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The helical electron beam is controlled by a constant magnetic field $B_z = B_0$ and moves in a high-frequency field described by:

$$
\begin{align*}
E_z &= E_a e^{i(\omega t + z)} \\
H_z &= H_a e^{i(\omega t + z)}
\end{align*}
$$

The waves of the field propagate in a uniform cylindrical waveguide in the direction $z$. $\gamma$ is the "hot" propagation constant and $\gamma$ is a propagation constant in the absence of an electron beam. The axis of the helix $z$ is parallel to the axis of the waveguide.

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than the components $x_1$ and $y_1$; the latter can therefore be neglected. An equation for the starting current of the system is derived and it is shown that this is similar to the small signal scattering equation of a travelling-wave tube or a backward-wave tube. If the spread of the electron velocities $\Delta v_x = \phi$ is taken into account, the scattering equation becomes:

$$\left(x + ib\right)\left(x^2 + 4QC\right) - i = 0$$

where

$$\left(\frac{\phi}{2Cv_oz}\right)^2 = 4QC$$

The following notation is adopted in Eq. (21):

$$\begin{cases} \epsilon/C = b \\ \delta/C = \mu \\ \mu - ib = x \end{cases}$$

where $\epsilon$ is the detuning parameter. Eq. (22) is similar to that of a travelling-wave tube with space charge. The effect of the variations in the magnetic field is also taken into account and it is found that 1% variation can lead to the doubling of the starting current.

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