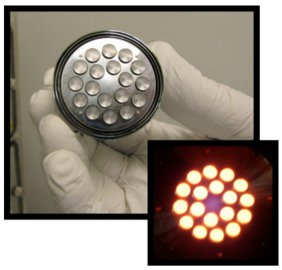
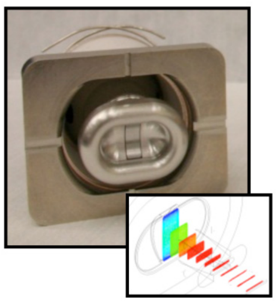
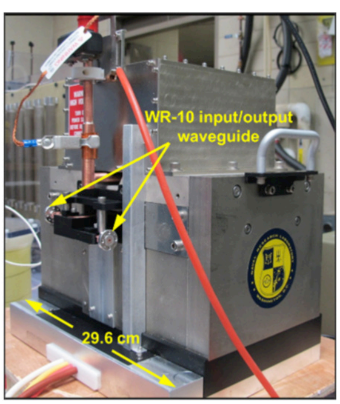
Vacuum Electronics

Spatially Distributed Electron Beams
In a vacuum electronic amplifier, an increase in device output power typically requires an increase in the electron beam power which, in turn, entails an increase in either the beam voltage or the beam current, or both. Space-charge forces — which limit the maximum current and current density of a single “pencil beam” of electrons — can be circumvented by spatially distributing the beam in one or more dimensions such as in an array of parallel beams or a “sheet” beam with rectangular cross section. ESTD has developed compact, low-voltage multiple-beam and sheet-beam electron gun designs capable of generating peak beam powers ranging from tens of kilowatts to almost two megawatts.

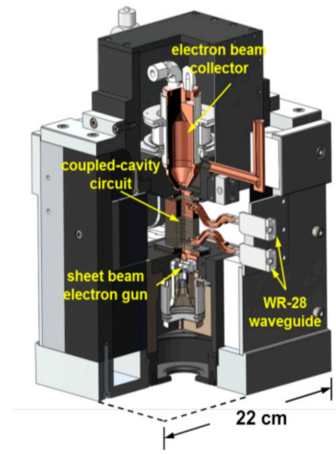




High-Power Sheet Electron Beam Amplifiers
Using spatially distributed electron beam technology, ESTD researchers have demonstrated a sheet-beam extended interaction klystron (SB-EIK) operating at a center frequency of 94 GHz. The SB-EIK employs a Nd-Fe-B permanent magnet to create an 8.5 kG solenoidal magnetic field, enabling operation at a relatively low voltage of 19 to 21 kV. This magnet system transports the 4 mm × 0.32 mm cross-section, 3.5 to 4 A beam from the cathode to a depressed collector with >99% efficiency. When optimized, the SB-EIK generated a maximum power of 7.7 kW with an electronic efficiency of 18%. The fully assembled amplifier has a compact footprint of 29.6 cm × 17.5 cm × 27 cm, resulting in a peak volumetric power density of over 550 kW/m^3.



To explore high-power broadband device designs, ESTD researchers slightly modified the 94 GHz sheet-beam gun design and used it to drive a sheet-beam coupled-cavity traveling-wave tube (SB-CCTWT) with an operating frequency centered at 35 GHz. The SB-CCTWT has a predicted peak RF output power of ~10 kW with a small-signal gain of 18 to 20 dB and a 3 dB bandwidth of >4 GHz. The predicted output power represents more than a 14-fold increase in single-device output power relative to the current pencil beam coupled-cavity TWT state of the art. The amplifier has a compact footprint (22 cm × 17 cm × 29 cm) and a predicted peak volumetric power density of over 900 kW/m^3.



High-Power Amplifiers Above 100 GHz
ESTD researchers have developed an ultraviolet photolithographic, electroforming and molding process that enables the creation of fine-grain, vacuum compatible, solid copper structures with high thermal and electrical conductivity. Structure dimensions can range from 10 to 1000 µm with vertical width-to-depth aspect ratios up to 15:1 and sidewall angles <1°. Combined with a novel method for integral beam tunnel formation, this process was used to create a G-band serpentine waveguide circuit that generated more than 60 watts of peak output power at a frequency of ~214 GHz with a 3 dB bandwidth of 14 GHz. The success of this device and the validation of the fabrication process paves the way for new classes of high-power amplifiers and oscillators operating from 100 GHz to 1 THz.