Breakdown of the ponderomotive approximation and efficient particle acceleration

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The present work investigates a mechanism of particle acceleration by electromagnetic waves, based on the breakdown of the ponderomotive regime so typically provided by slowly modulated high-frequency carriers. If one works far enough from wave-particle resonance conditions, the ponderomotive regime indeed dictates the dynamics, but as one approaches resonance, we show that particles are automatically captured by the high-frequency carrier with the proper phase for a very efficient catapulting acceleration. With help of ponderomotive modelling and full wave-particle simulations we determine parametric regions for maximal acceleration. In fact, with proper adjustment of control parameters like the wave amplitude and phase velocity, particles can be shown to be accelerated from small fractions of the speed of light, to nearly $c$. Acceleration of electron and ion beams are discussed, the latter in the context of fusion devices.