Asymmetric Electron Beams in Helix Traveling Wave Tubes

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ABSTRACT

In traveling wave tubes (TWTs) with a helical delay line it is critically important that the electron beam does not intercept the delay line. A low beam transmission causes a reduction in the efficiency of the device, as well as thermal problems that could potentially damage the delicate helix.
The design of the beam optics is usually done with the assumption of both geometric and magnetic rotational symmetry. This is in reality not the case, as manufacturing tolerances introduce an imperfect alignment between the electron gun and the delay line, resulting in a tilted or off-center beam injection. Also, there are various magnetic imperfections, the most important being a tilt in the axis of magnetization of the individual periodic permanent magnets (PPM) of the focusing stack.
The effect of these imperfections has been investigated with MVTRAD3D, a proprietary beam-wave interaction code [1]. The imperfections cause various kinds of rotations or oscillations of the beam axis around the center of the delay line, thus causing an increase in the effective diameter of the electron beam. This increase is visible in the linear small-signal regime, but translates almost unchanged to the large-signal regime, as shown in Figure 1.
Apart from the beam transmission, a second concern is the margin to backward wave oscillations (BWO). The coupling between the backward wave and the electron beam is very sensitive to the diameter of the electron beam, and therefore asymmetric beams decrease the stability margin. Also, the asymmetries can introduce an additional coupling between forward and backward traveling waves. The beam modulations due to interaction between the beam and the forward and backward waves are usually orthogonal, but this is no longer the case for asymmetric beams. Thus, there can be “pi-mode” oscillations at the frequency for which the forward and backward waves have the same propagation constant.
As a result, it is very important to control the alignment of the electron gun and the delay line as strictly as possible, as well as the quality of the focusing magnets.

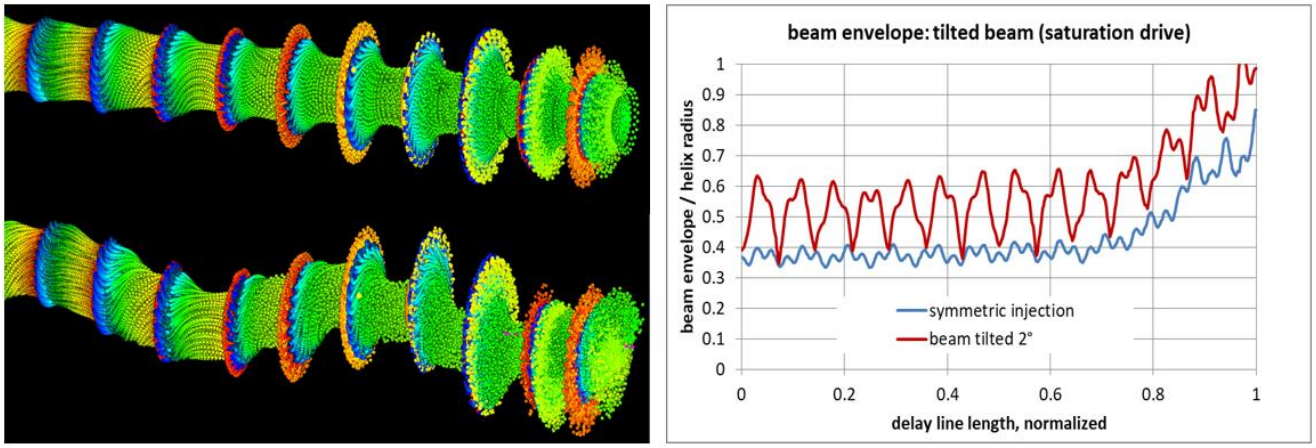

Figure 1: TWT electron beam under large-signal drive conditions: Symmetric and non-symmetric beam injection

[1] J.-F. David and G. Bariou, “A 3D largesignal model for helix TWT,” in *Proc. IEEE 14th Int. Vac. Electron. Conf. (IVEC)*, May 2013, pp. 1–2.