High-Efficiency TWT Design Using Traveling-Wave Bunch Compression

Shahid A. Naqvi, John A. Nation, Levi Schächter, and Qingyuan Wang

***Abstract*—A bunch compression scheme designed to obtain high efficiency in relativistic traveling-wave tube (TWT) amplifiers is reported. Bunch compression is achieved by making the bunches stay in more positive slopes of the axial electric field in the amplifier. The resulting momentum gradient across the bunch tends to oppose space-charge spreading and helps to sustain short bunch lengths for long distances. A faster than light structure is employed to produce the required bunching. At the optimal bunching point, a transition is made to a lower phase velocity structure where the narrow bunches are decelerated. An RF conversion efficiency of >50% in an *X*-band amplifier is achieved in particle-in-cell (PIC) simulations. This contrasts strongly with the 20%–30% efficiencies achievable from typical relativistic TWT's, where the bunching is not optimized.**

***Index Terms*—Bunching, efficiency, phase velocity, relativistic electron beams, traveling-wave tubes.**

in the decelerating phase for a long time. However, phase adjustments alone are often not sufficient to obtain a high-efficiency amplifier. Due to space charge, the bunch will spread to a width that is about a half wavelength, and no phase adjustment will help keep the entire bunch in the decelerating phase thereafter. The efficiency of a typical uniform structure relativistic traveling-wave tube (TWT) lies between 20%–30% [1]. A careful tailoring of the momentum distribution of particles is needed to form and sustain short bunch lengths, in order to achieve higher efficiencies.

In klystrons [2], there is a clear separation of the bunching from the deceleration/extraction stage. Although no such distinctions are possible in a continuous-structure TWT, we can nevertheless designate a section as a "decelerating" section, in which the major portion of the bunch energy is lost. The