Smart*Light

CURRENT ACTIVITIES AND FUTURE CONCEPTS
HIGH GRADIENT WORKSHOP 2021

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CQT Group

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Contents

Smart*Light: A Compact ICS

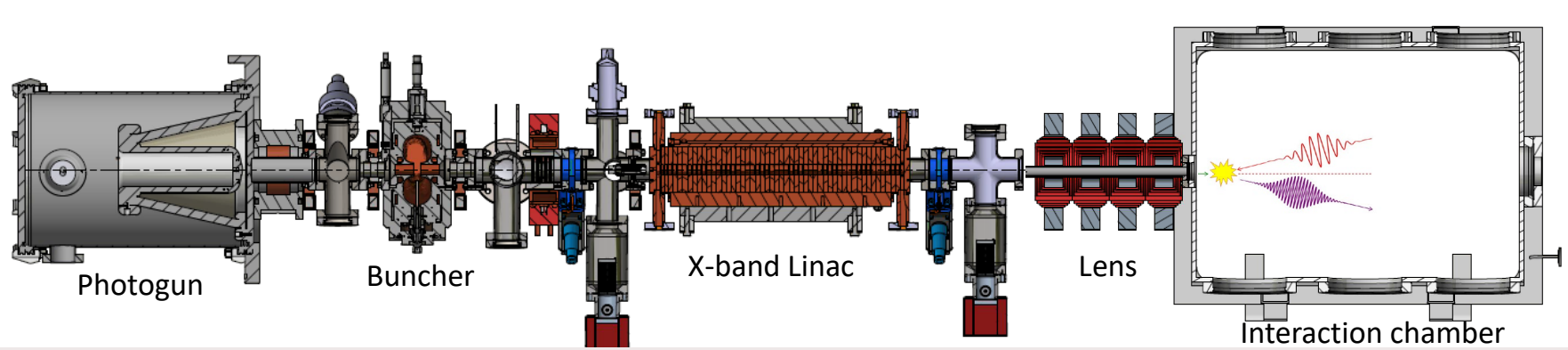
• Smart is a Compact Inverse Compton Scattering Xray Source (ICS) based on high gradient technology.

Main Attributes:

• DC photoinjector with 1.5 GHz bunching cavity.

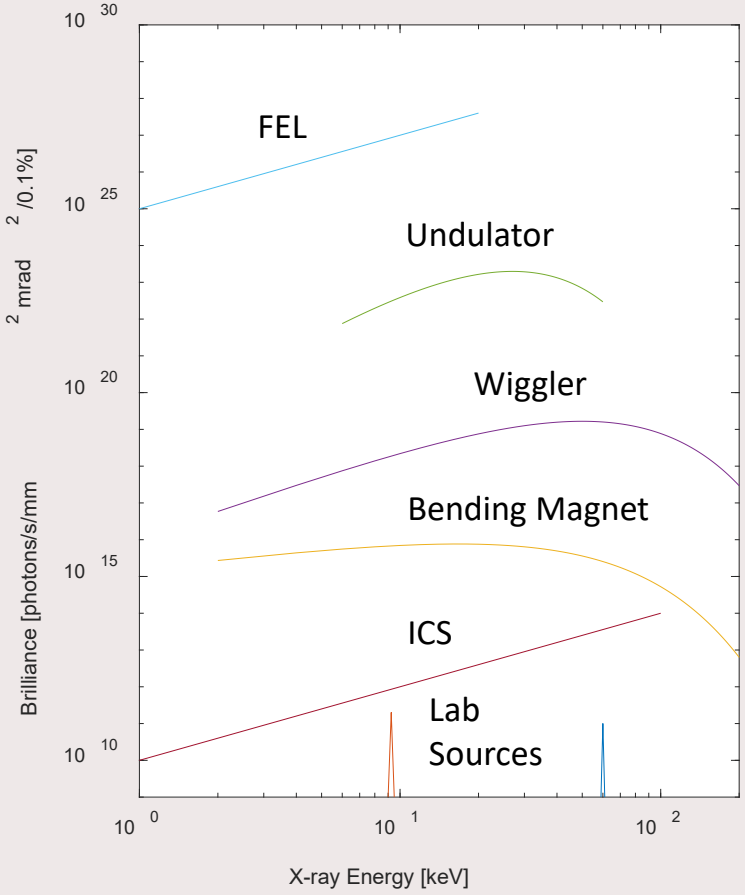
• 50-cell CLIC-style linear accelerator operating between 50-75 MV/m.

• Powered using high power RF infrastructure from CERN's Xbox 3.



Bridging the gap

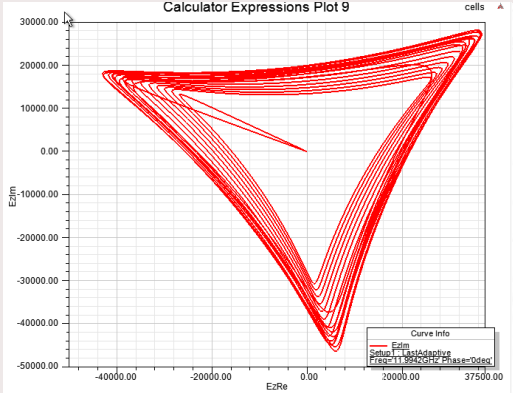
- Compact ICS Xray sources aim to bridge the gap between synchrotron light source bending magnets and lab sources.
- Bring tuneable X-ray sources to the lab.



