

PROGRESS OF HOM COUPLER FOR CERN SPL CAVITIES*

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Abstract

In this paper we present the progress of the Higher-Order-Mode (HOM) coupler design for the high beta CERN SPL (Superconducting Proton Linac) cavities. This includes the RF transmission behavior as well as mechanical and thermal requirements and their optimizations. Warm RF measurements are presented for the first four high beta SPL Cavities made of bulk niobium. Moreover the first prototype of a HOM coupler will be introduced and we discuss its characteristics and its tuning possibilities.

INTRODUCTION

The SPL [1] linac is composed of two types of cavities operating at 704.4 MHz in pulsed mode and with geometrical betas of 0.65 and 1. In order to limit beam induced HOM effects, it is considered to use coaxial type HOM couplers on the cut-off tubes of the 5-cell cavities. Based on RF and thermal simulations for the PROBE, HOOK and TESLA designs (already presented in [2]) it was decided to fabricate a prototype of the coupler with probe antenna (PROBE) as shown in Fig. 2. This coupler type was selected for the following features:

- Notch filter with a relative high bandwidth (50 kHz) and therefore very robust.
- High selectivity (steep transition between stop band and notch filter and pass band).
- Best coupling to the monopole HOMs at 1.3 GHz.
- No active cooling of the antenna necessary.

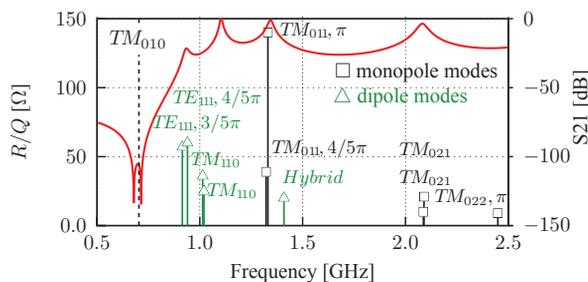


Figure 1: HOMs with the high (R/Q) for the high beta cavity [3, 4] and S21 transmission of the PROBE coupler.

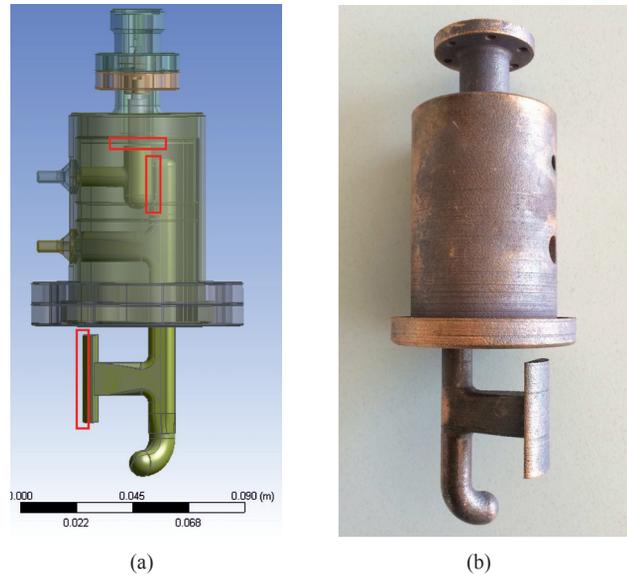


Figure 2: a) Mechanical layout of the first prototype. The red highlighted parts are the capacities to tune the filter. b) Rapid prototype made of plastic and coated with copper.

The first three points are clear when comparing the transmission curves of the optimized couplers [2]. The latter one will be discussed in the section about cooling requirements. In the following we start with the results of HOM measurements on the actual cavities, followed by the mechanical design and cooling requirements of the chosen PROBE coupler.

RF MEASUREMENTS OF THE CAVITIES

Extensive simulation studies have been already carried out for the HOM spectra of the SPL Cavities [3, 4] (Fig. 1) which are now compared with measurements on a copper cavity and on four niobium cavities (tuned in field flatness and length) at room temperature. The following types of measurement have been performed:

- Reflection and transmission type measurements to identify mode frequencies and quality factors (Q values) [5, 6].
- Analysis of the field pattern by positioning probe antennas around the equators of each cell (by drilling holes into the copper cavity).
- Bead-pull measurements to determine the field pattern along the bead path.

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Frequencies and Quality Factors

The loaded Q values have been determined via S21 measurements between input and pick-up port whereas the coupling factors (to determine the intrinsic Q 's) result only from S11 measurements. Figure 3 shows the results for the niobium cavities in comparison with frequency domain simulations with CST MWS. The highlighted frequency regions contain the modes with the highest (R/Q) (Fig. 1).

