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Beam Dynamics for a High Field C-band Hybrid Photoinjector

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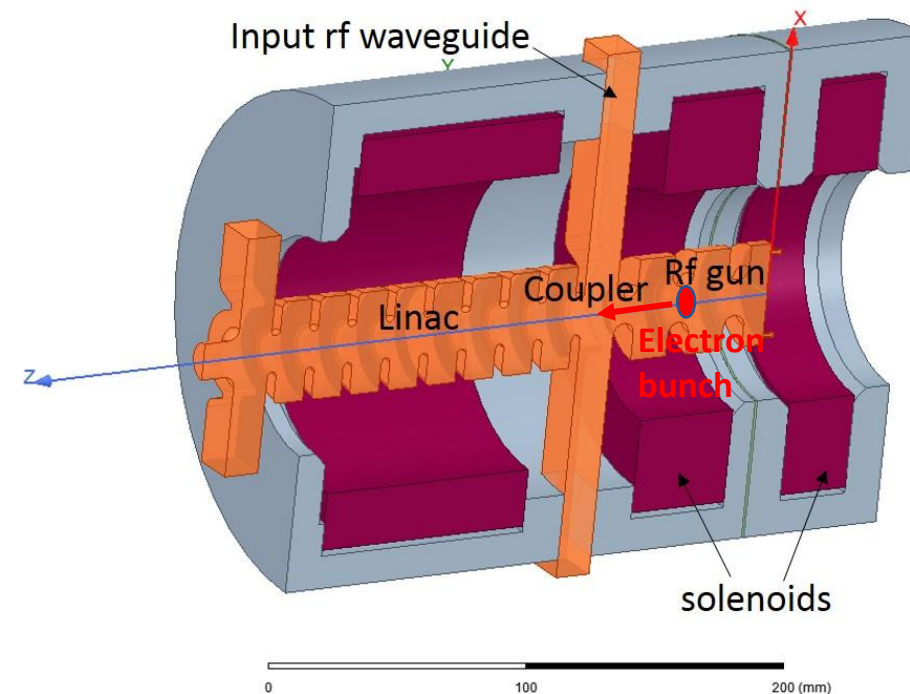
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12th International Particle Accelerator Conference - IPAC'21, May 24-28, 2021



- New class of a hybrid photoinjector in **C-Band**, $f = 5.712$ GHz (compact structure);
- Possibility of high brightness beams, proportional to λ^{-2} ; (more compact than S-band version and more cost-effective from the X-band version),
- Basic scheme RF Gun plus Linac is unchanged but the two structures are aligned and coupled through a single cell (*coupler*) → **Hybrid structure**;
- RF power is fed only from one waveguide into the coupler, that transmits it to both structures (mismatch avoided) → **No circulator**;
- **Velocity Bunching** between the SW and TW sections, due to $\pi/2$ phase-shift → ultra-short electron bunches;
- Solenoid and downstream linacs for **emittance compensation**.



