelerator that would meet the present-day requirements of the physical experiment. The recirculator circuit with the use of a superconducting accelerating structure TESLA is found to hold the most promise.

Technological decisions and circuit designs have been chosen to create the machine with an energy up to 730 MeV and with a continuous beam for investigations into high energy physics, nuclear physics, neutron physics and free-electron laser (FEL) physics.

INTRODUCTION

The Kharkov electron linacs LU-2000 and LU-300, built in the sixties of the last century, have become hopelessly obsolete, both morally and physically. The attempt to create a stretcher at the accelerator LU-2000 also appeared unsuccessful. The nuclear power engineering demands in Ukraine for scientific investigations and a rapid decrease in the number of specialists in the area of nuclear physics and engineering generate a need for creating a new accelerating installation that would meet the current requirements of the physical experiment. As it became clear from the analysis of physical programs on nuclear physics and devices used for the investigations [1-4], the electron accelerator must provide a continuous polarized electron beam of energy higher than 50 MeV. At present, the most promising accelerating structure for this accelerator seems to be a superconducting continuous-beam accelerating section developed for the linear collider TESLA. With the use of an RF-gun photo- injector, this structure may also provide short electron bunches needed for FELs and the neutron source.

THE CHOICE OF THE ACCELERATOR SCHEME

In the early eighties the majority of 100 ... 2000 MeV electron linacs built before exhausted their potentials for the use in nuclear physics experiments because of the small ratio of pulse length to the interpulse time. The second life of the accelerators was expected to be given due to the use of storage rings-beam stretchers, owing to which it was expected to extend the filling factor up to 50 ... 80%. About 15 projects of the facilities were proposed. By 2002, only 6 projects were realized:

- 1. Pulse Stretcher Ring EROS (Electron Ring of Saskatchewan),
- 2. Amsterdam Pulse Stretcher (APS), NIKHEF,
- 3. MAX I, MAX-lab, Lund,
- 4. SHR, MIT-Bates Linear Accelerator Center,
- 5. Electron accelerator ELSA, Bonn,
- 6. KSR, Kyoto University.

For the last decade there have no new stretcher designs, and the idea is dying together with physical destruction of old accelerators. By the present time the EROS and APS facilities have been shut down and disassembled; the nuclear-physical studies are performed only at three installations: MAX I, SHR, ELSA. The parameters of ejected beams in the stretchers are worse than in continuous microtrons and recirculators, therefore all nuclear-physical programs of the closed facilities were taken up to the accelerators of Jlab and MAMI.

The most part of nuclear-physical investigations with electron beams is conducted at present at continuousbeam facilities: S-DALINAC (TH Darmstadt), MAMI (Mainz U), and CEBAF (Jlab) [1-4]. The progress in the development of superconducting structures has put forward the possibility of creating superconducting linear accelerators with energy from 1 to 2 GeV that would operate in the continuous mode. With these accelerators as the basis it will be possible to develop higher-energy accelerators using the idea of multiple pass of the beam through the accelerator.

THE ACCELERATING STRUCTURE

At the moment it is the superconducting accelerating structure TESLA, devised at DESY, that has the parameters most suitable for electron acceleration. Developed are the processes for mass production of sections, cryomodules, and also, a few methods for the treatment of section surfaces that provide altogether the accelerating gradient up to 35 MV/m at a continuous mode of operation [5]. At really operating facilities that incorporate several sections, a 1 mA current was obtained in the continuous mode of operation [6] at an accelerating gradient of 10 MV/m. The performance characteristics of sections are time-stable and do not deteriorate the operating parameters provided that all service requirements are met. Several types of cryomodules were designed and manufactured for different numbers of sections. [4].

In all accelerator designs proposed, a 20 MV/m accelerating gradient was chosen as the one that can provide a rather high acceleration rate at moderate

expenditures for cooling the continuously operating sections [4]. At this gradient the refrigerator power, counting on one section, does not exceed 26 W at a temperature of 1.8 K.

High-frequency (1300 MHz) amplifiers with an average power up to 30 kW have been designed and are really in operation at continuous-beam facilities.

THE ELECTRON INJECTORS

The main lines of applicability of the accelerator under design are nuclear-physical investigations, intense neutron beam production and use, creation of FELs and their use for physical studies. To cope with the tasks, it is necessary to have several injectors at the accelerator.

