Analysis and Optimisation of RF Power-Klystrons by FCI-Code

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Abstract

FCI-Field Charge Interaction code is a 2 1/2 dimensional particle-in-cell simulation program dedicated to analyse and design high power klystron amplifiers. The code simulates the electron beam motion with cylindrical symmetry, by taking into account the space-charge fields, RF-cavity and external focusing magnetic fields. The cavity voltages and the output power are determined by solving the circuit equations selfconsistently. Simulations of real tubes give better understanding in beam dynamics and lead to improvements in stability and efficiency. Examples of simulations compared with measured data of high power klystrons are presented.

I. Introduction

Since the entrance of digital computers in the 60'th a lot of computer codes for simulation of particle movements forced by static electric and magnetic fields have been developed and presented (SLACTRAY/EGUN, EBQ, INP, DEMEOS, TRACE, etc.). Later on computer codes using disc models have been introduced to calculate the interaction behavior of linear beam tubes (DISK, LPDISK, etc.). But these codes were restricted to small signal simulation, because they did not take into account radial forces of space charge due to bunching effects. The latest developments in computer simulation for particle accelerators lead to particle-in-cell codes where the forces and movement of so called "superparticles" are calculated. With these codes a large signal simulation of high power klystrons is possible today.

II. Calculation

Taking the 6 cavity, 1.1 MW PHILIPS YK1303 klystron as an example the power of the particle-in-cell code FCI developed by T. Shintake at KEK [1] will be demonstrated.

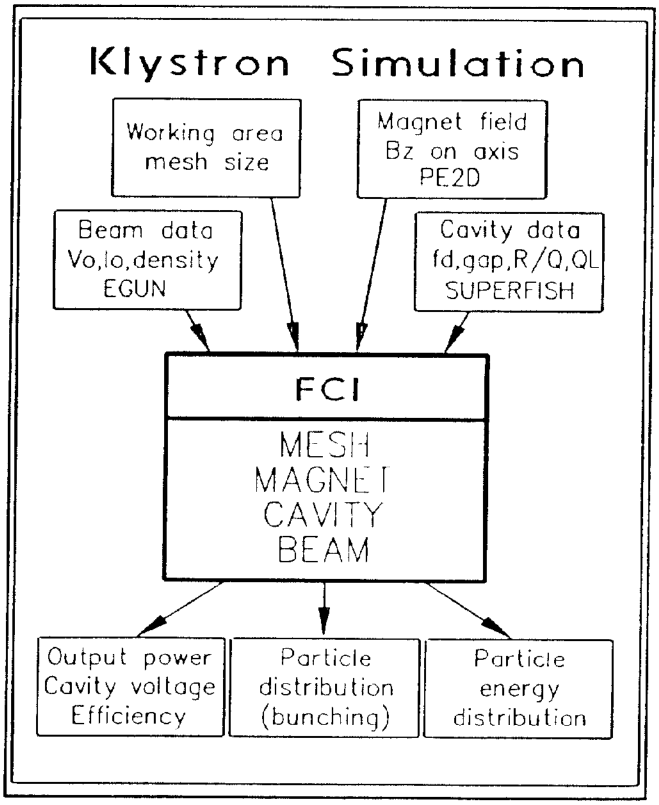

Figure 1. FCI-CODE Input and Output

The code's working area is restricted to the RF-section of a klystron. This area and the mesh size is definД by **MESH** routine. The **MAGNET** routine calculates the two-dimensional focusing field from on-axis mea-

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sured or calculated (Poisson, PE2D) data. The cavity fields inside the drift-tube regions are determined by **CAVITY** routine from data as f_{drive}, gap position and size, and harmonic number.

From beam voltage and current, beam radius and slope (calculated by EGUN), drive frequency and power, and cavity parameters R/Q, Q_L and f_0 (calculated by Superfish) **BEAM** routine **MODE-1** determine the beam admittances Y_b seen by the cavities. See Fig. 1.

With these Y_b as input parameters **BEAM MODE-2** finally simulates the particle trajectories and calculates all cavity voltages and output power.

III. Results

Fig. 2 shows 4 "snap shots" of beam profile for the YK1303 at P_d = 70W and output power P_0 = 1 MW. Time separation is one-quarter RF-cycles. In this presentation the bunching effect can be studied.