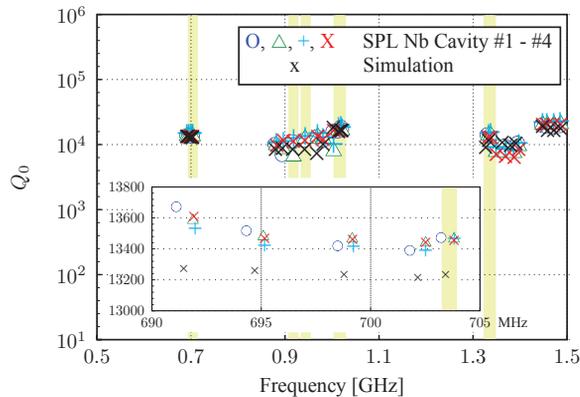


Figure 3: Measured intrinsic quality factors at room temperature for the four niobium SPL cavities in comparison with eigenmode simulations. The fundamental pass band is shown in detail. Modes with the highest (R/Q) values are highlighted.

Figure 4 and 5 show the frequency and Q spread. Most of the modes with high (R/Q)s exhibit a frequency spread of < 1.2 MHz. The majority of the investigated modes show a variation of less than 3 MHz. The relatively low frequency variance indicates that the resonances in the pass band of HOM coupler can be adjusted very precisely to specific modes. The higher spread for the TM_{021} modes at ~ 2.09 GHz is less problematic due to the more constant transmission behavior of the coupler in that regime. The Q values however vary within a relative range of $< 75\%$ up to the first HOM monopole band (1.33 GHz) and reach a slightly higher spread for the TM_{021} modes ($\sim 100\%$).

Field Characterization

Furthermore the field distribution of selected modes has been analyzed to enable a unique assignment of the modes and their (R/Q) values resulting from simulations. The first method applied to a cavity made of copper requires access to the entire field in the cavity via probe antennas. For this purpose 8 holes have been drilled around each cell equator. Due to the moderate sampling of the electrical field only simple modes as those of the fundamental pass band or of the first dipole band (Fig. 6) can be classified. Nonetheless the method allows to measure also the different polarizations of the mentioned dipole modes which agree well with the corresponding simulations (Fig. 7)

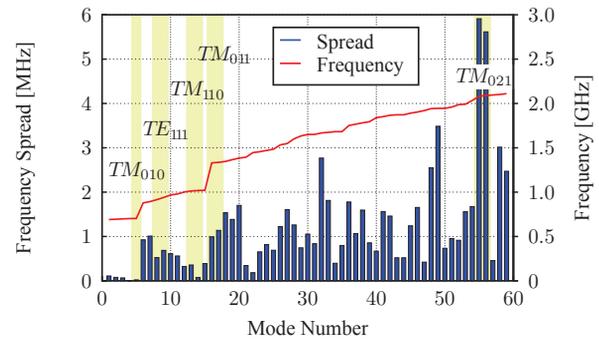


Figure 4: Maximum frequency spread for the measured modes between 690 and 2100 MHz (blue). Modes with highest (R/Q) values are highlighted and labeled.

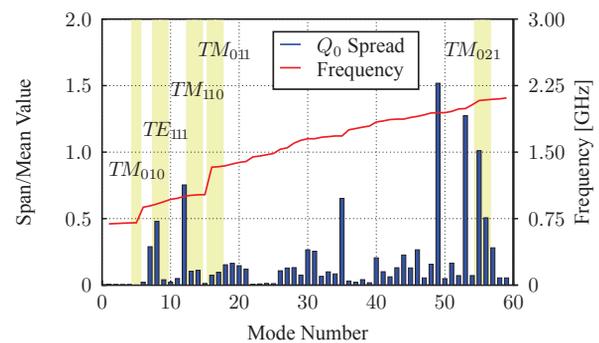


Figure 5: Relative spread of the Q_0 values resulting from reflection type measurements on the four niobium SPL cavities. Modes with highest (R/Q) values are again highlighted.

An alternative way of identifying the field pattern is based on bead-pull measurements. We use a dielectric bead which primarily perturbs the electrical field. The much higher local resolution permits to determine more complex modes as those of the first HOM monopole band at ~ 1.33 GHz. Figure 6 shows a comparison of the measured frequency shift (proportional to magnitude of the electric field squared) and the corresponding field pattern resulting from an eigenmode simulation. This method can be applied to the niobium cavities without the need of holes in the surface.

