NEW SUPERCONDUCTIVE LOW BETA STRUCTURES

V. Palmieri, ISTITUTO NAZIONALE DI FISICA NUCLEARE,
Laboratori Nazionali di Legnaro, Legnaro (Padua), Italy

1 INTRODUCTION

A review entitled "New developments in low beta superconducting structures" has been given [1] by the author just a few months ago, at the "7-th Workshop on RF superconductivity". In that occasion a certain amount of technical informations were furnished about the four different existing technological approaches for fabricating the low beta cavities: Lead plated Copper, bulk Niobium, Niobium-clad-Copper and Niobium sputter-coated Copper. Who is interested to how getting a Lead surface that is stable against a few days exposition to the air, or who desires to know if bulk Niobium changes its low temperature thermal conductivity after bending, will find there some experimental considerations and informations. In only a few months, very little has changed and low beta superconducting structures suffer still of the same old problem: "the experimental values achieved by the accelerating field is lower than the ones foreseen by theoretical expectations".

Hence in the following we will profit of the given opportunity to attack the problem under more general considerations.

2 WHY NEW SC LOW BETA STRUCTURES ?

Today, a nuclear physics laboratory may compete on a global scale no matter how small or local it is. Today, due to the possibility to exchange informations in real time thanks to the informatics revolution, the physical distance between two laboratories in two different part of the world is becoming less and less a limitation. Regardless of the size of a physics laboratory or of the particular branch of physics investigated, it is more and more probable to find somewhere else in the world, a competitor research team that is investigating your same problems and maybe with better tools or more advanced techniques.

The fall of the boundaries between the Western and the ex-Soviet scientific blocks, even has made becoming available a link between two different worlds that, although already formerly in contact for nuclear physics, had very rare opportunities of communicating in the field of advanced technologies. In this framework a research organism that would not progress in its structures remaining closed on itself, will unavoidably die in the long run.

A new type of nuclear physics asks for new technology, new instruments and new tools!

For the particle accelerator community, new rf structures serve as a strategic tool. To succeed at capturing and holding the leadership on a particular research with accelerators, a nuclear physics laboratory should necessarily: a) deploy its resources from its own arsenal and push its cavities working with maximum efficiency; b) insure that the quality of experiments realized with the accelerator are better than those previously carryed out, and not worse than those of all competitors.

Therefore an operational philosophy of continuous improvement of superconducting cavities is not only logical, but inevitable. The Rf structure is the heart of superconducting Linac. An heavy ion accelerator that operates with superconducting Lead plated Copper resonators for instance, should always dedicate a small effort to the development of the Lead plating technology, with the aim of achieving higher values of accelerating field at always lower power losses. And before or later this accelerator should think about switching from Lead to Niobium. The attitude "if it isn't giving us a problem, then leave it alone" is a sure formula for pushing the accelerator users' community to choose working on machines that instead offer beams of high quality and in a wide range at competitive costs and time flexibility.

An accelerator development team that promotes long-term planning on the rf structure, that practices a continuous improvement of resonators, or that takes care of the small opportunities for upgrading the RF structure, will gain opportunities not recognized by their less aud acious counterparts.

To give an example, in the eventual case of a serious cryogenic failure, it is not improbable that all resonators must be helium-conditioned again. The possibility to process Niobium sputtered cavities ten times faster than Lead electroplated cavities is a not negligible factor.

New superconducting structures having statistically less probability to fail, better in performances and easier to use, will also improve the laboratory environment and quality of work life. Users will "feel more involved" with their work. A management that prefers people partly working at the continuous improvement of new resonators rather then at the despairing recovery of old defected resonators, will probably encounter more productive people with fewer absentee or sick days.

