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IEEE Transactions on Nuclear Science, Vol. NS-22, No. 3, June 1975

RESEARCH PERFORMANCES ON SUPERCONDUCTING DEVICES FOR COLLECTIVE ACCELERATOR IN JINR

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Throughout a few years studies and investigations on creation of superconducting accelerating section of collective accelerator are being carried out in the Joint Institute for Nuclear Research. The main segments of the section are solenoids which produce axial magnetic field of the required shape and accelerating cells. The analysis of the possibilities of different systems creating the required magnetic field (2 Tesla) in the accelerator showed that the most perspective one appeared to be the system of superconducting solenoids. The system is noteworthy from the following point of view: it produces the stationary magnetic field and allows to avoid a number of difficulties connected with pulse current input of standard non-iron solenoids and heat extraction, etc.

At the same time the stationarity of currents in superconducting solenoids facilitates the task of providing the necessary precisions in the magnetic field distribution. At the present time thermostatic questions of superconducting solenoids with stationary field are not a problem of principle.

Taking into account the superconducting variant of the accelerating section solenoids, it's natural to take the next step -- to use superconducting cavities for acceleration of the ring. That was the foundation of Research Programme on Creation of "Cryogenic High-Frequency Accelerating Section of KOLTSETRON" [1,2, 3].

What advantages do the superconducting cavities in collective accelerator promise? As far as not very high quality-factors are concerned ($Q \sim 10^7 \div 10^8$), then the main advantage of such cavities in pulse power decrease of supplied generators Q^{-1} , where Q - quality-factor. Accordingly, high-frequency power supply system is simplified and cheaper. Nevertheless, some special difficulties due to the study of the aspect arise. For example, the growth and improvement of the requirements in accordance with precision of maintaining the preset frequency, etc. However, the difficulties can be got over.

At the indicated quality-factors heat losses in the cavities in each pulse of energy feeding are still great and thus, the operation under continuous routine is imposseble. Timing interval τ between consequent pulses of energy feeding into cavities is selected issuing from the accepted powers of refrigerative plants. We admit mean heat gains 30 w/m at the expense of the cavities. At the electron number in the ring $(3 \div 5) \cdot 10^{13}$ and $Q \sim 10^7 \div 10^8$, $\tau \gg Q/\omega$ has to be chosen, where ω - cyclic frequency in the cavity. We have $\omega = 2\pi \cdot 5 \cdot 10^8$ Hz. For τ decrease and increase of the mean current of accelerated particles, respectively, at such quality-factors a system for extracting the energy that has not been captured by electron-ion rings should be elaborated. The cavities' "Cleaning" can be made by the electron rings between acceleration cycles.

In case of $Q \geqslant 10^9$ continuous operative routine with efficiency close to unit is feasible. Then at the energy gradient on ions 2 MeV/m and continuous feeding of high-frequency power 3kw/m, acceleration of 100 rings per second is possible.

Presently, the design is mainly completed and assembly tests of KOLTSETRON cryogenic accelerating section [1,2, 3], which is intended for proton acceleration up to the energy of 0.5 GeV are being carried out (Fig.1, 2).

The section consists of four superconducting cavities of cylindrical type (λ = 60 cm), which are placed into axial stationary magnetic field 2 T. The cavities are made of copper and on the inner surface there is Nb-Ti coating with 10 μ thickness.

The utilization of superconductors in the superconducting cavities of the second type is explained by the fact that all the cavities of KOLTSETRON should perform at the presence of 2 T magnetic field. The magnetic field is produced by superconducting cylindrical solenoids. The main solenoid (SS-600), which envelope the cavities, has 60 cm inner diameter and 240 cm length. The preset homogeneity of the field at 2 T level, at 5 cm radius amounts to 0.15%.

Besides the main solenoid, six cylindrical correction the so-called "gradient" solenoids with the length of 31 cm are placed between the cavities. These superconducting solenoids are sectionalized and each consists of 16 coils with 17 cm inner diameter. The windings are made of multiple wire with 0.5 mm diameter. Matrix is made of copper. The number of superconducting filaments of alloy - 19, diameter - 65 μ . The insulation is double layered winding of lavsan filament. The wire length of one gradient solenoid (16 coils) is 6 kilometers.