50-Cell X-band Accelerating Structure

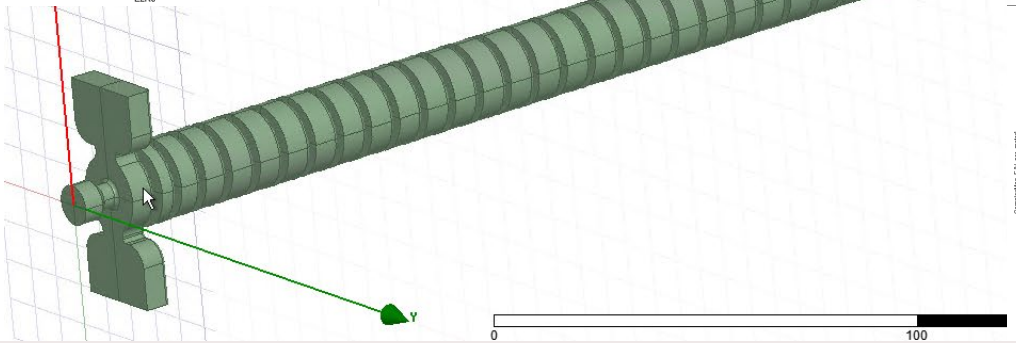
DESIGN, FABRICATION AND TUNING

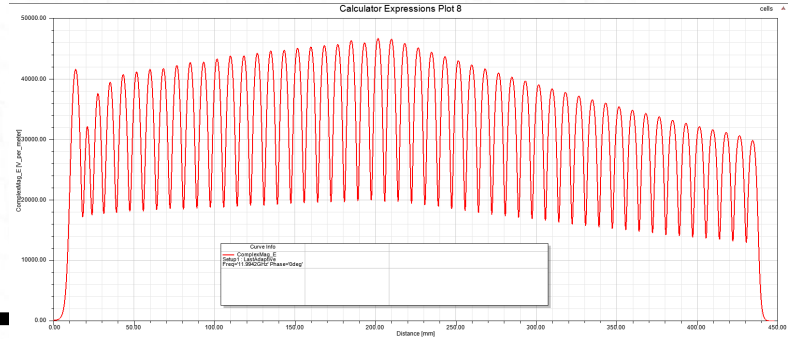
RF Design



S_{11}= -45.5 dB

S_{21} = -6.35dB = 23% transmission

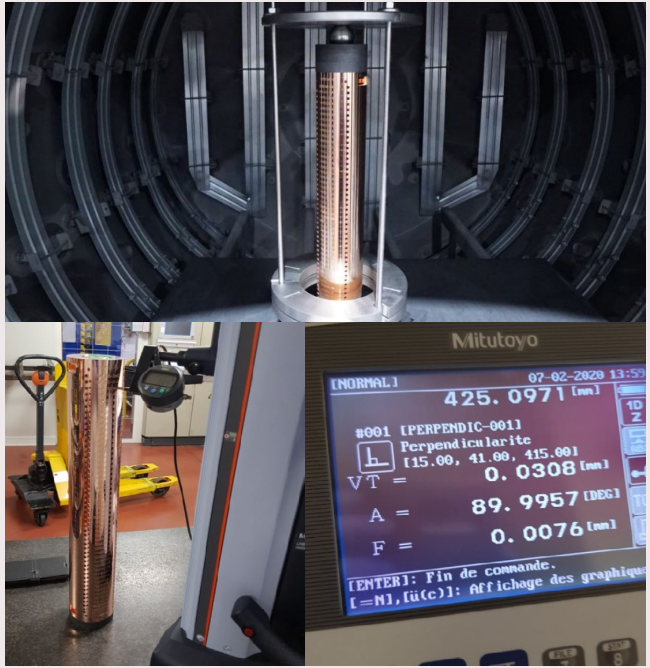




Design by Xavier Stragier based on T24 Cell design

Fabrication

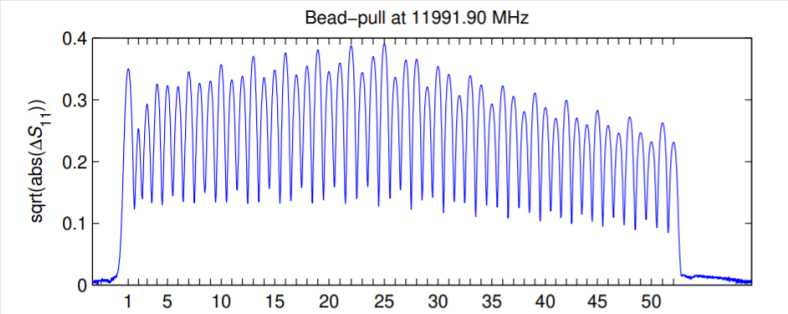
Fabricated by VDL

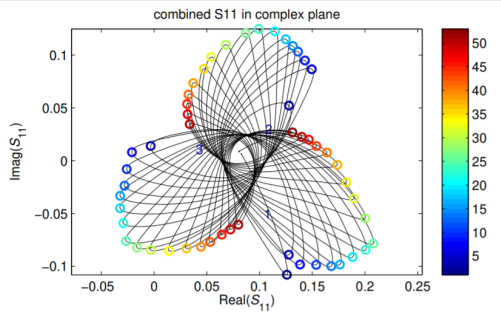


Alignment, Bonding and Brazing by BodyCote and CERN

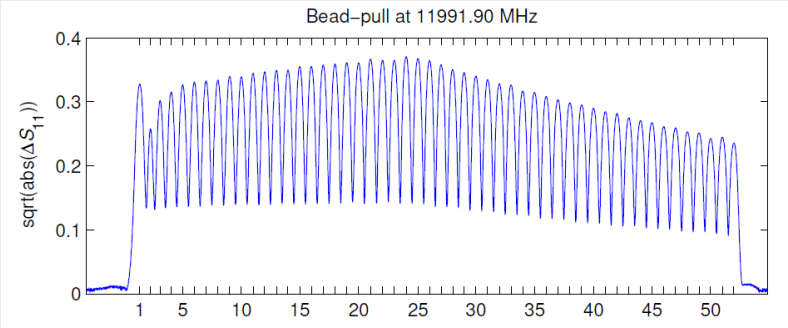
Tuning @ CERN

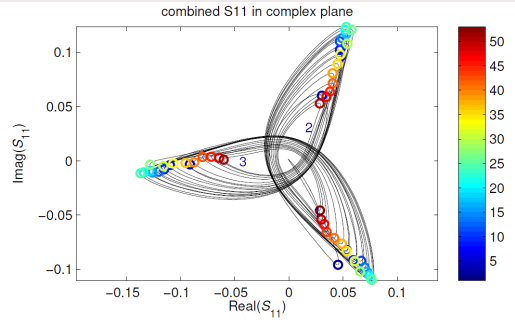
Before





