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A B S T R A C T

A time domain analysis of the normal modes in a cavity is used to obtain an analytical expression for the transverse momentum imparted to particles within an accelerated electron beam in a low frequency photoinjector. These analytical expressions form the basis of detailed simulations on the transverse momentum imparted to an accelerated beam. This analysis of the wakefields employs a modified form of the Panofsky–Wenzel theorem in which additional velocity dependent effects are taken into account. Simulations are presented for parameters of the ELSA photocathode.

1. Introduction

The progress of a charged particle beam through a cavity excites an electromagnetic field (e.m) which interacts back on the beam itself. This e.m field can be decomposed into a longitudinal component which influences the energy spread of the beam and a transverse component which causes an emittance dilution of the beam and can give rise to a beam break up instability [1–7]. This e.m field is conveniently represented as a wakefield which results from the influence of the e.m field scattered off the cavity wall and this we refer to as the geometric wakefield, or from Ohmic losses in the walls. The latter gives rise to resistive wall instability [8,9] and will not be studied in this paper. The focus of this paper is on the geometric wakefield. In either case, the wakefield may be viewed as an image charge setup by the beam which interacts back on the beam.

For a beam traveling ultra-relativistically (essentially at the speed of light) then the Panofsky–Wenzel theorem [10] relates the transverse component to the longitudinal wakefield. This formula is very convenient in beam dynamics simulations where the transverse momentum imparted to the beam is required. However, it is valid for a strictly ultra-relativistic beam. In the low-velocity regime, in a photocathode for example, velocity dependent corrections will be required. Here we drive these additional correction terms and obtain general relation between the transverse and longitudinal wakefield valid for non-relativistic and ultra-relativistic beams. These effects are particularly relevant in photocathodes where the initial acceleration of the beam takes place. Currently, there are several numerical computer codes available for modeling electron sources geometries which are able to include the effects of space charge fields. Among of these codes, we mention the classical code PARMELA [11] which incorporates electrostatic space–charge effects and TREDI [12] which incorporates e.m space charge forces using Lienard–Wiechart potentials in free space. These codes have been extensively used for simulating photoinjectors [13]. There are several approximations employed in these codes. In particular, the accelerating cavities are assumed to be electromagnetically decoupled from each other. These approximations require the deflecting field (higher order modes fields within the cavity) to be localized and to not propagate along the accelerator. These modes are excited by the beam and their relative amplitudes are dependent on the temporal length of the beam and on the velocity of the beam. However, these computer codes do not in general take into account these effects. These assumptions are quite accurate when the beam is sufficiently far from the cathode. However, the underlying assumptions are invalidated in the immediate vicinity

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