In 1972-1973 the superconducting coatings on KOLTSETRON cavities were fulfilled. For this purpose specially designed vacuum spray chamber was used , under operative conditions vacuum was 10^{-7} Torr. (Fig.3).

The cavities consist of two halves joint in the first variant mechanically. The first experiments on quality-factor measurements of the cavity have been carried out. The obtainable quality-factor of the cavity with such an imperfect joint (without magnetic field) was 2.10^6

The experiments with different joint variants on model cylindrical cavities at 1.3 Hz frequency allowed to rise the quality-factor by an order. Further investigations and studies were directed towards improvement of the superconducting surfaces of the cavities and creation of an optimal joint so that the quality should be increased to the calculated value of 10^8

The gradient solenoid was tested under operative conditions in KOLTSETRON. The mean magnetic field 2 T and the required field variation at independent current input of 16 coils of gradient module have been obtained.

The current input was obtained by different currents within the limits of ± 50 a. Power supplies provide the preset stabilization of the set currents. As far as it's known, it is one of the first experiments of current input of a large number of magnetically connected superconducting solenoids. The difficulties and rigidness of the system requirements are associated with the fact that at current input of one superconducting coil, the eddy currents, which arise in the other similar coil, are very slowly damping (ohmic losses are very small - within the coils they are equal to zero).

For winding the main solenoid multi-filament superconductor was used. The cross section of the superconductor is 2.5×5 mm^2; matrix is made of copper with resistance ratio R (300 K) / R (4.2 K) = 150, the superconducting filaments are made of Nb-Ti with 60 μ diameter. The insulation of glass fiber impregnated with epoxy compound is complete. The superconductor consists of two pieces, 1.5 kilometers each. It's wound in four layers. Critical current dependence of the superconductor samples on external magnetic field has been measured. Besides, two sample coils with 10 cm inner diameter, which contains 50 m of the superconductor, have been tested. The critical current of samples and coils in the field of 2 T is approximately equivalent and equal to 4300 a.

KOLTSETRON Helium system has been created basing on laboratory liquefier (MGL - Multi-Goal Helium Liquefier) with 60 litres of liquid Helium per hour capacity (250 watt under refrigerative routine).

The power supplies of KOLTSETRON gradient solenoids which have 16 independent outlets, provide stability of current maintenance with the accuracy of ± 1.5 ma. The main solenoid power supply allows to feed current up to 400 a with the accuracy of 0.07%.

KOLTSETRON high-frequency feed system can operate under the routine of pulse power 6 kW/m, pulse length up to 30 microseconds and repetition frequency = 0.2 ÷ 0.5 Hz.

If there are positive results of KOLTSETRON composite tests, a question of high energy particle accelerator design with the use of superconducting sections will be considered.

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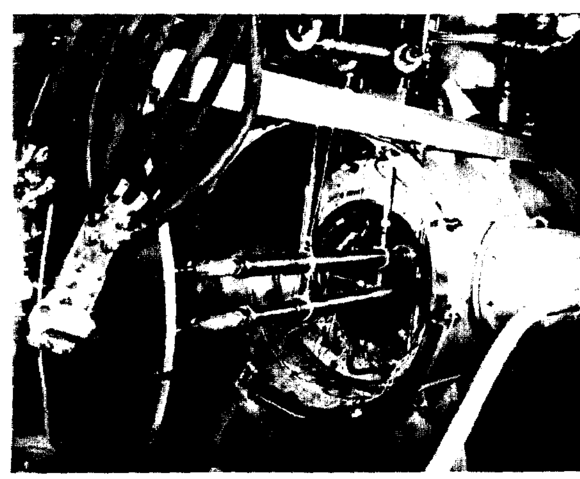

Fig. 1 Solenoid making up SS-600 with current lead-ins in vacuum shell of KOLTSETRON.

