The Center for Pulsed Power and Power Electronics
Department of Electrical and Computer Engineering
Texas Tech University, Lubbock, TX 79409-3102
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The Center for Pulsed Power and Power Electronics started as a Plasma research group at Texas Tech University in 1966. The initial work was concerned with harmonic ion cyclotron resonances in small mirror machines, laser heating of magnetized plasmas, and pellet injection in hot dense plasmas. In 1977 a small Tokamak was constructed and used for various wave propagation studies in the ion cyclotron range of frequencies. In the last few years the emphasis has been on power electronics, applications of plasma technology to pulsed power devices, high power microwave generation, explosive generators, and electric space propulsion engines.

Explosive power research at Texas Tech was started in 1998. It emphasizes Magnetic Flux Compression Generators and techniques for matching their outputs to various loads. Other explosive generators, such as ferroelectric and ferromagnetic generators have also been investigated.

The area of pulsed power research involves storing, shaping, transmitting, and measuring high voltage, high current pulses of electrical energy. This is of importance to many application areas, such as laser drivers, high power microwave generators, particle accelerators, nuclear fusion, nuclear weapons effects and lightning simulations, industrial manufacturing technology, and electromagnetic mass drivers. The voltages and currents involved may be in the MV and MA range and time scales may be as short as the sub-nanosecond regime. This calls for extremely difficult and challenging materials, shielding, and measuring techniques. High power (> 100 MW) microwave source development is an important area for military applications. Power Electronics involves high efficiency power supply designs, rotating machines, and special, high power solid state circuit designs.

The Plasma, Power Electronics, and Pulsed Power Group at Texas Tech consists of eight faculty members, with a wide range of expertise, from the departments of ECE, ME, and Physics, an average of 25 graduate students, and 15 undergraduate student assistants. The clerical and technical-support-staff comprise four research engineers, one machinist, two technicians, one accountant, and one administrative business assistant.

For further information about the plasma, power electronics, and pulsed power program at Texas Tech, contact any of the following faculty members. (Investigator and Research Area listed)

The University
Texas Tech University, founded in 1923, is a state-supported, coeducational institution and one of the principal institutions of higher learning in the Southwest. Texas Tech University prides itself on being a major comprehensive research university that retains the sense of a smaller liberal arts institution. Although enrollment is over 30,000, Texas Tech students boast of one-on-one interaction with top faculty and an environment that stresses student accomplishment above all else. We're large enough to provide the best in facilities and academics, but small enough to focus on YOU. Texas Tech students come from every county in Texas, all 50 states and more than 90 foreign countries. Tech offers 150 undergraduate degree programs through 11 academic colleges, a graduate school and a school of law. We offer more than 100 master's degree programs and over 50 doctoral degree programs. The Texas Tech University Health Sciences Center includes a School of Medicine with its Graduate School of Biomedical Sciences, a School of Nursing, and a School of Allied Health.

The Department of Electrical and Computer Engineering (ECE) has rapidly expanded and developed its graduate programs over the past decade and currently has 24 faculty members, approximately 450 undergraduates, and 75 graduate students. Thirty years ago, the annual research funding was $46,000 and has increased to an average of about $6,000,000.

The Department of Physics offers M.S. degrees in Applied Physics in addition to the traditional degrees. Applied Physics majors can do research in Pulsed Power and take courses in Electrical Engineering. The major Professor can be from Physics or ECE.
Faculty

S. B. Bayne (ECE)
(806) 742-0526
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Power Semiconductor Devices, Power Electronics, High Power Microwaves and Renewable Energy

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M. Giesselmann (ECE)
Department Chair
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Power Electronics, Rotating Machines, Utility Power systems, Gas Discharges, Electrical and Optical diagnostics, H.V. Measuring Techniques, High Power Switching

L. L. Hatfield (Physics)
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Surface Physics, Atomic Physics, Electrical Space Propulsion, Dielectrics, High Voltage Insulators, High Power Microwaves

M. Kristiansen (ECE / Physics)
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H. Krompholz (ECE / Physics)
(806) 742-1251
E-mail: hermann.krompholz@ttu.edu
Plasma Physics, Gas Discharges, Dielectric Surface Flashover, High Speed Diagnostics, High Power Microwaves, Breakdown in Gases, Liquids and Solids

