2019 Pacific Symposium on Pulsed Power and Applications
Kauai, Hawaii August 6 – 9, 2019
Hotel Map with Event Locations

1. LOBBY
2. PORTE COCHERE
3. RESTAURANT
4. HOTEL ROOMS
5. VILLAS
6. SALES GALLERY
7. PARKING
8. VALET PARKING
9. POOL
10. COURTYARD
11. STAGE
12. POOL RESTROOM
13. FITNESS CENTERS
14. YOGA LAWN
15. FIRE PITS
16. BARBECUE GRILLS
2019 Pacific Symposium on Pulsed Power and Applications
Technical Program

August 6 - 9, 2019
Sheraton Kauai Resort
Poipu Beach, Kauai, Hawaii, USA

Technical Topics

High-Power Microwave and RF Sources
Compact Pulsed Power Sources
Pulsed Power Systems, Switches and Components
Industrial, Commercial, and Medical Applications
Electromagnetic Launch Technology

Advisory Committee

Prof. Jiande Zhang
National University of Defense Technology
Changsha, China

Prof. John Mankowski
Center for Pulsed Power and Power Electronics
Texas Tech University, USA

Prof. Jianjun Deng
Institute of Fluid Physics, China Academy of Engineering Physics, China

Prof. David Wetz
Pulsed Power and Energy Lab
University of Texas Arlington, USA
Schedule

Tuesday, August 6th

Check-in / Registration
2:00 PM – 5:00 PM
Welcome Reception
6:00 PM – 8:00 PM
Ocean Courtyard, #10 Ocean Wing on the map

Wednesday, August 7th

Breakfast*
7:30 AM – 8:45 AM
Session 1: Plenary Session
9:00 AM – 9:50 AM
Coffee Break
9:50 AM – 10:15 AM
Session 2: HPM and RF Sources
10:15 AM – 12:00 PM
Lunch Break
12:00 PM – 2:00 PM
Session 3: PP Systems, Switches and Components I
2:00 PM – 3:30 PM
Bus Pick-up
3:45 PM
Smith Family Sunset Lu’au Dinner
4:00 PM – 9:00 PM
Bus departs 4:00 PM at Sheraton

*Breakfast: Po’ipu II, Across from #13 Garden Wind on the map
Sessions: Po’ipu I, Across from #13 Garden Wind on the map

Thursday, August 8th

Breakfast
7:30 AM – 8:30 AM
Session 4: Compact Pulsed Power
8:45 AM – 10:15 AM
Coffee Break
10:15 AM – 10:45 AM
Session 5: Electromagnetic Launch Technology
10:45 AM – 11:45 AM
Lunch Break
11:45 AM – 1:00 PM
Sunset Dinner Cruise
1:00 PM – 8:00 PM
Bus #1 Pick up 1:00 PM at Sheraton
Bus #2 Pick up 2:00 PM at Sheraton

Friday, August 9th

Breakfast
7:30 AM – 8:30 AM
Session 6: PP Systems, Switches and Components II
8:45 AM – 10:00 AM
Coffee Break
10:00 AM – 10:30AM
Session 7: Industrial, Commercial, & Medical Apps
10:30 AM – 12:15 PM

NOTE: SCHEDULE IS SUBJECT TO CHANGE
Technical Program

Session 1: Plenary
Wednesday, August 7th
9:00 AM – 9:50 AM

**Chair:** Prof. John Mankowski – Center for Pulsed Power and Power Electronics, Texas Tech University, Lubbock, TX, USA

**9:00 AM**

**INTRODUCTORY REMARKS**

Prof. John Mankowski – Center for Pulsed Power and Power Electronics, Texas Tech University, Lubbock, TX, USA

**9:05 AM – PLENARY**

**APPLICATIONS OF PULSED POWER TO HIGH POWER MICROWAVES**

Dr. Thomas J. Karr

*Assistant Director, Directed Energy*

**OUUD (R&E)**

**3030 Defense Pentagon**

**3C168**

**Washington, DC 20301 USA**

**9:50 AM – Coffee Break**

Session 2: HIGH POWER MICROWAVES AND RF SOURCES
Wednesday, August 7th
10:15 AM – 12:00 PM

**Chair:** Prof. James Dickens – Center for Pulsed Power and Power Electronics, Texas Tech University, Lubbock, TX, USA

**10:15 AM**

**EXPERIMENTAL STUDY OF E-BAND RELATIVISTIC BACKWARD WAVE OSCILLATOR**

Ahmed Elfgani, Liangjie Bi, Dmitrii Andreev, Antonio De Alleluia, Artem Kuskov, and Edl Schamiloglu

*Department of Electrical and Computer Engineering*

**MSC01 1100, University of New Mexico**

**Albuquerque, NM 87131-0001 USA**

Experimental results are presented of a relativistic backward wave oscillator (RBWO) operating in E-band. An overmoded slow wave structure (SWS) with rectangular corrugations was designed to generate a higher order mode at 78GHz. In order to increase the interaction impedance and to avoid RF breakdown, rectangular corrugations with a relativistic hollow electron beam were chosen. The characteristics of this millimeter wave source were studied for electron energies 400 – 500 keV and beam currents 2.5 – 3.5 kA.
The SWS was SLA 3D printed and Semibright copper finished using electroplating method. The RBWO was driven by a voltage pulse that has a half sinusoidal wave-like shape and FWHM duration of 12 ns (SINUS-6 accelerator). Heterodyning technique was used to step down the frequency using an E-band balanced mixer and mechanically tuned Gunn oscillator as a local oscillator. Also, power measurement was utilized using an amplitude detector. In addition, open-shutter photography and a neon bulb array were used to capture the radiation pattern of the output mode.


*Work supported by DARPA Grant #N66001-16-1-4042

10:30 AM

**CALCULATION OF ACCURATE DISPERSION DIAGRAMS FOR MILLIMETER-WAVELENGTH SLOW-WAVE STRUCTURES (SWSs) OF VACUUM ELECTRON DEVICES (VEDs)**

Andrey D. Andreev, K. Nusrat Islam, Ahmed Elfrgani, Artem Kuskov, and Edl Schamiloglu

*Department of Electrical and Computer Engineering*

*MSC01 1100, University of New Mexico*

*Albuquerque, NM 87131-0001 USA*

The most important characteristic of any VED’s SWS is the dispersion diagram, which basically shows how many wavelengths of each specific electromagnetic (EM) mode fits within the given SWS characterized by its own specific geometry, dielectric properties, and boundary conditions. Additionally, since a wavelength of an EM mode uniquely determines the frequency of electric field oscillations of the given EM mode, the dispersion diagram shows curves or relationships between wavelengths and frequencies of all EM modes possible to exist inside the given SWS.

For azimuthally varying SWSs found in magnetrons and amplitrons, the dispersion diagram is usually constructed as the dependence of the frequency of electric field oscillations on the azimuthal angle within which one wavelength of an EM mode oscillating with that frequency is constrained for all EM modes. For the axially varying SWSs found in O-type Cherenkov VEDs, the dispersion diagram is constructed as a dependence of a frequency of electric field oscillations on the wavenumber of all EM modes possible to oscillate at that frequency.

The operating point of a VED may be found in the vicinity of the intersection between the VED’s dispersion curves and the so-called beam line showing how fast the beam electrons move along a distance determined as one wavelength on the VED’s dispersion diagram.