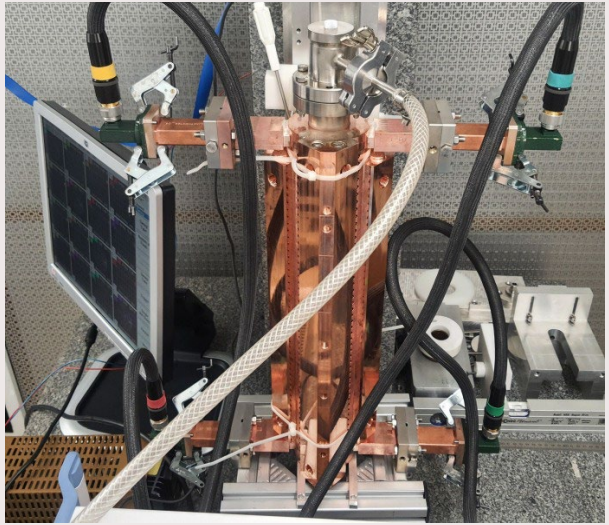
After

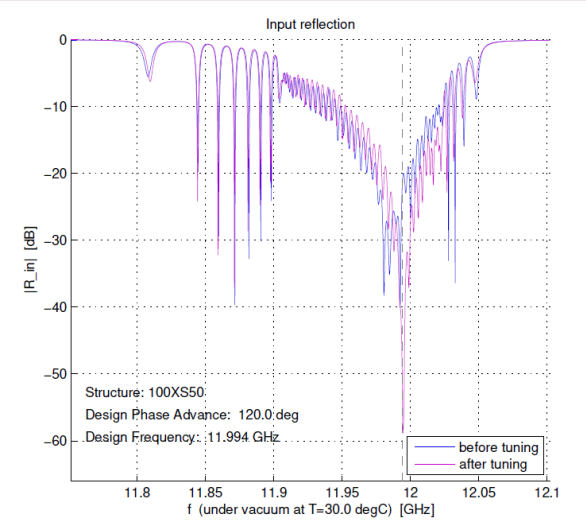


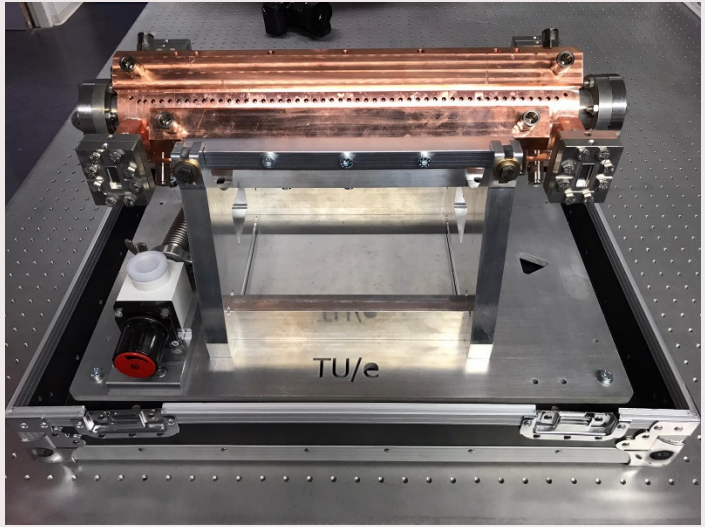


Performed by Hikmet Bursali and Rolf Wegner

Low Power Testing @ CERN







Performed by Hikmet Bursali and Rolf Wegner

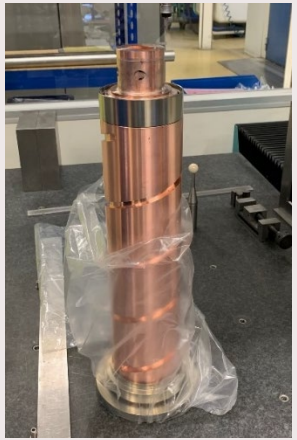
High Power RF System

CURRENT STATUS

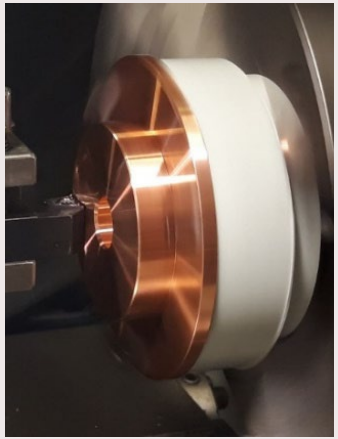
Klystron and Modulator

- E37113 klystron original design
- Klystron 1: Window broken in factory of modulator. No conclusion provided on the cause. Early 2020.
- 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).

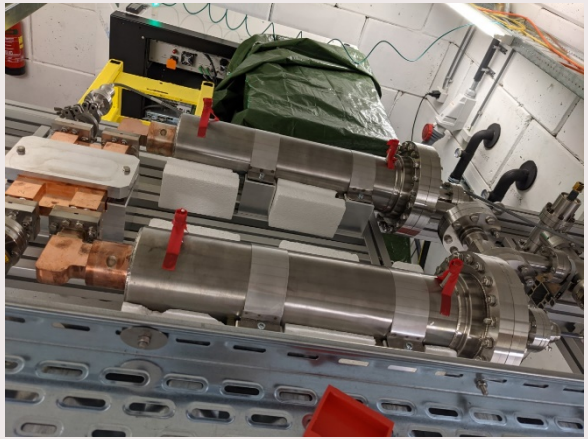


