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Theory of THz superradiant waveguide FEL

Following first light measurement at the Israeli THz Superradiant waveguide FEL we developed theoretical analysis corresponding to the concept scheme. We use analytical expressions to calculate the spectrum and energy emited into the rectangular waveguide LSM (Longitudinal Sector Magnetic) modes. The results compare well with numerical simulations using UCLA GPTFEL and are consisted with the measured THz energy. GPT simulations of the e-beam transport show that the chirp provided by the hybrid photocathode RF gun can produce tight bunching at the wiggler bellow sigma=100ftS. The bunch duration limits the bunching factor, and consequently diminishes the superradiant emission. Phase-space analysis shows that tight bunching and consequent high THz frequency operation are limited by the energy spread of the beam in the gun. The superradiant scheme provides narrow bandwidth radiation of the radiation of the individual modes. We propose a Fourier optics scheme for spatial separation of the mode, and derive their diffraction patterns using Fresnel diffraction calculation.

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