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THE 50KW-TRANSMITTER FOR THE MUNICH HEAVY ION POSTACCELERATOR

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Summary

The layout of the radio frequency system for a heavy ion linear accelerator with variable drift tube structure will be described. The electrical and mechanical design of the power stage is shown in detail.

Introduction

To raise the energy of the heavy ions passed through our MP-Tandem, they are postaccelerated by a RF-LINAC /1/. Its drift tube structure can be adapted to the velocity profile of different kinds of particles by changing the drift tube positions. Because of the resulting enormous resonance frequency shift of the accelerator cavity it had been necessary to develop a 50kW-transmitter tunable within the range from 60 to 90 MHz /2/. The aim in the beginning had been to produce a total acceleration voltage of 5 MV in the cavity. With the total shuntimpedance of about 500 MΩ this requires a rf-power of 50 kW /3/. With respect to future improvements it was desired to have a margin in power and frequency range. The layout of the rf-transmitter is done for the following specifications:

output power:	100 kW
rel.power stability:	10^{-2}
tunable frequency range:	50-100 MHz
rel.frequency stability:	10^{-5}
bandwidth:	500 kHz
interference radiation in 10 m distance:	300 μV/m
remote control and monitoring.	

System Considerations

The transmitter amplifier chain is shown in Fig. 1. The oscillator is a crystal controlled frequency synthesizer. Its output signal (20 mW) is splitted by a 3dB-coupler for an independent buncher supply.

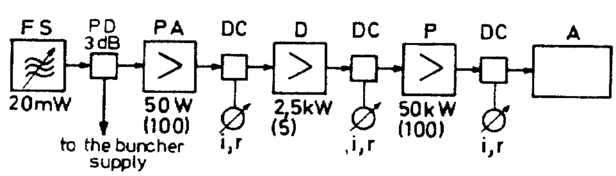


Fig. 1: block-diagram of the amplifier chain.

FS = frequency synthesizer
PD = power divider
PA = preamplifier
DC = directional coupler
D = driver stage
P = power stage
A = accelerator
i,r = signal of incident and reflected wave

The first stage is a broadband amplifier with 100 W maximum output power. It is followed by the 2.5 kW (5 kW) driver stage and the 50 kW (100 kW) power stage (numbers in brackets are for future operation). These both are grounded grid amplifiers with the tetrodes RCA 8793 and Siemens RS 2052 J. Their circuits are all realized as coaxial-line resonators with variable geometry for tuning. All inputs and outputs are matchable to 50 Ω to combine them by 50 Ω -cables. Between the separate stages there are directional couplers for monitoring the incident and reflected wave.

Design of the Power Stage

As shown in the equivalent circuit diagram of Fig. 2 the power stage is a grounded grid amplifier with directly grounded screen grid G2. The capacitors C_K, C_G and C_A

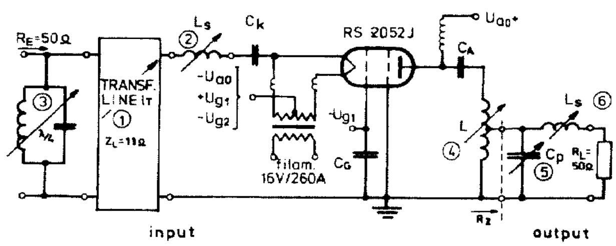
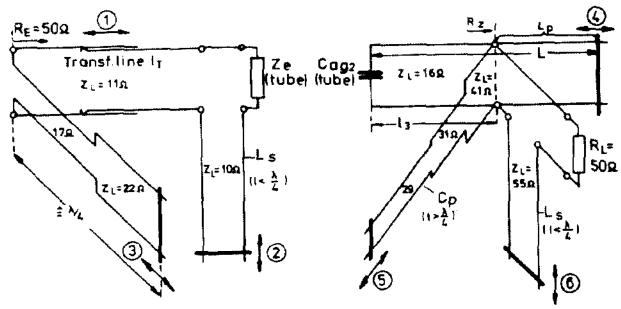


Fig. 2: equivalent circuit diagram of the power stage.
(1) = transformation line
(2) = series-connected inductance
(3) = quarter-wave section
(4) = output circuit inductance with tap
(5) = matching stub (parallel connected capacity)
(6) = matching stub (series connected inductance)

work as rf short circuits. The matching of the input impedance R_E=50 Ω to the input impedance of Ze of the tube is done by the variable transformation line l_T (1) and by a series-connected adjustable short L_S (2) (Fig. 3a). With these two parameters matching within the desired frequency-power range is possible. The resonant circuit at the input is realized by an adjustable quarter-wave section(3). It closes the open end of the transformation line without loading the input. The different characteristic impedances are caused by the mechanical design of the coaxial line, which is folded to be adjustable from the bottom.



a) input b) output

Fig. 3: equivalent diagram of the line circuitry.

