Laboratory Activities on RF Superconductivity at Peking University

Chen chia-erh, Zhao Kui, Zhang Baocheng, Wang Lifang, Yu Jin
Song Jinhu, Geng Rongli, Wang Qingyuan, Wang Tong, Wu Genfa

Institute of Heavy Ion Physics, Peking University
Beijing 100871, China

Introduction

This report describes the activities on RF superconductivity at Peking University in the past two years. Two projects are being undertaken in our group to develop RF superconducting techniques. One is the fundamental research of superconducting cavity. Another is the study of feasibility of superconducting RF Gun for FEL.

Fundamental Research of Superconducting Cavity

1. 1.3 GHz Nb Cavity.

We have set up a new project of manufacturing a L-band cavity for the purpose of getting enough knowledge to develop superconducting electron accelerators in China. Considering the specifications of the power amplifiers available in the domestic market as well as possible future applications of L-band superconducting cavity in China, we select an operating frequency of 1.3 GHz. In referring to parameters of the cavities with the same frequency in other countries, the geometry of a 1.3 GHz cavity was optimized and determined by using codes of URMELT and SUPERFISH. The designed parameters are shown in the table 2 and illustration Fig.1 as well.

Table 1. Parameters of 1.3 GHz Cavity

Frequency	1.3 GHz
Beam Aperture	7.0 cm
R/Q	51.06 Ω/m
Epeak/Eacc	2.16
Hp/Eacc	41.09 G/MV/m

In order to test forming and welding of Nb cavity, a set of steel dies have been designed and manufactured. A 1.3GHz cooper cavity has been formed successfully by deep drawing with this set of dies. The electron beam welding of 1.3 GHz cooper cavity has been completed and the test of electron beam welding for Nb is undertaken. The RF properties of 1.3 GHz cooper cavity has been measured. The frequency of fundamental mode is 1.2958 GHz.

The 1.3 GHz cavity will be made of pure Nb sheets. For this purpose the production of high purity Nb has been put to trial in a factory of China. The first batch samples was supplied in last year. The measured RRR of first Nb samples are only about 60 to 70. At that time, Dr. P. Kneisel gave us kindly help. A lot of test and analysis have been done for check the reason of low RRR. According to the testing results, the factory improved the melt technology and some Nb sheets have been supplied recently. The following Table 2. is the impurity contents of Nb sample.

Table 2. Impurity Contents of Nb Sample

Element	Wt. %	Element	Wt. %	Element	Wt. ppm
Si	0.001	Fe	0.001	O	50
W	0.001	M	0.001	C	20-30
Ti	0.001	Zr	<0.001	N	50
V	<0.001	Hf	<0.001	H	5
Al	<0.001	Cu	<0.001		

2. The Study of Superconducting Cavity

In the past several years, a single cell of 1.5 GHz Nb cavity has been studied in detail. The RF superconducting experiment of 1.5 GHz Nb cavity was performed using a vertical LHe cryostat. The temperature of working area can be cooled down to 2K by a depressed system. Fig. 2. gives the measured results of Eacc vs. Qo at 4.2K and 2.35K respectively. The field gradient up to 12.6MV/m with Qo=10^9 was obtained.

For the further study of superconducting cavity, our laboratory was rebuilt. A DI recirculator water system and a new class 100 clean room are installed and operated. A 200W microwave power source was manufactured and tested. A half cell cavity has been designed, which will be used for the studies of the field emission and photocathode testing.

The Feasible Study of Photo-RF Gun Using Superconducting Cavity

1. Photo-RF Gun using superconducting cavity

High quality electron beam is essential for the linear collider and free electron laser. The brightness of accelerated beam is usually determined by the performance of the gun. The realization of a photoemission RF gun using superconducting cavity is very attractive.

