We present time-domain simulations of terahertz quantum cascade laser frequency combs, based on the numerical solution of Maxwell-Bloch equations. We extend the classical two level density matrix model to include one optical and one resonant tunneling transition. We show how this correctly captures the complicated dynamics between four wave mixing, coherent tunneling and spectral splitting, group velocity dispersion, as well as spatial hole burning, as it delivers simulation results in good agreement with experiment. In contrast to existing simulation approaches for investigation of frequency combs [1, 2], our model is not based on prior assumptions on the longitudinal mode-spacing or perturbative solutions of any kind, and we were able to simulate both comb and non-comb regimes of operation. Furthermore, our simulations verify the presence of a pulse switching behaviour, only recently reported in experiment and denoted as “temporal hole burning” [3]. We also investigate the dispersion characteristics of the simulated device and the onset of nonlinear phenomena. We believe that our manuscript will have a significant impact onto the QCL, frequency comb and THz communities and beyond.

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