THE FABRICATION AND CHARACTERIZATION OF AN S-BAND RF-GUN CAVITY

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Abstract

A single cell rf-gun cavity is designed and fabricated for the purpose of examining the feasibility of installing a thermionic rf-gun at NSRRC instead of a photocathode rf-gun considered previously. The operating frequency of the rf-gun cavity is set at 2856 MHz in order to utilize the available XK-5 klystron and linac. The fabricated parts of the OFHC copper cavity are brazed together in-house and then the cavity is characterized by rf measurement. It shows that the cavity gives very good character in terms of high quality factor, relaxed tuning range, adequate coupling coefficient, and reasonable reproducibility. The properties of the cavity are further explored by measuring the field profile and its response to an rf pulse in which the filling time is deduced. The measurement results of this brazed cavity are described and summarized in this report.

INTRODUCTION

The preparation of installing an rf-gun at the site of NSRRC made progress in the past few years concerning rf-system construction [1, 2] and experience on building photocathode rf-gun cavities [3, 4]. However, integration of the rf-gun and laser systems was pending due to extra budget need for laser system and project priority rearrangement. Consequently, it seems worthwhile to examine the feasibility of developing a thermionic-cathode rf-gun on site and to explore its possible applications concerning the generation of short electron pulses. A single-cell OFHC copper rf-gun cavity is considered in this case as a test-run example. It was designed, fabricated, and brazed in-house and has been characterized by rf measurement. In order to estimate the effectiveness of the accelerating field strength, the field profile along beam centerline is measured using bead-pull method. The dynamic property of this cavity is further explored by feeding an rf-pulse into the cavity and monitoring the associated reflection and transmission signals. The results are summarized and described in the following paragraphs.

CAVITY FABRICATION

The test unit fabrication was outsourcing to local machine-shop in order to explore potential collaborators. The engineering information for components fabrication was provided. Some of the major parameters of the OFHC copper cavity are listed in table-1. The numbers listed for each of the parameter is the expected dimension while the number in the parenthesis is the final fabricated dimension. The difference between these two quantities, if there is any, results from various compromised selection in the fabrication process. Whether the difference is tolerable or not, in terms of cavity characterization, will be verified in the rf measurement described in this report.

Table 1: Major parameters of the rf-gun cavity

Parameter	Dimension
Radius	40.2 (40.75) mm
Length	32 mm
Coupling aperture	10-20-0.5 (W-L-T) mm
Tuner diameter	20 mm
Field monitor	H-field loop

Note that the 1% deviation of the cavity radius shifts the resonant frequency to around 2830 MHz. The needed frequency tuning is expected to be accomplished by using the built-in tuner. The cavity components are fabricated according to the engineering layout and brazed in-house. The brazing furnace installed in NSRRC has been acquired through cooperation with ITRI (Industrial Technology Research Institute, Hsinchu) since 1998. It has served the rf-gun project for L-band [3], X-band [4], and S-band [5] cavities fabrication with great satisfaction. Figure-1 illustrates typical examples of the design layout of cavity. The brazed cavity is shown in figure-2. The leak rate is better than $1*10^{-9}$ mbar.l/sec.

RF MEASUREMENTS

The measurement of this single-cell rf-gun cavity has been carried out at test bench. It includes cavity quality factor and impedance measurement. Also, its response to a drive rf-pulse has been carefully examined, in which the filling time is deduced. The measured results are summarized in this section.

Linearity of Tuner Position vs. Frequency Shift

The cavity resonance frequency and tuning capability are examined and the result is shown in figure-3. The tuning range of 15 MHz seems reasonable. Yet, the resonance frequency is low with respect to 2856 MHz if one intends to make use of the available XK-5 klystron.

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Therefore, further improvement on the examination of work items from outsourcing machine shop will be developed for long-term collaboration purpose.

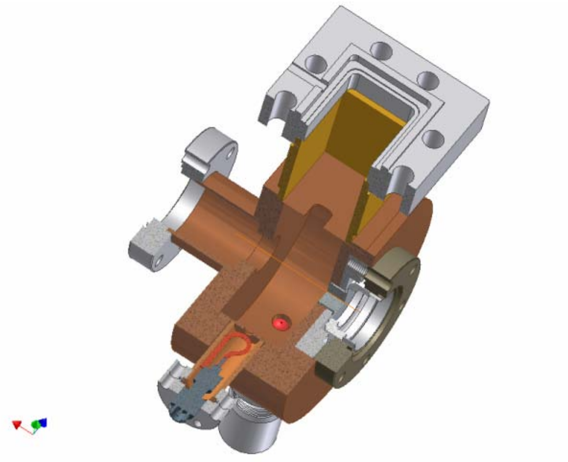

Figure 1: Typical examples of the cavity layout.

