

PRELIMINARY RESULTS ON THE SIMULTANEOUS EXCITATION OF THE TM_{010} AND TE_{011} MODES IN A SINGLE CELL NIOBIUM CAVITY*

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Abstract

Simultaneous excitation of both TM_{010} and TE_{011} mode has been carried out on a CEBAF single cell cavity. The cavity has two beam pipe side-ports for each mode for input and pick-up couplers. Coupling to the TE_{011} mode is done by magnetic loop couplers while for the TM_{010} mode coaxial antennas are used.

Simultaneous excitation of both TM and TE modes has been proposed recently for superconducting photoinjector applications to take advantage of the accelerating electric field of the TM mode, combined with the focusing magnetic field of the TE mode.

The TE_{011} mode has the property of having zero surface electric field, surface magnetic field orthogonal to the one in the TM_{010} mode and concentrated in the iris/wall regions of the cavity. The presence of both modes in the cavity at the same time can also be used to investigate the so-called high field Q -drop in the TM_{010} mode.

This paper will present some preliminary result on the test of the single cell cavity at 2 K.

INTRODUCTION

In this paper we present some preliminary results on the simultaneous excitation of the TM_{010} and TE_{011} modes in a single cell cavity of the original CEBAF shape. The TE_{011} mode has the property of having no surface electric field and the separate excitation of the TM_{010} and TE_{011} modes has been recently applied to investigate the origin of anomalous high field losses (known as “ Q -drop”) [1].

The simultaneous excitation of the TM_{010} mode and of the TE_{021} mode has been recently proposed as a possible solution to build superconducting RF guns with high average current and low emittance [2]. This is achieved by using the on-axis electric field of the TM_{010} mode to accelerate the beam and the on-axis magnetic field of the TE_{021} mode to provide focusing. In the configuration proposed in Ref. [2], the maximum value of the vector sum of the surface magnetic field in both modes was 144 mT.

The main electromagnetic parameters of the TM_{010} and TE_{011} modes, computed with Superfish [3], are given in Table 1.

The surface fields distribution in both modes is shown in Fig. 1.

Table 1: Electromagnetic parameters of the TM_{010} and TE_{011} modes for a CEBAF single cell

	TM_{010}	TE_{011}
Frequency [MHz]	1472.599	2830.723
E_p/\sqrt{U} [(MV/m)/ \sqrt{J}]	17	0
B_p/\sqrt{U} [mT/ \sqrt{J}]	43	50
$G (=R_s Q_0)$ [Ω]	271	701

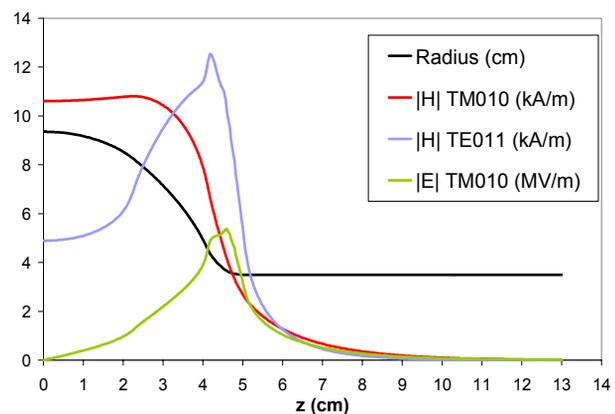


Figure 1: Surface fields for the two modes for 50mJ stored energy and cavity profile.

CAVITY FABRICATION AND PRELIMINARY TEST RESULT

A first attempt to simultaneously excite the TM and TE mode was made on the single cell cavity used in Ref. [1]. The TE mode was excited with magnetic loop couplers inserted in side-ports, perpendicular to the beam pipes and close to the irises. The TM mode was excited with copper antennas inserted in the beam pipes to form a coaxial line. With this configuration, the quality factor in the TE mode was about one order of magnitude lower than expected. Since the frequency of the TE mode is close to the cut-off frequency of the beam pipes, we suspected that some RF field was present on the stainless steel feedthroughs and antennas used for the TM mode, causing additional losses.

