PAUL SCHERRER INSTITUT

Thomas Geoffrey Lucas :: Tenure-Track Scientist :: Paul Scherrer Institut

A Travelling-Wave Radio-Frequency Photogun for a Brightness Upgrade to SwissFEL

67th ICFA Advanced Beam Dynamics Workshop on Future Light Sources

Contents

PAUL SCHERRER INSTITUT

Motivation for Travelling-Wave

A *non-exhaustive* list of reasons to move to TW technology includes:

1. Able to operate with very short RF pulse lengths.

- Possibility to operate at higher gradients: $E^{30}\tau^{5} \propto BDR$

2. *TW guns can be designed with many more cells than possible in SW structures, whose total number of cells is limited by mode separation.*

- Interesting for applications that need electrons with energies greater than 10 MeV

3. TW gun does not require an RF circulator as the input power is passed through the structure into the output RF loads rather than reflected back towards the power source. This makes TW guns appealing for higher frequency applications where the design of RF circulators is complicated.

- Circulators are notoriously difficult at high frequencies.

Motivation for Travelling-Wave

4. Travelling-wave structures are less sensitive to design tolerances.

- Making them easier to fabricate and operate. Good for high repetition rate operation as the structures are less sensitive to changes.

5. *TW guns have the ability to operate with RF pulse lengths shorter than the nominal filling time while maintaining a nominal peak cathode field.*

6. TW guns can use phase manipulation to achieve unique compression schemes.

RF Design

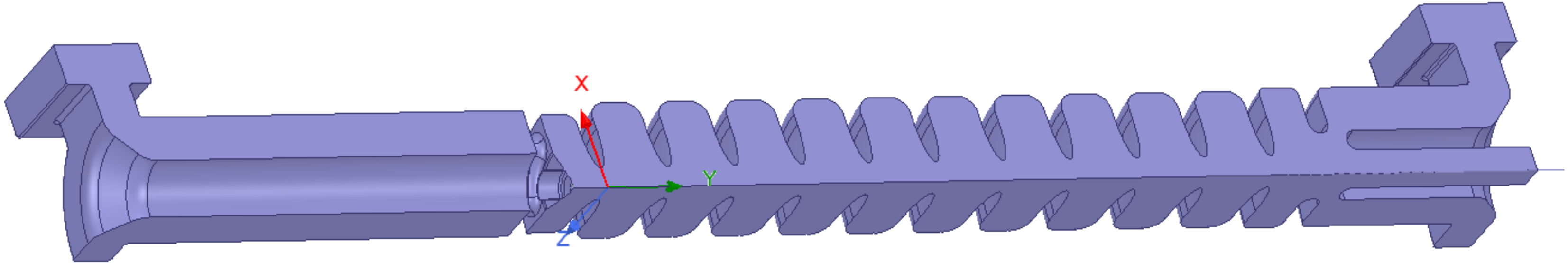


Figure 1: The travelling-wave RF Photogun's internal volume.