2. Tuning:
Each Cavity tuned to within 2 kHz of one another.

3. RF testing:

$$Q_L = \frac{f_0}{\Delta f} = 51{,}600$$

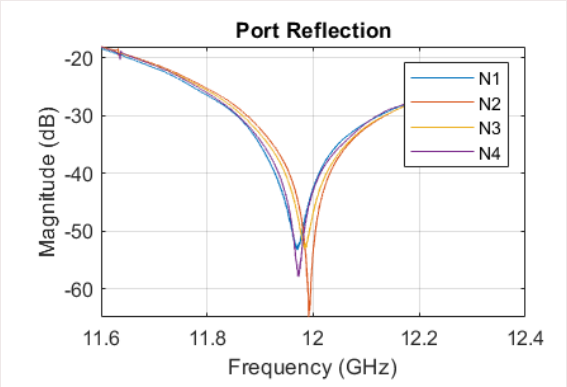
$$\beta = \frac{1+S_{21}}{1-S_{21}} = 2.96$$



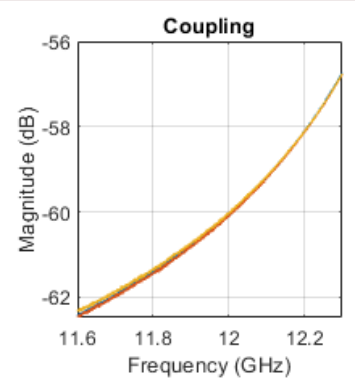
4. Installation:
Installed in March 2021 and pumped down to ensure that all connections were OK.
Ready for high power.

High Power RF Components

Pumping Port

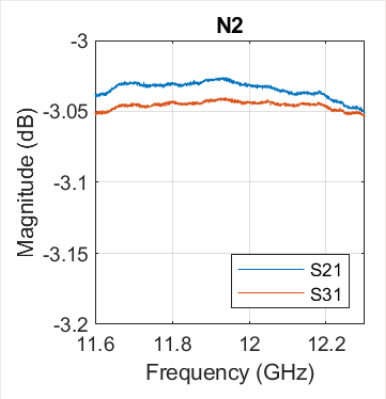


Directional Coupler



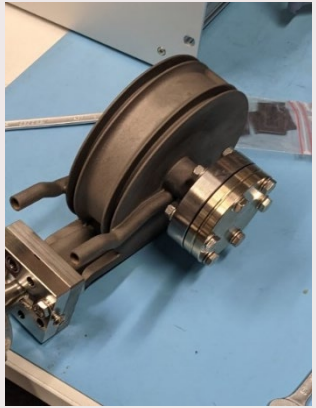
1. Coupling = -60.08 dB
2. Coupling = -60.10 dB
3. Coupling = -60.12 dB

