VARIABLE INPUT TRANSFORMER FOR HERA SUPERCONDUCTING CAVITIES

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Abstract Superconducting cavities in HERA will have to cover a wide range of beamloading. Fixed coupling of the main coupler allows matched operation only for one value of the beam current. Variation of the beam current as typical for storage ring conditions results in severe mismatch. Consequently there is an urgent need for variable coupling in order to transfer as much transmitter power as possible to the beam. This can be realized by mechanical adjustment of the coupler antenna. Another type of match variation is shown in this report. HERA superconducting cavities will be matched by variable waveguide transformers within transformation ratios of 0.2 to 5.0. Transformer design philosophy, realization, high power test and operation conditions of transformer and cavity will be treated.

INTRODUCTION

Superconducting cavities are under use or will be used for an increasing number of accelerator projects [1]. The superconducting surface resistance has a nonvanishing value but the resulting power loss is small as compared to the extracted beam power. Thus a varying beam current results in a strong change of the coupling conditions between generator and cavity. The generator power can only be transferred effectively to the beam for a small range of beam current values where a matched condition is established. At twice the value of the matched beam current the accelerating voltage even goes to zero if the coupling remains fixed [2]. This is quite a different situation as compared to normalconducting cavities where the surface

losses are equal or even larger than the beam extracted power.
The coupling from generator to cavity can be changed by several means. For example the depth of an electric antenna or the orientation of a magnetic antenna changes the coupling conditions. It is difficult, however, to construct a variable mechanism which is high power capable. Another means is to produce discontinuities in the feed-waveguide. If they are properly designed they act as a transformer between generator and cavity. These discontinuities are physically seperated from the coupler itself and can be made tuneable. In this paper we describe the transformer which has been developed to supply the HERA superconducting cavities at power levels of up to 100 KW.

BASIC CONSIDERATIONS

A basic conception of a transformer is readily derived from the known techniques of a capacitive screw tuner. This kind of tuner normally is used for low power matching in coaxial lines or in TE waveguides [3]. At DESY this principle is in use since a lot of years for electrical length tuning purposes of the waveguide system. The screws were changed to plungers of special top shape in order to meet high power requirements. Pairs of equal plungers were fastened inside the waveguide by screws. The distance of a quarter wavelength should compensate their VSWR.
Hence it suggested itself to use this cylindrical plunger shape for a special high power cavity impedance matching device. The procedure of developing a transformer was first to measure the plunger behaviour dependent on its height, then to develop some theory of transformation with it and afterwards to confirm predictions of multiplunger transformation behaviour by measurement. Finally high power tests were to be performed.

ONE PLUNGER MEASUREMENTS

The plunger is positionned in the middle of WR1800 waveguide which is operated in TE 10 mode. All measurements are performed at a frequency of 500 MHz which is the operating frequency of the superconducting cavities at DESY.

We used a plunger of 100 mm diameter and variable height. It behaves electrically like a capacitor and an inductor in series. But because of the high diameter to height ratio their behaviour proved to be mainly capacitive. A series resonance would occur if the capacitive gap between plunger top and opposite waveguide wall is getting very small. But this case is not reasonable for practical applications because at high RF power the small distance would lead to sparking.

The plunger transforms a piece of waveguide into a capacitor. Hence the plunger is characterized by its admittance and the related reduction of waveguide length. Both informations are used to calculate a multiple plunger device. Fig. 1 shows the single plunger characteristics.

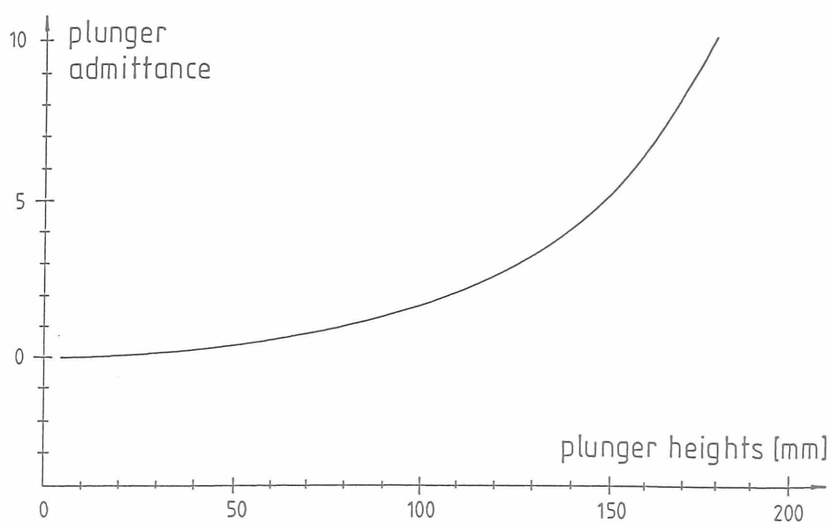

FIGURE 1 Normalized plunger admittance of a 100 mm diameter plunger in WR 1800 waveguide