RF Design

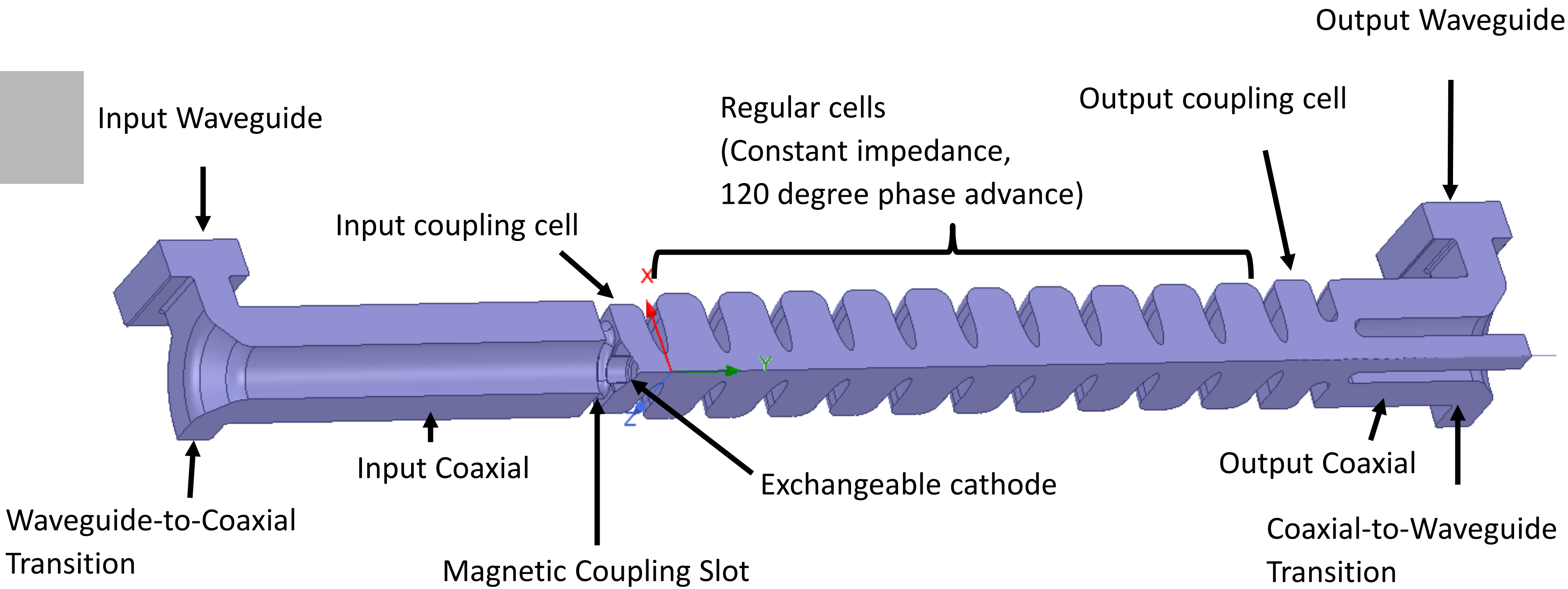