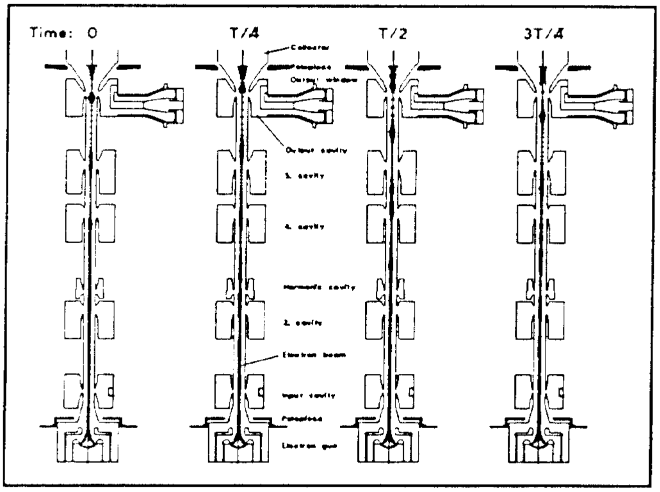

Figure 2. Beam Profile YK1303

Fig. 3 is a result of 7 calculations at varying input power. The gap voltages of 4th and 5th cavity show good linearity, while output power is saturated at a drive power of 70W. The measured data of P_o show good agreement with the simulation.

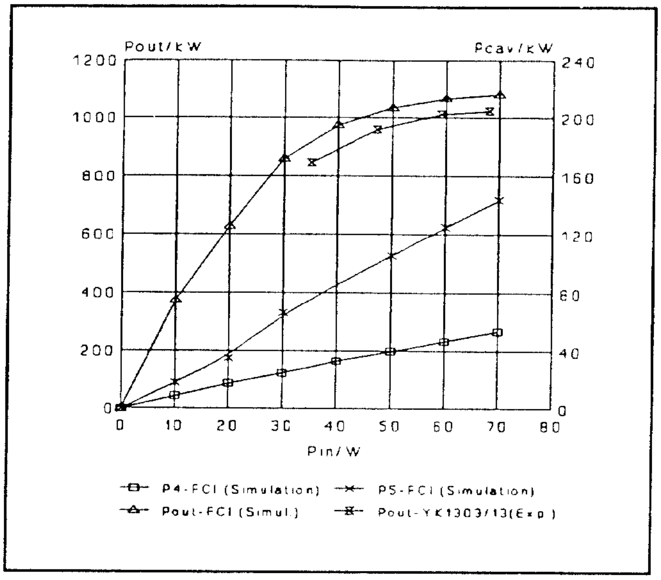

Figure 3. Power Simulation YK1303

The influence of harmonic cavity tuning on output power is shown in Fig. 4. Also in this case the simulated data show good agreement with measured data.

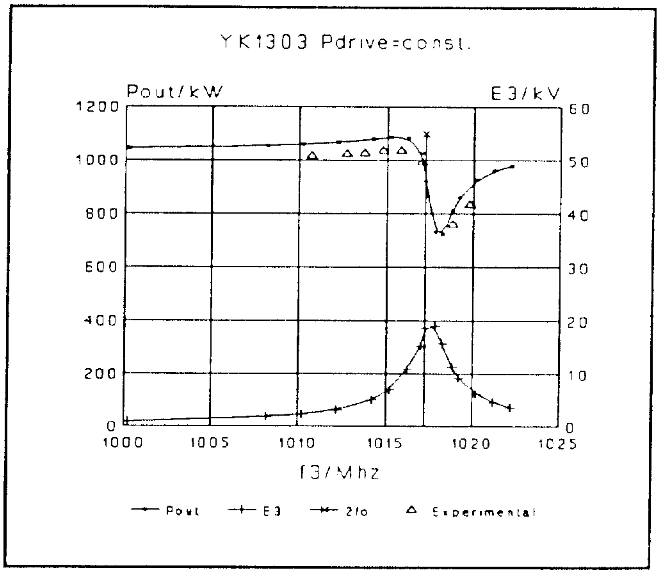

Figure 4. Detuning harmonic cavity

CPU-time for executing CAVITY and BEAM MODE-2 routines takes about 2h on APOLLO 4500 work station.

IV. References

[1] T. Shintake, "High-Power Klystron Simulations using FCI - Field Charge Interaction Code", KEK Report 90-3 May 1990 A/D.