We calculated accurate SWS’s dispersion diagrams for a circular dielectric loaded TWT designed to operate at 94 GHz\(^1\) and for a circular overmoded BWO designed to operate at 75 GHz\(^2\). Both dispersion diagrams are calculated numerically using the 2D Poisson SuperFish code by taking advantage of the fact that SWSs of both tubes are azimuthally symmetric and both are intended to operate in one of the azimuthally symmetric TM\(_{0n}\) EM modes with zero circumferential electric field oscillations.


* This work supported by DARPA Grant #N66001-16-1-4042 and Los Alamos National Laboratory Contract #436121.

10:45 AM

ELECTRIC WEAPONS AND MILITARY ENERGY TRENDS

Geoff Staines and Juleigh Perona
General Atomics Electromagnetic Systems Group
16530 Via Esprillo, San Diego, CA 92127

While the advantages of electromagnetic launch are usually expressed in terms of improved performance of individual weapon systems, especially hypervelocity, there is a larger context provided by a likely trend in increased electrification of military energy that further incentivizes the development of electric weapons, including those based on pulsed power systems.

As combustion powered the 20th century, electric propulsion is set to power the 21st and beyond. This technology disruption is being driven by technical advances in artificial intelligence, computing power, batteries, electric powertrains, and ride-hailing services.

It is reasonable to assume that such dramatic technical disruption in civilian transportation technology over the next 10-40 years will drive increasing electrification of military energy usage, including both mobility and weapons. Characteristics of electric civilian transportation with obvious military benefits include autonomy, improved safety/survivability, high efficiency, high peak power available instantly, and higher reliability/availability of platforms. In addition, reduced vehicle thermal and acoustic signatures provide important stealth advantages for electric powertrains.

The potential for technological surprise exists if the US continues to invest primarily in incremental advances to combustion-powered technology while emerging nations leapfrog to electric mobility. This is occurring right now in the civilian automotive industry as strong Chinese investment in electric vehicles renders moot its need to catch up in the quality of its combustion-powered vehicles.

Increasing electrification of military power and energy will favor the development of electric weapons such as lasers and electromagnetic launchers, eliminating dedicated propellant logistics. Rather than trading off magazine depth against platform range, using electrical energy for both mobility and firepower enables both to be maximized simultaneously. Further, these weapons can make use of onboard battery and power conversion.

This presentation will provide an overview of trends in the electrification of civilian transportation that are expected to drive increasing electrification of military power and energy. The potentially revolutionary benefits of this trend will be discussed, including simpler integration of electric...
weapons on electric platforms compared to today’s non-electric platforms. In the future, electric weapons such as railgun launchers will not only offer advantages such as hypervelocity launch but will be easier to integrate into electric platforms than conventional non-electric weapons.

11:00 AM

RECENT DEVELOPMENT ON THE MODELING OF MULTI-FREQUENCY AND NON-SINUSOIDAL FIELD DRIVEN MULTIPACTOR*

Peng Zhang¹, Asif Iqbal¹, De-Qi Wen¹, Patrick Y. Wong¹, John Verboncoeur¹,²

¹Department of Electrical and Computer Engineering, Michigan State University, East Lansing, Michigan, 48824, USA
²Department of Computational Mathematics, Science and Engineering, Michigan State University, East Lansing, Michigan, 48824, USA

Multipactor discharge¹ is a ubiquitous phenomenon observed in a multitude of devices that employ microwaves. Multipactor has been a major concern for high power microwave (HPM) sources, rf accelerators, and space-based communication systems. The satellite communications community is placing great effort into mitigating multipactor². This paper summarizes recent modeling efforts at Michigan State University on multipactor discharge driven by multi-frequency or non-sinusoidal electric fields. We investigate multipactor susceptibility³ and the time dependent physics⁴ of multipactor discharge on a single dielectric surface by a novel multiparticle Monte Carlo (MC) simulator with adaptive time steps. We also explore possible mitigation of multipactor by controlling the non-sinusoidal waveform of the driving electric field⁵. It is found that decreasing the half peak width of an incident Gaussian electric field can reduce the strength of the multipactor by an order of magnitude at fixed time-averaged input power. This technique is potentially applicable to increase the breakdown threshold of rf windows in high power microwave transmission devices Also highlighted is the effect of multipactor on the quality of a signal⁶.


*Work supported by AFOSR MURI Grant No. FA9550-18-1-0062.

11:15 AM

CROSSED-FIELD, HIGH POWER MICROWAVE OSCILLATORS AND AMPLIFIERS *

Ronald M. Gilgenbach, Steven Exelby, Drew Packard, Stephen Langellotti, Brendan Sporer, Christopher Swenson, Nicholas Jordan, Ryan McBride and Yue-Ying Lau

Plasma, Pulsed Power and Microwave Laboratory
Nuclear Engineering and Radiological Sciences Dept.,
University of Michigan, Ann Arbor, MI 48109-2104 USA
Experiments and simulations are underway at UM on several innovative variants of crossed-field devices for HPM generation. A Recirculating, Planar Crossed-Field Amplifier (RPCFA) is based on the device invented at UM. A copper, slow-wave structure was fabricated with lost-wax, 3-D printing. The amplifier is driven by MELBA at parameters: V=300 kV, I=1-10 kA and pulse lengths typically 0.5 microseconds. Input microwave power up to MW levels is supplied by a MG5193 magnetron at 3 GHz. For input power >150 kW, the RPCFA demonstrates mean gain of 8.7 dB and output power up to ~6 MW, limited by RF breakdown.

The second, innovative, crossed-field device under investigation is the Harmonic Recirculating Planar Magnetron (HRPM). This device utilizes two separate arrays of cavity-slow-wave-structures at two different frequencies. In order to stimulate the emission of harmonic radiation, the resonant frequencies of the cavities are 1.15 GHz (L-band) and 2.3 GHz (S-band). By placing the S-band cavities downstream of the L-band cavities, the harmonic content of the spokes excites the generation of 2.3 GHz. This mechanism has been verified by reversing the direction of beam velocity. Experiments driven by MELBA have generated nearly 10 MW of harmonically-primed S-band radiation.

The third crossed-field device to be explored is the Magnetically Insulated Line Oscillator (MILO). Single and multifrequency MILO devices are being designed to be driven by the MELBA Marx-generator facility, the 4-cavity BLUE LTD facility, and a 6-cavity, 60-MW, 10-J, 1-ft3 Mini-LTD recently donated to UM from AFRL. The BLUE facility (50 GW, 8 kJ, 1 m3, 150 kA, 100 ns) will provide a variable drive voltage (50–800 kV) and a variable driver impedance (0.7–20 ohm), which will be well-matched to a low-impedance MILO load (2–6 ohm).


*Research supported by AFOSR Grant FA9550-15-1-0097, by the Office of Naval Research under grant numbers N00014-16-1-2353, N00014-18-1-2499 and N00014-19-1-2262, L3 Electron Devices, and AFRL for ICEPIC access.