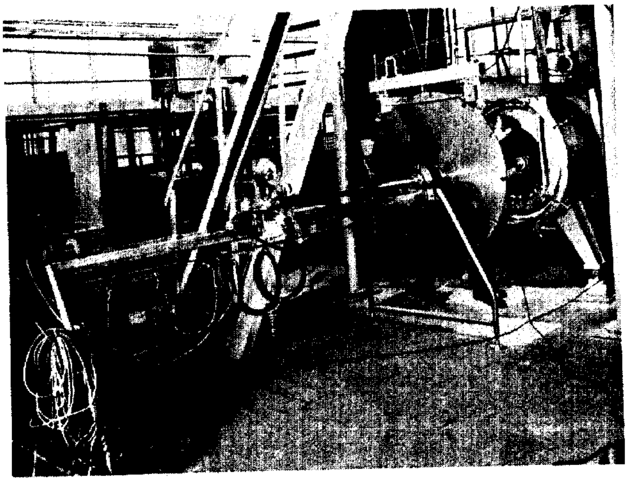

Fig. 2 System making up of KOLTSETRON magnetometry.

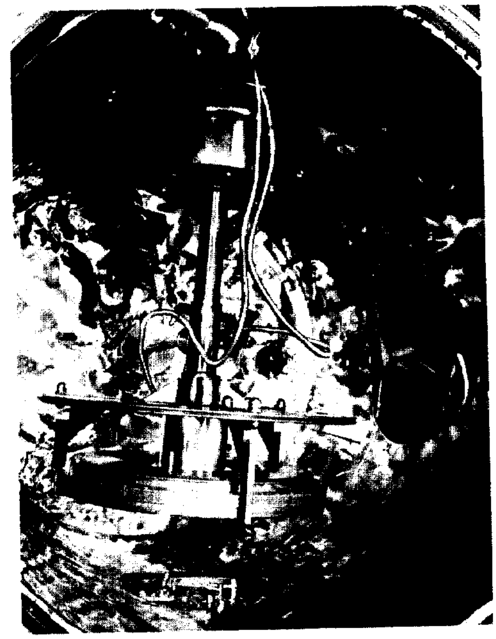

Fig. 4 Operative KOLTSETRON cavity in chamber for fulfilling superconducting coating.

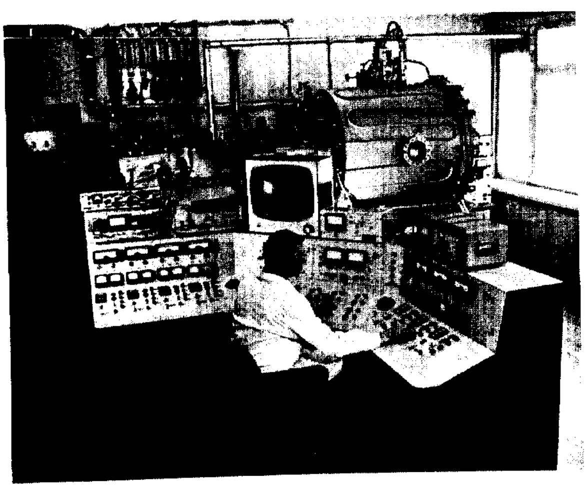

Fig. 3 Installation for fulfilling superconducting coatings onto KOLTSETRON cavity.

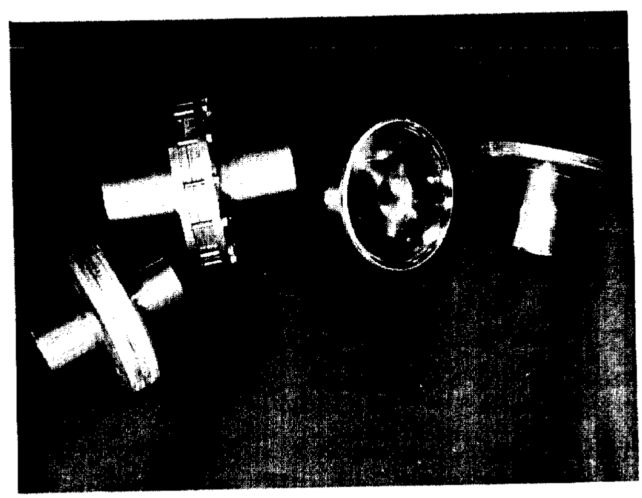

Fig. 5 Experimental superconducting cavities.