Z_L = characteristic impedance
Z_e = input impedance of the tube
C_{ag2} = tube capacitance:plate - screen grid

The characteristic of the input transformation is shown in Fig. 4.

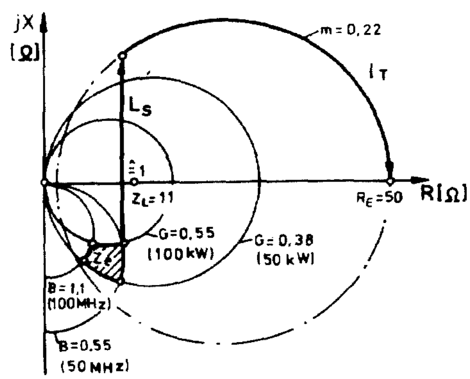


Fig. 4: input transformation in the impedance plane.

G = constant conductance
B = constant suszeptance
m = reziprok constant VSWR

At the output side (Fig. 3b) the tube capacitance between screen grid and plate is completed to a resonant circuit by the variable inductance L (4). A fixed directly coupled tap serves as power output. Within the desired operating range (50-100 MHz, 50-100 kW) a resistance R_Z=150-650 Ω has to be offered at this coupling point which is about 20 cm away from the tube output contacts. The matching of the load R_L=50 Ω to the variable R_Z is done by the two additional matching stubs C_P (5) and L_S (6) which both are adjustable coaxial lines. The transformation of R_L via R_Z into Z_a (tube load) is given in the diagram of Fig. 5.

It is considered that the part of the inductance L between the short plane and the fixed tap effects as an parallel-connected inductance L_P. The other part forms a transformation line of the length l_3.

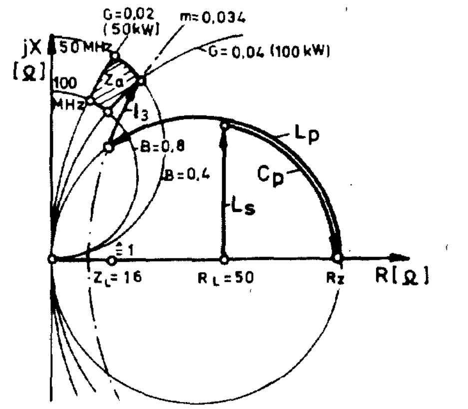


Fig. 5: Output transformation in the impedance plane.

The mechanical design of the power stage is shown in Fig. 6. The tube is mounted on the top and all coaxial line resonators go downward.

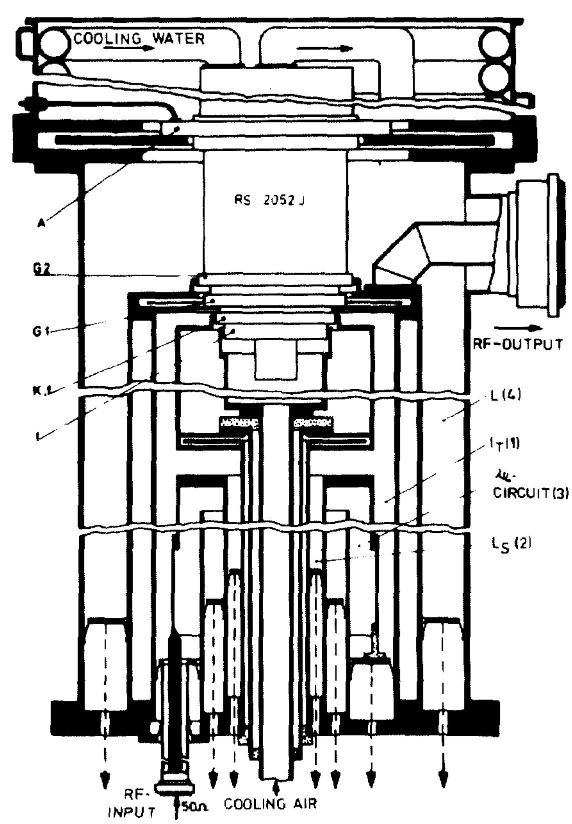


Fig. 6: mechanical design of the power stage

A = plate
G_2 = screen grid
G_1 = control grid
K = cathode
f = filament

The advantages of this arrangement are:
- easy change of the tube,
- complete rf-screening,
- mechanical holes just at the bottom which looks into a screened housing,
- all threaded control shafts for moving the short planes are directed downward,
- favourable thermic behaviour because the main heat sources are on top.