To perform many nuclear and physical investigations at energies higher than 50 MeV, polarized electron beams are needed. Here, the polarized electron sources of the MAMI microtron and the Thomas Jefferson National Accelerator Facility [7, 8] present the greatest interest as prototypes, because the micro- and macrostructure of the beams from these accelerators are close to the ones expected at the SALO facility. These sources provide quasi-continuous electron beams with a current up to 100 μ A, polarization of ~ 80-90% and a continuous running period of the injector equal to a few hundreds of hours.

For the injectors of neutron sources and FEL, of importance are the requirements of obtaining the highest possible values of average current and the current in the bunch. The photoinjectors with a RF gun most fully meet these requirements [4], because this design makes it possible to accelerate the highest charge in the bunch. For the facility under development, the superconducting RF gun-based injector being developed for the ELBE accelerator can be taken as a prototype [9]. The gun uses $3 + \frac{1}{2}$ cavities of the accelerating structure TESLA at a frequency of 1300 MHz. The charge in the bunch is up to 1 nC, the average current is up to 1 mA.

THE RECIRCULATOR WITH A SUPERCONDUCTING ACCELERATING STRUCTURE FOR AN ENERGY OF 400 TO 750 MEV

First of all, we discuss the restrictions on the overall dimensions of the accelerator, following from the possibility of placing it in the existing rooms of the linear accelerator LU-2000 (see Fig. 1).



Fig.: 1

The target hall appears to be the most suitable place to install the recirculator. This is due to the fact that the target hall is adjacent to the hall SP-103 accommodating the magnetic spectrometer, and also to Building 46 that can be used to place the accelerator complex control. The hall SP-103 can be used for both accommodating new spectrometers and the experiments with FEL radiation. The reload hall, via which the equipment was admitted to the target hall, may also accommodate the equipment designed for experiments with the electron beam and the FEL radiation. Across this hall, the electron beam will be transported to the neutron source. Along the lens corridor, the beam may be guided to the LU-2000 bunker and the pre-existing hall of direct exit. So, the location of the recirculator in the target hall permits not only the use of the pre-existing experimental halls, but also the construction of some new rooms. The floor area that may accommodate the recirculator elements is equal to $3739m^2$.

The elaboration of the recirculator design is performed by the NSC KIPT and the Technische Universiteit Eindhoven (The Netherlands) on the basis of the Agreement about joint creation of the accelerator at the NSC KIPT that would meet the present-day requirements of the physical experiment. For realization of the project, in 2003, in the framework of the Agreement, the Technische Universiteit Eindhoven (The Netherlands) transferred 10 dipole magnets and 32 quadrupole magnets of the electron storage ring EUTERPE to the NSC KIPT.

Twelve sections placed in a standard 15.927 m long cryostat, designed for the TESLA collider, were chosen as an accelerating system. The accelerating gradient is expected to be 20 MeV/m. The first turn of beam is accomplished by means of 10 magnets of the storage ring

EUTERPE (B1) (see Fig. 2), the second turn is realized with the use of other-type 10 magnets (B2). Electrons of 9.5 MeV energy are injected into the recirculator magnet with its yoke turned outside. With this arrangement of the gun in the recirculator, the highest beam energy will be obtained in the SP-103 hall. The spacing between the straight gaps of the recirculator is equal to 5.45 m; the gap length is 19 m. The beam focusing will call for 20 quadrupoles. The second straight gap may be used to accommodate the undulator for the FEL.



The injection magnet (see Fig. 2) bends the beam from the injector, that acquires a 240 MeV gain in the accelerating structure and may be used in the SP-103 hall. With five magnets switched on the beam may be directed to the reload hall and further, to the neutron target. With additional 5 magnets of the first ring in the "on" condition the beam will pass through the accelerating structure for the second time, and being of 490 MeV energy may be used in the SP-103 hall. As the first five magnets of the second ring are switched on, the beam may be used in the reload hall, in the neutron target hall; and when the other two magnets of this ring are switched on, the beam may be directed to the LU-2000 bunker. A full actuation of all the magnets of the second ring makes it possible to produce a 730 MeV electron beam in the SP-103 hall. The target beam current will not exceed 100 µA.

At neutron-source operating conditions, the energy gain at the accelerating structure is expected to be 120 MeV, the current on the uranium or tungsten target is to be 1 mA.

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