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Smith-Purcell free-electron laser

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We analyze the operation of a free-electron laser in an open periodic structure. When operated as an amplifier, it is shown that exponential gain can develop in such a device. An analytic expression for this gain is presented, and it is shown that this gain decays exponentially with the beam height above the grating; the gain dependence on the beam thickness is also analyzed. As the energy extraction rate is much higher in an exponential gain regime, we also investigate the operation of an oscillator based on the same concept. In this case, the Smith-Purcell radiation "provides the start-up" through a feedback system. The latter consists of several mirrors, which are placed in such a way that (1) only a wave with the desired frequency develops and, at the same time, (2) small deviations in the wave parameters due to the wave-beam interaction do not cause deflection of the wave from the feedback loop. The minimal current needed to sustain oscillations is given in an analytical form. Numerical calculations show that this current is more than three orders of magnitude lower than that necessary for an oscillator which operates in an algebraic gain regime.