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# SUPERCONDUCTING MATERIALS TESTING WITH A HIGH-Q COPPER RF CAVITY*

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## *Abstract*

Superconducting RF is of increasing importance in particle accelerators. We have developed a resonant cavity with high quality factor and an interchangeable wall for testing of superconducting materials. A compact TE01 mode launcher attached to the coupling iris selectively excites the azimuthally symmetric cavity mode, which allows a gap at the detachable wall and is free of surface electric fields that could cause field emission, multipactor, and RF breakdown. The shape of the cavity is tailored to focus magnetic field on the test sample. We describe cryogenic experiments conducted with this cavity. An initial experiment with copper benchmarked our apparatus. This was followed by tests with Nb and $MgB_2$. In addition to characterizing the onset of superconductivity with temperature, our cavity can be resonated with a high power klystron to determine the surface magnetic field level sustainable by the material in the superconducting state. A feedback code is used to make the low level RF drive track the resonant frequency.

## DESCRIPTION OF APPARATUS

The system [1], which resonates at ~11.424GHz, consists initially of a $TE_{10}$ height taper, a planar $TE_{10}$ to $TE_{20}$ mode converter and a rectangular $TE_{20}$ to cylindrical $TE_{01}$ mode converter as shown in Fig. 1.

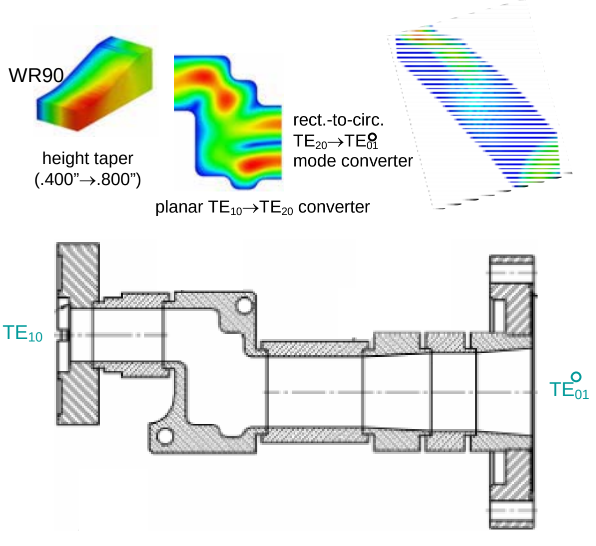

Figure 1: WR90-WC150 compact high-purity TE01 mode launcher.

Finally, a mushroom-type cavity is attached to the mode launcher, where material samples are placed at the bottom flange. Figure 2 shows this cavity.

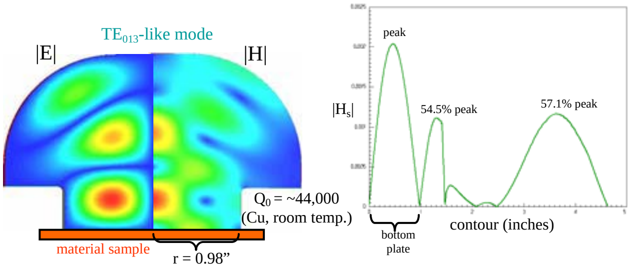

Figure 2: Electric and magnetic fields in the "mushroom" cavity (left) and magnetic field profile along the surface of the cavity (right).

## *Main Features*

- X-band frequency allows for already available high power and RF components.
- Fits in cryogenic Dewar.
- Requires relatively small samples (3" diameter disk).
- Mushroom-type cavity guarantees no surface electric fields, i.e. no multipactor.
- Magnetic field concentrated on bottom (sample) face, where it is 75% higher than anywhere else.
- Purely azimuthal currents allow demountable bottom face (gap).

Figure 3: Picture of mushroom cavity attached to the mode launcher (left), and vertical cryostat (right).

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Figure 3 shows a picture of the cavity with the mode launcher and the vertical cryostat for testing.

## COPPER AND NIOBIOUM TESTS

Tests with copper and niobium samples have been performed successfully, and the quality factors are shown in Figs. 4 through7.

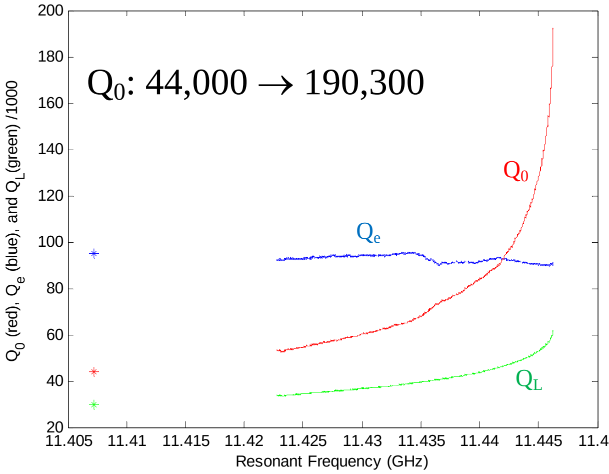

Figure 4: Loaded ($Q_L$), unloaded ($Q_0$) and external ($Q_e$) quality factors with copper sample on the bottom flange as a function of frequency.