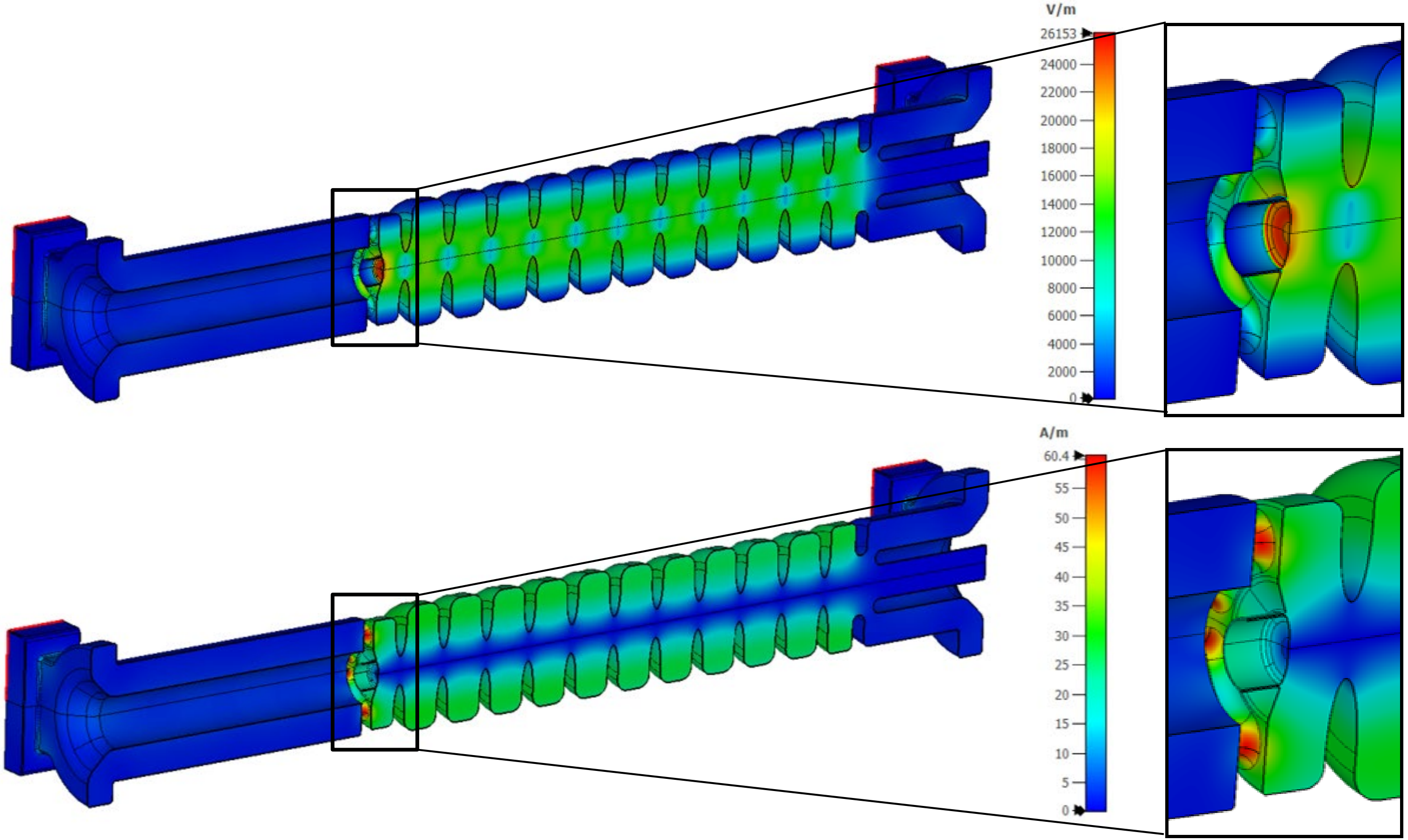
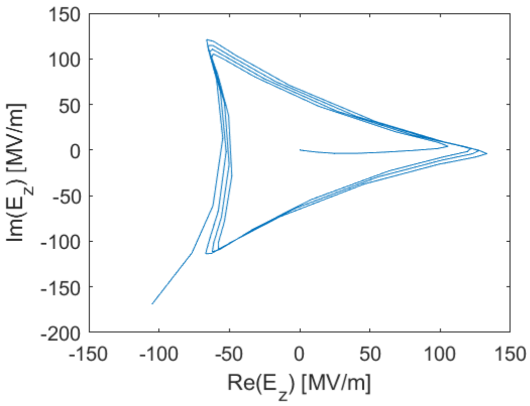