J. J. Mankowski (ECE)
(806) 742-3441
E-mail: john.mankowski@ttu.edu
HPM Sources, Pulse Forming Networks, Liquid Breakdown, Electric Space Propulsion, Pulsed Power Technology

A. A. Neuber (ECE)
Co-Director
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Dielectric Breakdown of Gases, Liquids, and Surfaces in Vacuum and at Elevated Pressure (Cryogenic to Room Temperature) Under Pulsed DC or HPM Fields, Explosive Driven Pulsed Power, High Power Microwaves, High Voltage Insulation, Low Temperature Plasmas
<table>
<thead>
<tr>
<th>Faculty / Researchers</th>
<th>Institution / Location</th>
<th>Years</th>
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<tbody>
<tr>
<td>C. H. Watson-Munro</td>
<td>Univ. of Sydney</td>
<td>1971</td>
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<tr>
<td>Arndt Eberhagen</td>
<td>Max Planck Institut fur Plasma Physik at Garching, Munich</td>
<td>1972, 1973</td>
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<tr>
<td>F. J. Paoloni</td>
<td>Univ. of Sydney</td>
<td>1973</td>
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<tr>
<td>Karl I. Selin</td>
<td>Royal Institute of Technology, Stockholm</td>
<td>1973, 1974</td>
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<tr>
<td>A. H. Guenther</td>
<td>Adjunct Professor, Kirtland Air Force Base, Los Alamos National Laboratory, Sandia National Laboratories</td>
<td>1974-1989</td>
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<tr>
<td>Bogdan Miedzinski</td>
<td>Technical University of Wroclaw, Poland</td>
<td>1978, 1979</td>
</tr>
<tr>
<td>Alan Watson</td>
<td>University of Windsor, Canada</td>
<td>1979, 1985, 1986</td>
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<tr>
<td>Boy Blackwell</td>
<td>Univ. of Sydney</td>
<td>1980</td>
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<tr>
<td>John Fletcher</td>
<td>School of Physical Sciences, The Flinders University of South Australia</td>
<td>1982</td>
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<tr>
<td>Jean-Pierre Boeuf</td>
<td>Laboratoire de Physique des Discharges, Ecole Superieure d'Electricite, France</td>
<td>1982</td>
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<tr>
<td>Frank Rose</td>
<td>Adjunct Professor, Naval Surface Weapons Center, Dahlgren, Virginia</td>
<td>1984, 1986</td>
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<tr>
<td>H. Akiyama</td>
<td>Kumamoto University, Kumamoto</td>
<td>1984, 1986</td>
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<tr>
<td>Shinsuke Watanabe</td>
<td>Yokohama National University, Yokohama</td>
<td>1992</td>
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<tr>
<td>Toru Iwao</td>
<td>Tokyo University, Tokyo, Japan</td>
<td>2000</td>
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<tr>
<td>W. Baker</td>
<td>Adjunct Professor, Air Force Phillips Laboratory, Albuquerque, NM</td>
<td>1988-1993</td>
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<tr>
<td>Thomas Muller</td>
<td>Deutsche Forschungsgemeinschaft, Bonn, Germany</td>
<td>1993-94</td>
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<tr>
<td>Kevin Woolverton</td>
<td>Intel</td>
<td>2000</td>
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<tr>
<td>Jian De Zhang</td>
<td>National University of Defense Technology, Changsha, Hunan</td>
<td>2002</td>
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<tr>
<td>Takao Namihira</td>
<td>Kumamoto University</td>
<td>2003-04</td>
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<tr>
<td>Douyan Wang</td>
<td>Kumamoto University</td>
<td>2003, 2004</td>
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<tr>
<td>Euan Choi</td>
<td>Kwangwoon University, Seoul, South Korea</td>
<td>2004</td>
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<tr>
<td>Han-Yong Ryu</td>
<td>Agency for Defense Development, South Korea</td>
<td>2005</td>
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<tr>
<td>Klaus Frank</td>
<td>Erlangen University, Erlangen, Germany</td>
<td>2007, 2008, 2009</td>
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</tbody>
</table>
The Center for Pulsed Power and Power Electronics Texas Tech University, Lubbock Texas

