Electron emission physics, beam transport, and their interaction with circuits and waves are central to the operation of cathodes and electron emitters, vacuum electronics, high power electromagnetic radiation sources, pulsed power systems, and particle accelerators. This talk presents an overview of our generalized quantum mechanical modeling of electron emission, based on exact solutions of the time-dependent Schrödinger equation (TDSE). The single formulation is applicable to electron emission from surfaces under a wide range of excitations and various combination of them, including background fields (DC or RF), photon-driven excitation (laser intensity, wavelength, pulse duration, etc), and thermal effects. The effects of laser pulse length, pulse shape, and spectral phase on electron emission will be addressed. Also highlighted are our recent studies of short-pulse electron beam dynamics, the influence of series resistance on quantum tunneling, as well as large signal beam-cavity gap interactions at high frequencies.