Decelerating field on a bunch moving in a periodic symmetric structure

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Abstract

We develop an analytic expression for the upper limit of the decelerating field acting on a bunch moving in an azimuthally symmetric structure with periodic loading of arbitrary geometry. This field is a result of the electromagnetic field scattered by the confining periodic wall. The latter is electromagnetically characterized by a reflection matrix and the extremum determined here is subject to the assumption that the absolute value of each diagonal term of this matrix is smaller than unity.

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Electron acceleration by a short and intense laser pulse in vacuum [1] has some inherent advantages as well as drawbacks in comparison to optical schemes invoking plasma [2]. Maybe the most important advantage is lack of the kind of instabilities plasma schemes are prompt to. On the other hand, for acceleration in vacuum, the boundary conditions of the electromagnetic field need to be altered by a metallic or dielectric structure. For gradients competitive to plasma schemes, high electric fields develop at the surface of the structure and thus the latter is prompt to breakdown. Reduction of the breakdown probability is possible by increasing the internal radius \( R_{\text{int}} \) of the structure however, doing so we also reduce the interaction impedance implying a lower gradient for the same laser power. In parallel, reduced interaction impedance leads to lower wake fields and thus smaller deceleration of the electron bunch. A design of an optical acceleration structure is, in principle, an optimization process that needs to balance between these contradicting trends and it is therefore important determine the effect of the other parameters. In the present Letter we shall focus on the various parameters that affect the wake field generated by a bunch moving in an acceleration structure.

The electromagnetic wake generated by a relativistic bunch of particles in a periodic structure or single cavity, that RF accelerators consist of, was the subject of many studies [3–8]. However, due to the complexity of the problem there are only a few analytic or quasi-analytic solutions: for example, Bane et al. [3] have developed a simple model that describes the energy loss of a bunched beam traversing a cavity attached to a cylindrical waveguide. Their calculation was subject