The Interaction of Symmetric and Asymmetric Modes in a High-Power Traveling-Wave Amplifier

Samer Banna, *Member, IEEE*, John A. Nation, *Fellow, IEEE*, Levi Schächter, *Senior Member, IEEE*, and Pingshan Wang, *Member, IEEE*

***Abstract*—A three-dimensional (3-D) model has been developed for the investigation of the coupling of the lowest symmetric and asymmetric modes in a high-power, high-efficiency traveling-wave amplifier. We show that in a uniform structure and for an initially nonbunched beam, the interaction efficiency of the asymmetric mode may be much higher than that of the symmetric mode. It is also shown that the coupling between these two modes is determined by a single parameter that depends on the beam characteristics; its value varies between zero when no coupling exists and unity in case of maximum coupling. For a beam that is uniform at the input end, this parameter varies linearly with the guiding magnetic field. In case of a bunched beam, it decreases linearly with the increasing phase-spread of the bunch. Because of the interaction, the radius of the beam increases linearly with the power associated with the asymmetric mode at the input end; it increases rapidly in the case of an initially uniform beam relative to the case of a prebunched beam. Selective damping to suppress the asymmetric mode is described and analyzed.**

***Index Terms*—Amplification of radiation, asymmetric mode, electron acceleration, hybrid mode.**

Most of the experimental and theoretical efforts in the last decade were directed toward X-band operation [1]–[3], [5], [24], [25], [30]–[35]; however, the demand for high gradients at higher and higher frequencies for the next linear collider (NLC) pushes the operating frequency toward the Ka-band (e.g., 35 GHz), and as a result, this study focuses on this frequency regime [36]–[38]. The same trend is also motivated by a military need to deposit a large amount of energy in a relatively small area far away from the source—obviously, this ability is improved at higher frequencies.

Theoretical analysis [36] and preliminary experimental studies [37] indicated the feasibility of a 35-GHz traveling-wave amplifier based on a set of coupled cavities when only the symmetric mode was considered. We found that the difficulty with the scaling up the frequency is associated with beam power requirements. In order to benefit from the frequency increase, the rf power has to remain the same as in X-band; therefore, assuming similar efficiencies, the power