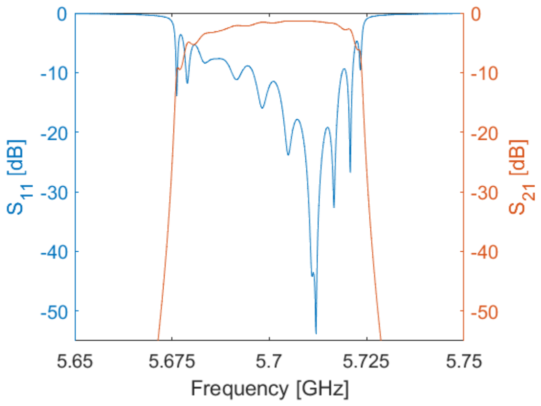
Figure 1: The travelling-wave RF Photogun's internal volume.

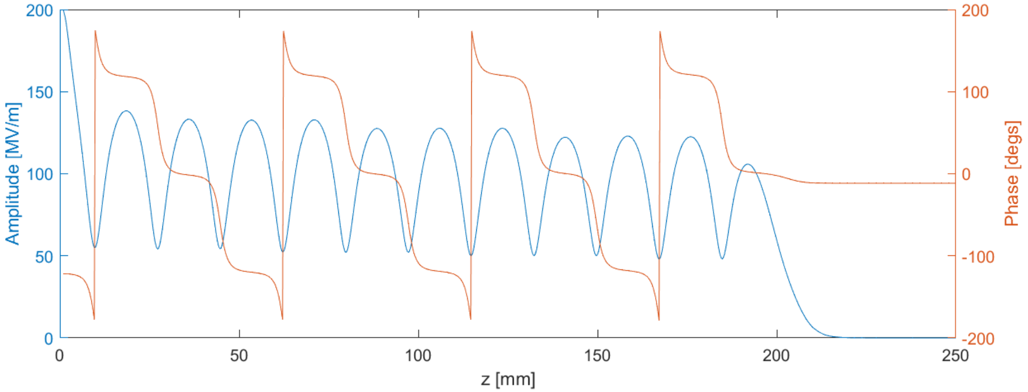
Electromagnetic Fieldmaps



Electromagnetic Performance

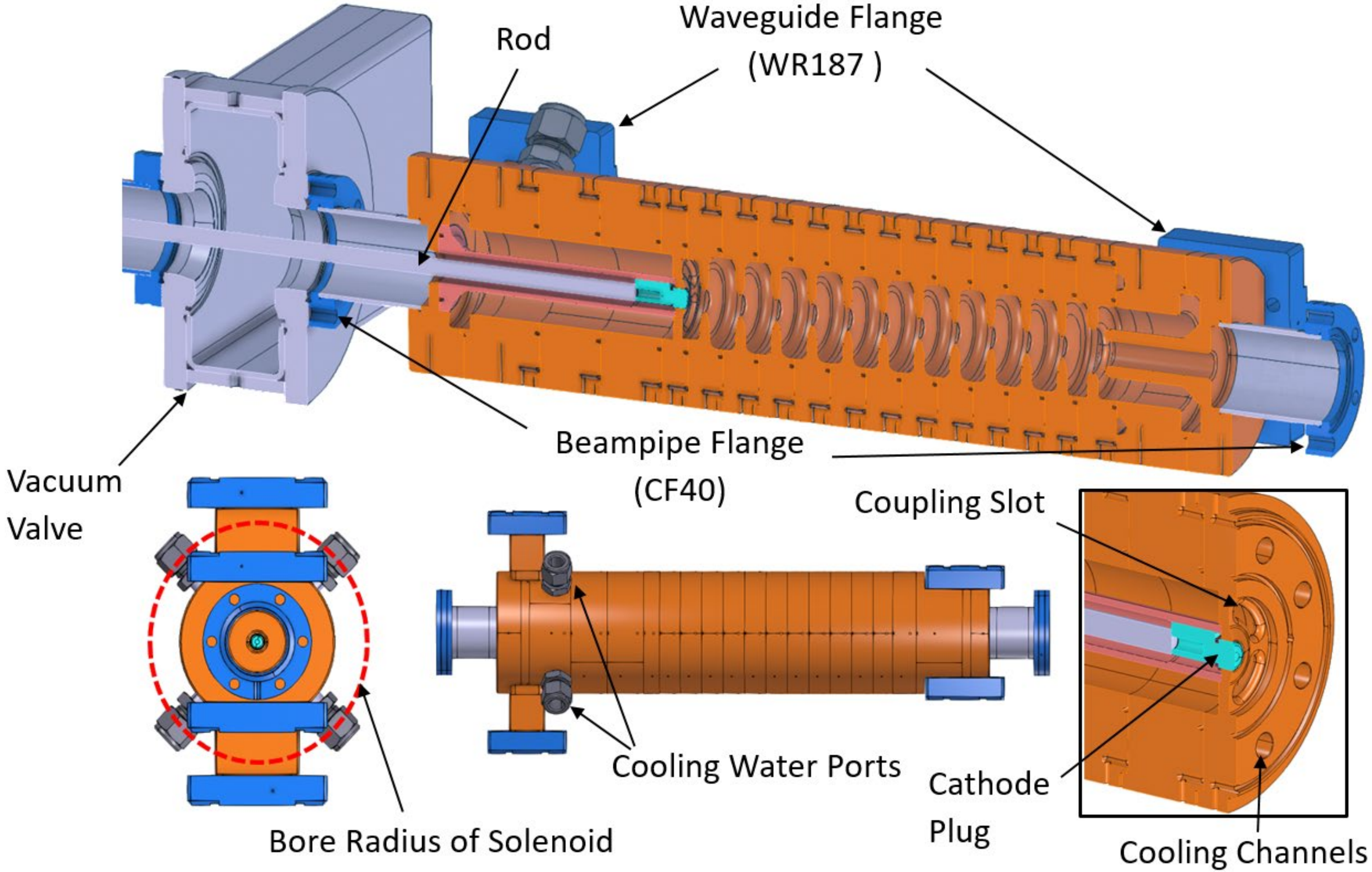






Parameter	Value	Units
Frequency	5.712	GHz
No. of Accelerating Cells	12	
Cell Length	17.495	mm
Structure Active Length	250	mm
Phase Advance	120	°
Attenuation	-1.41	dB
Group velocity	0.79	%c
Filling Time	90	ns
Input Power	82	MW
