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## FEL Resonance of Circular Waveguide Modes

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The THz gap is a region of the electromagnetic spectrum where high average and peak power radiation sources are scarce while scientific and industrial applications grow in demand. Free-electron laser coupling in a magnetic undulator can provide radiation generation in this frequency range, but slippage effects require the use of relatively long and low current electron bunches in the THz FEL, limiting the amplification gain and output peak power. We show how a circular waveguide in a meter-long strongly tapered helical undulator can be used to match the radiation and e-beam velocities, extracting energy from an ultrashort 200 pC 5.5 MeV electron beam along the entire undulator. E-beam spectrum measurements, supported by energy and spectral measurements of the THz FEL radiation, indicate an average energy efficiency of 10% with some particles losing >20% of their initial kinetic energy.

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