Splitters



1. S31 = -3.01 and S21 = -3.04, dϕ = 0.41
2. S31 = -3.04 and S21 = -3.03 , dϕ = 0.19
3. S31 = -3.03 and S21 = -3.02 , dϕ = 0.47
4. S31 = -3.03 and S21 = -3.05 , dϕ = 0.61
5. S31 = -3.03 and S21 = -3.04 , dϕ = 0.08

3D printed Load

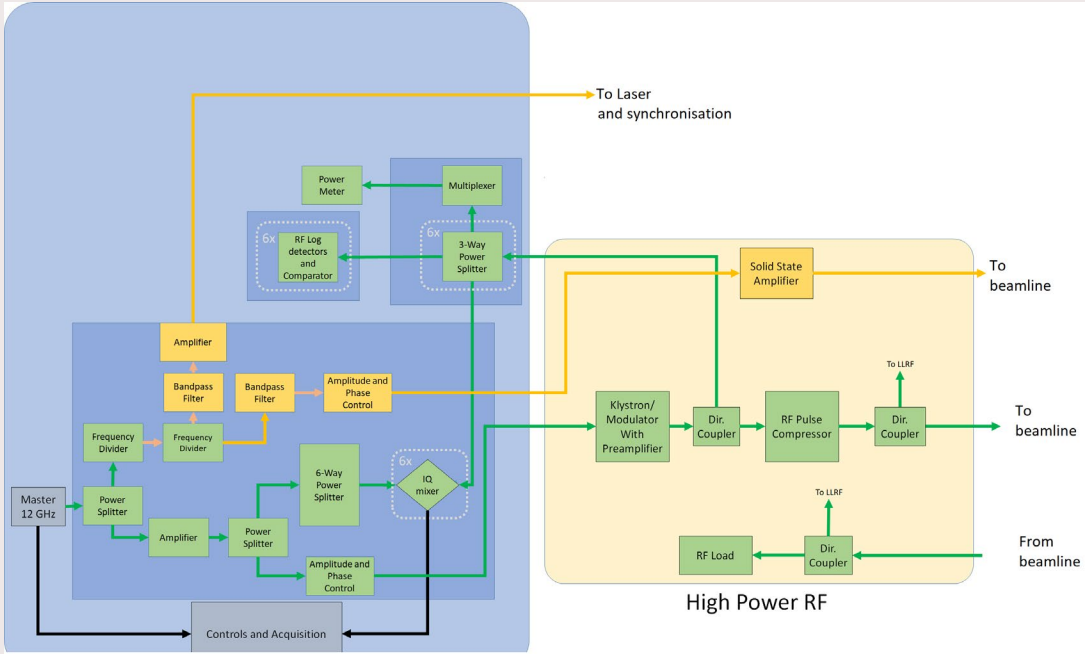


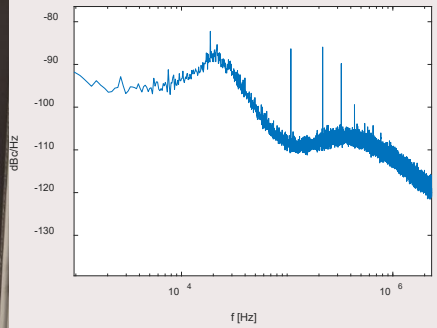
1. S11 = -23 dB

Low Level RF System

OVERVIEW

Overview of the Low Level RF





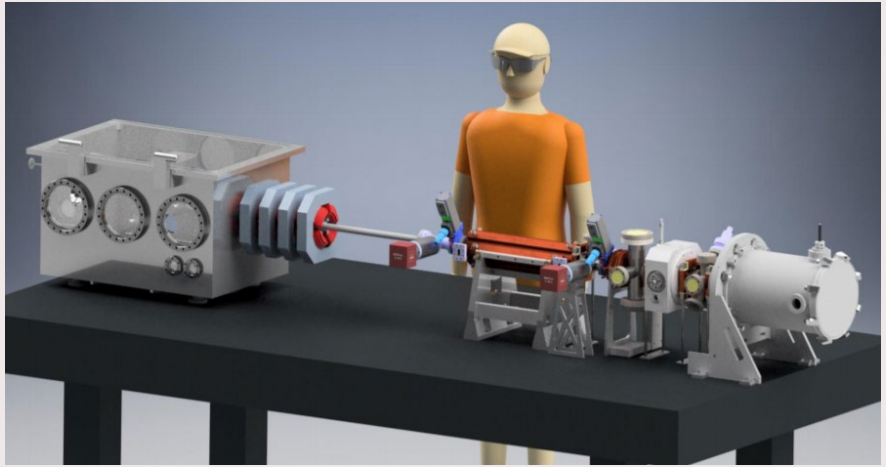