**Research Areas**
- Electrical Space Propulsion Devices
- Breakdown in Liquids and Solids
- Industrial Applications of Pulsed Power Technology
- Various Novel Switch Concepts
- The Interaction of Arc Channels with Electrodes and Insulators
- High Power Microwave Studies
- The Surface Physics of Insulators
- Solid State Power Electronics
- Erosion Resistant Materials for Space Propulsion
- Sub-nanosecond Pulsed Gas Breakdown
- Explosive Driven Pulsed Power
- Non-Equilibrium Plasmas
- Pulsed Vacuum UV Generation
- Corona Formation and Mitigation
- Circuit And Rotating Machine Modelling
- Electromagnetic Launchers

**Graduate Studies**
Numerous grants and contracts support a variety of research that provides opportunities for graduate students to interact with prominent researchers in industry and at national laboratories. These associations are valuable to the research in progress and the long-term benefits are inestimable. Financial support ($2,200 - $2,600 per month) for graduate study is for the most part obtained from Research Assistantships and Graduate Fellowships. All supported students pay in-state tuition and most of the tuition and fees are provided.

The Pulsed Power and Power Electronics Research Program at Texas Tech University has generated approximately 100 theses and dissertations over the past ten years. Plasma, Power Electronics and Pulsed Power related graduate courses offered in the ECE Department include:
- Electromagnetic Field Theory
- Pulsed Power Technology
- Gaseous Electronics
- High Power Microwave Sources
- Plasma Engineering
- Laser Spectroscopy
- Power Electronics
- Machine Modelling and Control

**Laboratories and Support facilities**
A new Electrical Engineering research building, largely devoted to pulsed power related research was completed in 1980. Today, after the addition of a high bay laboratory space in 1999, the P3E Center occupies a total floor area of over 15,000 square feet. Additional space of 12,000 square feet is used in the off-campus research building.
The computer resources available in the Pulsed Power Laboratory include several state-of-the-art MPS workstations, high-end 3-D graphics coprocessors and high-speed network connections. Also available in the lab are various workstation class PC’s, color and black & white printers, scanners, image converter cameras, mega-pixel SLR digital cameras and MS Windows domain servers with redundant hard drives and domain backup servers.

Like the hardware, an impressive list of software is available in the Center. This software includes professional versions of Orcad PSpice, Synopsys Saber, Simplore (high-end circuit solvers), Maxwell 3-D (electro and magneto static / eddy current field solver), Ansoft HFSS (3-D electromagnetic field solver), Matlab (technical programming language), Autodyn 3-D (interactive non-linear dynamic and hydro-dynamic analysis software), CTH 3-D hydrodynamic code and COMSOL (finite element method for solving systems of partial differential equations).

In addition to its own computing facilities, the Pulsed Power Laboratory has access to the university’s High Performance Computing Center (HPCC) which houses several hundred Intel computer nodes on several clusters and grid servers with data stored on large Luster file systems.

Equipment and Facilities
A representative sample of the equipment and facilities available for research includes:

- Pulsed high voltage, high current diagnostic equipment including conventional probes and optical detectors of electric fields
- Fast Oscilloscopes
- Numerous spark gaps, rail gaps, ignitrons, thyatrons and solid state switches
- Numerous high voltage D.C. power supplies
- Marx generators (up to 2 MV)
- Line pulsers and PFN’s
- Laboratory power capability: 500 kVA single outlet; 1MVA total
- Scanning electron and optical microscopes
- Double wall Faraday cages
- Optical equipment, detectors and spectrometers
- Pulsed and CW lasers with a wide range of wavelengths and power outputs
- Image converter streak and framing cameras with picosecond or nanosecond temporal resolution
- High voltage, high power loads
- Residual gas analyzers
- Spectroradiometer
- Microwave equipment
- Rotating prism and mirror framing cameras
- Numerous vacuum stations
- Microwave Interferometers
- Magnetic coil systems and associated power supplies
- Various large vacuum tanks
- FT IR-Spectrometer
- Closed cycle refrigeration system
- Fluorescence detection system for CW and transient measurements
- Programmable pico-ammeter and voltage sources
- High potential testers
- Febetron flash x-ray, 300 keV
- High power microwave equipment
- OMA systems for VUV-UV-VIS-NIR spectroscopy
- Multiple explosive chambers
- Space simulation chamber
- Dimension SST 1200es 3-D printer
- Class 100,000 (ISO8) clean room
- Haas TL-1 tool room lathe
- Haas TM-1 tool room mill
- Haas GR-510 Gantry router
- Haas VF-3 vertical machining center w/ 4th axis
- 26 foot shielded mobile diagnostic trailer