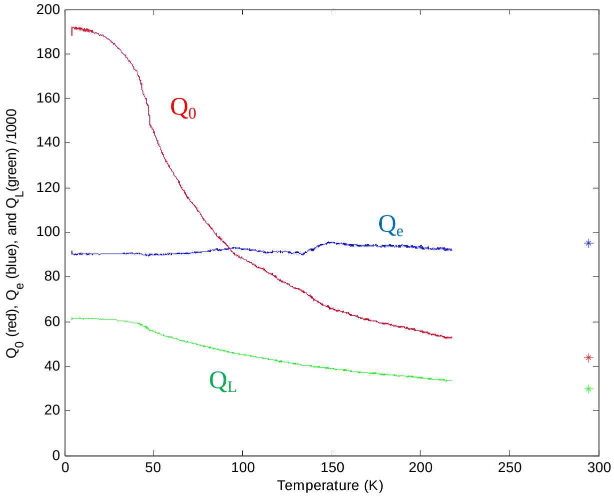

Figure 5: Quality factors with copper sample on the bottom flange as a function of temperature.

Figure 8 shows the transition of cavity $Q_0$ during warm-up from liquid helium temperature for reactor grade niobium. The graph shows a very sharp and clean change as the niobium sample undergoes the phase transition around 9.3 K.

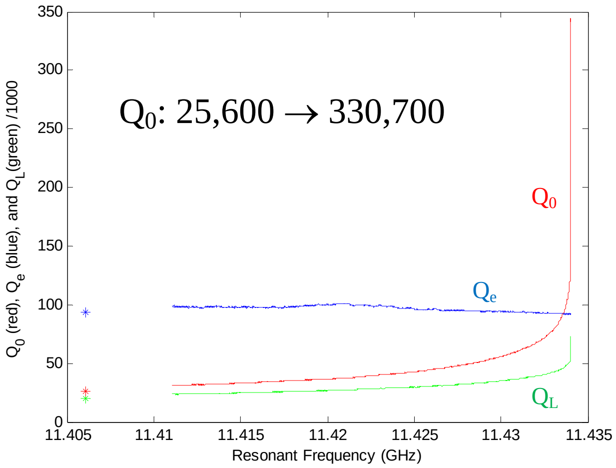

Figure 6: Quality factors with niobium sample on the bottom flange as a function of frequency.

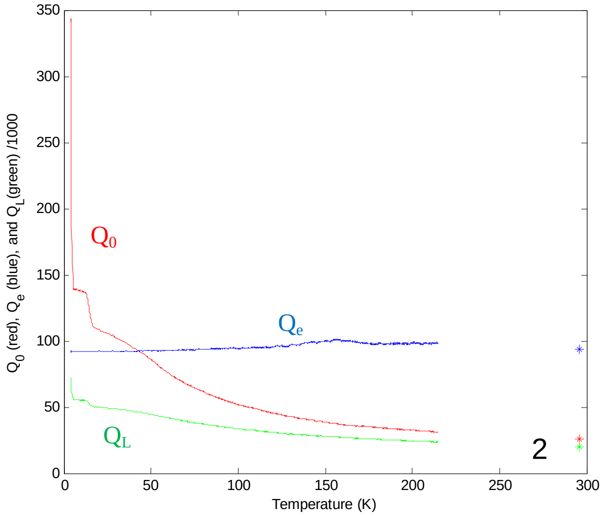

Figure 7: Quality factors with a reactor grade niobium sample on thebottom flange as a function of temperature.

## $MgB_2$ TEST

A sample prepared by Superconductor Technologies Incorporated (STI), where $MgB_2$ was coated on top of sapphire, has been tested. The thickness of the $MgB_2$ layer is ~500 nm and the method of coating is reactive evaporation (RE) [2]. The first result of alow power test of the film is shown in Fig. 9, where a clean Q drop is observed at the transition temperature.

It has been found out that the current system is sensitive enough to obtain the surface resistance of the sample. This is achieved by comparing the cavity $Q_0$ with the sample and that with copper.A preliminary estimation of the surface resistance for the $MgB_2$ sample is shown in Fig. 10.