THE MULTIPLE PLUNGER DEVICE

We proved experimentally that for a plunger distance of larger than 15 cm the plunger interaction can be neglected. Under this condition we calculated the multiple plunger behaviour. A multiple plunger device generally will transfer the load resistance into a complex impedance as well as shift the phase between generator and load. From our calculations and measurements [4] we concluded that at least a three plunger device is needed to realize sufficient transformation ratios for matching different cavity impedances and in addition independently to yield sufficient phase control. Fig. 2 shows the three plunger transformer. With the given single plunger admittance characteristics of Fig. 1 the three free electrical length parameters are choosen to be: $\Phi = 22^0$ (distance to load), $\Phi_1 = \Phi_2 = 90^0$ (distances between plungers). The resultant operating area of real transformation ratio and phase variability is illustrated in Fig. 3.

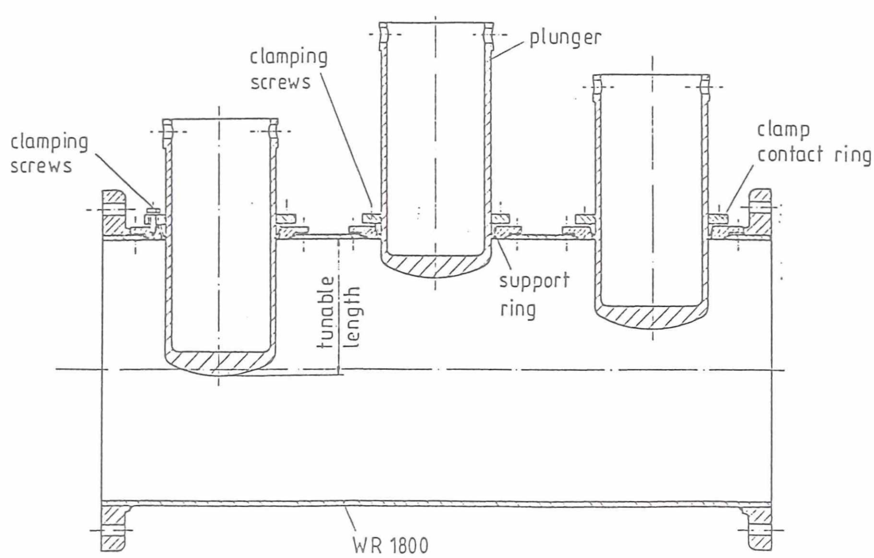

FIGURE 2 Cross section of the three plunger transformer

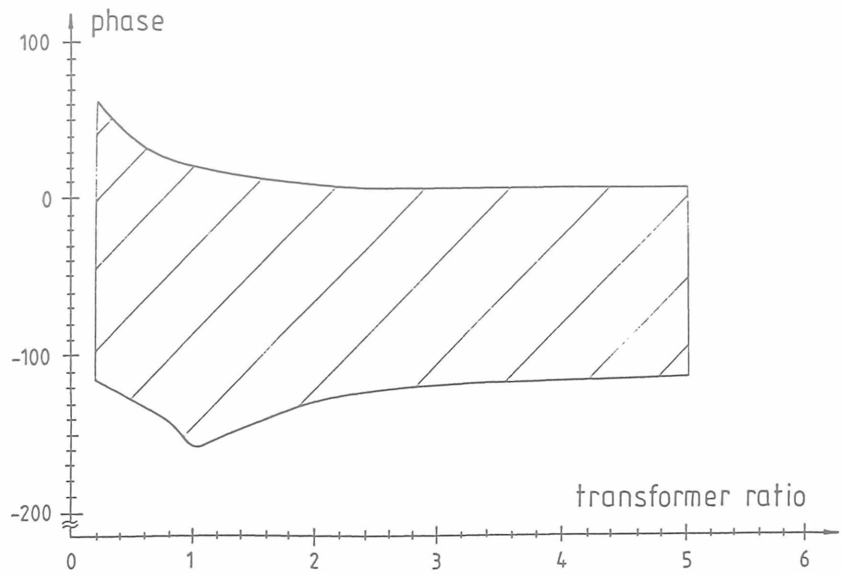

FIGURE 3 Operation area of phase and transformation ratio of the three plunger transformer