The idea of photoemission source of high brightness using a superconducting cavity is suggested by Prof. H. Piel and Dr. C. K. Sinclair. Some studies and experiments have been done by Dr. A. Michalke at Wuppertal. In 1992, a proposal was made by the group of superconducting cavity of Peking University to study the feasibility of S. C. photo-RF gun for FEL. As a first step, we have decided to develop a pre-testing device based on our existing conditions. The diagram of such device is shown in Fig.3. The heart of the pre-testing device is a 1.3 GHz 1+1/2 superconducting cavity made of high thermal conductivity niobium. The photocathode will be located in the center of the end plate. Mode-locked Nd:YAG laser, RF power and control system are in preparation.

The design studies of beam dynamic properties and the optimization of half cell are carried out using ITACA code on VAX-station 3100 computer. Table 3 gives the parameters of our pre-testing photo-RF gun with superconducting cavity. The initial values assignment are $E_{cathode}$=18MV/m, R_{laser}=2mm, $Length_{laser}$=10ps, $Phase_{in}$=54° respectively.

Table 3. Parameter of S. C. Photo-RF Gun

Charge of Bunch (nC)	0.08	1.3
Energy Gain (Mev)	0.9471	1.049
RMS Energy Spread (%)	0.289	0.379
I_{peak} (A)	12.44	77.12
Norm. Trans. Emmit. (mm mrad)	3.0972	12.083
Norm. Brightness (A/(mrad)^2)	0.82x10^{10}	0.33x10^{10}
RMS Half Length (mm)	0.9593	
RMS Radius (mm)	3.258	4.372

2. Photocathode using for superconducting cavity

We are concerned with the mutual interactions between photocathode and superconducting cavity. We hope to develop a photocathode with high QE and more practical.

Two respects will be investigated in our photocathode program. First, various samples of photocathodes will be tested under DC field in order to select a suitable cathode; second, the field emission and dark current effects will be studied under RF field without laser irradiation while the photocathode is introduced into the superconducting cavity.

Multi-alkali cathodes and special Ag-Ba-O cathode whose substrate is BaO embedded with silver ultra-fine particles are being developed in cooperating with Department of Radio-Electronics of Peking University. Since April 1993, a novel photocathode based on the concept of ion beam implantation has been in progress at our laboratory and low energy alkali metal ions have been successfully implanted into several kinds of substrates, such as cooper, aluminum, nickel and niobium. Photoelectric experiments with 2nd, 3rd and 4th harmonics of a Q switched Nd:YAG laser, 6ns pulse duration have been performed. The testing results have shown that photo-emissive characteristics have been improved compared with pure metals. Especially, both of the Special Ag-Ba-O and ion-implanted cathodes can be exposed to atmosphere recycled by simple heating procedure. The further experiments are now being attempted to fabricate a practical photocathode compatible with superconducting cavity.

Conclusions

The Nb material will be improved by the factory. In the near future, a single cell 1.3 GHz Nb cavity will be finished. The feasible study of photo-RF gun with superconducting cavity is undertaken. As the first step, we are focusing on the study of mutual interaction of cathode and cavity. In Peking University, we got a lot of support and help from Physics Department, Chemical Department and Department of Radio Electronics.

Acknowledgment

We would like to thank Prof. Q. D. Wu, Prof. X. Sh. Zhao and their group's colleagues of Peking University for their continuous support and help. We are also pleased to acknowledge Dr. D. Proch, Prof. Y. Kojima, Prof. Pagani, Dr. Serafini and Dr. Knersal for their continuous encouragement, help and discussion.

Reference

1. C. Travier, Review of Microwave Guns, Particle Accelerators, 1991, Vol.36, pp.3374
2. A. Michalke, Photocathodes Inside Superconducting Cavities, External Report, WUB DIS 92-1, January 13, 1993
3. C. Chia-erh, et al., Superconducting RF Activities at Peking University, Proceedings of the 5th Workshop on RF Superconductivity, 1991, pp. 102-109
4. Geng Rongli, et al., A promising photocathode with Ions of Alkali Metals Implanted in Transition Metals, Internal Report, IHIP of Peking University, 1993
5. Yu Jin, et al, Measurement and Analysis of Chinese-built Niobium's RRR, Internal Report, IHIP of Peking University, 1993
6. Song Jinhu, ET al., Preliminary Calculation for Photocathode RF Gun, Internal Report, IHIP of Peking University, 1993
7. Wang Tong, et al., 1.3 GHz RF SC cavity Geometry Optimization, Internal Report, IHIP of Peking University, 1993