11:30 AM

**WIDEBAND MATCHING OF EM-PIC SIMULATIONS USING A MULTIPLE PHASE VELOCITY METHOD WITH APPLICATION TO FOLDED GUIDE TWAS**

Larry D Ludeking

*Northrop Grumman Innovation Systems*

A multi-phase velocity method based on the Higdon\(^1\) operator approach using the auxiliary variable method is used to provide a wide band absorbing boundary condition. The method can be employed to arbitrary order. Used up to 4th order, it provides for the injection of extremely low reflection incident waves into the simulation interior, as well as near perfect absorption of scattering outgoing waves. Typical numerical reflections across the bandwidth for rectangular waveguides are of the level -50dB, with some degradation near the cutoff frequency.
The Higdon operator of order $J$ may be described as follows for wave propagation of the transverse electric field, $E_T$, along the $z$ axis:

$$\left[ \prod_{j=1}^{J} \left( \partial_z + v_j \partial_z \right) \right] E_T = 0$$

The parameters $v_j$, can be seen to represent phase velocities of the wave. For $J=1$, this reduces to the familiar 1-dimensional wave equation in which the sign of the phase velocity may be used to indicate a forward or backward traveling wave. Use of this expression directly for values of $J=2$, leads to the 2nd order phase velocity model previously reported by the authors\(^2\). Using the auxiliary variable approach, the method can be employed to high order with relative simplicity.

As $J$ increases it becomes necessary to capture information that is more remote spatially and temporally from the boundary edge. This runs into the issue of geometry variation as the information capture is carried deeper into the simulation. We will report on our implementation of this method, the performance and bandwidth characteristics. We will also describe the application to a moderately high gain serpentine amplifier at 95GHz.


Work supported by Northrop Grumman Innovation Systems

11:45 AM

**IMPLICIT AND HYBRID TECHNIQUES FOR THE SIMULATION OF HIGH-DENSITY VOLUMETRIC AND ELECTRODE PLASMAS FOR PULSED POWER APPLICATIONS**

Dale R. Welch

_Voss Scientific, LLC, Albuquerque, NM 87108 USA_

Recent advances in implicit and hybrid techniques have demonstrated that finite-difference-time-domain particle-in-cell (PIC) simulation codes can effectively model volumetric and electrode plasmas at high density. Plasma generation and evolution can seriously affect pulsed performance. Accurate plasma modeling is critical for understanding the performance of existing machines and for designing the next generation of machines. Energy-conserving implicit kinetic algorithms greatly relax the spatial Debye length and temporal plasma frequency constraints allowing for larger simulations volumes and times. Including PIC hybrid techniques further accelerates the computational speed. These capabilities are being applied to pulse-power accelerators, high power diodes, microwave sources, and gas switches. We will describe PIC methodologies for kinetic and multi-fluid simulation as well as hybrid techniques for blending the various PIC descriptions into a single integrated simulation. Finally, practical examples of these techniques in stressing plasma physics environments will be presented using the LSP code.\(^1\)

1. LSP is a commercial software product of Northrop Grumman (https://www.northropgrumman.com/Capabilities/PICCodeSoftware/LSP).
A COMPARISON OF OIL BASED ENERGY DIVERTER SWITCH GEOMETRIES FOR USE ON PULSED POWER DRIVERS ENABLING DYNAMIC MATERIAL PHYSICS EXPERIMENTS*

Brian S. Stoltzfus, Landon Collier, Joseph Felix and Cayetano Wagner

Sandia National Laboratories, 1515 Eubank Blvd. SE
Albuquerque, NM 87123 USA

Electromagnetic pulsed power drivers have been used to generate acoustic pulses for use in Dynamic Material Physics (DMP) experiments at Sandia National Laboratories for the past 20 years. A recently employed style of DMP driver at Sandia utilizes many distributed, transit time isolated, energy storage units to shape a current pulse through a load in time. Being that these loads are relatively low inductance short circuits, the reflections sent back to the driver are reverse polarity and carry a significant fraction of the forward going wave energy. Well-designed energy diverters can be used to dissipate this reflected energy efficiently, which protects the machine from late time insulator failures and reduces the energy dissipated in the load region of the machine after the experiment is complete.

This paper compares four different oil diverter electrode geometries each with a presumed advantage. These geometries range from a highly enhanced, highly divergent, point type electrode to a near uniform field, full radius, spherical electrode. The oil gaps were 1-2 mm and the peak voltage was ~120 kV. It was noted that the highly divergent configuration gave the most reliable performance in this test configuration. In addition to electrode geometry, we tested the effect of voltage polarity on performance. As expected, having the enhanced electrode as the cathode during the main pulse resulted in a wide operational range while the reverse configuration was ineffective.

*Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.
The Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory (LANL) uses two linear-induction accelerators (LIAs) for flash x-ray radiography of hydrodynamic tests. The Axis-I LIA uses a single beam pulse of 60 ns, 20 MeV, and 2 kA. The Axis-II LIA uses a long beam pulse, and a kicker to generate four radiation pulses.

This presentation reviews the status of the accelerators, their performance, and describes plans for future upgrades and technology enhancements to increase the radiographic capability of the machines and facility.

*Work supported by the US National Nuclear Security Agency and the US Department of Energy under contract DE-AC52-06NA25396

2:30 PM

INVESTIGATION OF LOW AMPLITUDE LIGHTING STRIKES ON LOW VOLTAGE ELECTRICAL SYSTEMS

D. H. Barnett¹, L. Collier¹, W. Brooks¹, J. Dickens¹, J. Mankowski¹, D. Hattz², W. A. Harrison², Andreas A. Neuber¹

¹Center for Pulsed Power and Power Electronics, Dept. of Electrical and Computer Engineering, Texas Tech University, Lubbock, TX 79409, USA

²Mission Engineering Development Group
CNS Pantex, FM2373 and HWY 60, Amarillo, TX 79120

This study serves to investigate the voltage and current development in commercial electrical systems and the impact of various protection schemes. Various tests are conducted on miniature mock electrical systems to determine breakdown thresholds and mechanisms. The area of interest includes low current amplitude lightning impulses in the range of 2 kA to 5 kA peak. The test setup is constructed from a 4 stage, 44 kJ Marx generator capable of 400 kV impulses. To further control the testing, a low inductance ground path is used along with a variable resistor, inductor circuit to control the impulse characteristics. The risetime is adjusted from 500 ns to 5 µs with peak current from 2 kA to 5 kA. Under test are small sections of conduit systems of 10 ft to 50 ft with various junctions and connections to mimic commercial electrical systems. These flaws or lack thereof are evaluated for breakdown threshold and current flow direction. Common wires under test are 10 and 12 AWG both stranded and solid core THHN along with different types of MOVs placed at various points in the system to mimic typical lightning protection schemes. Voltage and current measurements are taken at the entry and exit points in the conduit system under test. A photomultiplier tube (PMT) is used for diagnostic measurement of arc characteristics inside the conduit during lightning impulses. Resulting voltage and current waveforms are presented for different various risetime impulses and setups ups along with MOV effects.

2:45 PM

INSULATOR SURFACE FLASHOVER PERFORMANCE IN VACUUM UNDER PULSED VOLTAGE OF REVERSED POLARITY*

Feng Li, Wenjie Yang, Jihao Jiang, Le Xu
The insulator surface performance in vacuum is an important factor in pulsed power system. The pulsed voltage was not an ideal single polarity pulsed waveform on the insulator in vacuum. The reversed polarity pulsed voltage would be applied on insulator after main pulsed voltage. This paper investigated the vacuum insulator surface performance under pulsed voltage of reversed polarity after main pulse. The experimental results show that the surface flashover voltage of XLPS in vacuum would be decreased by reversed polarity pulse voltage. The surface charge distribution might be changed by reversed polarity voltage. The electrons would be produced in original anode triple junction after polarity voltage action and the flashover could be formed quickly. Thus, the design of rep-rate pulsed power facility should consider the influence of the reversed polarity pulsed voltage.

