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Three-dimensional theory of the Smith-Purcell free-electron laser[1] JONATHAN JARVIS, HEATHER ANDREWS, Vanderbilt University — We present an analytic theory for the operation of a Smith-Purcell free-electron laser (SPFEL) that includes transverse diffraction of the optical beam. For the case of an infinitely wide electron beam, this theory agrees with previous two-dimensional analyses. When the electron beam is narrow compared to the mode, the gain (amplifier regime) is substantially reduced by diffraction, while its dependence on the beam current is increased due to gain guiding. A 5/2-power dispersion relation replaces the conventional cubic dispersion relation. The number and location of the physically allowed roots depends on the electron-beam energy. For low beam energies, an estimate of the start current (oscillator regime) of the device is obtained by satisfying the appropriate boundary conditions on the beam axis.

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Jonathan Jarvis
Vanderbilt University

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