MECHANICAL DESIGN

The mechanical sketch shown in Fig. 2 a) is the advanced version of the PROBE design presented in [2]. The design is extended by a coaxial connector with a 6 mm thick ceramic window. Moreover the band pass filter (upper part of the coupler) has been modified to be less sensitive by using larger capacitive plates with larger distance. According to RF simulation all parts satisfy at least a tolerance of 0.15 mm which is also valid for the very sensitive parts,

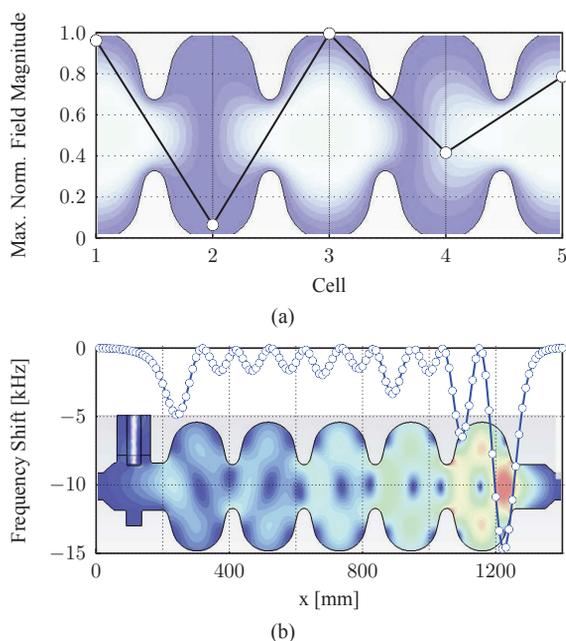


Figure 6: a) Maximum electrical field along the cavity for the $TE_{111} 3/5\pi$ Mode (918 MHz) measured by probe antennas around the equators. b) Bead-pull measurement for the $TM_{110}\pi$ Mode (1.333 GHz) in comparison with the electrical field magnitude resulting from a CST simulation.

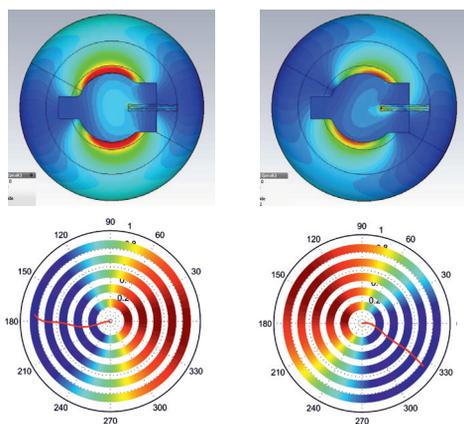


Figure 7: Simulated and measured polarizations of the $TE_{111} 3/5\pi$ dipole mode (920 MHz) excited by the input antenna. The measured values (below) are represented by color coded sine square fits for each of the 5 cells.

the notch capacitance and the both capacitors of the band pass filter. Accordingly the tuning procedure is planned in three stages beginning with the notch filter (rejection of the accelerating mode), continuing with the next upper capacitance (coupling to the first dipole band (~ 920 MHz)) and then the final capacitor close to the coaxial connector (coupling to the first HOM monopole band (~ 1.33 GHz)). Recently this design has been fabricated as a rapid prototype

made of plastic and then coated in a galvanic bath with copper (Fig. 2 b). For the final assembly the flange still needs to be attached.

COOLING REQUIREMENTS

The results of RF-Thermal co-simulations presented in [2] showed a very low heating of the coupler. Further investigations indicate that even for a duty cycle of 8% and a surface resistance of $5 \mu\Omega$ a moderate cooling of the outer tube with a heat flow of 50 mW/cm^2 would be enough to keep the superconductivity of the antenna. Hence the coupler does not need any internal cooling circuit using liquid helium. Cooling by thermal conductivity simplifies the fabrication of the coupler clearly. For this reason we no longer consider the TESLA design for SPL which is especially suited for active cooling.

CONCLUSIONS

Several measurements performed on the copper and niobium SPL cavities have been presented. The relatively low variations of mode frequencies as well as Q values give an idea of how exact the pass band of the coupler (its resonances) can and should be adjusted (tolerance of ± 3 MHz). A first prototype has been fabricated following a comparison between three different approaches, each of them optimized to the high beta SPL cavity. Likewise the planned tuning procedure as well as heat loss and resulting cooling requirements have been discussed.

OUTLOOK

As soon as the prototype is fully assembled it will be tested first on a copper cavity at room temperature to identify the external quality factors. Moreover the tuning strategy has to be evaluated which is so far only based on simulations. A further aspect concerning the cavities are dedicated sensitivity tests of the interesting HOMs, using measurements of the frequency and Q value shift due to mechanical deformation of the cavity. For this purpose a tuning bench is currently being prepared. Also a multipacting study is foreseen in the near future.

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