*Work supported by the National Nature Science Foundation of China under Grant 51307155, Grant 51277168, and Grant 51707180.*

3:00 PM

**THE SERIES PULSE-LINE INTEGRATED TEST STAND (SPLITS), A RECONFIGURABLE SERIES PULSE FORMING LINE FOR MULTIPLE 300KV PULSES***

Gregory E. Dale, Mark T. Crawford and Juan Barraza

Los Alamos National Laboratory, SM30 Bikini Atoll Rd, Los Alamos, NM, 87544

Patrick A. Corcoran, Doug Weidenheimer, David Spelts, Alannah Myers, Norman Link, Richard Stevens and Ray Jaitly

L3 Applied Technologies, Inc., 2700 Merced Street, San Leandro, CA 94577 USA

Joe M. Chen, Rena Berdine and Salvador Portillo

University of New Mexico
Department of Electrical and Computer Engineering
Albuquerque, NM 87131-0001 USA

The Advanced Sources and Detectors (ASD) Scorpius Project is responsible for developing a linear induction accelerator (LIA) that produces a multi-pulse, single-axis radiographic capability that will be deployed in the U1a Complex at Nevada National Security Site (NNSS). The LIA will have a 20-MeV end-point energy and will generate four ~ 80-ns electron beam pulses with variable pulse spacing between 200 and 1,000 ns.

Los Alamos National Laboratory, in partnership with L3 Applied Technologies and the University of New Mexico are developing a multi-pulse series pulse forming water line to generate the high voltage pulses for the Scorpius LIA cells. The components for this system are being developed on the Series Pulse-Line Integrated Test Stand (SPLITS).

SPLITS consists of four 60-ns water line sections in series, which will create four independent 120-ns high-voltage pulses. The water line charge voltage is over 600 kV which will create output pulses up to 300 kV. Each water line section is independently charged with a Marx charge unit to
allow for charge optimization with independent pulse timing. The system can also be charged with pulsed transformers if desired.

Each water line section is discharged by a laser-triggered high-pressure SF6 gas switch, allowing independent timing and amplitude adjustment of the four pulses. The water transmission line impedance is 5.5 ohms and is used to drive eight 44-Ohm cables. These eight cables will service four Scorpius LIA cells, which are driven through two 44-Ohm cables each.

The design of the pulse lines and system configurability is described and recent experimental results are presented.

*Work supported by the National Nuclear Security Administration

3:15 PM

**GENERATION OF ENERGETIC ELECTRONS WITH NANOSECOND PULSED POWER IN ATMOSPHERIC PRESSURE FUEL-AIR MIXTURES**

Sanjana Kerketta and Martin Gundersen

*Department of Electrical and Computer Engineering- Electrophysics, University of Southern California, Los Angeles, CA 90089-0483 USA*

Nonequilibrium nanosecond pulsed plasma, which is transient in nature due to the short time during which the pulsed power is applied, has energy efficient advantages and relatively low cost for a range of applications including in the areas of combustion and exhaust remediation. However, the understanding of the plasma physics underlying this transient plasma is incomplete. We report studies of these processes and investigation into the possibility that the efficacy is the result of generation of higher energy electrons leading to a different initial chemistry in the plasma. Transient plasma is hypothesized to produce a brief presence (<10ns) of significant overvoltage near the cathode surface. The presence of surface irregularities would then result in a combination of several emission processes including thermo-field emission, and these are potential sources of these higher energy electrons being drawn out from the cathode during the rising phase of the voltage. We will present cathode SEM images post exposure to high voltage pulses that indicate the involvement of such surface processes. Experiments to measure the electron beam energy will be discussed. It is concluded that the role of surface processes and higher energy electrons will be clarified with further experimentation and analysis in understanding the efficacy of transient plasma for these applications.

4:00 PM – Smith Family Garden Lu’au Dinner

*Bus departs Sheraton*

5:00 PM Welcome: Join us in paradise near the sacred Wailua River, a place once reserved for Hawaiian royalty. Receive your shell lei and either take a narrated tram tour or a leisurely stroll around the lush 30-acre gardens

6:00 PM Imu Ceremony: Meet some of our family members and learn of the Hawaiian cooking method called Kalua — where Kalua pig is wrapped in ti leaves and cooked to perfection in our earthen imu oven.
6:15 PM Cocktails and Music: Have a mai tai, beer, or glass of wine at the open bar while the Smith family entertains with Hawaiian songs. (Soft drinks and juice are also available.)

6:30 PM Luau Feast: The music continues while you enjoy traditional flavors and island favorites like kalua pork, beef teriyaki, chicken adobo, and sweet’n’sour mahimahi. Sample our ono local specialties like lomi salmon, fresh poi, Hawaiian sweet potato, mac salad, namasu salad and scrumptious tropical desserts!

8:00 PM Rhythm of Aloha Show: Move to the rhythm with colorful, authentic performances from Hawaii, Tahiti, Samoa, Philippines, New Zealand and Japan in our spacious open-air, torch-lit “Pele Amphitheater” (complete with erupting volcano!).

Session 4: COMPACT PULSED POWER
Thursday, August 8th
8:45 AM – 10:15 AM
Chair: Bill Nunnally – Chief Engineer, American Advanced Technologies Inc., Austin, TX, USA

8:45 AM
PORTABLE SHORT PULSE NEUTRON SOURCE FOR IDENTIFICATION AND LOCALIZATION OF CLANDESTINE NUCLEAR MATERIALS* **

Brady Gall, Michael Heika, Michael Blasco, Joseph Bellow, Tim Meehan, Paul Guss, Mark Gerling1, Yuri Podpaly2.

Mission Support and Test Services LLC, 2621 Losee Rd.
North Las Vegas, NV 89030 USA
1Sandia National Laboratories, 2Lawrence Livermore National Laboratory

The reliable detection of special nuclear materials continues to be a primary goal of national security programs conducted by Defense Nuclear Nonproliferation. While these programs are diverse, many share a core need for a small, robust pulsed neutron generator. This project addresses this need by deploying a recently developed portable dense plasma focus (DPF) neutron source to identify and localize special nuclear material objects. The portable DPF system weighs approximately 100 lbs and uses 750 W of utility electrical power. The DPF produces 30 nanosecond-wide neutron pulses with a total yield of 6E7 neutrons per pulse at the DD fusion energy of 2.45 MeV. The system has a repetition rate of 0.2 Hz., resulting in a time-average yield of approximately 1.2E7 neutrons per second and future iterations will be expandable to 10 times this rate. The portable DPF was deployed at the Device Assembly Facility (DAF), located at the Nevada National Security Site (NNSS), to measure the active interrogation response products of highly enriched uranium (HEU) objects. Three primary diagnostic systems were implemented to measure the response products of the HEU objects: 1. Sandia National Laboratories’ (SNL) Mobile Imager of Neutrons for Emergency Responders (MINER) detector array to determine the spatial localization of the neutron-stimulated HEU object; 2. Lawrence Livermore National Laboratory’s (LLNL) recently developed short-pulse fast fission diagnostic to obtain signature fast-fission neutron spectra of the fissioning HEU object; and 3. MSTS’s time-resolved gamma spectrometer
to measure prompt and delayed HEU photon fission products. These three compact diagnostics solutions, combined with the portable DPF system, provide safe, mobile, and effective integrated platform for sensing and locating clandestine nuclear materials.

* This work was done by Mission Support and Test Services LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy and supported by the Site-Directed Research and Development Program. DOE/NV/03624—0399

**Portions of this work were performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and were supported by the LLNL-LDRD Program under Project No. 19-FS-034.