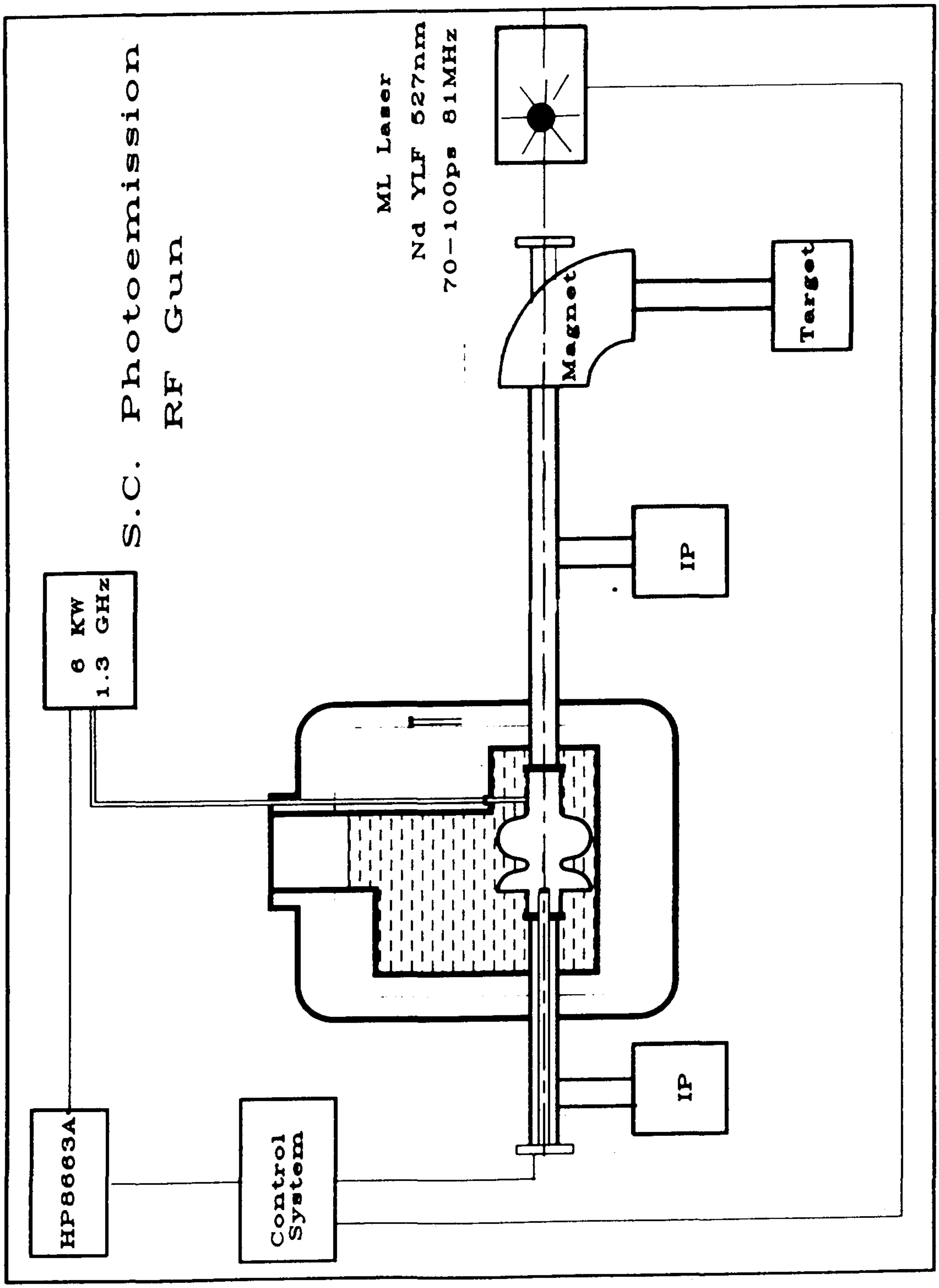

Figure 1. the pre-testing device of S. C. photo-RF gun for FEL

