Superconducting RF Activities at Peking University

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Abstract

Peking University is interested in the application of superconducting RF techniqu to the accelerator field. Research and development activities in this area have been carried out at Peking University for 3 years. As a start, a single cell resonator of L band is being studied and preliminary results have been obtained. The microwave properties of high Tc superconductors are being tested. The future project of S. C. RF Gun is being considered.

Introduction

High brightness electron beams are required for a number of applications, as well as for short wavelength FELs. As superconducting photoemission source appears to be promising in producing high current, low energy spread, high brightness electron beams, it is suggested to develop a high brightness superconducting RF gun of photo-cathode by joint efforts of related institutes in China. For this purpose the RF super-conducting group at IHIP of Peking University decided to gear their activities in developing Nb cavities for high-brightness electron source.

As a start a series of efforts have been made since fall 1988 to construct a class 100 laboratory suitable for processing and assembling of Nb cavities, as well as to develop equipments and techniques for designing, surface treatment and RF test of super-conducting cavities. The fields of fundamental mode and high order modes as well as wake field potentials were studied using SUPERFISH, URMEL and TBCI codes during designing.[1] Two high purity Nb cavities of L-band were kindly sent to us from DESY and Cornell so as to facilitate the development. In the present paper the preparation of the Nb cavity made by Donier and the structure of the cryostat will be described and preliminary results of Q value versus temperature are presented and discussed. An accelerating field of 8.6 MV/m was obtained with Qo of 6.5×10^8 at 2.25k.

In addition to the above, coaxial and pill box cavities are designed and constructed for the test of RF properties of high Tc samples developed by superconducting groups in the Department of Chemistry, Peking University. Results of these tests are also presented.

Preparation of the Nb cavity

A 1.5GHz single cell cavity, made of high RRR (300) Niobium, with a size and shape similar to that of Cornell's resonators was manufactured by Donier Co., and the final cleaning and chemical polishing work were implemented on the base of their preliminary treatment. A few tests of the postpurification of the Nb surface were done. Quite good results of our RF superconducting experiments were obtained by the following treatment procedure:[2]

* 1st chemical polishing (CP) removes by 20 μm of inner surface in $HF/HNO_3/H_3PO_4$ solution, using the DESY's method.[3]
* Rinsing with demineralized water ($\rho >$ 10 MΩ/cm).
* Drying by pumping
* Heat treatment with Titanium box at 850°C for 1.5 hours.
* 2nd chemical polishing removes by 5-10 μm of inner surface.
* Rinsing again with DI water first, then with ultrapure water ($\rho >$18MΩ/cm).
* move to a clean room of class 100.
* Rinsing again with ultrapure water.
* Assembling on a super clean bench.
* Vacuum evacuation and baking at 150°C for 20 hours.
* Mounting the cavity onto a vertical stand.

The above method will be improved according to the results of our experiments and the method of other labs.

The Cryostat

The cryostat for the L-band Nb cavity was manufactured by the Department of Physics, Peking University. The length and diameter of which is about 175 cm and 65 cm. The Nb cavity is mounted vertically in the cryostat, Fig.1, and to be evacuated separately by TMP and ion pump. Liquid He is fed from a big Dewar by a transmission line. No HOM coupler and frequency tuner are provided at the moment. Outer magnetic shield is wrapped by a high μ material foil. To reach a temperature as low as 2K, a depressure system is used.

Experiments and Results

The vertical test of 1.5GHz Nb cavity has been carried out since the end of last year. The RF system is shown in Fig.2. High stability RF signal is provided by HP 8663A signal generator, while sampling and control are completed by HP 54503A digital oscilloscope and HP PC-312 controller respectively. Reliable RF cable and connectors are used for low temperature area inside the cryostat, and every element was checked and calibrated before the test. A phase locked loop has been used under the superconducting condition. The pulse method was adopted for Eacc and Qo measurements. The decay time of the pick-up signal from the SC cavity and coupling coefficient (β) of the main coupler are measured with pulsed RF power at various field level. From those data, Qo and Eacc are calculated. Fig.3 is a sample of the measuring results of Ql and β. The unloaded Q value (Qo) of the cavity is calculated from Ql and β with the equation $Qo = Ql \times (1+\beta)$.

The acceleration field Eacc on the beam axis is calculated from Qo and β, using the following equation:

$$Eacc = (1/0.1)\sqrt{102 \times Qo \times (4\beta/(1+\beta)^2 \times Pi}$$

Here, factor ($102 \times Qo$) is the cavity's shunt impedance. Pi is the input RF power.

