Cold Test of Rocketdyne RF Gun

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Abstract

The RF gun to be used in the Rocketdyne 1 kW FEL was cold tested at UCLA. This gun follows the two cavity BNL design[1]. Data was taken, using a HP8510B network analyzer, on frequency tuning with a rotating paddle in the first (half) cavity and on frequency shift due to axial movement of the LaB_6 photocathode. Results and analysis will be presented.

[1]"Design of the Laser-Driven RF Electron Gun for the BNL Accelerator Test Facility", K. T. MCDONALD, IEEE TRANS. ELECT. DEV., VOL. 35, NO. 11, NOV 1988

I. INTRODUCTION

Rocketdyne has been developing components for a kW class FEL [1], [2]. The recent delivery of the radio-frequency power assembly (RFA), which consists primarily of a SLAC 5045 klystron and a command charge, feed forward modulator [3] allows testing of the RF gun at high power. Preliminary to this the gun was checked out at the UCLA High Frequency Laboratory to verify its operating characteristics. This paper will present the data obtained and analyses which verifies that nominal operating specifications had been met and calibration data for diagnostics.

II. THE GUN

The RF gun consists of two resonant cavities, highly coupled both through side slots which allow RF power input from the RFA and an axial hole through which the accelerated electron beam also passes.

The electron beam is generated in a quarter wavelength cavity, off of a 3 mm dia. LaB_6 cathode. The cathode is mounted on a linear feedthrough so that its position can be changed axially to allow fine tuning of electron beam parameters. To compensate for the frequency shifts cathode motion induces the cavity is also equipped with a small tuning paddle on the side wall which tunes the cavity inductively.

The gun is coupled to the RFA by a waveguide which ends with a half wavelength stub past the coupling slots to set boundary conditions correctly for the cavities. The stub also has a pumpout port in it to allow approximately 100 l/s conductance from the cavities.

Finally both cavities have RF pickup loop diagnostics.

III. THE MEASUREMENTS

A Hewlett Packard model 8510B Network Analyzer was used for the measurements. The maximum power output of +20 dBm allowed pickup of the signals through the high attenuation RF pickup loops installed into the two cavities of the gun. The RF probe was inserted into the waveguide through the pumpout port, so that coupling into the cavities would be the same as high power operation, while minimizing the path the low signal RF had to travel.

All measurements were performed at atmospheric pressure and

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approximately 75° F.

The measurements were made with the Network Analyzer were: Frequency as a function of axial cathode placement for both 0-mode and π-mode (tuning paddle fixed); frequency as a function of tuning paddle position (cathode position fixed); VSWR with the cathode in position and removed; and pickup loop attenuation.

VSWR measurements were 2.16 with the cathode removed and the tuning paddle at 172°, and 1.93 with the cathode in place and the tuning paddle at 208°, a position for which the π-mode and 0-mode are degenerate.

Table I gives data for frequency vs. cathode position.

TABLE I

Dial(in)	π-mode(GHz)	0-mode(GHz)
.223	2.8551875	2.8525750
.222	2.8551875	2.8525750
.220	2.8551875	2.8525750
.215	2.8552125	2.8527375
.210	2.8552250	2.8528250
.205	2.8552500	2.8529250
.200	2.8552625	2.8529875
.199	2.8552625	2.8529875

with the tuning paddle position 172°

Cathode position as measured on indicator from linear feedthrough, with .205" corresponding to the cathode flush with the wall of the cavity, so that travel corresponds to .018" into the cavity to .006" recessed back into the wall.

Table II gives data for frequency vs. tuning paddle position.

TABLE II.

Paddle Pos.(°)	π-mode(GHz)
75	2.8565000
170	2.8552000
208(degen)	2.8557250
245	2.8565525
245(1 rot.)	2.8564875
248	2.8565000
250	2.8565125
252	2.8565125
252(1 rot.)	2.8565125
258	2.8565125
340	2.8551875
348	2.8551875

with the cathode fixed at .200" (slightly retracted)

These data show the doubly periodic frequency tune shift of the paddle with respect to rotation, with the nominal midpoint (where the paddle has no net effect on cavity frequency) near 208°±an odd multiple of 90°.

IV. DATA ANALYSIS

The RF gun was specified to operate at 2.8560 GHz ± 100 kHz at 35° C in vacuum. In order to compare the raw data presented it is necessary to correct for differences in temperature and pressure. The dielectric effect of dry air in changing the frequency is about 800 kHz, and the gun was originally tuned at the manufacturer (Schonberg Radiation Corp.) for a central frequency of 2.8552 GHz. This was done at the nominal operating temperature of 35° C. From the formula:

$$f = 2.405/(n*R)$$

with f=freq., n=index of refraction, and R=radius of cavity. The change in frequency w.r.t. temp, T, is:

$$\delta f/\delta T = -(f/R)*dR/dT$$

With R*dR/dT = 5*E-6 cm/°C for Copper and taking f=2.856 GHz then the calculated change of frequency with temperature is:

$$\delta f/\delta T = 14.3 \text{ kHz/°C}$$

This leads to a downshift of 0.514 MHz in going from 24°C (75°F) to 35°C (95°F.) The central frequency, corrected for temperature is then:

2.85534 GHz

The manufacturer's measured central frequency is:

2.85520 GHz

The difference of 0.14 MHz is within

tolerances for agreement.

V. CONCLUSION

The Rocketdyne RF gun was measured first at the manufacturer's and then at the High Frequency Lab. at UCLA with good agreement after appropriate corrections. Additional information needed for calibration of rf pickups and the tuning loop were also performed. This work has prepared the rf gun for installation onto the power distribution system from the radio frequency power assembly, RFA, allowing the Rocketdyne FEL program to proceed to high power test and evaluation of the RF gun.

VI. REFERENCES

[1] R.A. Cover, G.T. Bennett, R.J. Burke, M.S. Curtin, M.C. Lampel, G. Rakowsky,"Simulations of the Rocketdyne free-electron laser with a 4 m wiggler," Nuc. Inst.&Meth. in Phys. Res. A318 (1992) 623-627.

[2] R.A. Cover, G.T. Bennett, R.J. Burke, M.S. Curtin, M.C. Lampel, G. Rakowsky, J.P. Stone,"Rocketdyne FEL For Power Beaming Using a Regenerative Amplifier," OE LASE '93 SPIE Proceedings Vol.1868, Jan. 18, 1993.

[3] M.C. Curtin, these proceedings