Smart*Light
CURRENT ACTIVITIES AND FUTURE CONCEPTS
HIGH GRADIENT WORKSHOP 2021
Thomas Lucas on Behalf of the TU/e Team
1. Brief Overview of Smart*Light
2. 50-Cell High Gradient X-band Linear Accelerator
   a) Design
   b) Fabrication
   c) Tuning
   d) Low Power Testing
3. High Power RF System
   a) Klystron/Modulator
   b) RF Pulse Compressor
4. A new injector for future Compact Light Sources
5. Conclusion
Smart*Light: A Compact ICS

- Smart is a Compact Inverse Compton Scattering Xray Source (ICS) based on high gradient technology.

**Main Attributes:**
- DC photoinjector with 1.5 GHz bunching cavity.
- 50-cell CLIC-style linear accelerator operating between 50-75 MV/m.
- Powered using high power RF infrastructure from CERN’s Xbox 3.
Bridging the gap

• Compact ICS Xray sources aim to bridge the gap between synchrotron light source bending magnets and lab sources.
• Bring tuneable X-ray sources to the lab.
50-Cell X-band Accelerating Structure

DESIGN, FABRICATION AND TUNING
RF Design

$S_{11} = -45.5 \text{ dB}$

$S_{21} = -6.35 \text{ dB} = 23\% \text{ transmission}$

Design by Xavier Stragier based on T24 Cell design
Fabrication

Fabricated by VDL

Alignment, Bonding and Brazing by BodyCote and CERN
Tuning @ CERN

Before

After

Performed by Hikmet Bursali and Rolf Wegner
Low Power Testing @ CERN

Performed by Hikmet Bursali and Rolf Wegner
High Power RF System

CURRENT STATUS
Klystron and Modulator

- E37113 klystron original design
- Modulator arrived: November 2 2020
- Klystron 2: Klystron borrowed from CERN. Xbox 3’s original klystron with phase jump. Window brazing problem? Gun voltage reduction to 7.7 V from expected 15 V.
- Klystron 3: Installation to occur in coming week. Borrowed klystron from CERN.
- Klystron 1: Being fixed. Expected arrival 1-2 months.
RF Pulse Compressor

1. Fabrication: Vacutech (NL) Brazing: Mat-Tech (NL).
2. Tuning: Each Cavity tuned to within 2 kHz of one another.
3. RF testing:
   \[ Q_L = \frac{f_0}{\Delta f} = 51,600 \]
   \[ \beta = \frac{1+S_{21}}{1-S_{21}} = 2.96 \]
4. Installation: Installed in March 2021 and pumped down to ensure that all connections were OK. Ready for high power.
High Power RF Components

Pumping Port

Directional Coupler

Splitters

3D printed Load

1. Coupling = -60.08 dB
2. Coupling = -60.10 dB
3. Coupling = -60.12 dB

1. $S_{31} = -3.01$ and $S_{21} = -3.04$, $\phi = 0.41$
2. $S_{31} = -3.04$ and $S_{21} = -3.03$, $\phi = 0.19$
3. $S_{31} = -3.03$ and $S_{21} = -3.02$, $\phi = 0.47$
4. $S_{31} = -3.03$ and $S_{21} = -3.05$, $\phi = 0.61$
5. $S_{31} = -3.03$ and $S_{21} = -3.04$, $\phi = 0.08$

1. $S_{11} = -23$ dB
Low Level RF System

OVERVIEW
Overview of the Low Level RF

150 fs @ 100 Hz to 1 MHz
X-band TW RF photogun

A CONCEPT STUDY
Reason for a new injector

• Temperature requirements on 1.5 GHz buncher are very tight <10 mK.
• No need for GHz rep. rate gun when structure has a kHz repetition rate limitation.
• Simplify the RF system.
• Bunch charge increase leading to a greater brilliance.
X-band Travelling-wave Radiofrequency photogun
Electric field Distribution
Peak Surface fields

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Length</td>
<td>216</td>
<td>mm</td>
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<tr>
<td>Regular Cells</td>
<td>24</td>
<td>degs</td>
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<tr>
<td>Phase Advance</td>
<td>120</td>
<td>GHz</td>
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<tr>
<td>Frequency</td>
<td>11.994</td>
<td>GHz</td>
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<tr>
<td>Attenuation</td>
<td>-2.26</td>
<td>dB</td>
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<tr>
<td>Power</td>
<td>27.5</td>
<td>MW</td>
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<tr>
<td>Fill time</td>
<td>50.2</td>
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<tr>
<td>Gradient</td>
<td>73.4</td>
<td>MV/m</td>
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<tr>
<td>Peak Cathode field</td>
<td>120</td>
<td>MV/m</td>
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<td>Peak Surface E field</td>
<td>215</td>
<td>MV/m</td>
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<td>Peak Modified Poynting Vector</td>
<td>3.18</td>
<td>MW/mm²</td>
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<td>Average RF Power</td>
<td>1.381</td>
<td>kW</td>
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<tr>
<td>Peak Steady State Temperature rise</td>
<td>10</td>
<td>K</td>
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<tr>
<td>Pulsed Surface Heating ($\tau = 50$ ns)</td>
<td>7.75</td>
<td>K</td>
</tr>
<tr>
<td>Peak Magnetic Field</td>
<td>0.6</td>
<td>T</td>
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<tr>
<td>Repetition Rate</td>
<td>1</td>
<td>kHz</td>
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<tr>
<td>Flow Rate</td>
<td>15</td>
<td>L/min</td>
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Thermal Simulations
Start-to-end Beam Dynamics

- Beam dynamics calculations performed in GPT using 100k particles and full 3D space charge.
- Full three dimensional map included to understand higher order mode effects on beam.

<table>
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<tr>
<th>Bunch Charge [pC]</th>
<th>10</th>
<th>40</th>
<th>80</th>
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<tbody>
<tr>
<td>Electron Bunch Energy [MeV]</td>
<td>33.8</td>
<td>33.8</td>
<td>33.8</td>
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<tr>
<td>Electron Bunch Energy Spread [%]</td>
<td>0.05</td>
<td>0.1</td>
<td>0.15</td>
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<tr>
<td>Electron Bunch length RMS [fs]</td>
<td>371</td>
<td>465</td>
<td>523</td>
</tr>
<tr>
<td>norm. x emittance [mm mrad]</td>
<td>0.103</td>
<td>0.335</td>
<td>0.485</td>
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<tr>
<td>norm. y emittance [mm mrad]</td>
<td>0.098</td>
<td>0.266</td>
<td>0.72</td>
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</table>
Conclusions and Future Work
Conclusions and Future Work

• An accelerating structure designed specifically for low energy electron capture has been designed, fabricated, tuned and tested at low power through a large collaborative effort between TU/e and CERN.
• The accelerator will begin high power testing this year with the waveguide network being assembled.
• Several HPRF components using the designs developed for CERN’s test stands have been fabricated and operate within specification.
• Low level RF system designed and built in-house. Calibration underway.
• A new TW X-band RF photogun has been designed for compact light sources like Smart*Light with the idea that this may one day replace the DC photogun and adjusted X-band accelerator.
Thank You for Listening and Special Thanks to:

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CERN Team particularly Nuria Catalan-Lasheras and Gerry McMonagle

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SLAC: Valery Dolgashev