BEAM LOADING AND TEMPERATURE DETUNING OF 10 MEV RF LINAC AND THE REVISED COUPLER GEOMETRY FOR OPTIMAL PERFORMANCE

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Abstract

A 10 MeV, 10 kW on-axis coupled cavity RF electron linac is installed and commissioned at Electron Beam Centre (EBC), Kharghar, Navi Mumbai. In this contribution the experimental results of beam loading and temperature detuning effects on the linac performance will be presented. The waveguide to cavity RF input coupler was designed at β = 2.3 to match the beam current of 250 mA. The experimental results of beam loading shows an effective coupling β = 1.3. To understand the coupling issue the present RF structure with the coupler geometry is simulated with the CST-MWS. A revised coupling aperture taking into account the real aperture depth has been designed to get the efficient beam propagation at 250 mA.

INTRODUCTION

The use of standing-wave accelerators in industrial and medical applications are well established and documented [1,2]. The Accelerator and Pulse Power Division of BARC pioneered the design of bi-periodic on-axis coupled cavity standing wave linac in the range of 3-10 MeV. A 10 MeV, 10 kW on-axis coupled cavity RF electron linac is installed and commissioned at Electron Beam Centre (EBC), Kharghar, Navi Mumbai [3]. The linac is intended to be operated at 10 kW. Presently the linac is being operted at 4.5 kW. To achieve the design goal the experiments are carried out to understand the behavior of the linac from point of view of beam loading, temperature detuning effect on the performance of the linac. This article presents the experimental results of beam loading and coupling aperture effect on the coupling coefficient β. The final section of the paper shows the effect of pulse repetition (PRF) frequency on the waveguide-cavity coupling coefficient β for a fixed beam current.

THEORETICAL ASPECTS OF BEAM LOADING

In the equivalent circuit representation of Figure 1, the generator power is transmitted to the RF cavity using the transmission line coupled to the cavity side by a transformer. The generator is tuned to the cavity resonance. The beam current and the generator voltage are 180^0 out of phase for the maximum acceleration.

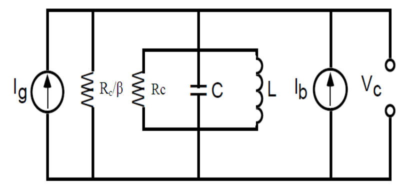

Figure 1: Equivalent circuit of beam loaded cavity when transformed into the resonator side.

The variation of P_r/P_g with the cavity coupling coefficient β for different beam loading is shown in Figure 2.

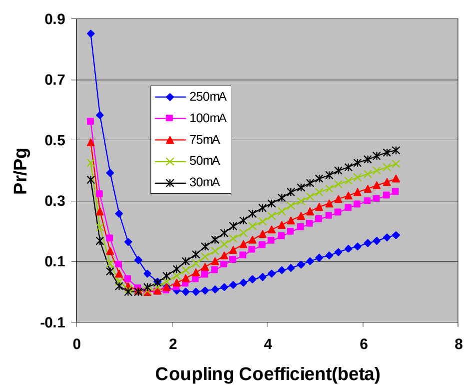

Figure 2: Variation of Pr/Pg with the cavity coupling coefficient.

From this plot it is seen that for a fixed beam current the unloaded cavity coupling coefficient β can be evaluated for designing the coupling aperture of the input coupler. In order to achieve the design goal of 10 MeV, 10 kW, 250 mA, 400 PRF, the unloaded cavity coupling coefficient should be 2.3.

MEASUREMENT OF GENERATOR POWER WITH BEAM CURRENT

The unloaded power requirement for the 10MeV acceleration is 2.38MW. With the increase of beam current we have to accordingly increase the input power to keep the final energy gain same. Figure 3 shows the theoretical curve and the experimental data points for the input power requirement with the increasing beam current. The measurement is in well agreement of the theoretical curve. Figure 4 shows the measurement of Pr/Pg with the change in beam current for a fixed PRF of 300 Hz and final energy gain of 10 MeV.

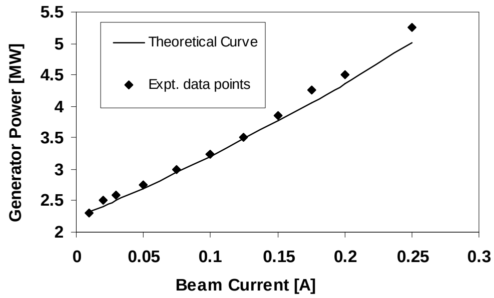

Figure 3: Generator power requirement with the increasing beam current.