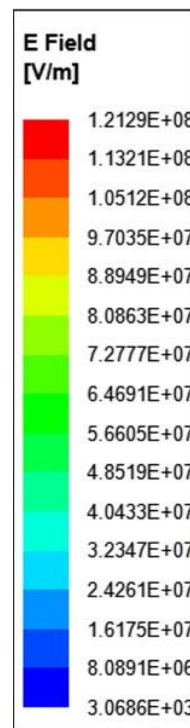
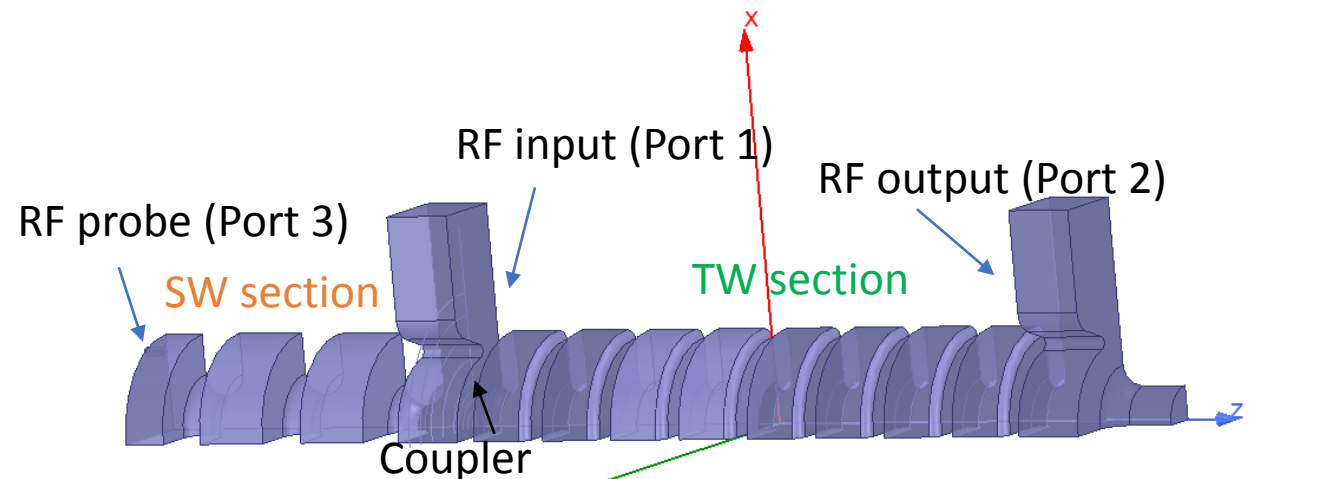
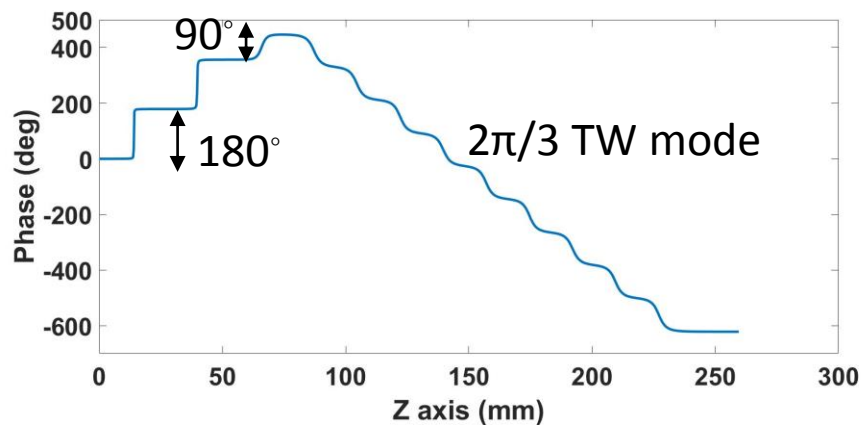
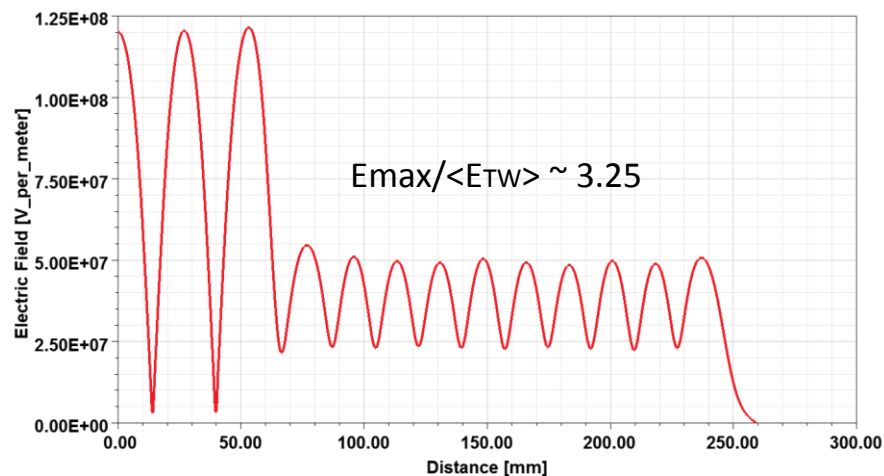
Applications

Injector for FELs interdisciplinary scientific research (biology, medicine, materials science, non-linear optics).

- **Inverse Compton Scattering** (100 MeV electron beam)



- Optimized SW and TW sections in order to obtain $E_{\max}=120$ MV/m at the cathode with < 20 MW RF input power;
- Operating Frequency 5.712 GHz.

