# BSCCO geometrical and soldering optimization for high current lead applications [#ID 969]

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## Abstract

In all superconducting applications it is necessary to bring the current from the power supply, always at room temperature, to the cold mass using *current leads*. In order to reduce the heat transferred to the cold mass, those connections must be carefully designed. In a big amount of applications those current leads are composed by different stages and in particular by a HTS (*High Temperature Superconductor*) superconducting stage. Those materials are extremely efficient for carrying current but at the same time they are very expensive and extremely fragile.

This poster presents the result of a geometrical and soldering technique optimisation in order to build an high current superconducting lead minimizing the amount of expensive materials and avoiding the use of helium.

## Introduction

A weel designed current lead has to minimize the two heat contributions to the cold mass: heat conduction and Joule dissipation. In this case those two contributions are minimized optimizing the length and the cross section of the resistive part and using a superconductive stage with a low thermal conductance and zero Joule generation.

The goal of this project is to design a current lead able to carry 5 kA from room temperature to a cold mass at 25 K. The current lead is composed by 3 different stages as shown in **Figure 1**:

1. Resistive stage (RT – 77 K)
2. BSCCO stage (77 K – ~30 K)
3. ReBCO stage (~30 K – 25 K)

The more expensive and critical stage is the BSCCO one because of the large amount of tape and the big temperature gradient.

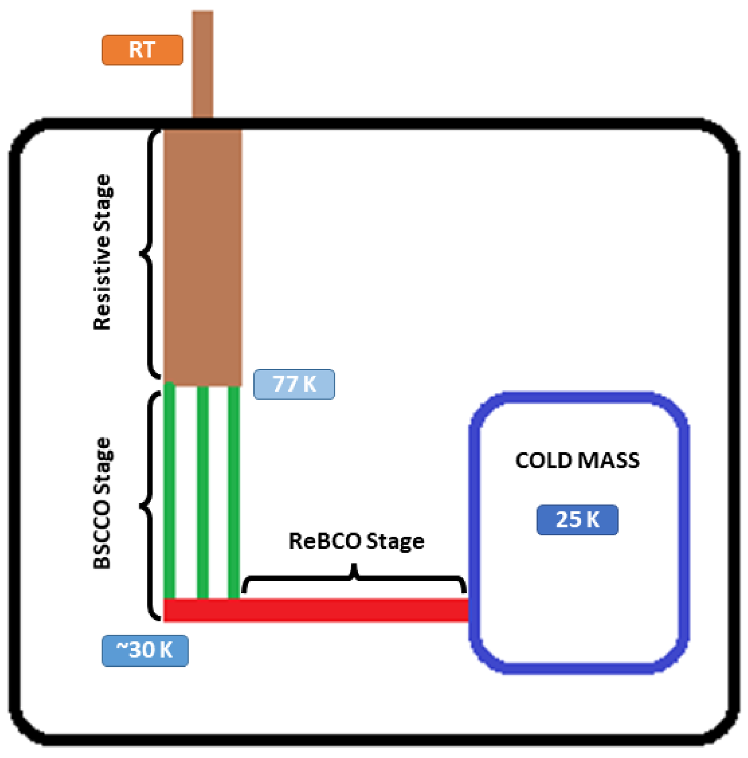


**Figure 1.** Sketch of a multiple stage current lead


| Specification | Value |
|---|---|
| Width [mm] | 4.2 ± 0.2 |
| Thickness [mm] | 0.23 ± 0.01 |
| Matrix | Ag – Au 5.4% wt |
| $I_c$( 77 K, self field) [A] | ≥ 170 |
| Critical tension* [N] @ RT | 80 |
| Critical tensile strength* [Mpa] @ 77 K | 130 |
| Critical tensile strain* [%] @ 77 K | 0.2 |
| Critical double bend diameter [mm] @ RT | 80 |

**Figure 2.** BSCCO Type – G properties by Sumitomo Electric[1]

*95% of $I_c$ retention

## BSCCO properties

For this study BSCCO Type – G tape by Sumitomo Electric[1] is used. This type of BSCCO was chosen for some of its good properties:

