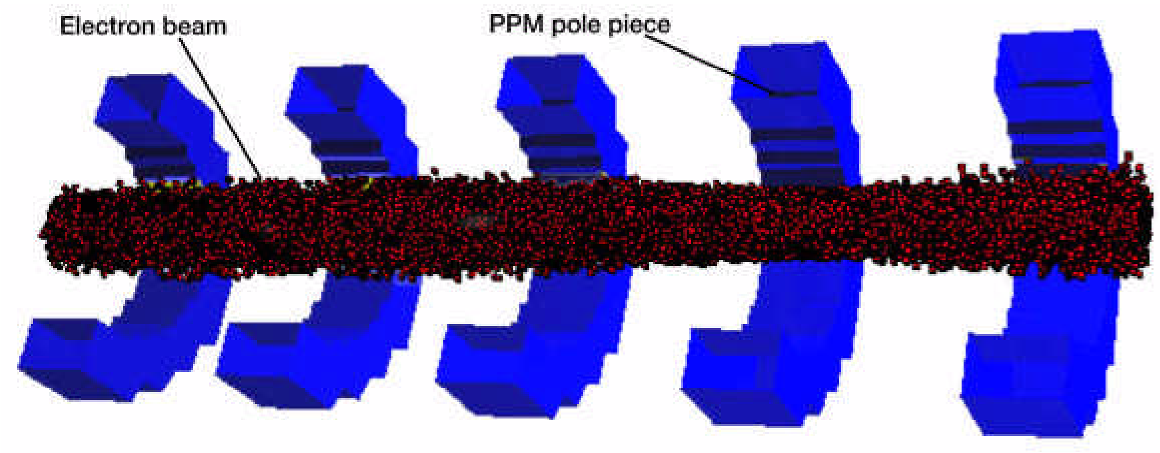
Three-Dimensional Electron Optics Model Developed for Traveling-Wave Tubes

A three-dimensional traveling-wave tube (TWT) electron beam optics model including periodic permanent magnet (PPM) focusing has been developed at the NASA Glenn Research Center at Lewis Field. This accurate model allows a TWT designer to develop a focusing structure while reducing the expensive and time-consuming task of building the TWT and hot-testing it (with the electron beam). In addition, the model allows, for the first time, an investigation of the effect on TWT operation of the important azimuthally asymmetric features of the focusing stack.

The TWT is a vacuum device that amplifies signals by transferring energy from an electron beam to a radiofrequency (RF) signal. A critically important component is the focusing structure, which keeps the electron beam from diverging and intercepting the RF slow-wave circuit. Such an interception can result in excessive circuit heating and decreased efficiency, whereas excessive growth in the beam diameter can lead to backward wave oscillations and premature saturation, indicating a serious reduction in tube performance. The most commonly used focusing structure is the PPM stack, which consists of a sequence of cylindrical iron pole pieces and opposite-polarity magnets.

Typically, two-dimensional electron optics codes are used in the design of magnetic focusing devices. In general, these codes track the beam from the gun downstream by solving equations of motion for the electron beam in static-electric and magnetic fields in an azimuthally symmetric structure. Because these two-dimensional codes cannot adequately simulate a number of important effects, the simulation code MAFIA (solution of Maxwell's equations by the Finite-Integration-Algorithm) was used at Glenn to develop a three-dimensional electron optics model (refs. 1 and 2). First, a PPM stack was modeled in three dimensions. Then, the fields obtained using the magnetostatic solver were loaded into a particle-in-cell solver where the fully three-dimensional behavior of the beam was simulated in the magnetic focusing field. For the first time, the effects of azimuthally asymmetric designs and critical azimuthally asymmetric characteristics of the focusing stack (such as shunts, C-magnets, or magnet misalignment) on electron beam behavior have been investigated. The illustration shows a cutaway portion of a simulated electron beam focused by a PPM stack.



Three-dimensional cutaway of electron beam focused by a PPM stack (magnets and beam tunnel not shown).

Although solid-state electronics have replaced vacuum devices in many areas, certain applications such as satellite communications and radar require frequencies and power in excess of what solid-state devices can provide. The phenomenal growth of satellite communications and planned NASA missions anticipating significantly higher data rates have created great demand for TWT amplifiers with greater efficiencies, frequencies, and power than existing designs. Accurate simulation tools such as the three-dimensional electron optics model are imperative if these demands are to be met with first-pass TWT designs satisfying system specifications.

Find out more about this research http://ctd.grc.nasa.gov/5620/5620.html.

References

1. Weiland, T.: On the Numerical Solution of Maxwell's Equations and Applications in the Field of Accelerator Physics. Part. Accel., vol. 15, 1984, pp. 245–292.

2. Weiland, T.: On the Unique Numerical Solution of Maxwellian Eigenvalue Problems in Three Dimensions. Part. Accel., vol. 17, 1985, pp. 227–242.

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