Application of rf-superconductivity to an accelerator requires an energy gradient of more than 1 MeV/m to be an economic design. The energy gradient can be expressed by the magnetic peak field, which is about 100 G per MeV/m for a typical electron accelerator structure and about 300 G per MeV/m for a helix accelerator structure. At the moment, in any structure the energy gradient seems to be limited by the magnetic peak field obtained. There exists a technological gap between the best experimental results in test cavities and those obtained in real accelerator structures throughout the various laboratories. Within the state-of-the-art are now magnetic peak fields in the order of 300 G, even in unfired niobium structures. However, there exists evidence that much higher fields can be achieved. So far in very small niobium cavities fields in the order of 1 kG have been obtained. Still higher fields should be available because the theoretical limit for niobium as a superconductor is a critical field of about 2 kG. The experiments show that still a lot of surface development work has to be done to demonstrate the possibility of high-gradient devices for application in a linac.

This, again, will take some time. For that reason, even if fields in the order of 1 kG would have become commonly available within a real accelerator structure, there are additional unsolved problems for the construction of a superconducting proton or heavy ion machine. Therefore it seems reasonable to follow a second line of problems simultaneously with the surface development work. I would like to mention 3 representative problems:

1. The choice of an adequate low-energy structure raises problems of mechanical stability due to large and complicatedly shaped low frequency structures.
2. The fast tuning especially needed in such mechanical weak structures has not been demonstrated. Two individual accelerator sections have to be tuned to the same frequency within the very small bandwidth of the resonators.
3. The question of beam loading and beam break-up is more severe for protons than for electrons.

Therefore, it is justified in my opinion to set-up a first part of a proton linac with any energy gradient one can get, and to study rf-control, beamloading as well as cooling problems in full scale.

From various points of view, the helical structure seems to be an attractive possibility for the use in the very first part of a superconducting proton linac. Focusing considerations and power consumption in superconducting accelerators favour very strongly a low frequency helix. We have chosen a frequency of 90 MHz in connection with a 0.8 MeV cascade injector as a compromise, because the necessity of a frequency jump between the helix part and the following resonator structure favours higher frequencies. The use of two different types of structures is a demand of the goal to have a real prototype accelerator for a large machine (pion factory). At the moment our efforts are concentrated on the injection system and the first helix section. We investigated an unfired niobium helix within a lead plated outer cylinder and measured quality factors and breakdown fields. This is a short helix operated at 90 MHz with a length of 1/2. Recently, magnetic peak fields in the order of 100 G were measured. The limit seems to be given by thermal breakdown induced by rapid changes in the quality factor probably caused by electrons.

Radiation pressure can be another practical limitation to high fields, i.e. due to the very large deformability of the helix. Radiation pressure causes an appreciable static eigenfrequency shift yielding a strongly non-symmetrical resonance curve. For the 1/2-helix a frequency shift as 50 kHz at 90 G has been measured. In addition this causes dynamic instabilities.

Without any feedback system stable operation of a helix resonator is impossible on the lower frequency side of the overhanging resonance curve (fig. 1).

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On the upper frequency side there is static stability, but small mechanical vibrations caused by external forces can be enhanced because an energy transfer from the rf-field into the mechanical vibrations will occur.

With an rf-control system it is possible to handle both, static and dynamic stability even in a way, that damping of mechanical modes can be achieved. Damping or enhancement by radiation pressure depends on the parameters of the rf-control system only.

We checked these theoretical predictions by experiment. For the 1/2-helix an rf-control system has been developed by H.Strube. The results of several experiments can be summarized by the following statement: the problem of frequency stability of a helix resonator at low temperature has been solved in principle by the use of an adequate rf-control system.

In a superconducting accelerator besides the rf-generator the particle beam will also couple to the rf-field. This probably changes the parameters of the rf-control system and influences the problem of radiation pressure.

According to the policy outlined above the following list of activities at Karlsruhe should be included:

1. A helix section with 5 electrically coupled short helices with metallic supports is under construction.
2. Surface development work on niobium helices will be continued in a smaller experimental set-up.
3. A fast tuning device will be developed to tune a second helix section to the same frequency.
4. The rf-control system will be set-up similar to the one already tested in the helix experiments. The rf-generator follows the eigenfrequency changes of the helix section.
5. A strongly overcoupled rf-input is under construction to match the expected heavy beam loading.
6. A new chopper-buncher for 90 MHz has been developed and is installed at the moment together with the proton beam injector.
7. A new cryostat for superfluid helium has been constructed, which is designed for 3 helix sections.
8. The necessary refrigeration facility has been installed, a 300 W refrigerator with 1.8 K came into operation.

In principle, I think, there is a good chance to demonstrate the application of rf-superconductivity pretty soon. All own efforts should be concentrated to solve the more technical problems to end up with an economic superconducting linear accelerator design.

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