Fig.4 is the curve of Rs vs. Tc/T. In the figure, the dots represent the measured data, the line is a theoretical curve given by BCS theory. The dots fall well on the line till Tc greater than 4.0. Then they deviate from the theoretical value considerably, which in turn show the existence and value of Rres.

Fig.5 gives two curves of Eacc vs. Qo. One is the data measured at 4.2K, while the other is at 2.25K. The Eaccmax so far reached is 8.6MV/m (Qo=6.5x10^8, f=1.46GHz) at 2.25K. The maximum value of Eacc in the test was actually limited by RF power available.

R&D of HTS

We are interested in RF superconductivity of high Tc material and its applications in accelerating cavity. For this purpose, an coaxial resonator and a pill box cavity have been used for RF properties tests of YBaCuO and BiPbSrCaCuO film samples. Large area high Tc film with good quality is made by electrophorese deposition technique,[4] provided by the Department of Chemistry, Peking University. The RF properties was tested in our lab. Working frequency is around 0.5-1.2GHz for coaxial resonator and about 8-10GHz for pill box cavity. The results of preliminary experiments show considerable RF superconductivity. At 79K, Rs=(50±20)mΩ (pill box cavity, f=8.9GHz, TE011), and for the coaxical resonator Rs=(0.8±0.1)mΩ with f=1.0GHz. fig.6 is the measuring results of two samples.

Acknowledgement

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Reference

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2. Z. Kui, et al., IHIP report SC-91-02, July(1991).
3. D. Proch et al., DESY M-84-10, July(1984).
4. G. Mueller, Proceeding of the 4th Workshop on RF Superconductivity, 267, (1990)