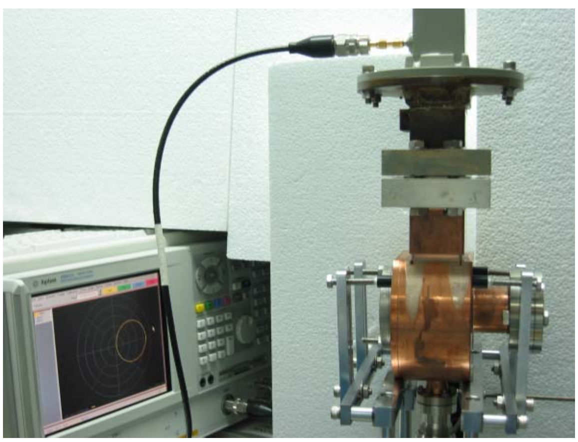

Figure 2: Experimental setup for cavity measurement.

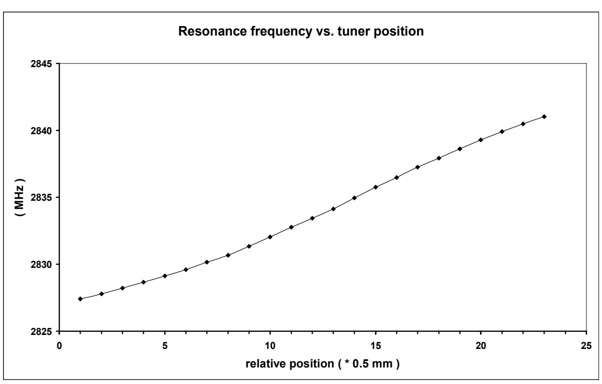

Figure 3: Cavity frequency vs. tuner position.

Quality Factor and Impedance

The measured quality factor and cavity impedance are: Q ~ 20000 and Z ~ 50 Ω, respectively, with unity couple, as shown in figure-4 and figure-5. It is worth of noting that the measurement results are sensitive to cathode installation. This perturbation factor is, however, unavoidable since aged cathode will have to be changed in the field once it is put into operation. Therefore, the installation procedure has been carefully developed and examined with bench practice so as reproducible results can be assured.

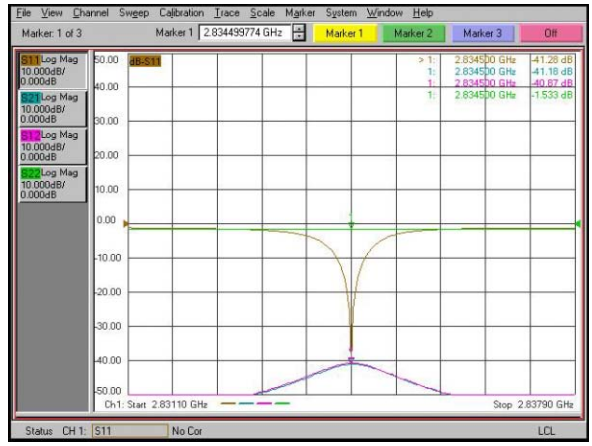

Figure 4: The measured S11 and S21 signals.

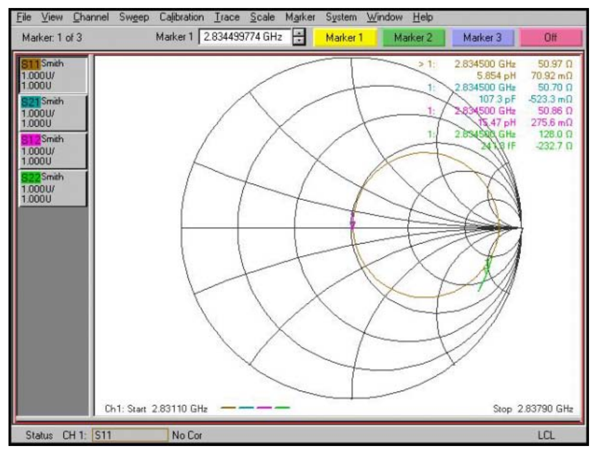

Figure 5: Cavity impedance deduced from S11 and S21.

Cavity Field Profile

The field profile along beam centerline of the cavity is obtained by using a simple bead pull setup for this particular purpose. The measured result is shown in figure-6. The uniform field is distorted nearby the exit port and it stretches over the cavity boundary to some extent.

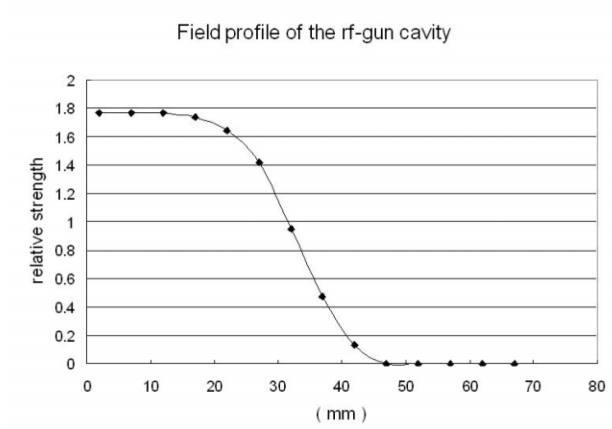

Figure 6: Field profile of the cavity; length: 32 mm.