150 fs @ 100 Hz
to 1 MHz

X-band TW RF photogun

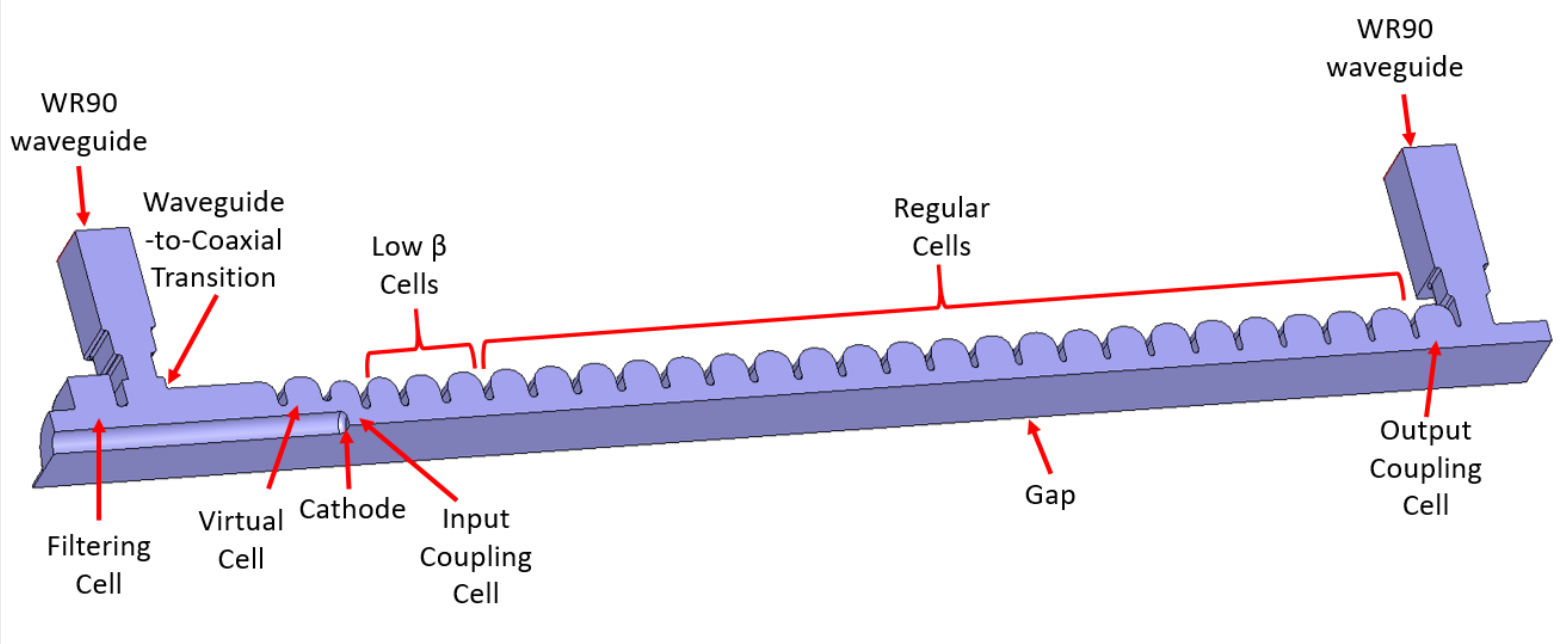
A CONCEPT STUDY

Reason for a new injector

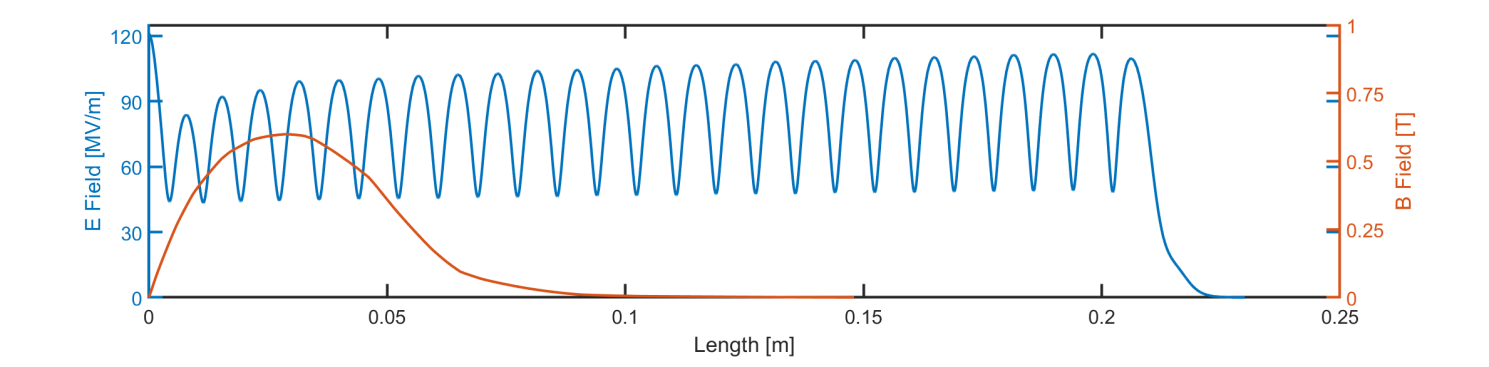
- Temperature requirements on 1.5 GHz buncher are very tight <10 mK.
- No need for GHz rep. rate gun when structure has a kHz repetition rate limitation.
- Simplify the RF system.
- Bunch charge increase leading to a greater brilliance.

