Wake-field generated by a line charge moving in the vicinity of a dielectric cylinder

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Abstract

The wake-field generated by a moving line charge in the vicinity of a dielectric cylinder is analyzed. It is shown that the emitted energy increases logarithmically with the kinetic energy \((\gamma - 1)\) of the line charge and decays exponentially as a function of the ratio \(h/R\), where \(R\) is the cylinder radius and \(h\) is the distance of the line charge from the cylinder’s axis. Upon investigation of the angular distribution of the radiated energy we found it to be almost uniform in the non-relativistic case, whereas for the relativistic case most of the emitted energy is radiated parallel to the direction of motion of the line charge. For a relativistic regime, the emitted energy is almost independent of the cylinder dielectric coefficient \((\varepsilon_r)\) provided the latter is frequency-independent. Frequency dependence of \(\varepsilon_r\) reduces significantly the deceleration of the line charge. For the ultra-relativistic case the transverse kick is inversely proportional to the kinetic energy and, as expected, increases as the line charge gets closer to the cylinder. Finally, a finite size bunch has been considered. As the transverse width of the bunch is increased, the total emitted energy also increases and the spectrum is broadened. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

In recent years, a significant effort has been directed in various laboratories and universities around the world towards the development of a new generation of particle accelerators driven by high-power lasers [1–6]. One of the concepts being pursued requires a dielectric optical structure in order to confine the radiation and eventually, to accelerate the electrons. Metallic and dielectric accelerator structures have been extensively investigated in the microwave range in the past implying that the geometry of a single cell is of order of a centimeter. A similar cell operating in the optical range will exhibit dimension in the order of micro-meters and therefore the manufacturing constraints dictate completely new geometries not allowing simple scale-down of microwave designs. Specifically, if in the S-band and X-band cylindrical structures are readily manufacturable, photolithography dictates planar structures for laser driven accelerators [7–12]. It is clear that for frequencies over 30 GHz it is almost impossible to produce axis-symmetric structures. Recently, planar structures have gained more and more interest...