- Thermal conductivity

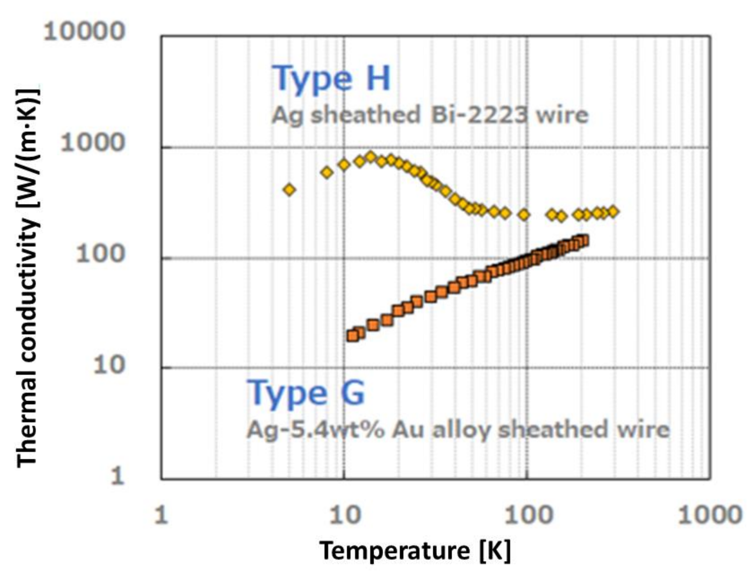


**Figure 3.** Thermal conductivity of Type H and Type G BSCCO from Sumitomo Electric[1].

A low thermal conductivity helps to thermally decouple the different stages of the current lead, allowing to have a big thermal gradient in a small space.

- Critical current and temperature

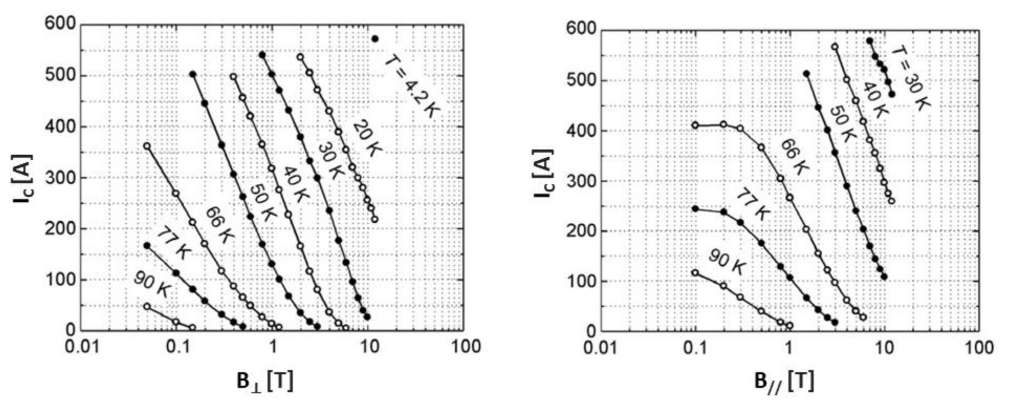

**Figure 4.** Critical current as function of temperature, perpendicular and parallel external field, from Sumitomo Electric[2].

The high critical temperature and the high critical current of this material, allow to use liquid nitrogen as cryogenic fluid instead of liquid or gas helium.

## Design Optimization

As shown in **Figure 4**, BSCCO tape is very sensible to the external field, in particular to the perpendicular one. In order to reduce the amount of tape used for the current lead a minimization of the external field is done implementing a FEM simulation using Cobham Opera[3]. The parameter used for the optimization is the integral of the perpendicular magnetic field through the section of the tape. In particular, the integral of the self-field generated at 160 A was taken as reference value.

$$\int_0^L B_{self\perp} \cdot dx \qquad (1)$$

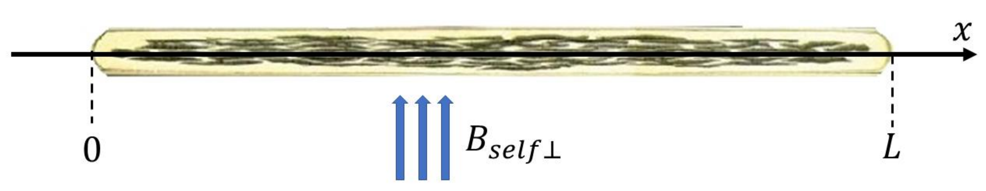

**Figure 5.** Cross-section of BSCCO tape.

Using this constrain it is possible to find a geometrical configuration that minimizes the amount of the BSCCO tape, and consequently the cost, maintaining a sufficient margin on the critical current.