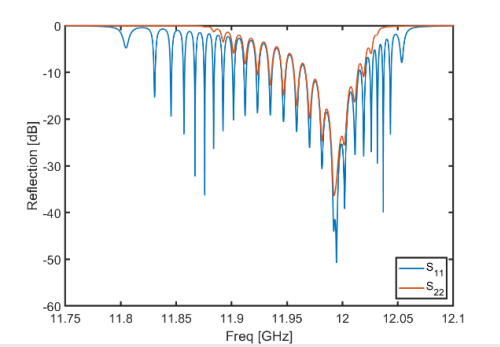


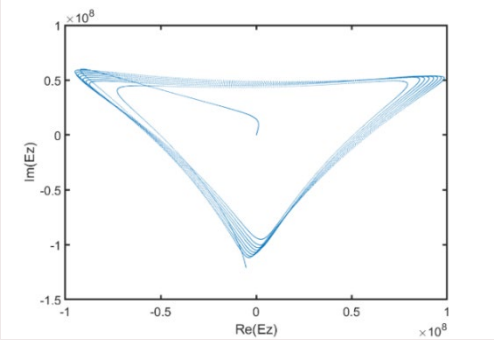
X-band Travelling-wave Radiofrequency photogun



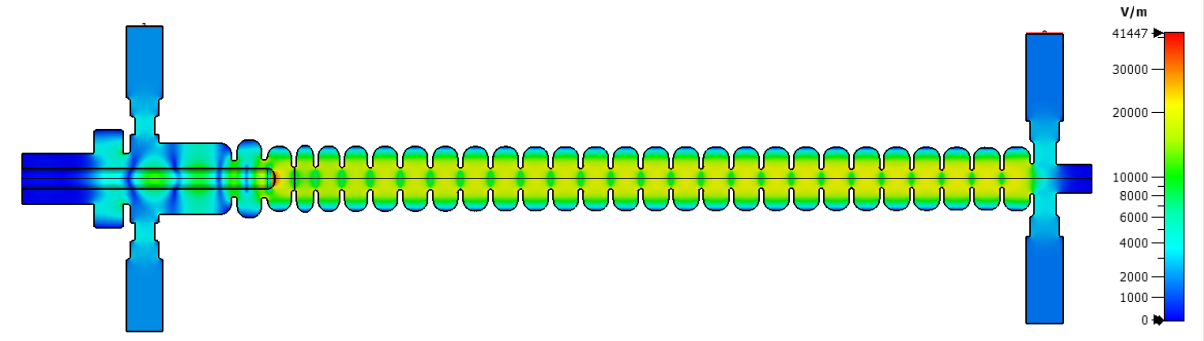
Electric field Distribution

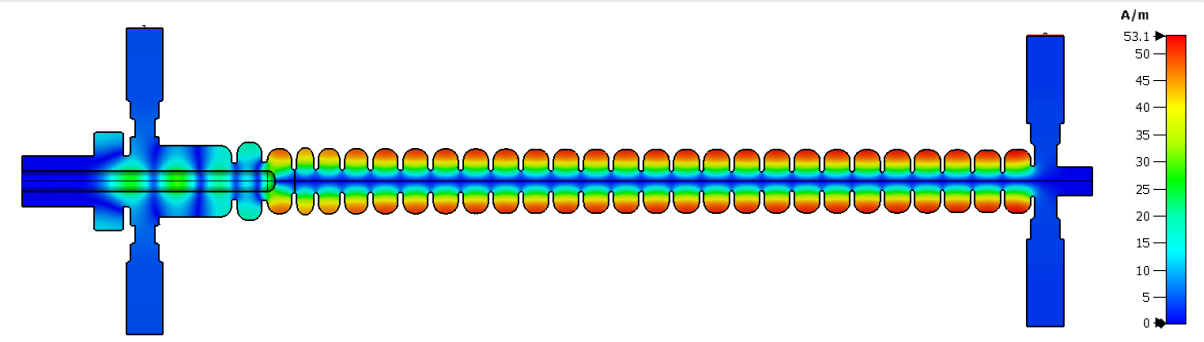






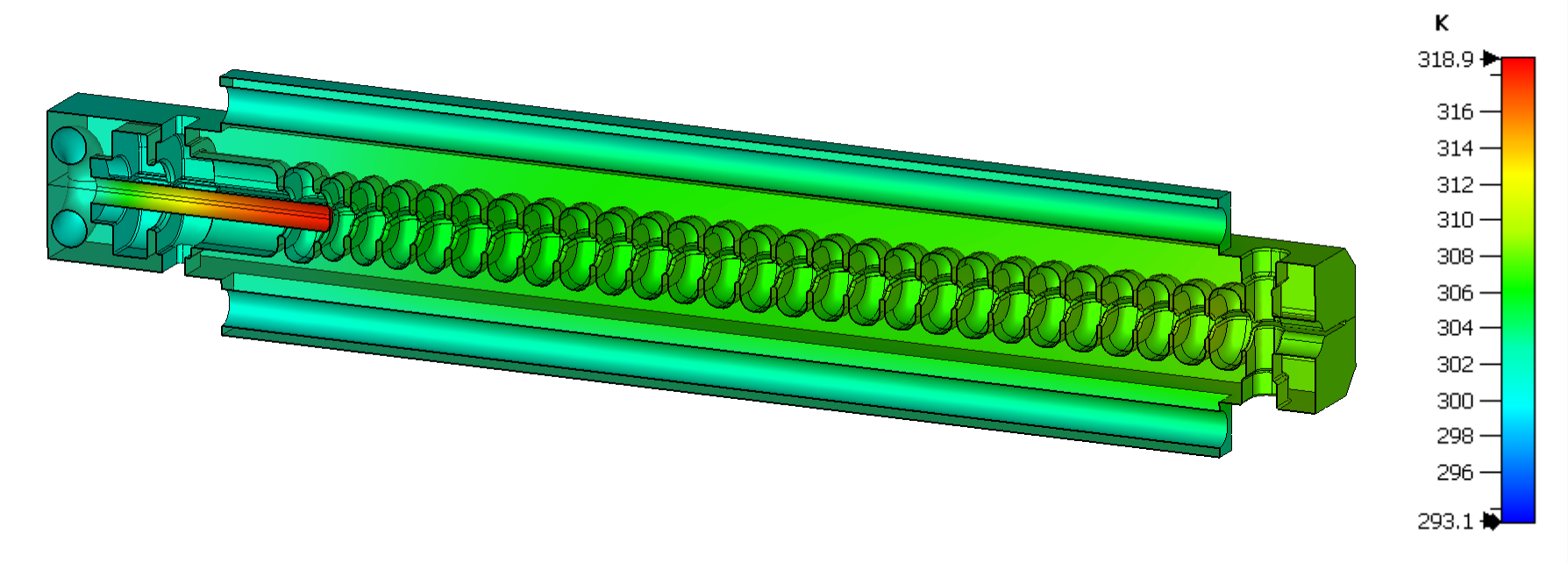
Peak Surface fields





Parameter	Value	Unit
Length	216	mm
Regular Cells	24	
Phase Advance	120	degs
Frequency	11.994	GHz
Attenuation	-2.26	dB
Power	27.5	MW
Fill time	50.2	ns
Gradient	73.4	MV/m
Peak Cathode field	120	MV/m
Peak Surface E field	215	MV/m
Peak Modified Poynting Vector	3.18	MW/mm^2
Average RF Power	1.381	kW
Peak Steady State Temperature rise	10	K
Pulsed Surface Heating ($\tau = 50$ ns)	7.75	K
Peak Magnetic Field	0.6	T