The mechanical design of the separate matching stubs is given in fig. 7. The parallel-connected capacitance is produced by a folded line of the length $l > \lambda/4$. The series-connected inductance is formed by a line $l < \lambda/4$ which is effective by a gap in the outer conductor of the 50 Ω-line

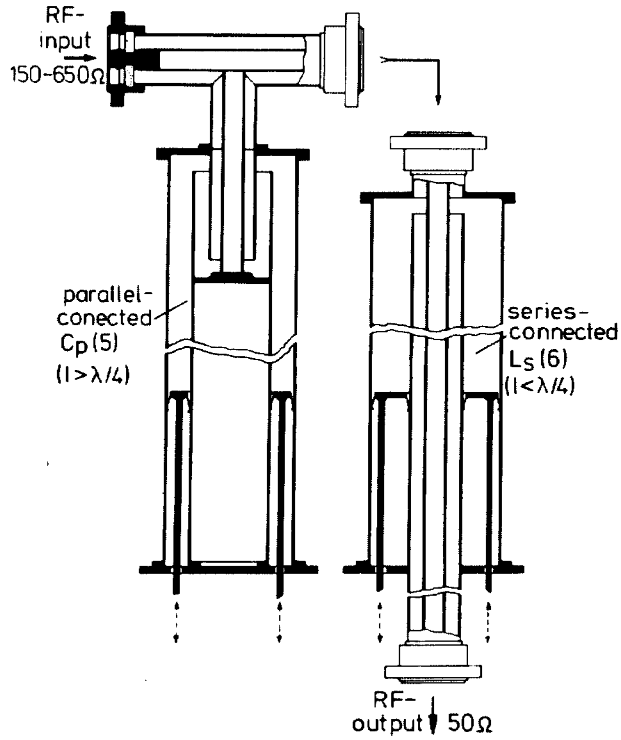


Fig. 7: mechanical design of the matching stubs.

The output power goes through a 3 m long 50Ω-cable (Flexwell HF 4 1/8" Cu 2Y) to the accelerator. There the coupling is done by a capacitive compensated magnetic loop through a ceramic vase. For the input impedance matching the loop can be turned without disturbing the vacuum of the cavity. The compensation of the loop-inductance is provided by a variable vacuum capacitor (10-75 pF) which is integrated series-connected at the centre conductor of a coaxial 50Ω-line. The capacitance variation for matching is done by a motor driven PTFE-axle leading from outside to the capacitor. (Fig. 8).

All variable parameters are steered by stepper motors. The step numbers are counted, stored and displayed as an information for the positions of the sliding short contacts. Therefore, for an operator it is easy to adjust the system with given numbers out of a table, where the different operating modes are collected.

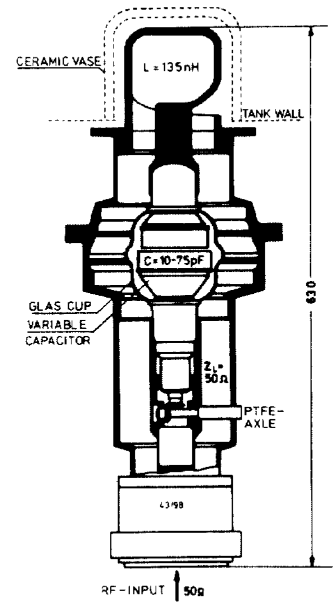


Fig. 8: capacitive compensated coupling loop.

The complete system is protected by an interlock for the various power supplies. The power tube is protected against stochastic disruptive discharges by an active sparking gap.

The generous layout of the system is important for starting the accelerator cavity when it had been opened for a longer time. Otherwise it would be difficult to overcome its gas discharges which result in rf-mismatching.

Acknowledgement

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