9:00 AM

DEVELOPMENT OF PULSED POWER GENERATOR’S CONTROLLER USING ARDUINO AND FPGA

Shunsei Kawamura and Masahiro Akiyama
Iwate University
3-18-8 Ueda, Morioka, Iwate 020-8550 Japan

Pulsed power generators have been used in various fields, such as biology, environmental agriculture, health occupation and so on. Therefore, researchers have demanded functions such as high power, short pulse, safety, miniaturization, low cost and ease of use. Our research aims to develop the generator high performance, low cost and ease of use. Developing pulsed power generator consists of a charger (152A-1.5kV-POS), a pulsed power unit and a controller. Pulsed power unit is a circuit to create pulsed power.

Our developing pulsed power generator’s controller consists of an Arduino Nano (Arduino-A000005) and a Field Programmable Gate Array (FPGA). Arduino functions are connecting from a PC to the FPGA (Spartan-3AN), sending data to the FPGA, displayed on a Liquid Crystal Display (LCD) and connecting sensing devices. FPGA functions are receiving data from the Arduino and controlled the charger and a switching device in the pulsed power unit.

The controller has a Manual mode and a PC mode. The Manual mode can output various pulses without the PC. Available setting values are frequency, voltage and number of shots. The PC mode can output more various control by the original software. Available setting values are frequency, voltage, number of shots and outputting time. Furthermore, it can combine some pulses and repeating the pulse.

Operating environment of the software is Windows 7, 8.1, 10. Development environment is Visual Studio 2017 on Windows 10. The software is imported a Graphical User Interface (GUI). Users can operate only a pointing device. The software is composed of buttons, drop boxes, text boxes, check boxes and tab pages. It can be updated depending on the pulsed power generator evolves. Easy operations have been achieved with our control systems.

9:15 AM

GAS GUN CONFIGURED MAGNETIC COMPRESSION GENERATOR*
This project explored the concept of achieving current amplification by principles of high-explosive magnetic compression generation\(^1\) (HEMCG) but without the use of high explosives. Moreover, the project was designed to prove that a gas gun or launcher could be configured to provide the input energy and action necessary for magnetic compression generation performance in a more controlled, cost-effective safe manner.


*This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy and supported by the Site-Directed Research and Development Program. DOE/NV/03624--0486.

9:30 AM

**DESIGN AND IMPLEMENTATION OF SOLID-STATE INJECTION KICKER MODULATOR & FAST COUNTER KICKER MODULATOR FOR PLS-II**

Suk-Ho An, Byung-Joon Lee

*Pohang Accelerator Laboratory, Po-hang, 37673 Korea*

The Pohang Light Source (PLS) - II is a 3 GeV third-generation synchrotron radiation facility. To inject electron beam from LINAC, an injection kicker modulator is installed in the PLS-II storage ring tunnel. A fast counter kicker modulator is also installed for beam oscillation reduction during Injection. This paper describes the design and implementation of the solid-state injection kicker modulator and the fast counter kicker modulator for PLS-II. The achieved capability of the injection kicker modulator demonstrates that it fulfills the design requirement of providing half-sine pulsed current of 10kA (peak), 6µs (Base-width), with jitter < 2ns (Standard deviation). The achieved capability of the fast counter kicker modulation is also presented. The simulation and experimental results are presented to demonstrate the performance of the implemented modulators.

9:45 AM

**DESIGN OF COMPACT SOLID-STATE PULSED POWER MODULATOR FOR KICKER**

Sung-Roc Jang, Hyoung-Suk Kim, Chan-Hun

*KERI, Changwon 51543, Korea*

Suk-Ho An, Byung-Joon Lee

*PAL, Pohang 37673, Korea*

Hong-Je Ryoo

*Chung-Ang University, Seoul 06974, Korea*
This paper describes the design of compact solid-state pulsed power modulator for accelerator kicker system that requires 10 kV, 200 A with rising & falling time less than 10ns and pulse width less than 80ns. In order to improve the switching performance of series stacked MOSFETs, the gate driving circuit is designed with one turn transformer that provides synchronous signal and driving power. To minimize inductance of the signal line for gate driving as well as the power line for delivering output pulse, the design of compact stacking structure is presented. In addition, the active pull-down circuit is proposed to discharge the stored energy on the parasitic capacitance and shorten the falling time. The detailed design and implementation of the proposed nanosecond pulsed power modulator are discussed with experimental verification.


*This work was jointly supported by Korea Electrotechnology Research Institute (KERI) Primary research program through the National Research Council of Science & Technology (NST) funded by the Ministry of Science and ICT (MSIT) (No. 19-12-N0101-12)

10:00 AM

MITIGATION OF SURFACE FLASHOVER IN MEDIUM VOLTAGE DC COMPONENTS USING LAYERED POLYCRYSTALLINE AlN SUBSTRATES

Jane M. Lehr¹, Lisa Fisher¹, Cameron Harjes¹, Leonardo Rossetti¹, and Jason Neely²

¹University of New Mexico, Electrical and Computer Engineering Department
²Sandia National Laboratories, Albuquerque, New Mexico

Power electronic packaging is one of the fastest changing areas of technology in the power electronic industry due to the rapid advances in power integrated circuit (IC) fabrication and the demands of a growing market. This includes the development and maturation of advanced electronic materials such as wide bandgap and ultra-wide bandgap semiconductors, which enable the realization of higher voltage switching devices, as well as insulating substrates that are compatible with these materials. In this work, a compact insulating polycrystalline Aluminum Nitride substrate is described, and its voltage breakdown characteristics are evaluated. In particular, due to the properties of AlN, the operating voltage of the substrate depends most on the surface flashover voltage. Thus, this work focuses on modeling the physical mechanisms of surface flashover and mitigating this breakdown mechanism by incorporating features to inhibit surface avalanche due to secondary electron emission.

10:15 AM – Coffee Break
DESIGN AND COMMISSIONING OF A MEDIUM VOLTAGE TESTBED DEPLOYING TRANSIENT LOADS*

Alex N. Johnston, David A. Dodson, Brian J. McRee, David A. Wetz, Greg K. Turner, and Jacob L. Sanchez

University of Texas at Arlington (UTA), Electrical Engineering Department, 416 Yates Street, Rm. 518, Arlington, TX 76019 USA

Microgrids have been studied considerably over the last decade and are now able to be uniquely designed and controlled to handle a wide variety of loads, many of which may operate in a transient manner. Historically, electric grids have relied upon fossil fuel powered motors to spin generators that source the vast majority of the electric power they need. Microgrids deploy a host of different distributed generation sources that are interconnected and controlled in real time to improve overall grid reliability and redundancy. Multiple microgrids are able to be interconnected to form a larger grid where power can be shared across smaller grids when needed. The use of a medium-voltage-direct-current (MVDC) is one possible solution to minimize power loss in the conductors and to reduce the power conversion requirement when high voltage loads are used. The non-continuous operation of such loads could introduce harmonics into the power system that severely impact power quality. In an effort to study the reliable operation and control of such a power system, the Pulsed Power and Energy Laboratory (PPEL) at the University of Texas at Arlington (UTA) has designed and installed a testbed that can be used to study a small microgrid deploying transient loads. The testbed, operating at power levels in excess of 300 kW, utilizes distributed AC and DC power sources and loads operating at the 480 VAC, 4160 VAC, 1 kVDC, 6 kVDC, and 12 kVDC, respectively. The testbed is being extended utilizing a hardware in the loop (HIL) simulator. The paper presented here will discuss the design of the testbed, the test plan methodology, and the results collected so far.

