SCALING LAWS OF STRUCTURE-BASED OPTICAL ACCELERATORS

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A structure-based laser accelerator harnesses technological progress developed by the laser and optical fiber industries, potentially facilitating a compact and efficient system. In the optical regime, dielectrics sustain higher electric fields and gradients of the order of a few GV/m may become available, but the acceleration structures are different than those used in the microwave regime. Various dielectric structures have been analyzed, and from the pure accelerator parameters perspective (gradient, interaction impedance, group velocity, wake-fields), their performance is of great promise. Operation similar to current linear accelerators may lead to a prohibitively low efficiency. Therefore, including a feedback attached to each module may improve the efficiency from a few percents to higher than 90% – in fact, the efficiency is limited only by the constraints on the stability of the optical system. Single mode operation in the optical regime imposes that at least one of the dimensions of each micro-bunch ought to be sub-micronic leading to a stringent constraint on the emittance and thus on the luminosity. Attempting to increase the latter, imposes high energy density in the vacuum tunnel as well as in its adjacent dielectric layer(s). This, in turn, is bounded by the maximum stress, temperature increase and heat dissipation, dielectrics can sustain at these scales.

1. Introduction

Motivated by the availability of solid-state lasers with increasing wall-plug to light efficiencies, optical acceleration of charged particles is a subject of growing interest. Acceleration is facilitated by laser light rather than by microwave radiation, and accordingly, the acceleration structure must be made of dielectric materials as these have lower loss and are less susceptible to breakdown comparing to their metallic counterparts. An example of an open optical structure is the LEAP\(^1\) crossed laser beam experiment where the interaction between the crossed laser beams and the particles is limited by slits to satisfy the Lawson-Woodward theorem\(^2,3\). Another example is the travelling wave acceleration structure, where a laser pulse is guided in a