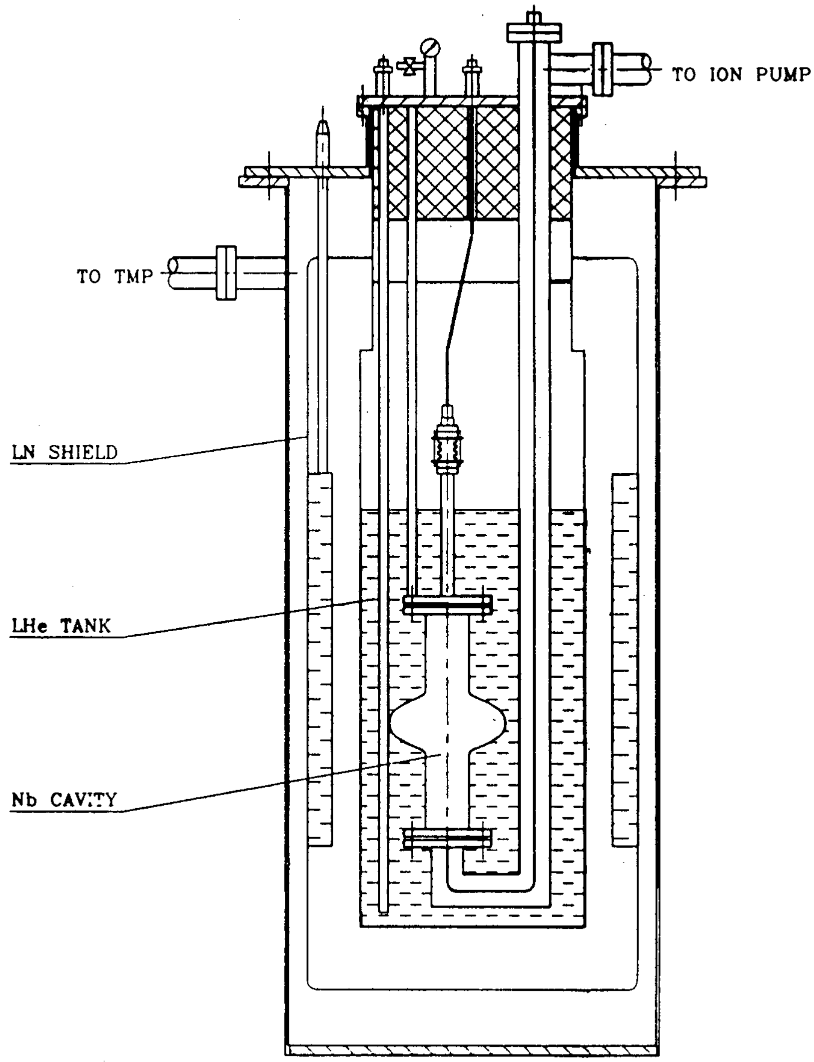
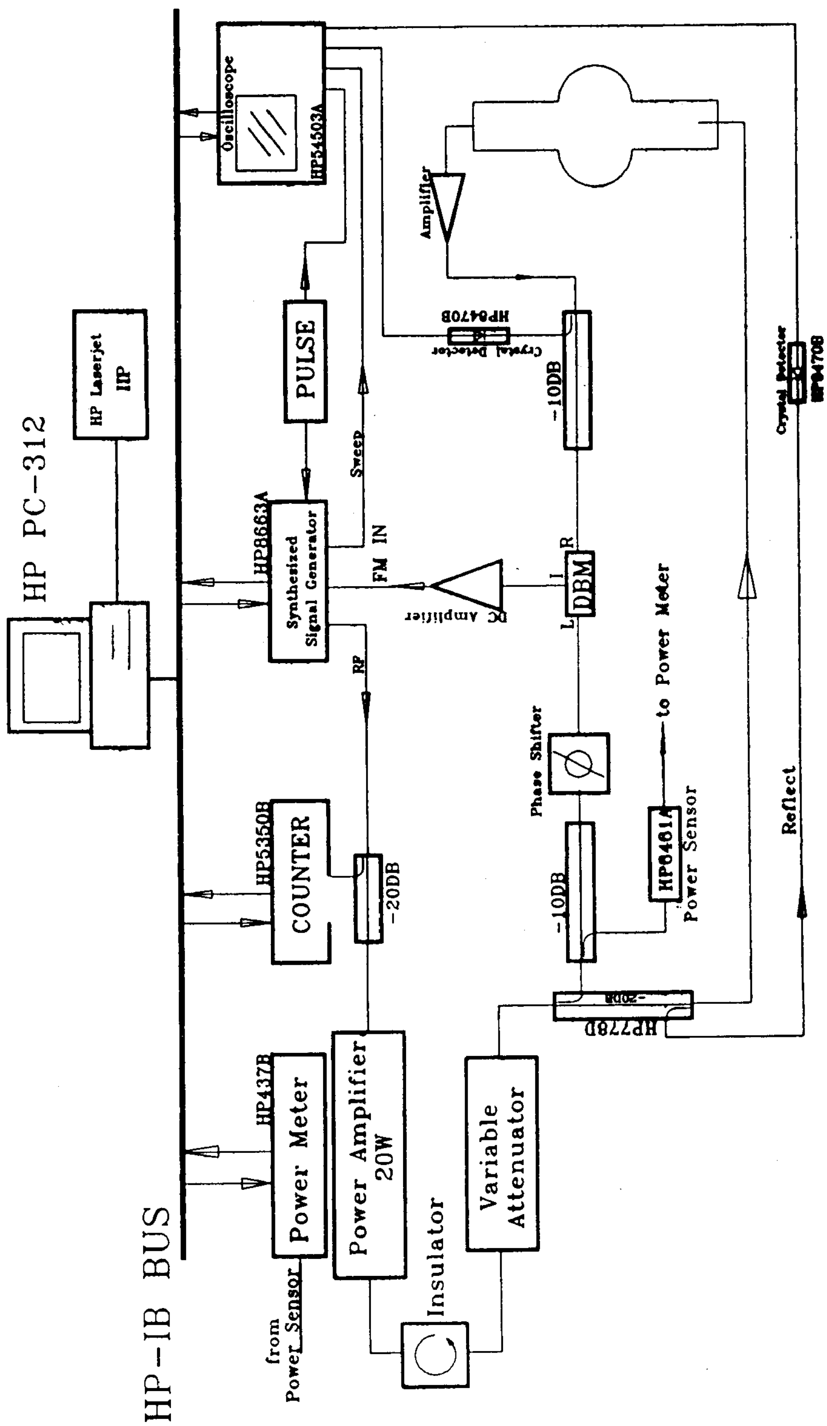