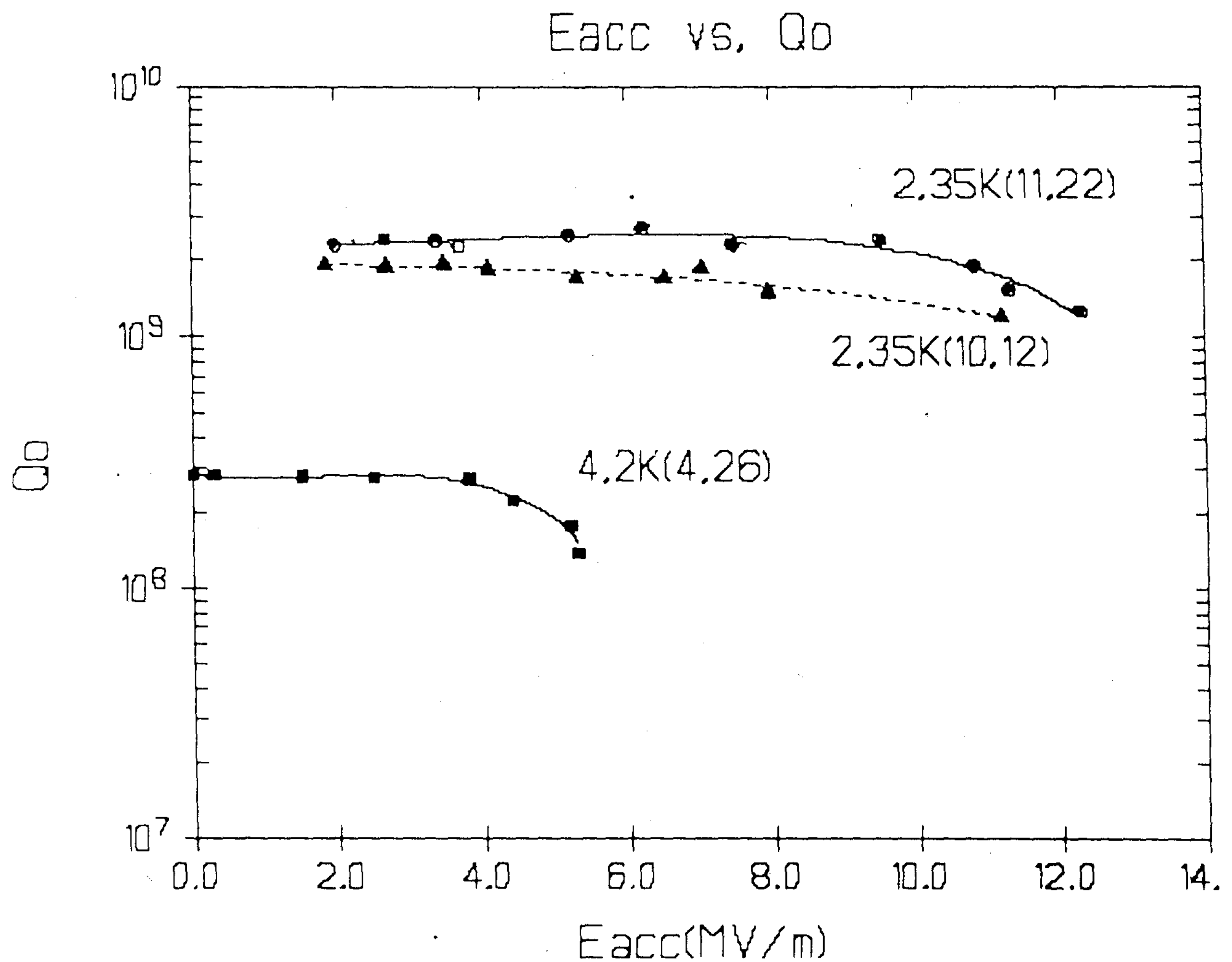

Figure 2. the measuring results of Eacc vs Q_0 at 4.2K and 2.35K respectively.