*Work supported by the US Office of Naval Research (ONR) under grants N00014-17-1-2801 and N00014-18-1-2206

EXPERIMENT AND NUMERICAL ANALYSIS ON THE RESISTIVE OVERLAY RAIL WITH THE 40 MM BORE RAILGUN

Sanghyuk An, Young-Hyun Lee, Seong-Ho Kim, Byungha Lee, and Youngseok Bae

Agency for Defense Development, Yuseong, Daegeon, 34186 Korea

The gouging phenomenon is the one of the biggest difficulties to make the electromagnetic propulsion useful. The resistive overlay rail, where two different materials are bonded together, is known as one of the possible solutions to increase rail life of electromagnetic launchers [1,2].
Meanwhile, the energy transfer efficiency to the armature decreases, as the rail area of high resistance increases within a given rail area.

We designed and manufactured the resistive overlay railgun where the bore size is 40 mm by 50 mm. A C-shaped aluminum armature was shot several times with the velocity over 2 kilometers per second and the gouging was not induced, while it was shown in the experiment with a copper rail.

In this paper, we analyze the transient velocity skin effect (VSE) in terms of current diffusion using the two-dimensional and three-dimensional finite element methods (FEM). When current is spread through the rail and armature, VSE changes the amount of current in the internal and external metals of the overlay rail. The magnetization effect of the inner steel rail was also reflected in the simulation from the results using the Gauss meter. The propulsive inductance gradient calculated from the axial Lorentz force of the armature due to transient changes of the current profile shows the dependence on the movement of the armature. The rail inductance gradient obtained without an armature was compared with the propulsive inductance gradient. We also simulated the circuit using the calculated inductance gradients and compared the simulation results with the experimental data.


11:15 AM

TRANSIENT LOADING OF ULTRACAPACITORS*

Alex N. Johnston, Charles N. Nybeck, and David A. Wetz

University of Texas at Arlington (UTA), Electrical Engineering Department, 416 Yates Street, Rm. 518, Arlington, TX 76019 USA

Ultracapacitors are of increasing interest in the high voltage community due to their ability to source high transient power while also offering a modest energy density. A market study of commercially available ultracapacitors finds a few different models available with slightly different internal resistance, energy density, and power density parameters, among others. Hybrid ultracapacitor technologies, such as lithium-ion capacitors, have also been developed that have much higher energy density with nearly the same power density. In the work presented here, a few different commercially available off the shelf ultracapacitors and lithium-ion capacitors have been procured and evaluated into a low impedance load, few hundred micro-Omhs, in a transient manner. The design of experiments as well as the impedance and power density results obtained will be presented.

*Work supported by the US Office of Naval Research (ONR) under grant N00014-17-1-3015

11:30 PM – Lunch Break
1:00 PM – Bus #1 to Catamaran Dinner Cruise – bus departs Sheraton

50 foot sailing catamaran - Watch the colors of the coastline change as the sun sinks into the ocean; it’s truly gorgeous. Make sure you bring your camera on this spectacular sightseeing tour. With her sleek construction and design, Leila slips quickly and smoothly through the waters. The catamaran design allows for level sailing. With no more than 10 degrees of “heel,” you won’t be sailing sideways. Although Leila’s two-hull design is based on a historical prototype, she truly is a modern, state-of-the-art vessel.

2:00 PM – Bus #2 to Catamaran Dinner Cruise - bus departs Sheraton

65 foot powered catamaran - At 65’, this agile power cat is long and wide enough to give you a swift, adventurous ride even at her top speeds. Built with safety and comfort in mind, Holo Holo’s design is wide enough to eliminate any long, side-to-side rolling motion and the hulls are narrow to slice easily through the water, resulting in a smooth ride to see the beautiful sights.


Session 6: PULSED POWER SYSTEMS, SWITCHES, AND COMPONENTS II
Friday, August 9th
8:45 AM – 10:00 AM

Chair: Prof. Andreas Neuber - Center for Pulsed Power and Power Electronics, Texas Tech University, Lubbock, TX, USA

8:45 AM

GENERATION of MEGAHertz REPETITIVE PULSES BASED ON LASER DIODE DRIVEN PHOTOCONDUCTIVE SEMICONDUCTOR SWITCHES*

Jianqiang Yuan, Weiping Xie, Yu Gu, Hongwei Liu, Lingyun Wang and Sheng Ding

Key Laboratory of Pulsed Power, Institute of Fluid Physics, CAEP, Mianyang 621900, China

Photoconductive semiconductor switches (PCSSs) are considered a promising device for applications in compact pulsed power generator due to their advantages over conventional switches, such as fast rise time, negligible time jitter, optical electrical isolation, compact packaging and high repetition rate up to MHz level.

In order to obtain trigger laser pulses with the repetition rate in MHz, driven module based on MOSFET has been developed for laser diode. Digital delay generator was used to generate pulsed signals with the repetition rate up to MHz as the trigger of MOSFET. For a lateral GaAs PCSS with a gap of 5 mm and a depth of 3 mm, the pulses with repetition rate in 9 MHz (limited by digital delay generator) and photocurrent less than 1 A has been obtained when the switch operated in linear mode. Numerical analysis shows that the observed trend of minimum on-state resistances of the switch is directly related to the carrier mobility, which changes with the electrical field strength. At bias voltages of 16 kV, the PCSS operated in nonlinear mode, and a photocurrent of
Technical Program

200 A, which is thousand times higher than that in linear mode, has been achieved. With the pulse delay of 13 μs set by digital delay generator, the pulses with repetition rate in 77 kHz has been obtained for now.

*Work supported by National Natural Science Foundation of China (51007085, 51207147, 51407170 and 51477185)

9:00 AM

ENERGY CHARACTERISTICS OF UNDERWATER DISCHARGE USING CAPACITOR DISCHARGE IN 3KV OR LESS*

Mikimasa Sugawara, Shun Kudo, Shunsei Kawamura and Masahiro Akiyama

3-18-8 Ueda, Morioka, Iwate 020-8550 JAPAN

Iwate University

Recently, pulse power has been used many fields such as agriculture, biology, environment and so on. Our research is underwater discharge using capacitor discharge in 3kV or less.

Underwater discharge was needed over voltage of 15 kV using magnetic pulse compressor (MPC). In this research, underwater discharge was succeeded about 3 kV using capacitor discharge. Output voltage, capacitor and conductivity are 1 kV to 3 kV, 0.5 or 1.0 μF, and 110 (tap water) to 45000 (sea water) μS/cm. Size of reactor is 10 cm × 10 cm × 10 cm and 500 ml, and experiment circuit is composed of DC power supply (Matsusada Precision Inc. Model HAR-5P6), and high voltage probe (Tektronix P6015A), and current monitor (Pearson Current Monitor Model 6595), and gap switch. Check the light emission at capacitor discharge in water using photosensor module (Hamamatsu H10721). Sterilization E. coli in water using capacitor discharge. Output voltage, capacitor, conductivity and E.coli are 3 kV, 1.0 μF, 45000 (sea water) μS/cm, and K-12.

As a result, discharge plasmas in 110 μS/cm were generated 3 kV by 0.5 μF and 1.0 μF, in 45000 μS/cm were generated 1 kV to 3 kV by 1.0 μF, and 0.5 μF in 45000 μS/cm were 1.5 kV to 3 kV. Discharge voltages concerned capacitance and conductivity.