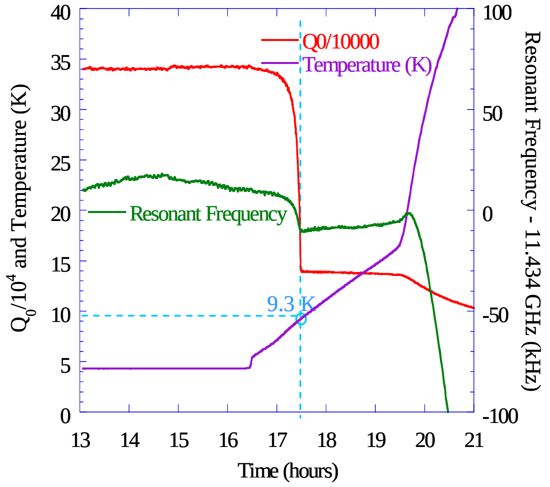

Figure 8: Changes of cavity $Q_0$ and resonant frequency during warm-up from liquid helium temperature to ~40 K for reactor grade niobium.

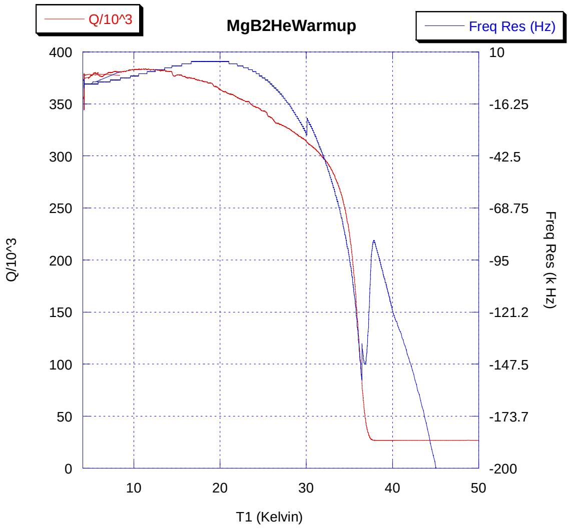

Figure 9: Change of $Q_0$ and resonant frequency of a STI $MgB_2$ sample during warm-up.

## HIGH POWER TEST

A high power test has been performed on niobium to determine the RF critical magnetic field. Figure 11 shows preliminary data of the high power test for reactor grade niobium at 4.2 K. It clearly showed the point where $Q_0$ degrades due to the magnetic quench. However, the power needed for quench was ~80 kW contrary to the estimated ~500 kW for the critical field of 180 mT. This discrepancy is under investigation.

The experimental setup is still maturing. A high-power circulator was added in order to isolate the klystron from the cavity reflection. A silicon diode and a Cernox temperature sensor will also be added.

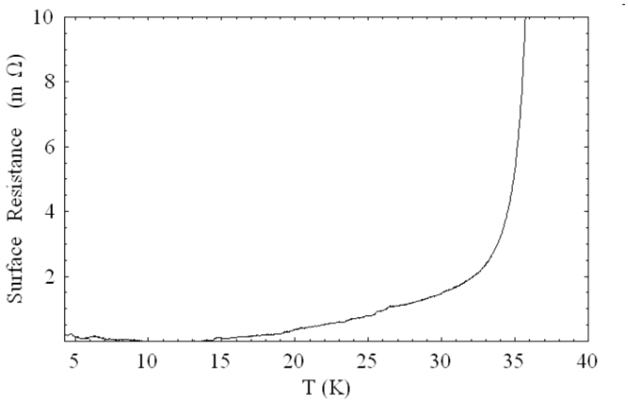

Figure 10: A preliminary result of the $MgB_2$ surface resistance calculated from the $Q_0$ measurements

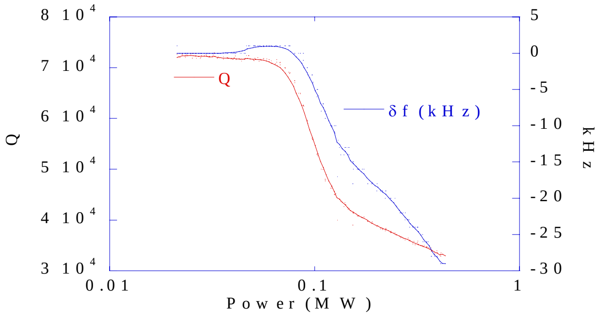

Figure 11: $Q_0$ and change of resonance frequency as a function of power in the cavity during the high power test of reactor grade Nb. The pulse length was 1.5 µs

## CONCLUSIONS

A compact, high-Q RF cavity optimized for economically testing the RF properties of material samples and their dependence on temperature and fields by means of frequency and Q monitoring has been designed and fabricated at SLAC.

Tests on copper, niobium and $MgB_2$ samples have been performed.

High power tests for $MgB_2$ and other Nb samples such as single grain samples will be tested soon. Aslo a similar cavity will be used for pulsed heating material testing.

## REFERENCES

[1] C. Nantista et al., "Test Bed for Superconducting Materials", *Proceedings of the 21st Particle Accelerator Conference (PAC05)*, Knoxville, TN, May 16-20, 2005, p. 4227.

[3] T. Tajima et al., "Tests on MgB2 for Application to SRF Cavities", *Proceedings of the European Particle Accelerator Conference (EPAC06)*, Edinburgh, United Kingdom, June 26-30, 2006.