Theoretical studies of high-power Cerenkov amplifiers

L. Schächter, J. A. Nation, and D. A. Shiffler
Laboratory of Plasma Studies and School of Electrical Engineering, Cornell University, Ithaca, New York 14853

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The main theoretical aspects of the experiments performed and reported recently are discussed here. First the one stage amplifier is considered. As a preliminary step the behavior of the electrons is followed in the phase space at different points along the interaction region. This analysis reveals that about 30% of the interaction region is utilized for construction of the electron bunches. It is shown that although the average energy of the electrons remains unchanged along most of the amplifier, their energy spread increases substantially. Since the system consists of two long tapered sections, it is suggested that the effective length of the interaction region might be significantly longer than the physical length of the uniform structure. It is further suggested that the electrostatic periodic potential induced by the beam may also improve the interaction process. The next subject addressed here is the bandwidth of a single stage amplifier. It is shown that the reason for the narrow measured bandwidth is the gain of the system. In fact the output signal from a short amplifier is narrowed by exactly the same amount the amplitude of the electromagnetic wave is increased. This result is general as long as part of the radiation field is reflected from both ends of the amplifier. In the second part of this paper the two stage amplifier is analyzed. As in the case of the single stage amplifier the behavior of the electrons is followed in phase space at various locations along the system. This discussion leads to an analysis of the development of "sidebands" which are not symmetrically located around the initial frequency at power levels that do not correspond to a nonlinear process. It is suggested that these sidebands are amplified noise—produced basically in the first stage. The sharp selection of frequencies is due to the constructive interference of the waves bouncing between the two ends of the second stage. This selection is not symmetric relative to the initial frequency. Some considerations regarding the bandwidth of the system are also presented.