A new cavity made of niobium $RRR > 200$ was fabricated with four side-ports (two on each side of the cavity). The side-ports are at the same longitudinal position, separated azimuthally by 110° . Magnetic loop couplers are used for TE mode excitation, while copper antennas are used for the TM mode. The beam pipes are closed with niobium plates (with one opening for pump-out) and sealed with indium wire. Conflat flanges 2

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3/4" made of Nb55Ti are welded on the side ports and copper gaskets are used to seal the couplers to the cavity.

The inside surface of the cavity was chemically etched by Buffered Chemical Polishing (BCP) 1:1:1 and High Pressure Rinsed (HPR) for 1.5 h. After drying overnight in a class 10 clean room, the cavity was assembled with the four couplers and end-flanges, evacuated to about 10^{-8} mbar and attached to a vertical test-stand (Fig. 2).



Figure 2: Single cell cavity used for the simultaneous excitation of the TM_{010} and TE_{011} mode.

The two resonant modes are locked by two independent Phase Locked Loops (PLL). Pass-band filters (PBF) are used on the transmitted and reflected powers to reduce the RF signal coming from the other mode. A schematic of the cavity excitation is shown in Fig. 3.

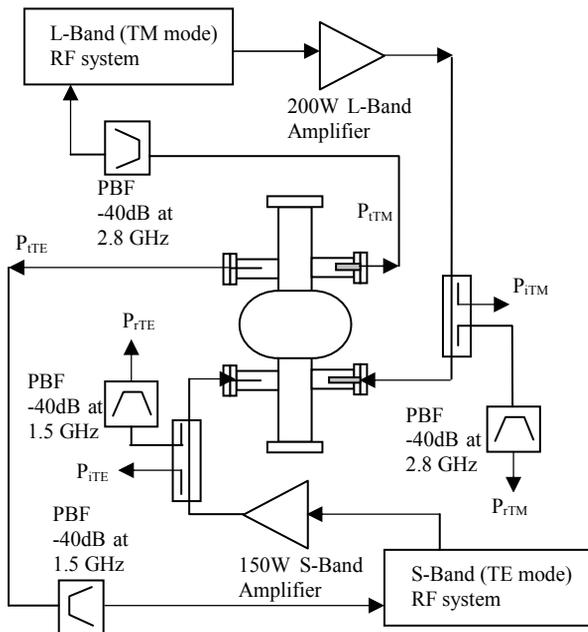


Figure 3: Schematic of the excitation of both modes in the single cell cavity.

The results of the RF test at 2 K are shown in Fig. 4. The Q_{ext} of the input and transmitted couplers for the TE mode were too high: 2.3×10^{11} and 9.9×10^{11} respectively. The Q of the TE mode at low field was about 10^{10} and the amplifier saturated at about $B_{pTE} = 70$ mT. Besides, some of the power in one mode was measured on the power meters of the RF system driving the other mode, in spite of the presence of the filters. All the values of Q_{ext} , Q and B_p had to be corrected for this additional power, increasing the overall measurement error.

The quality factor as function of B_p in the TM mode for different values of field in the TE mode (Fig. 4) showed the Q -drop (without field emission) starting at about $B_p = 95$ mT. There seems to be a decrease of the Q in the TM mode for higher field in the TE mode, although they are within experimental errors.

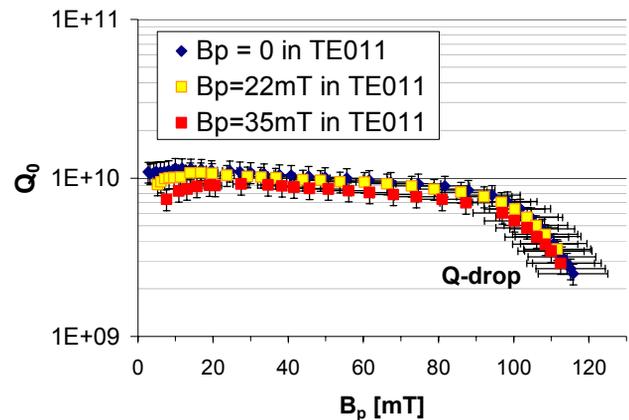


Figure 4: Q vs. B_p in the TM mode for different values of B_p in the TE mode, measured at 2 K.