Peak E Field (Irises)	175	MV/m
Peak E field (Cathode centre)	200	MV/m
Peak H Field	558	kA/m
Pulsed surface heating (100 ns)	30.6	K

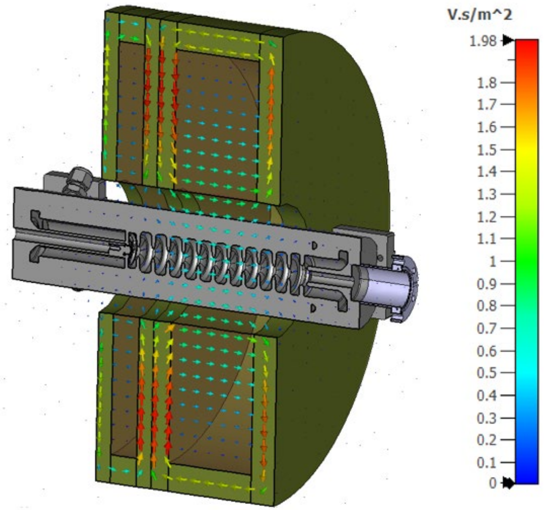
Mechanical Design

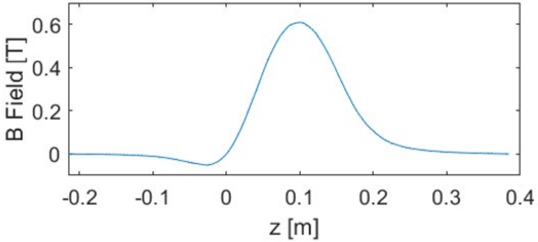


Main Solenoid Design

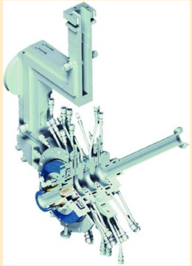
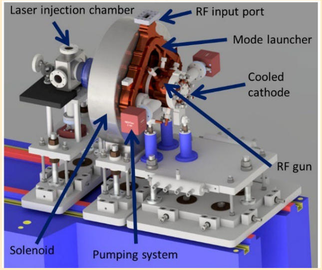
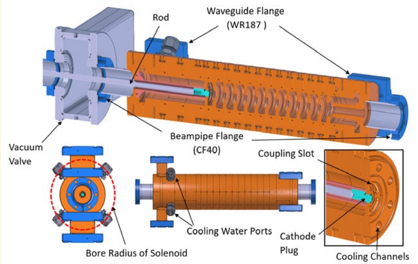
- Magnetostatic simulations of the magnet performed in CST.
- Combined main solenoid and bucking coil.
- Main parameters:

Parameter	Main Solenoid	Bucking Coil
Cable geometry [mm]	8x8 (rectangular)	8x8 (rectangular)
Cooling Channel Bore [mm]	5 (circular)	5 (circular)
Turns	230	96
Amps [A]	305	100
Current Density	7.01	3.22
Power Consumption [kW]	10.75	0.9
Pressure Drop	2.8	0.7
Temperature Rise	20	10

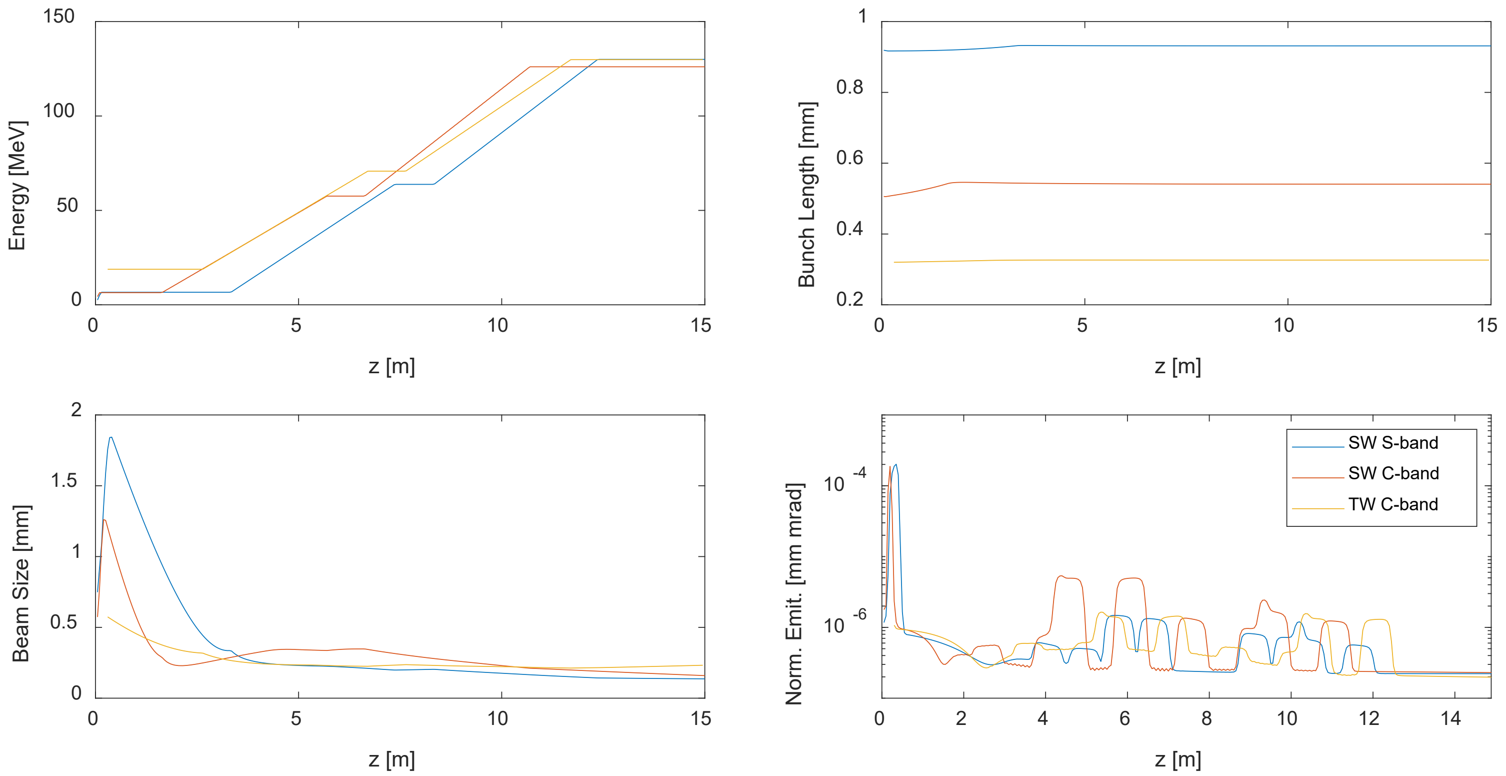




S-band Vs C-band

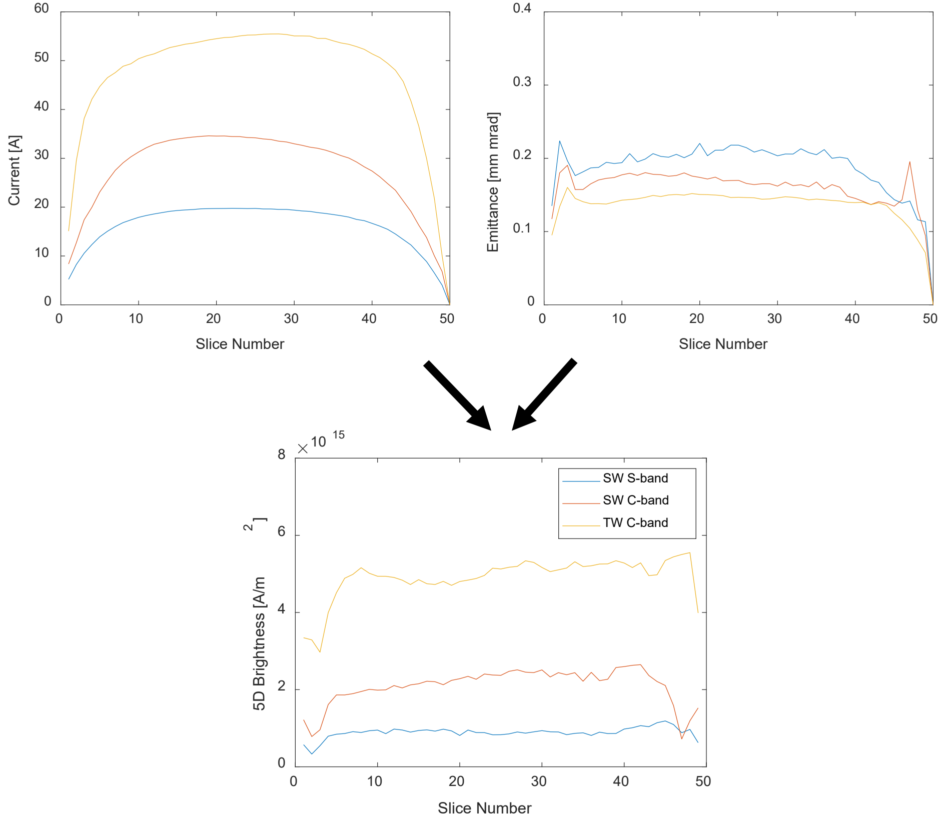
Parameter	S-band SW Photogun (SwissFEL gun)	C-band SW Photogun	C-band TW Photogun
			
Cathode Gradient [MV/m]	100	180	200
Bunch Charge [pC]	200	200	200
Extraction Field Strength [MV/m] and Phase off-crest [deg]	75.3 / 41.3	112 / 51.56	173.8 / 24
Transverse Laser Profile	Uniform	Uniform	Uniform
Longitudinal Laser Profile	Uniform	Uniform	Uniform
Laser Beam Radius	342	359	322
Thermal Emittance	0.55	0.55	0.55
Laser Pulse Width FWHM	9.9	6.47	2.83