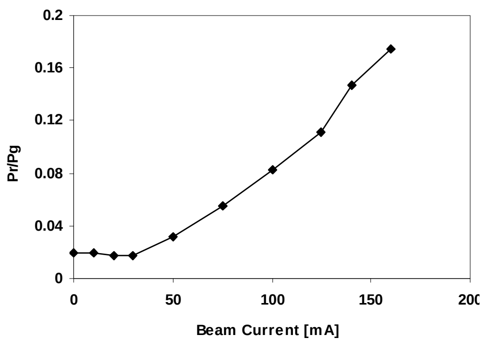

Figure 4: Variation of the Pr/Pg with I_b.

REVISED COUPLING APERTURE β = 2.3

When Figure 4 is compared with the Figure 3 it shows that the unloaded cavity coupling coefficient is between 1.3 and 1.4. In the next step the coupler cavity is being simulated by CST-MWS [4] in the existing structure with the dimensions of the coupling aperture 33mm x 20mm with a depth of 5.15. The simulation shows a cavity coupling factor $\beta = 1.4$. To get a coupling of 2.3 the aperture size is changed to 35.6 mm x 20 mm with a depth of 5.15mm. The cavity model for 2856 MHz and coupling aperture details are shown in Figure 5a and 5b. The dependence of the field energy on time is more convenient for calculating the cavity external quality factor Q_e, as illustrated in Figure 6 for the revised coupling aperture. For the particular case shown in Figure 6, the external quality factor $Q_e = 4972$. Therefore, the coupling is 2.3.

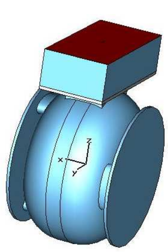

Figure 5a: Model Cavity

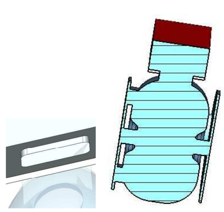

Figure 5b: Cut-View of the Model Cavity

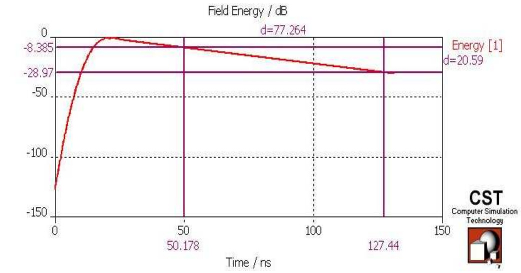

Figure 6: Field energy decay (red) from time-domain calculations and plot measure lines (magenta).

EFFECT OF PRF ON VSWR (COUPLING COEFFICIENT β)

An experiment was carried out to find the dependence of PRF on the voltage standing wave ratio (VSWR). In this experiment the beam current was fixed to 100 mA, the final beam energy was 10 MeV for an input power of 3.25 MW. Figure 10 shows the experimental data and theoretically calculated points.

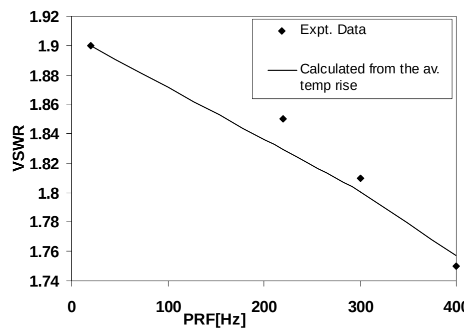

Figure 7: Effect of PRF on the VSWR

The theoretical points are calculated taking a shift in frequency of 50 kHz/^{0}C and the temperature coefficient of the resistivity of copper 0.004/^{0}C.

CONCLUSION

The experimental studies show that the cavity coupling coefficient $\beta = 1.3$ and is matched for 50 mA beam and it shows a minimum reflection. To match the 250 mA beam under the beam loading the coupling coefficient is 2.3 and the new aperture size is 35.6mm x 20mm. The frequency detuning with the temperature rise due the increase in PRF leads to a decrease in unloaded Q_0. Further experimental results will be reported later.

REFERENCES

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