During the RF test, we noticed that the field in the TE mode was constant while raising the field in the TM mode up to the Q -drop onset. In the Q -drop region of the TM mode, the field in the TE mode decreased, at constant drive power, by about 30 %, as shown in Fig. 5. A possible explanation is that the additional losses in the TM mode lower the Q in the TE mode. Therefore, for the same incident power, the coupler/cavity mismatch increases and less energy gets stored in the TE mode. This effect will be investigated in future tests.

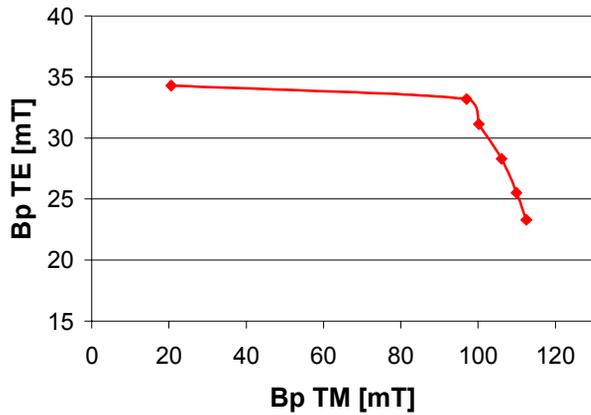


Figure 5: Decrease of B_p in the TE mode observed in the Q -drop region of the TM mode. The incident power in the TE mode was constant.

The frequency shift as function of the square of the accelerating field in the TM mode was measured for different values of the RF field in the TE mode (Fig. 6). The Lorentz force coefficient K_L , given by the slopes in Fig. 6, did not change significantly and is about $-2.5 \text{ Hz}/(\text{MV}/\text{m})^2$, although an offset of about 200 Hz between $B_{p\text{TE}} = 0$ and $B_{p\text{TM}} = 30 \text{ mT}$ was measured.

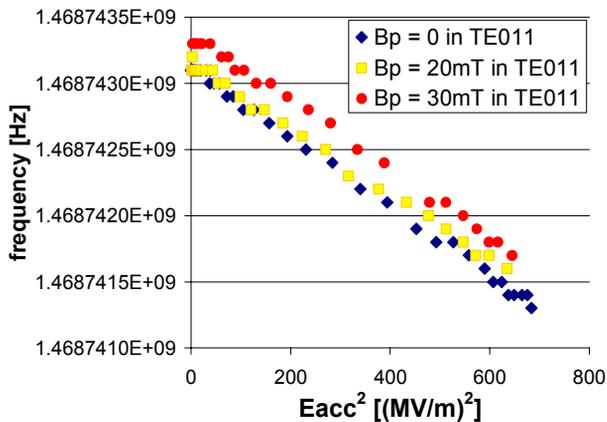


Figure 6: Frequency as function of E_{acc}^2 in the TM mode for different field amplitudes in the TE mode.

SUMMARY

We were able to excite simultaneously the TM_{010} and TE_{011} modes in a single cell cavity up to a total magnetic field of about $B_p = 113 \text{ mT}$. Even though simultaneous excitation of two cavity modes members of a passband have been reported in Ref. [4], we believe that this experiment is the first in superconducting cavities for two totally different field configurations.

The orientation of the loop couplers for the TE mode has to be adjusted for better coupling, in order to reach higher fields and for more accurate measurements. The cavity performance in the TM mode was limited by the so-called Q -drop. The initial results are encouraging enough to pursue further the idea of acceleration and magnetic focusing as proposed in Ref. [2]. Further tests

with a new set of loop couplers will be conducted in order to reach higher fields in both modes.

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