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DYNAMIC PROPERTY

The dynamic property of this cavity is further explored by feeding an rf-pulse into the cavity and monitoring the associated reflection and transmission signals. The functional block diagram of measurement setup is given in figure-7.

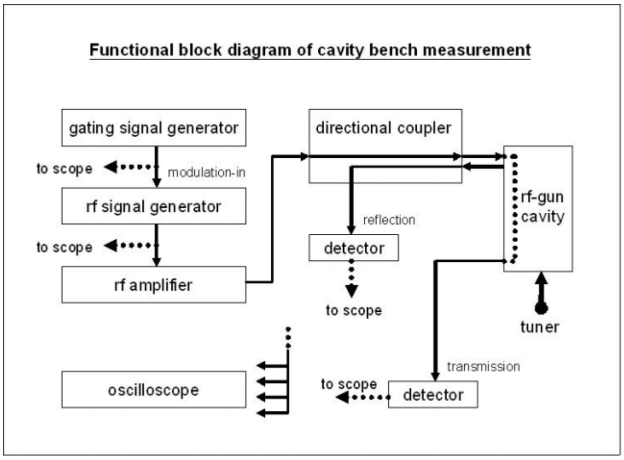

Figure 7: Block diagram for rf-pulse measurement.

As illustrated in figure-7, the rf-signal @2835MHz is chopped by the gate signal at appropriate pulse length for downstream application. The pulse width is set to be long enough to establish a steady state rf-field in the cavity for further examination. On the other hand, it shall not be too long to deviate from practical need. The rf-signal is amplified to the appropriate power level so that the transmission signal is valid for quantitative analysis. The directional coupler provides capability in filtering necessary information of reflection signal, from which the dissipation time of the cavity is deduced. The measured results are shown in figure-8.

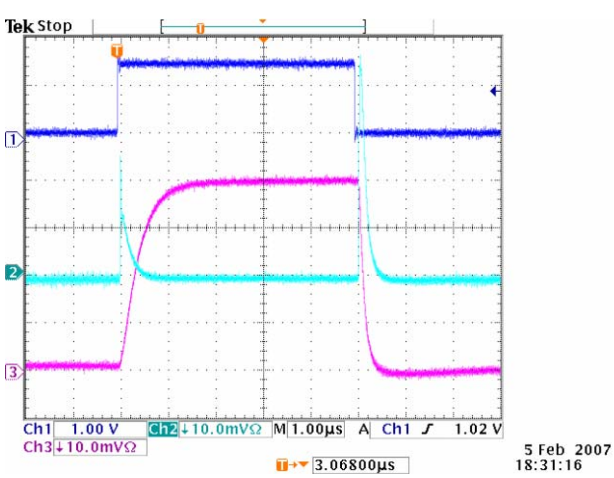

Figure 8: Measured signals: Ch1: rf-pulse; Ch2: reflection; Ch3: transmission.

Illustration of the transmission signal indicates that it takes about 1.2µs for the rf-pulse to fill-up the cavity. Therefore the filling time of the cavity is 1.2µs. Similar arguments are also applicable to the case in obtaining dissipation time constant. Once the rf-pulse is switched-off, the incoming rf-power is terminated. Then the rf-field established in the cavity dissipates away accordingly. Ch2 signal indicates that the rf-power is dissipating in the form of reflection signal. At the same time, the field monitor, Ch3 signal gives similar rf-power dissipation pattern in the cavity with the same time constant, i.e. 400ns.

Estimation on the coupling coefficient can also be quantitatively achieved by examining the reflection power at the steady state of the rf-pulse, i.e. within the rf-pulse where the saturation field has been established in the cavity. The coupling coefficient is obtained by using the following relation [6]:

$$P_r = [(\beta - 1) / (\beta + 1)]^2 * P_f$$

Where P_r and P_f stands for the reflection and feeding rf-power, respectively; and β is the corresponding coupling strength. Calibration of the rf-power readings on the reflection and transmission signals is required for accurate estimation of the coupling.

SUMMARY

A single-cell, rf-gun cavity has been design, fabricated, and brazed in-house for thermionic rf-gun development at NSRRC. The results indicate that the cavity is well characterized by rf measurement. The rf properties of the cavity are obtained by S-parameters measurement. The filling time and dissipation time are deduced from the rf-pulse measurement. Proper checkpoint for outsourcing components will be developed for future needs. Further tuning of the cavity coupling needs to be developed for beam loading study. The measurement results are:

Leak rate	<	$1*10^{-9}$ mbar.l/sec
Q	=	20000
β	=	1
Z	=	50 Ω
$\tau_{filling}$	=	1.2 µs
$\tau_{dissipation}$	=	400 ns

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