Fig.1



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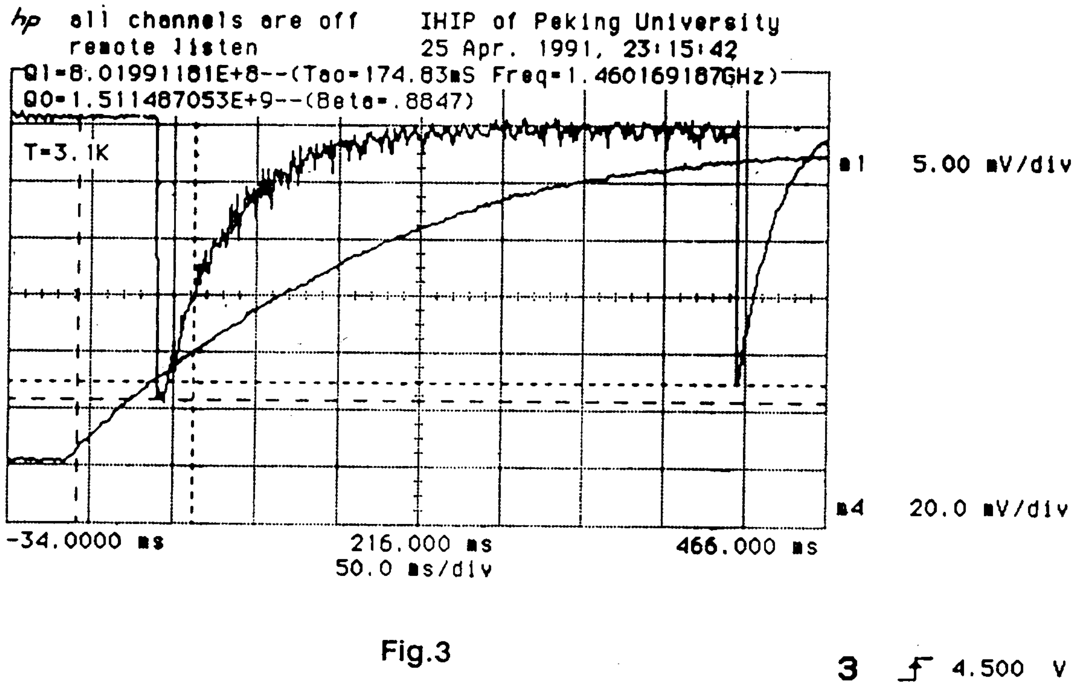
HP PC-312
HP Laserjet
HP
Oscilloscope
HP54503A
PULSE
HP8663A
Synthesized
Signal Generator
Sweep
FM IN
RF
DC Amplifier
Amplifier
HP8470B
Crystal Detector
-10DB
L
I
R
DBM
Phase Shifter
-10DB
HP8481A
Power Sensor
to Power Meter
HP5350B
COUNTER
-20DB
HP437B
Power Meter
from
Power Sensor
Power Amplifier
20W
Insulator
Variable
Attenuator
HP778D
-20DB
Reflect
Crystal Detector
HP8470B

Fig.2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IHIP of Peking University
25 Apr. 1991, 23:15:42
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Q0=1.511487053E+9--(Beta=.8847)
T=3.1K
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m4 20.0 mV/div
-34.0000 ms
216.000 ms
50.0 ms/div
466.000 ms
3 4.500 V

Fig.3

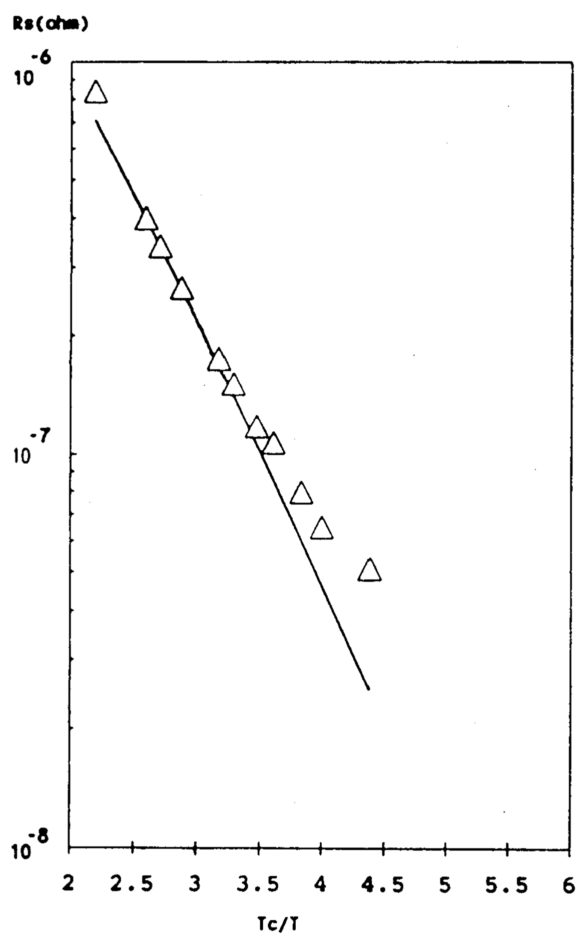
Rs(ohm)
10^{-6}
10^{-7}
10^{-8}
2
2.5
3
3.5
4
4.5
5
5.5
6
Tc/T