3 RESEARCH ON NEW STRUCTURES MIGHT BE IN COMPETITION WITH THE OPERATION OF A LOW BETA MACHINE

The final goal for searching new sc structures is the enhancement of the *quality* of experiments planned on the machine. Two frequent innovations and a never-ending continuous improvement cannot be self-consistent. A machine always opened for substituting cavities would be considered a low quality facility. Analogously to the Q-factor of a resonator, the *quality* of the experiment could be definable as the reciprocal of the loss that an user suffers when the rf structure has functioning problems. When a resonator cannot be hanged in frequency, or a multipactoring level cannot be overcome or even when hot spots on the superconducting surface steel energy lowering the accelerating gradient, this produces a loss in beam time. This is bad *quality*. More quantitatively *quality* is the loss due to the deviation of the results obtainable by the resonator from the desired target value as mandated by design. The function correlating the loss versus the deviance from specifications approximate a quadratic behaviour, with its minimal point at the target value for user's community satisfaction.

That implies that not only bad resonators contribute to losses, but even too good resonators overcoming the prefixed target are a loss source. In practice if a section of a linac has been designed for resonators working at 3 Mv/m at 7 W, the adoption of cavities reaching 10 MV/m with high probability will be a non-convenient operation. Such high values for example would have been certainly obtained after years and years of costly R&D. Too good results rarely indeed are fruit of new and revolutionary ideas. More often it is the output of small incremental improvements or refinements involving everyone in the research team.

At a first sight this approach could give hint to disagreement and criticism. Everybody having a cavity operating at 10 MV/m at 7 W when the linac target is 3 MV/m at 7 W, would immediately excite it at 3 MV/m trying to consume less rf power (such field should be obtainable with only 2 W). That's obvious! What is not obvious instead, is that if the deviance from the target value is spread out in a too wide range for resonators made by the same technique, it means that the technique itself is not under control. To give an example, more than once the author has gathered from different sources in informal contexts the assumption "under Lead plating of copper resonators there is black magic; you do two completely equal cavities, one makes 2 MV/m and an other 4 MV/m". In such a case even if the target value is only 2 MV/m, this situation is enough dangerous because it means that there is a parameter that we do not take into account in our research.

This unknown parameter is a noise factor that can be more or less dangerous, depending if the cause of the undesired effect is an *outer noise factor* (temperature and humidity of the environment, contamination collected by the superconducting surface), *an inner noise factor* (deterioration of chemicals, aging of the organic moderator for the electrolytic bath, the impoverishment of solutions, or a *variational noise factor* (manufacturing imperfections, in other words the variation occurring between like products manufactured to the same specifications).

4 TO LOOK FOR INNOVATION OR TO RECONSIDER UNDER NEW ASSUMPTIONS ALREADY WELL-ESTABLISHED TECHNOLOGIES ?

As was already reported in the introduction, there exist four different approaches for fabricating superconducting low beta resonators. Today however there are many new forms of materials, new kind of deposition techniques, and new type of processes, much more than ever before in the past. Combining hypothetically new materials with new technologies, the number of possibilities immediately diverges. It is in the author's opinion that whenever asking to a good specialist to find out new techniques of cavities fabrication, he would have no particular difficulties for proposing at least ten reasonable ideas. For coated cavities indeed you could play by changing both the superconductor and the substrate. And it is not at all a postulate that good coated cavities may be done only by sputtering Niobium onto Copper. The real problem is that 10 years in average are not enough for delicate technologies from the birth of a nice idea to the phasis of prototyping and from the fabrication of a pre-series to the arrival to industrial production. The simple operation of coating a metallic substrate by a superconductor, for all the parameters to control, is an infinite story, already without considering the interesting chapter of buffer layers. If one would work full time to the scanning of all new possibilities only one life would not be enough.

Still room there is for better understanding unsolved problems with old technologies. New superconductive low beta structure can be obtained looking with new eyes to old structures.

A strong breakthrough in fact would be obtained for bulk structures once having adopted Niobium of better purity. But better purity does not mean higher RRR values up to when RRR is not measured by resistive methods. Percolative paths at 700 RRR inside Nb do not mean that Niobium in its entirety has 700 RRR.

Also a considerable stepforward would be obtainable for thin films cavities if highly oriented substrates would be possible.

New low beta sc structures would be really noteworthy is for instance the sputtering technique would be showed applicable to resonators of more tricky shape as for instance RadioFrequency Quadrupoles.

References

[1] V. Palmieri, "New developments in low beta superconducting structures" Proceedings of the "7-th Workshop on RF superconductivity", to be published on Particle Accelerators (1996).