Tentative Design of a W-Band Hollow-Beam Klystron for Frequency Tripling

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Abstract

The main purpose of the w-band klystron is power amplification and signal tripling. A hollow beam is modulated by a rotating TM_{110} mode at 30 GHz in the input, idler and penultimate cavities. In the drift space the beam develops a cork-screw like shape. In order to triple the frequency the output section is designed for the TM_{310} at 90 GHz, Fig. 1. A power gain of 22 dB is achieved and output power is 1000 W with an extraction rate of 2 %. Beam parameters are 1 A and 50 kV yielding a relative velocity of 0.412. The cavities are 12-sided polygons to minimize the error caused by discrete meshes in the simulation.

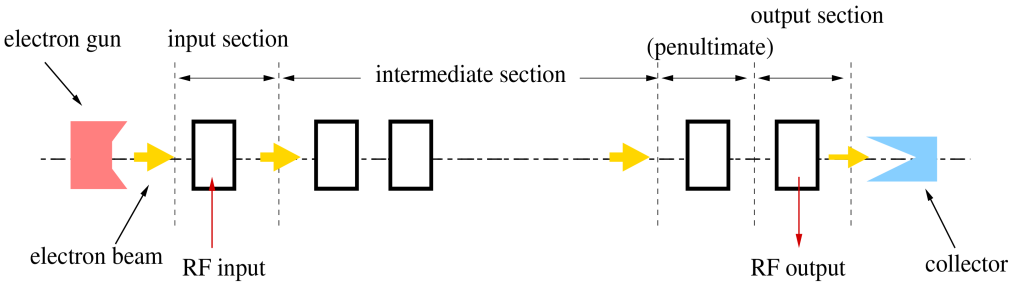

Figure 1. Arrangement of a w-band klystron

The investigation started with the output cavity. Since it works with a different frequency than the other sections, the beam pipe opening is determined with respect to the these sections. The number of output gaps is increased step by step to achieve maximum extraction efficiency. With six gaps the output power is 2% of the electron beam power, while the same amount of power is lost in the cavity wall. The coupling between the gaps is via the beam pipe. A „penultimate“ cavity is ahead of the output cavity to improve the beam quality. It has a phase shift near 90° while the phase shift of the idler cavities is smaller, around 80°. Three types of idler structures are compared: Single cell, coupled cell pair, clustered but isolated cells. It turned out that a clustered isolated pair gives the best results, since they correspond to two single cells. The input section is fed through four wave guides.

The drift length of the modulated beam was found by simulation. A modulation of 1% , 2.5 % and 4 % was assumed before entering the idler section. The expected drift length, one quarter of the plasma wavelength, is 42 mm. But with increased power level, i.e. with increased modulation depth, the drift length is somewhat shorter, „ballistic“ bunching takes over. For 4 % modulation depth it is only 12 mm, whereas for 1 % it is more than 100 mm.

The final klystron reached a power gain of 22 dB with 6 W input power and three clustered isolated pairs of idler cavities. The linearity is good and the w-band klystron has the capability as a RF signal amplifier.