Repetition Rate	1	kHz
Flow Rate	15	L/min

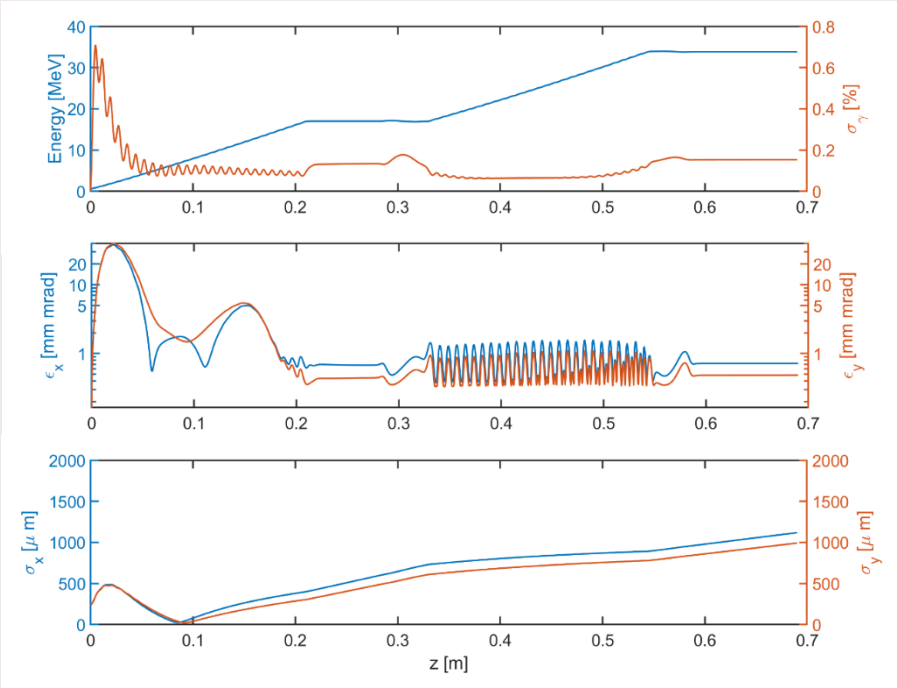
Thermal Simulations



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.

Bunch Charge [pC]	10	40	80
Electron Bunch Energy [MeV]	33.8	33.8	33.8
Electron Bunch Energy Spread [%]	0.05	0.1	0.15
Electron Bunch length RMS [fs]	371	465	523
norm. x emittance [mm mrad]	0.103	0.335	0.485
norm. y emittance [mm mrad]	0.098	0.266	0.72



Conclusions and Future Work

DESIGN STUDY

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:

TU/e Team: Peter Mutsaers, Tom Lucas, Xavier Stragier, Marco van der Sluis, Jom Luiten.

CERN Team particularly Nuria Catalan-Lasheras and Gerry McMonagle

PSI: Paolo Craievich and Riccardo Zennaro

SLAC: Valery Dolgashev