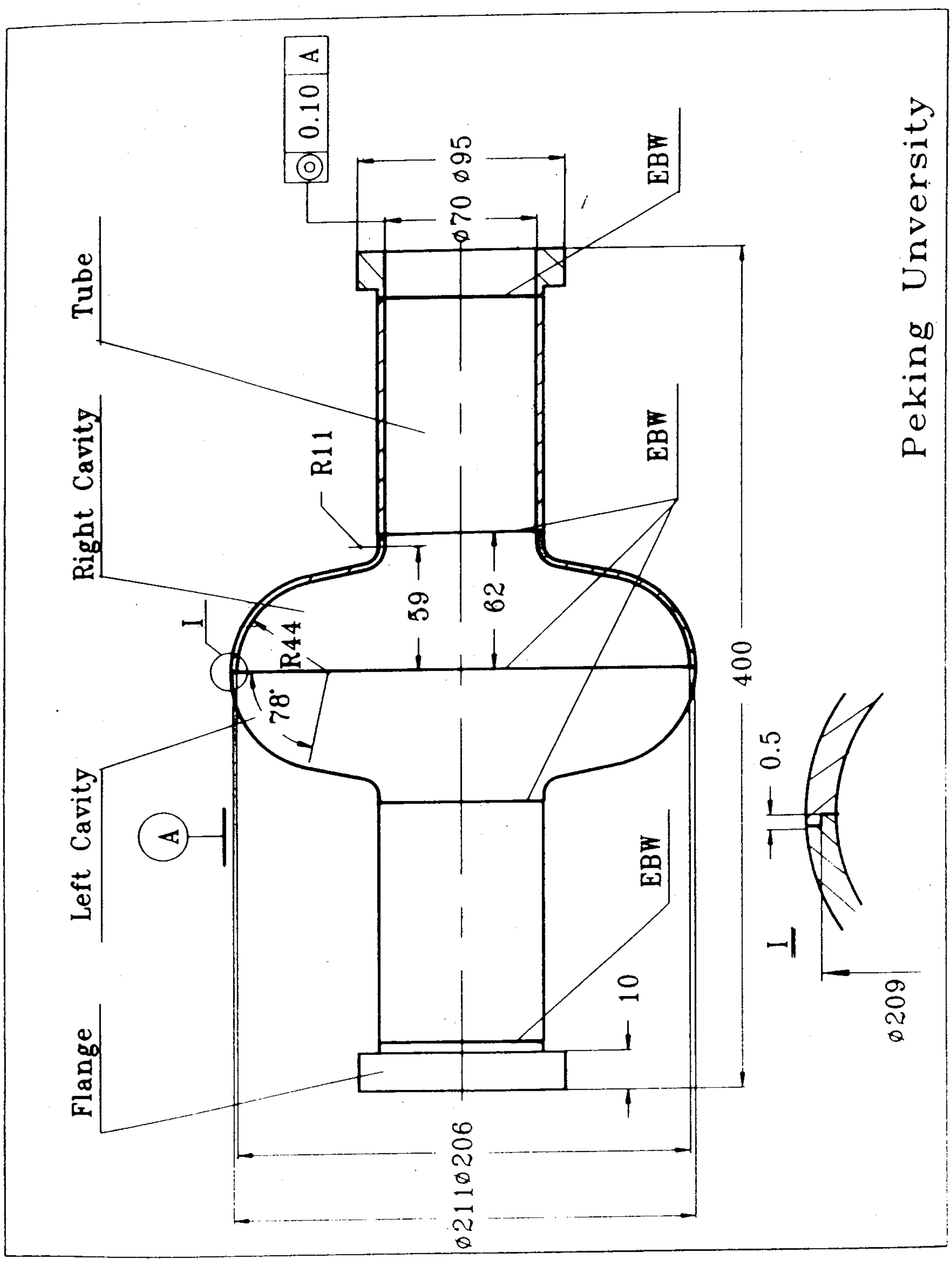

Figure 3. a 1.3Ghz Nb single-cell cavity with geometrical parameters