• "A compact 45 kV curve tracer with picocampere current measurement capability," Review of Scientific Instruments, 2013


• "All solid-state high power microwave source with high repetition frequency," Review of Scientific Instruments, 2013


• "Characterization of Annealed HPSI 4H-SiC for Photoconductive Semiconductor Switches," Materials Science Forum, 2012


• "A finite-difference time-domain simulation of high power microwave generated plasma at atmospheric pressure," Physics of Plasmas, 2012

• "Charged Electret Deposition for the manipulation of High Power Microwave Flashover Delay Times," Physics of Plasmas, 2012

• "Electric Field Enhanced Conductivity in Strongly Coupled Dense Metal Plasma," Physics of Plasmas, 2012


• "Shallow Incorporation of Nitrogen in HPSI 4H-SiC through the Laser Enhanced Diffusion Process," 2012 Materials Science Forum


• "Reliable Operation of 1,200-V SiC Vertical Junction-Field-Effect-Transistor Subjected to 16,000-Pulse Hard Switching Stressing," Materials Science Forum, 2012


• "Evaluation of High Power Experimental SiC SGTO Devices for Pulsed Power Applications," Materials Science Forum, 2012

• “Investigation of the delay time distribution of high power microwave surface flashover,” Physics of Plasmas, 2011


• “Rapid formation of dielectric surface flashover due to pulsed high power microwave excitation,” IEEE Transactions on Dielectric and Electrical Insulation, 2011

• “Statistical analysis of high power microwave breakdown surface flashover delay times in nitrogen with metallic field enhancements,” Physics of Plasmas, 2011


• “Phenomenology of Streamer Propagation during Pulsed Dielectric Surface Flashover,” IEEE Transactions on Dielectrics and Electrical Insulation, 2011

**Conference Proceedings (2011 - May 2013)**

• “Bias Field Controlled Phasing of Ferrimagnetic Coaxial Nonlinear Transmission Lines,” 2013 Pulsed Power Conference

• “High Voltage Solid Dielectric Coaxial Ferrimagnetic Nonlinear Transmission Line,” 2013 Pulsed Power Conference


• “Rapid Capacitor Charger and Battery System for Portable Pulsed Power Applications,” 2013 Pulsed Power Conference

• “Current Capabilities of a Low Inductance Marx Generator for Driving a High Power Microwave Source,” 2013 Pulsed Power Conference

• “Burst Mode Operation of > 100 MW Reflex Triode Vircator,” 2013 Pulsed Power Conference

• “Performance of NEG Getter Material in a Sealed Reflex-Triode Vircator at 225 A/cm²,” 2013 Pulsed Power Conference

• “Frequency Tunable Sealed Tube Reflex Triode Vircator,” 2013 Pulsed Power Conference

• “Pulsed Power Switching of 4H-SiC Vertical D-MOSFET and Device Characterization,” 2013 Pulsed Power Conference

• “Post Pulse Recovery of HPM Generated Plasma at Close to Atmospheric Pressure,” 2013 Pulsed Power Conference

• “Study of Low-Temperature Plasma Development Utilizing a GPU-Implemented 3D PIC/MCC Simulation,” 2013 Pulsed Power Conference

• “Selective Electron Beam Irradiation of High Purity Semi-Insulating 4H Silicon Carbide Substrates to Characterize the Effects on Photoconductive Semiconductor Switch Operation,” 2013 Pulsed Power Conference

• “Microwave Radiation from a SiC PCSS Driven Gyromagnetic NLTL,” 2013 Pulsed Power Conference
• "Performance and Characterization of a 20 kV, Contact Face Illuminated, Silicon Carbide Photoconductive Semiconductor Switch for Pulsed Power Applications," 2013 Pulsed Power Conference


