Electron beam guiding by a laser Bessel beam

Levi Schächter[1,*] and W. D. Kimura[2]

[1]*Technion–Israel Institute of Technology, Haifa 32000, Israel*
[2]*STI Optronics, Inc., Bellevue, Washington 98005, USA*

(Received 7 April 2020; accepted 15 June 2020; published 3 August 2020)

We investigate the dynamics of electrons counterpropagating along a radially polarized optical Bessel beam (OBB). (i) It is shown that a significant fraction of the electrons can be transversally trapped by the OBB even in the case of "unmatched" injection. Moreover, (ii) these transversally trapped particles (TTPs) can be transported without loss along many thousands of wavelengths. As long as there is full longitudinal overlap between the electrons and laser pulse, this transport distance is limited only by the length of the OBB region. (iii) The unique profile of the transverse field components facilitates guiding either azimuthally symmetric pencil beams or annular beams. Space charge tends to totally suppress the annular beams, and it reduces the amount of charge trapped on axis for pencil beams. (iv) Assessment of the emittance of the TTPs *alone* reveals typical values of 10–50 pm. In fact, our simulations indicate if we trace the emittance of those particles that are trapped from the input to the output of the OBB, we find that this emittance is conserved. (v) We developed an analytic model whereby we average over the fast oscillation associated with the counterpropagating electrons and OBB. The resulting Hamiltonian has a Bessel potential $J_1^2(u)$, which, when operated in the linear regime near equilibrium, causes rotation of the phase space. A Kapchinskij-Vladimirskij beam-envelope equation is derived including space-charge and emittance effects. Relying on conservation of the longitudinal canonical momentum, the energy spread in the interaction region is determined in terms of the OBB intensity and the electron energy.

DOI: 10.1103/PhysRevAccelBeams.23.081301