*Work supported by a Government Agency

9:15 AM

FIBER-DELIVERED LASER TRIGGERED GAS SWITCH*

Sean C. Simpson

Sandia National Laboratories, 1515 Eubank Blvd. SE
Albuquerque, NM 87123 USA

Charles E. Rose
Colorado State University, Fort Collins, CO 80523 USA

Future pulsed power and accelerator applications may benefit from compact spark gap switches capable of operating at low percentages of self-break while delivering fast rise times into low impedance loads. Switches of this design would allow near-synchronous firing of 100’s to 1000’s of switches while remaining impervious to pre-fire. Previously, we’ve reported on a high pressure, air-filled, spark gap switch with small gap geometries of 1.5 - 3.5 mm triggered using a laser
induced plasma with laser energies as low as 500 uJ via fiber delivery while operating at <30% of self-break\textsuperscript{1}. We present here a second-generation switch capable of >200 kV operation with pressures >2000 PSI. This new design incorporates optical access allowing for various diagnostics such as: direct imaging, schlieren photography, ultra-fast spectroscopy, Thomson scattering, etc. In this work, we will present our most recent switch lifetime testing under various conditions, measurements of the radial channel growth, and comparison to the Martin switch model\textsuperscript{2}. Experiments are ongoing and the latest results will be reported.


*Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-6123

9:30 AM

**PULSED NEUTRON PRODUCTION PRODUCED BY 14 MeV-LEVEL INTENSE ION BEAMS ON HERMESIII AT SANDIA NATIONAL LABORATORIES**

Timothy J. Renk  
*Sandia National Laboratories Albuquerque, NM 87185 USA*

Paul F. Ottinger  
*Syntek Technologies, Fairfax, VA 22030 USA*

Russell Durrer  
*Sigma Science, Albuquerque, NM 87110 USA*

The HERMES-III accelerator (18 MV, 700kA, 40 ns) uses Inductive Voltage Adder (IVA) architecture to drive a magnetically insulated transmission line (MITL) with a 34-ohm vacuum impedance. In normal operation, the load is a Bremsstrahlung diode operated in negative polarity, from which an intense electron beam can be extracted for gamma generation. The relatively high output voltage makes HERMES attractive as a source for high-energy ions which could be used to generate pulsed neutrons using thin metal targets with high neutron-yielding cross section. To preserve the dominant negative polarity mode, ion beams are generated and propagated to neutron targets and objects for neutron exposure inside the HERMES center conductor. A radial self-field (no external coils) ion diode is designed to be compatible with the MITL impedance, and operated undermatched (~17 ohms) to capture the incoming MITL flow (2/3 of the output current).

Previous experiments indicated a diode operating voltage of 13-14 MV, and point to two proton beam currents propagating in both the ‘forward’ (e.g. into the accelerator) and ‘backward’ directions, with each beam in the 50-100 kA range, all consistent with LSP simulations. Extensive use has been made of the MCNP code to design the neutron target to maximize a) neutron energy spectrum, and b) neutrons in the forward direction. Compared to a reference thick-target
tantalum plate, two combined sub-range Co-Nb foils are predicted to produce twice the total neutron yield, and 3 times the number of neutrons > 1 MeV energy (about 60% of the total). About 5% of neutrons produced have energies > 5 MeV, and in that case, forward-directed fluence is > factor 5 compared to the rear direction. The predicted neutron spectrum is thus much more energetic than the photoneutron spectrum produced by the Bremsstrahlung diode. Additional experiments are planned, and latest results will be discussed.

*Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.

9:45 AM

SEALED HIGH ENERGY DENSITY GAS SWITCHES TOWARD COMPACT POWER CONDITIONING SYSTEMS WITH A LONG SHELF LIFE

Jane M. Lehr¹, M.D. Abdalla² and M.C. Skipper²

¹University of New Mexico
²ASR Corporation
Albuquerque, New Mexico

Safe and reliable pulsed power is a key technology for its use as special power conditioning for a wide range of industrial and military high voltage applications. Reductions in size, weight and footprint reap significant advantages over current technologies. The development of compact pulsed power systems for deployable systems requires a shift in paradigm from that of the laboratory environment where large spaces ensure reliability. A key technique to reduce the overall system size is to reduce or eliminate auxiliary systems. Towards this end, a hermetically sealed spark gap switch has been designed to eliminate the need for a gas reservoir to maintain pressure. The sealed switch has a nominal voltage rating of 100 kV and demonstrated a shelf lifetime of over one year, to date.

10:00 AM – Coffee Break

Session 7: INDUSTRIAL, COMMERCIAL AND MEDICAL APPLICATIONS

Friday, August 9th

10:30 AM – 12:15 PM

Chair: John Mankowski - Center for Pulsed Power and Power Electronics, Texas Tech University, Lubbock, TX, USA

10:30 AM

INTEGRATED KLYSTRON TEST STAND

Marcel P.J. Gaudreau, Luan Jashari, Michael Kempkes, Rebecca Simpson

Diversified Technologies, Inc. (DTI)
Bedford, MA, USA, 01730

Diversified Technologies, Inc. (DTI) recently delivered an Integrated Klystron Test Stand for klystrons under development at the Naval Research Laboratory (NRL) and Communication and
Technical Program

Power Industries, Inc. (CPI). The test stand provides an HV beam and depressed collector power supplies, mod-anode modulator, controls, and circuit/klystron protection. The Integrated Klystron Test Stand simplifies and speeds the ability of the user to safely and efficiently test and exercise the klystron over the full range of its capabilities.

The design of the equipment draws directly on previous DTI solid-state systems in operation today and shares common design elements based on DTI’s patented solid-state switching technology—which has a history of reliable operational performance across more than 600 high voltage systems around the world. A single capacitor and solid-state cathode switch provide the peak beam power while providing protection for the klystron in the event of an arc, with the ability to remove cathode voltage within ~ 1 μs after an arc is detected.

10:45 AM

STERILIZATION OF E.COLI IN BALLAST WATER USING PULSED POWER

Masahiro Akiyama, Namito Saitou and Hisanori Sone

Iwate University, Japan

Ballast water is seawater that is loaded as a weight to maintain restoring force when a large cargo ship isn’t loading luggage. Ballast water contains inherent microorganisms and bacteria. Our work is sterilization of E. coli using electrical discharge in water and dielectric barrier discharge. This conductivity of water was 44,500 μS/cm. A pulsed power generator was magnetic pulse compression circuit, and voltage was about 30 kV. The conductivity was adjusted by placing potassium nitrate from purified water. The amount of water was 500 ml., and the initial number of E. coli was 0.15 at a wavelength of 600 nm. As a result, the number of bacteria was hardly changed until 10,000 pulses.

11:00 AM

ESS KLYSTRON PRODUCTION TEST STAND

Marcel P.J. Gaudreau, Ian Roth, Noah Silverman, Michael Kempkes, Rebecca Simpson

Diversified Technologies, Inc. (DTI)
Bedford, MA, USA, 01730

Diversified Technologies, Inc. (DTI) has delivered a new long-pulse modulator klystron test stand to Communication and Power Industries (CPI) in Palo Alto, CA for full power testing of production VKP–8292A klystrons for the European Spallation Source (ESS). The output is flat to less than 0.5% over 3.3 ms. This test stand was built using hardware and designs from an earlier SBIR effort for the Department of Energy, with modifications to support ESS requirements and klystron testing operation. Earlier versions of this design are in use at IPN Orsay and CEA Saclay in France to test RF components for ESS.