• "An Experimental System for the Measurement of Vacuum UV below 115 nm from Pulsed Plasma in an N₂/O₂ Environment," 2013 Pulsed Power Conference

• "Design of an Advanced Modular Automated Evaluation System for Experimental High Power Si and SiC SGTOs," 2013 Pulsed Power Conference

• "Hydrodynamic and Magnetohydrodynamic Modeling of Exploding Wires in Opening Switch Type Operation," 2013 Pulsed Power Conference

• "Electro-Thermal Transient Simulation of Silicon Carbide Power Mosfet," 2013 Pulsed Power Conference

• "Development and Characterization of a Pulsed Micro Hollow Cathode Discharge Array," 2013 Pulsed Power Conference

• "Comparison of Csl coated Carbon Velvet and Aluminum Cathodes Operated at Current Density on the order of 300 A/cm²," 2012 IEEE International Power Modulator and High Voltage Conference

• "Experimentation and Simulation of High Current Density Surface Coated Electro-Explosive Fuses", 2012 IEEE International Power Modulator and High Voltage Conference

• "A 50 kV Silicon Carbide Photoconductive Switch for Pulsed Power Systems", 2012 Euro-Asian Pulsed Power Conference

• "Fiber Optic System for High Frequency Burst Operation of a Silicon Carbide Photoconductive Semiconductor Switch," 2012 IEEE International Power Modulators and High Voltage Conference

• "The Effects of Sub-Contact Nitrogen Doping on Silicon Carbide Photoconductive Semiconductor Switches," 2012 IEEE International Power Modulators and High Voltage Conference


• "Anode Material Outgassing at 250 A/cm² Current Density Under UHV Conditions," 2012 IEEE International Conference on Plasma Science

• "Gas Evolution of Nickel, Stainless Steel 316, and Titanium Anodes in Vacuum Sealed Tubes," 2012 IEEE International Power Modulators and High Voltage Conference
<table>
<thead>
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<th>Conference Proceedings</th>
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<tr>
<td>&quot;Design of an Automated Test Bed for Experimental Si and SiC SGTO Devices,&quot; 2012 IEEE International Power Modulators and High Voltage Conference</td>
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<td>&quot;Recent Experiments of Vacuum UV Emission and Absorption during Pulsed Atmospheric Breakdown,&quot; 2012 European Electromagnetics Symposium</td>
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<td>Analysis of SiC Super Junction Transistors during pulsed operation,&quot; 2011 IEEE Pulsed Power Conference</td>
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<td>&quot;Design of a diagnostic system for use in optical and VUV spectroscopy of explosive emission,&quot; 2011 IEEE Pulsed Power Conference</td>
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<td>&quot;Exploration of Self-Produced Vacuum Ultraviolet Radiation from Dielectric Surface Flashover at Atmospheric Pressure,&quot; 2011 IEEE Conference on Electrical Insulation and Dielectric Phenomena</td>
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<td>&quot;Recombination lifetime modification in bulk, semi-insulating 4H-SiC photoconductive switches,&quot; 2011 IEEE Pulsed Power Conference</td>
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<tr>
<td>&quot;Unique high energy test bed for experimental thyristor devices,&quot; 2011 IEEE Pulsed Power Conference</td>
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<tr>
<td>&quot;Diagnostic measurements on explosive emission cathodes operating at high current densities and UHV pressures,&quot; 2011 Pulsed Power Conference</td>
</tr>
<tr>
<td>&quot;Nanosecond-Scale Spectroscopy of Vacuum Ultraviolet Emission from Pulsed Atmospheric Discharges,&quot; 2011 Pulsed Power Conference</td>
</tr>
<tr>
<td>&quot;Laser enhanced diffusion of nitrogen in high purity semi-insulating 4H silicon carbide substrates for non-rectifying contact formation to photoconductive semiconductor switches,&quot; 2011 Pulsed Power Conference</td>
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</table>
Research Projects

Rapid Capacitor Chargers

High Voltage SiC Switch Testbed

Advanced Large Area Cathode Preparation