Diversified Technologies, Inc.

Daresbury Laboratory Short Pulse Klystron Modulators

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Diversified Technologies, Inc.

- Founded 1987 by Dr. Marcel Gaudreau (MIT PSFC)
  - Located Outside of Boston
  - 60 Employees, 6 PhDs
  - Diverse Technical Background (EE, Physics, Aero)
- Core Technology: High Power Solid-State Switching Systems
  - Solid State Modulators, Power Supplies
  - RF Transmitters
  - HV Pulsed Electric Field (PEF) Systems
- Major Market Applications
  - Radar Systems
  - Particle Accelerators
  - Power Conversion
  - DC Power Distribution
  - PEF / Food / Biomass Processing

DTI 33,000 ft² Corporate Headquarters in Bedford, MA
Solid-State Switching

- Series String of Transistors
  - All Operate Synchronously
  - Patented Design
- Very High Voltage & Current Demonstrated
  - Up to 500 kV (500,000 Volts)
  - Up to 20 kA (20,000 Amperes)
- Extremely Uniform & Reliable Pulses
  - Sub-Microsecond Switching
  - Arbitrary Pulsewidth & Frequency
  - 1 ns – CW; > 300 kHz Continuous
DTI’s Core Technology

Product Examples
Three Klystron Modulators for the CLARA Project at Daresbury Laboratory, UK

- Based on previous units delivered to Daresbury and Lawrence Berkeley National Lab in 2014
- Similarities in design allow for complete, replicable package
- Pulse voltage flatness and stability crucial to LINAC operation
- Good pulse fidelity over all conditions, optimized near nominal peak power of preferred klystron
<table>
<thead>
<tr>
<th>Specifications</th>
<th>CLARA 2018 (3x)</th>
<th>CLARA 2014 (1x)</th>
<th>LBNL 2014 (1x)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak RF Power</td>
<td>80</td>
<td>45</td>
<td>25</td>
<td>MW</td>
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<tr>
<td>Modulator Avg Power</td>
<td>250*</td>
<td>20</td>
<td>2.5</td>
<td>kW</td>
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<tr>
<td>Cathode Voltage</td>
<td>40-450</td>
<td>350</td>
<td>270</td>
<td>kV</td>
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<tr>
<td>Beam Current</td>
<td>50-545</td>
<td>375</td>
<td>250</td>
<td>A</td>
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<tr>
<td>Pulse Width</td>
<td>0.25-3.0</td>
<td>3</td>
<td>10</td>
<td>µs</td>
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<tr>
<td>Repetition Rate</td>
<td>400*</td>
<td>400</td>
<td>10</td>
<td>Hz</td>
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<tr>
<td>Voltage Flatness</td>
<td>&lt; ± 0.02</td>
<td>0.1</td>
<td>1</td>
<td>%</td>
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<tr>
<td>Voltage Reproducibility</td>
<td>&lt; ± 0.05%</td>
<td>0.25%</td>
<td>0.10%</td>
<td>Of Vmax</td>
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<tr>
<td>Pulse-to-Pulse Jitter</td>
<td>&lt; ± 1</td>
<td>4</td>
<td>0.5</td>
<td>ns</td>
</tr>
</tbody>
</table>

*System is upgradeable to 500 kW / 1 kHz with addition of another 250 kW DTI HVPS
Modulator Design

• Topology: Solid-State Switch-Driven Pulse Transformer

• Components Include:
  – High Voltage Power Supply
  – Storage Capacitor
  – High Voltage Series Switch
  – Step-up Pulse Transformer

• Benefits
  – Small Footprint (Moderately Sized Storage Capacitor)
  – Direct Switching = Low Losses, Fast Rise and Fall Times
  – Klystron Protection
  – Inherent Redundancy
Modulator Schematic
System Packaging

- Control Rack & Low Voltage Electronics
- DTI 250 kW HVPS
- Auto Transformer Rack
- Solid-State Switch
- Capacitor Bank & Pulse Flattening Circuitry
- Pulse Transformer

Klystron
Tank Details

- Tube Socket
- Lift for Ease of Access
- Pulse Transformer
- Reset Coil
- Capacitor Bank
- Solid State Switch
Pulse Performance

350 kV, 300 A, 6.5 μs Pulse into resistive load, no bouncer

Yellow – Pulse Command
Green – Current
Blue – Cathode Voltage
Pulse Performance

420 kV, 400 A, 4 μs Pulse, into resistive load, no bouncer

Yellow – Pulse Command
Pink – Cathode Voltage
Conclusion & Project Status

• System 1
  – Factory Acceptance Test Complete
  – Unit Shipped
  – Installation May 2018

• Systems 2 & 3
  – Factory Acceptance Test to be Complete June 2018
  – Installation Summer 2018
Thank You

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