Title: A quantum mechanical analysis of Smith-Purcell free-electron lasers

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Abstract: The paper presents a quantum mechanical treatment for analyzing the Smith-Purcell radiation generated by charged particles passing over a periodic conducting structure. In our theoretical model, the electrons interact with a surface harmonic wave excited near the diffraction grating when the electron velocity is almost equal to the phase velocity of the surface wave. Then, the surface harmonic wave is electromagnetically coupled to a radiation mode. The dynamics of electrons are analyzed quantum mechanically where the electron is represented as a traveling electron wave with a finite spreading length. The conversion of the surface wave into a propagating mode is analyzed using the classical Maxwell equations. In the small-signal gain regime, closed-form expressions for the contributions of the stimulated and spontaneous emissions to the evolution of the surface wave are derived. The inclusion of the spreading length of the electron wave to the emission spectral line is investigated. Finally, we compare our results based on the quantum mechanical description of electron and those based on the classical approach where a good agreement is confirmed.