Beam Dynamics Over an FEL Injector



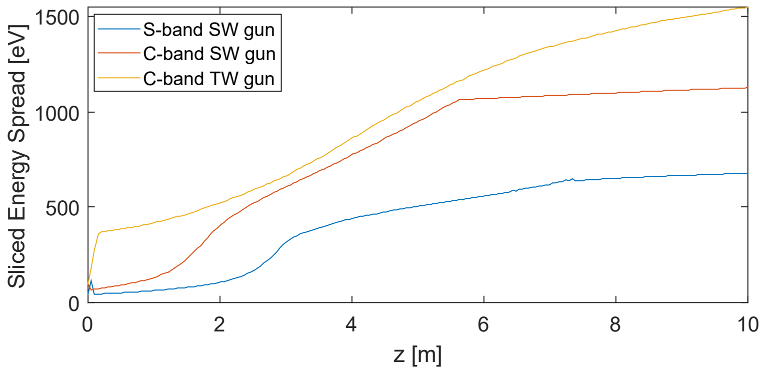
Sliced Parameters after 15 metres

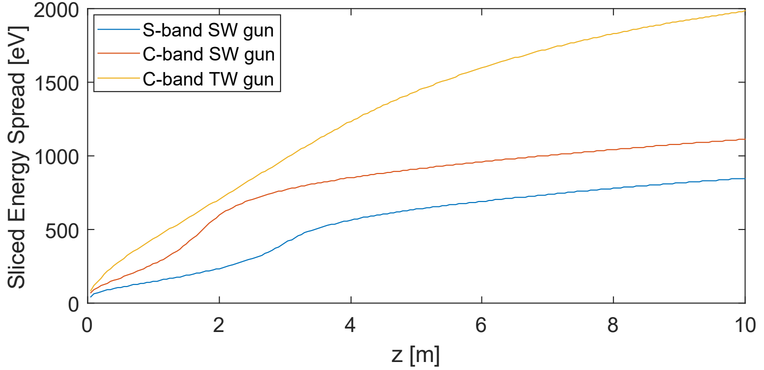
Parameter	S-band SW Photogun	C-band SW Photogun	C-band TW Photogun
Energy [MeV]	6.6	6.4	18.2
Bunch Length [µm]	931	541	326
Project Emittance [mm mrad]	0.21	0.21	0.18
Sliced Emittance [mm mrad]	0.2	0.17	0.146
Peak Current [A]	19.76	34.4	55.46
Central 5D Brightness [TA/m²]	988	2380	5197



Sliced Energy Spreadv growth due to IBS

- Calculations of sliced energy spread through:
  - One-to-one simulations in General Particle Tracer
  - Analytical model from Piwinski
- Two methods gave similar results.
- The increased brightness of the C-band guns appear to increase the sliced energy spread but do not completely undo the gains from the higher cathode gradient.





Conclusion

- A travelling-wave RF photogun has been designed and is currently under fabrication as part the IFAST programme.
- The design features a load-lock capability for the use of semiconductor cathodes.
- Thermal simulations demonstrate that the low power dissipation opens up the possibility of operating up to 1 kHz.
- Beam dynamics simulations illustrate that, if one can achieve a cathode gradient of 200 MV/m, it is possible to increase the 5D brightness by a factor of 5 when compared to current S-band SW gun.
- The increased brightness results in an increase in sliced energy spread due to IBS although this does not completely undo the increase when considering 6D brightness.

Find out more soon:

Under Review in PRAB: T. G. Lucas et al. Towards a Brightness Upgrade to the SwissFEL: A High Gradient Traveling-Wave RF Photogun

Thank you for your attention.

- Any questions?

- Funding: This project has received funding from the European Union’s Horizon 2020 Research and Innovation program under GA No101004730.