Development of automated RF conditioning on CLARA

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On behalf of conditioning automation team at Daresbury Laboratory
Contents

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CLARA

- S-band linear acceleration up to 250 MeV
- Bunch charge 20-250 pC
- High repetition rate up to 400 Hz
- Electron bunch lengths 250-850 fs
- FEL wavelengths in the UV
CLARA RF structures

- CLARA has 8 normal conducting RF structures
- A new photoinjector has been designed to replace the old one.
- Both operate with solenoids around the cavity.

<table>
<thead>
<tr>
<th></th>
<th>Old Photoinjector</th>
<th>New Photoinjector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradient</td>
<td>~90 MV/m</td>
<td>120 MV/m</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>10 Hz</td>
<td>400 Hz</td>
</tr>
<tr>
<td>Probe</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Load-lock</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Coupler</td>
<td>Single feed coaxial</td>
<td>Dual feed coaxial “H coupler”</td>
</tr>
</tbody>
</table>
Motivation

- Repeatability and speed of conditioning
- Minimise damage to high gradient structures
- Move towards unmanned operation

2013 conditioning of VELA photoinjector
Implementation

- Python script with C++ API with EPICS control system
- Increase power at constant rate
- Switch off power when breakdown detected
- Keep breakdown rate under given value
Breakdown detection

- RF traces
  - Phase of reflected signal from cavity
  - Amplitude of reflected signal from cavity
  - Phase of cavity probe signal
  - Amplitude of cavity probe signal
- Dark current
- Pressure spikes in cavity vacuum
Technical issues..

- LLRF system is I-tech Libera
- Timings of measured RF traces are not repeatable, at 100 Hz is impossible to match a set of traces.
- New software upgrade implementing now, we will have access to raw trace data as single output, perform our own I/Q demodulation.
Beta test: VELA gun conditioning

1. Low power multipactor
2. Slow pressure rise
3. Spurious breakdown detections
4. Pulse count error
5. Temperature effect on phase
6. Solenoid effects
Low power multipactor

Two bands of soft multipactor at 100 kw and 1.7 MW peak forward power.
Low power multipactor in new CLARA gun
Slow pressure rise

- No change seen in RF traces
- Some kind of localised heating effect?
- Neutral gas outgassing?
- Gauge error?
Spurious breakdown detections

- Forward power drops to zero
- Other traces show noise, which is outside mask.
- Problem with acquisition
- Became more frequent with change in trigger
- Fix involves checking forward signal before others but need to be sure they are the same pulse

Pulse count errors

- Some overlaps in pulse numbering
- Mechanism for changing pulse length needs work
Temperature effect on phase

- At pulse lengths above 2 µs, reflected phase varies towards the end of the pulse.
- This correlates with cavity temperature.
- Vicious circle: phase change detected as a breakdown → RF off → no load on water cooling system → less cooling when RF comes back on.
Temperature effect on phase (2)

- Simulated by cavity S11 convolution with forward power pulse in frequency domain
- S11 frequency varied with respect to forward power pulse
- We know 1 °C temperature change gives ~50 kHz frequency change
Solenoid effects

- Oscillation from -250 A to + 250 A caused vacuum spikes up to 1 x 10^{-8} mBar.

- Solenoid switch on to 150 A caused pressure increase to 2.7 x 10^{-9} mBar. Which recovered slowly.

- Solenoid oscillation from 100 to 200 A caused decaying oscillation of the pressure.
Further work

• Implement Libera software upgrade
• Finish digitisation of dark current measurements
• Switch off water cooling PID when RF is off
• Automate pulse length changes
• Study breakdown behaviour with and without solenoid
• Condition CLARA photoinjector!
Acknowledgements

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Thanks to the team at the XBOXs for sharing their knowledge and answering my questions on their conditioning process.