This new klystron test stand allows testing of klystrons at the full ESS specifications: 120 kV, 50 A, 3.5 ms pulse, 14 Hz with margin for operating at voltages up to 130 kV. This design is based on a patented non-dissipative regulator that compensates for the capacitor droop voltage (~20%) during the pulse. This allows a much smaller capacitor than would nominally be required for the long ESS pulse, eliminating the need for a larger, more expensive capacitor bank. This test stand will speed delivery of ESS klystrons, and similar, long pulse, high power klystrons at CPI.
LARGE SCALE SYSTEM USING PULSED ELECTRIC FIELDS AS AN INVASIVE FISH BARRIER*

Michael Kempkes, Marcel P.J. Gaudreau, Ian Roth, Rebecca Simpson

Diversified Technologies, Inc. (DTI)
Bedford, MA, USA, 01730

Invasive species have become a global issue, as plants and animals are transported around the globe and introduced to ecosystems without natural predators or controls. One of these invasive species is the Asian Carp, which has infested the Mississippi river in the USA, and threatens the Great Lakes. To prevent migration of this invasive species into the Great Lakes, the US Army Corp of Engineers has built and operated two demonstration barriers using pulsed electric fields for a number of years. These barriers, installed in the Chicago Sanitary and Ship Canal downstream of Chicago, are designed to block Asian Carp from crossing from the Mississippi river into Lake Michigan through one of the known connections between the two bodies of water. As a result of the performance of these demonstration barriers, Diversified Technologies, Inc. was recently awarded a subcontract from exp Federal, under a prime contract from the US Army Corps of Engineers, to build the large pulsers required for a permanent barrier near Chicago, IL. This barrier uses bi-polar pulses driving an array of electrodes crossing the Chicago Sanitary and Ship Canal. The goal of this system is to create an electric field across the canal, from the bottom to the surface and shore to shore, sufficient to dissuade the Asian carp from crossing the field, and swimming upstream to Lake Michigan. The electric field requirements are designed to prevent even small fish from transiting the barrier. This field must also operate continuously, even in the presence of barges and ships transiting the canal. Two pulsers are planned, with the first in construction now. Each pulser includes: 4.5 MW, +/- 4 kV DC power supply, with voltage regulation; 4 MJ capacitor bank, which stores energy for the pulses; Solid State pulse switches, which produce currents up to 30 kA with a frequency of up to 100 Hz, and pulsewidths of 1 – 1,000 milliseconds; Mechanical output reversing switch, allowing the pulse polarity on the electrodes to be reversed. This paper will provide details on the design and intended operation of this pulser which will be the largest known PEF system in the world when completed.

*This effort is funded under US Army Corps of Engineers contract W912P6-18-C-0021 with exp Federal.

CHARACTERISTICS OF NANOSECONDS PULSED DISCHARGE IN ATMOSPHERIC AIR

T. Namihira and D. Wang

Institute of Pulsed Power Science, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, JAPAN

T. Ryu and H. Yamaguchi

Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, JAPAN

Nanosecond pulsed streamer discharge has unique characteristics which has difference from longer pulsed discharges. The very fast rise time, the high peak, the short duration, and the fast
fall time of the applied pulse voltage enable a large volume and uniform nonthermal plasma generation at atmospheric pressure. The properties of the nonthermal plasma formed using the nanosecond pulse voltage application are characterized by the streamer head during its propagation. In the presentation, the propagation process of and the electric field in the streamer heads would be introduced. In the experiments, the streamer heads propagation was imaged by the emICCD camera with 500 ps gate time. The electric field with time history during the streamer heads propagation was calculated from the optical emission spectroscopy. As the results, the propagation process of the streamer heads was split to two phases. First phase is the formation process of the streamer heads, on the other hand, second phase is the propagation process of the streamer heads with constant velocity (≈10 mm/ns). The electric field of the streamer heads was derived around 1,200 Td. Additionally, the control way of the streamer heads property would be also explained.


11:45 AM

**NANOSECOND PULSED PLASMA PILOTING SYSTEM FOR AN ULTRA LOW NOX INDUSTRIAL BURNER***

Robert Geiger, Jackson Pleis, and Donald Kendrick

*Clearsign Combustion, 12870 Interurban Ave S.
Seattle, WA 98168 USA*

A nanosecond pulsed power supply was used to investigate plasma-assisted combustion within an industrial burner. The burner used for this work was developed by Clearsign Combustion Corporation. The burner is an Ultra-Low NOx burner capable of achieving sub 5 ppm NOx emissions. This low NOx performance is achieved by carrying out combustion within a ceramic tile. Stabilizing the flame in the ceramic tile can be difficult under certain conditions. Low Temperature Plasma (LTP) is known to increase flame stability and therefore has the potential to bolster the performance of the burner. To generate the plasma in the burner an array of pointed electrodes placed under the ceramic tile within the test furnace. The electrodes were powered using an Eagle Harbor Technologies nanosecond power supply. This power supply was designed to generate a constant pulse width of 150 ns and up to 30 kV at pulse frequencies up to 30 kHz. This power supply can generate up to 5 kW of power which can be controlled by varying the primary voltage and/or current as well as the pulse frequency. The power supply was able to
generate and maintain an LTP that increased the flame stability and operating envelope within the burner.

2. Y. Ju and W. Sun, Prog. in Energy and Combustion Science 48 (2015)

*Work supported by a grant from the DOE SBIR program (Contract #: DE-SC0018707). Nanosecond power supplies were provided by Eagle Harbor Technologies.

12:00 PM

PULSED ELECTRIC FIELDS FOR ALGAE PREDATOR CONTROL IN OPEN POND*

Michael Kempkes, Ian Roth, Rebecca Simpson

*Diversified Technologies, Inc. (DTI)
Bedford, MA, USA, 01730

Thomas Dempster and Henri Gerken

*Arizona State University., Tempe, AZ, 85281 USA

Pulsed Electric Field (PEF) treatment of algae predators appears to be a cost effective, chemical-free approach, which can be continuously applied to algae ponds without damage to the microalgae itself. PEF processing uses short, high voltage electrical pulses to disrupt cell membranes. The difference in size and structure of typical predators, when compared to algae cells, provides a treatment window where the predators are killed without impacting the algae. Our objective is to demonstrate PEF processing as a low-cost, chemical-free method for microalgae crop protection, and to determine the cost and effectiveness of this approach in open-pond raceways. Diversified Technologies, Inc. (DTI), in cooperation with the Arizona Center for Algae Technology and Innovation (AzCATI) at Arizona State University (ASU), is in the second year of our investigation into the application of PEF for predator control in algae cultivation. In our initial testing, naturally occurring contaminated cultures were PEF-processed in the laboratory under a range of conditions. Our results indicated that PEF treatment successfully killed rotifers, ciliates, amoeba and Poteriochromonas, at field strengths that were non-lethal to algae strains, including Chlorella vulgaris. In early 2019, DTI installed a PEF system at AzCATI for long term assessment of its ability to control predators in open ponds in both continuous and intermittent applications. This system will be operated alongside non-treated ponds, under the same conditions, to assess the effectiveness of the PEF predator control. Microorganism predators are responsible for crop losses up to 30% in open pond systems, representing a huge cost for commercial algae growers. Existing crop protection methods, such as chemical treatment, are expensive, and can be difficult to apply without damaging the algae or downstream products. The operation of PEF units on pre-commercial scale, open-raceway ponds at AzCATI will allow us to collect long-term data on the costs and effectiveness of PEF predator control in real-world conditions and provide a basis for scaling to larger ponds.

*This effort is funded by USDA NIFA Phase II SBIR Grant 2017-33610-27016.
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