Fig.4

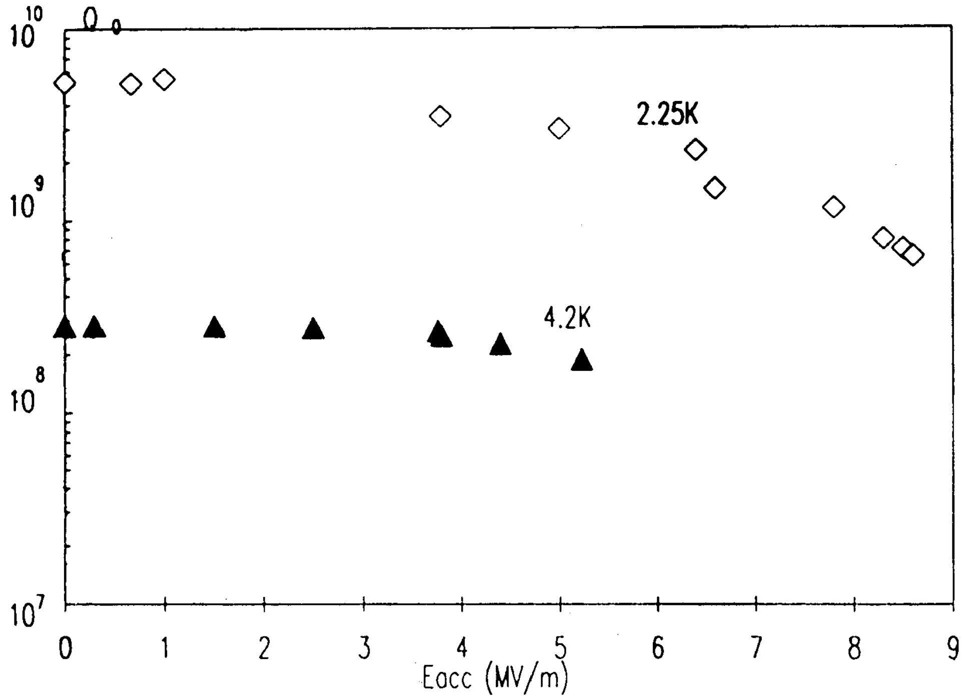
10^10
10^9
10^8
10^7
2.25K
4.2K
0
1
2
3
4
5
6
7
8
9
Eacc (MV/m)

Fig.5

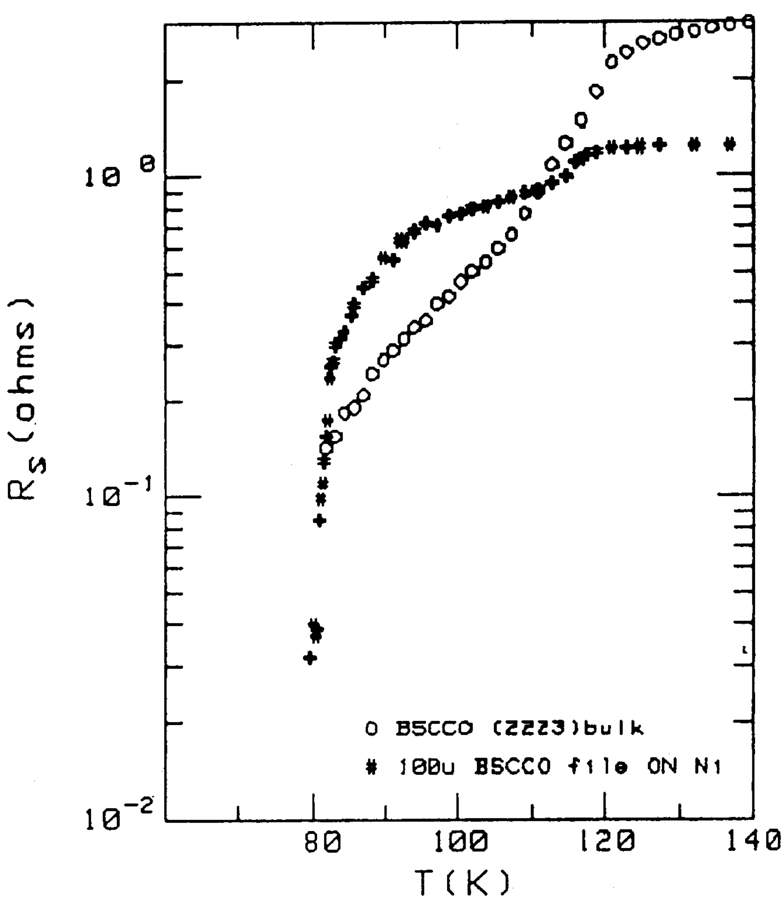
10^0
10^-1
10^-2
Rs (ohms)
80
100
120
140
T(K)
o BSCCO (2223)bulk
100u BSCCO file ON Ni

Fig.6