The position of the BSCCO tapes is also forced by the HTS stage size requirements. The result of the design optimization process is shown in **Figure 5**.

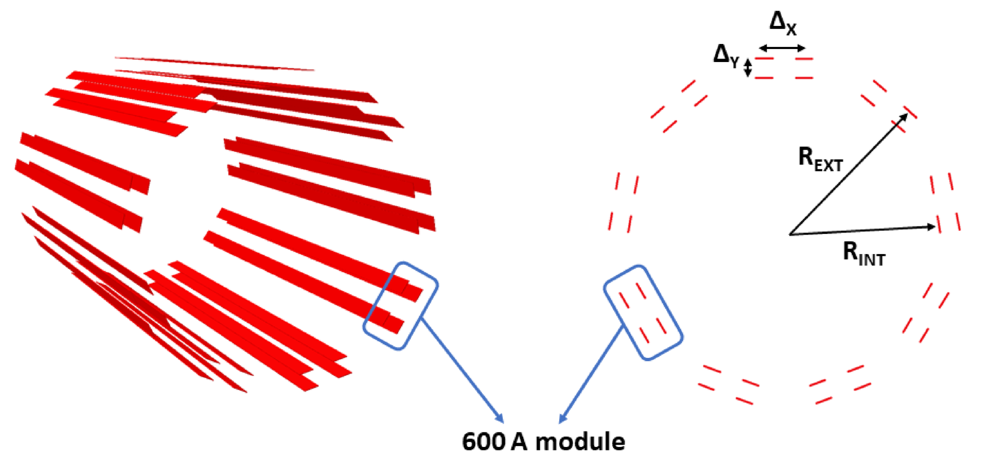


**Figure 5.** Isometric (left) and top (right) view of the BSCCO tapes as arranged in the current lead.

## Soldering techniques

The BSCCO stage of the lead is designed so that, during the manufacturing process, all the parts can be tested individually without the need of a complex test of the whole system. Indeed, the system is composed by several modules, each of them can be tested at 600 A in liquid nitrogen.

One of the main task of the project is to minimize the heat dissipation due to the resistive joints between the different stages. Two main strategies can be used in order to reduce this loss:

1. Enlarge the soldered surfaces
2. Improve the quality of the solder.

The first method is easy to improve but it increases the overall dimensions of the lead; for this reason the focus was point to the second strategy.

To improve the quality of the solder it is necessary to set a quality control parameter in order to evaluate the goodness of the joint. The criterion chosen in this case, is to achieve a voltage drop of 1 µV/cm for each 600A module including the resistive joints.

A soldering procedure was identified to achieve the quality criterion. It was noted that it is necessary to:

- Remove all the oxide from the surfaces to be soldered.
- Carefully handle the BSCCO tapes.
- Carefully control the thermal process of the welding.
- Keep the surfaces in contact with a mechanical constrain during the soldering process and also during the cool down to room temperature
- Avoid large thermal gradient or localized heat generation during the tinning process.

## Conclusions

HTS current leads have two advantages: a reduction in the thermal input and a reduction in volume and spaces. On the other hand, HTS, and BSCCO in particular, are expensive and difficult to handle.

With this work, ASG showed that an industrial use of BSCCO tape is possible. It is possible to achieve the same result of very expensive HTS current lead using less material with great economic benefits.

However, it remains a difficult material to handle because of its fragility. It is necessary, for industrial use, improve the manufacturing process in order to reduce the waste due to the material brittleness.

After many test, a specific soldering procedure has been developed.

The overall voltage drop of the developed modular lead BSCCO stage (Copper to Copper) is less than 1 uV/cm.

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