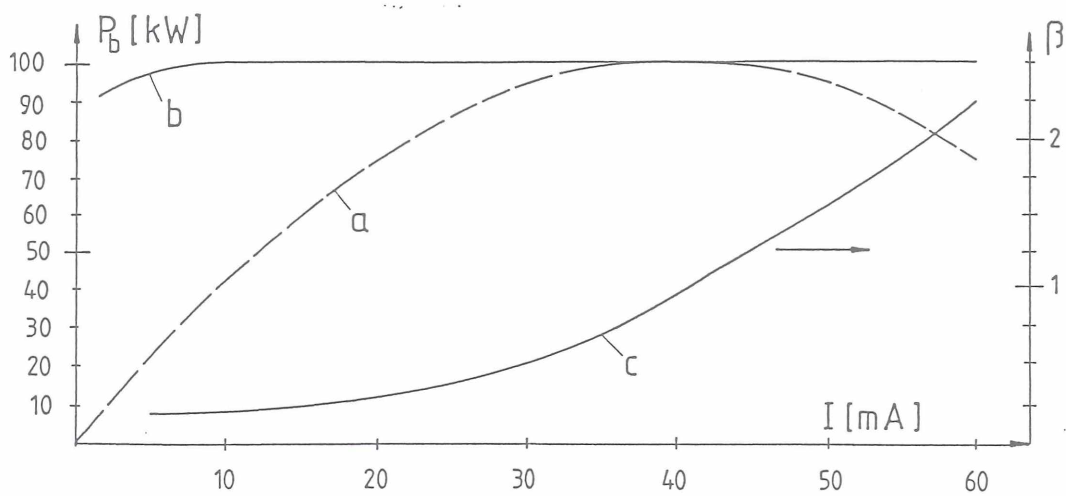

FIGURE 4 Transferred beam power P_b per cavity with 100 kW fixed generator power. The cavity coupler is matched at 40 mA beam current: a, without and b, with transformer; c, related transformation ratio ß

PRACTICAL APPLICATION

An early model of a two plunger tuner has been used before and during the PETRA beam test of the superconducting prototype cavity [5]. At that time a set of fixed plungers were fixed with screws inside the WR 1800 waveguide. Transformer ratios of 3 and 6 were adjusted and operated up to 30 kW generator power.

For the HERA superconducting cavities the three plunger transformer of Fig. 2 will be used. The input coupler will be matched to a beam current of 40 mA. Fig. 4 and Fig. 5 compare the operating conditions with and without using the variable input transformer. The beam power and the accelerating field are calculated for constant generator power of 100 kW.

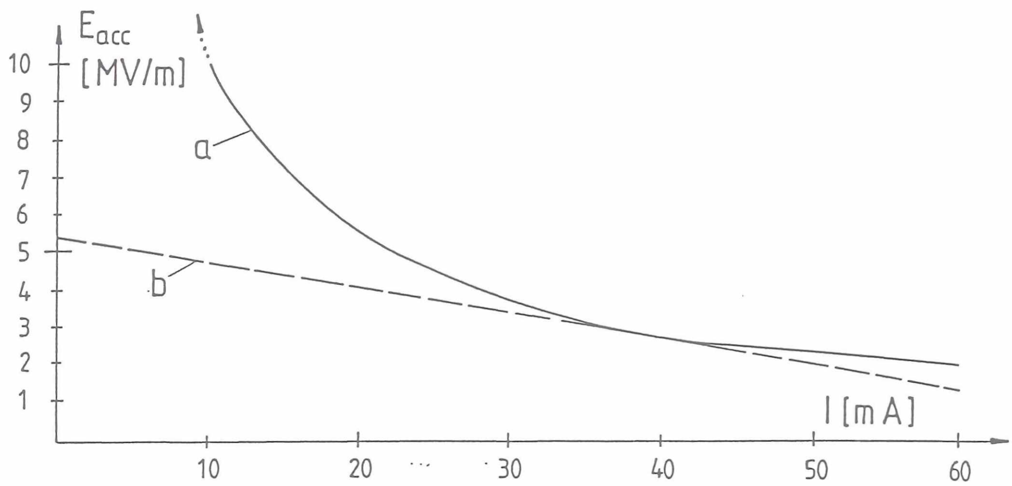

FIGURE 5 Accelerating gradient per cavity with 100 kW fixed generator power without (b) and with (a) variable input transformer

REFERENCES

1. P. Kneisel, Proceedings of XIV International Conference on High Energy Accelerators, (1989)
2. D. Proch, Proceedings of the European Particle Accelerator Conference, (1988), p. 29
3. R.E. Collin, Foundation for microwave engineering, (MC. Graw Hill, 1966), p. 220
4. B. Dwersteg, DESY, M-89-08, (1989)
5. B. Dwersteg et al., Proceedings of the European Particle Accelerator Conference, (1988), p. 1430