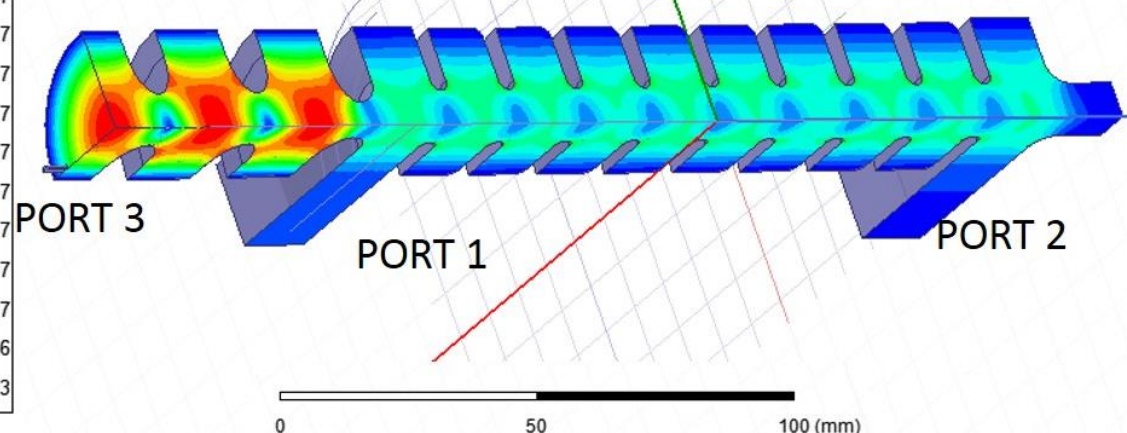


SW rf gun parameters

Operation mode = π
 Quality Factor = 9900
 Eff. Shunt Impedance = 52 M Ω /m
 Mode Separation 21.5 MHz
 Time constant = 530 ns

TW section parameters

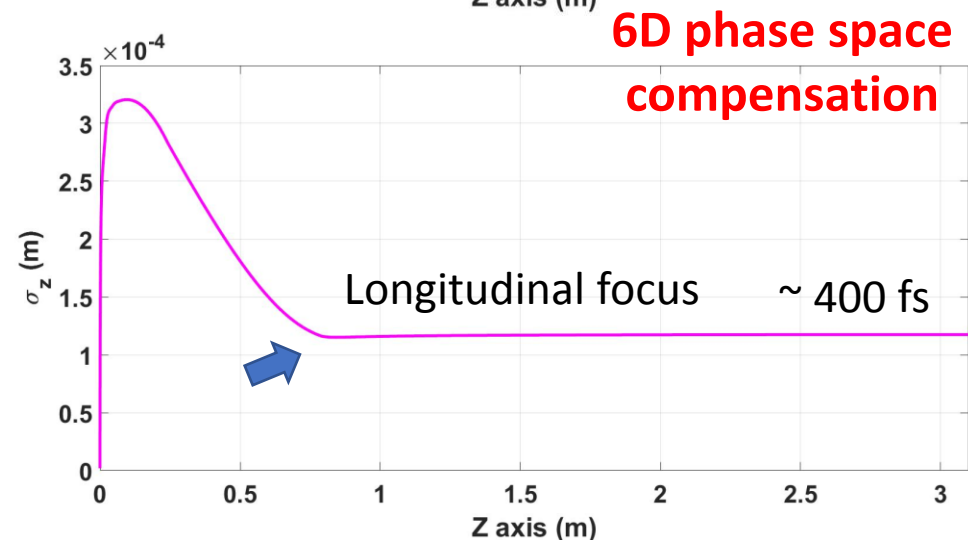
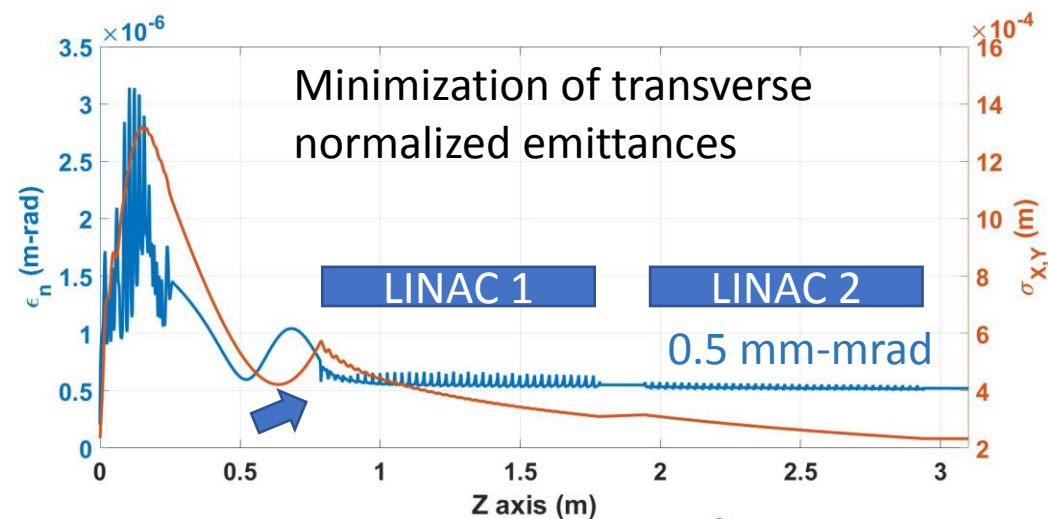
Operation mode = $2\pi/3$
 Group velocity = 2.73 %
 Attenuation $\alpha = 0.23$ m $^{-1}$
 TW filling time = 21.3 ns





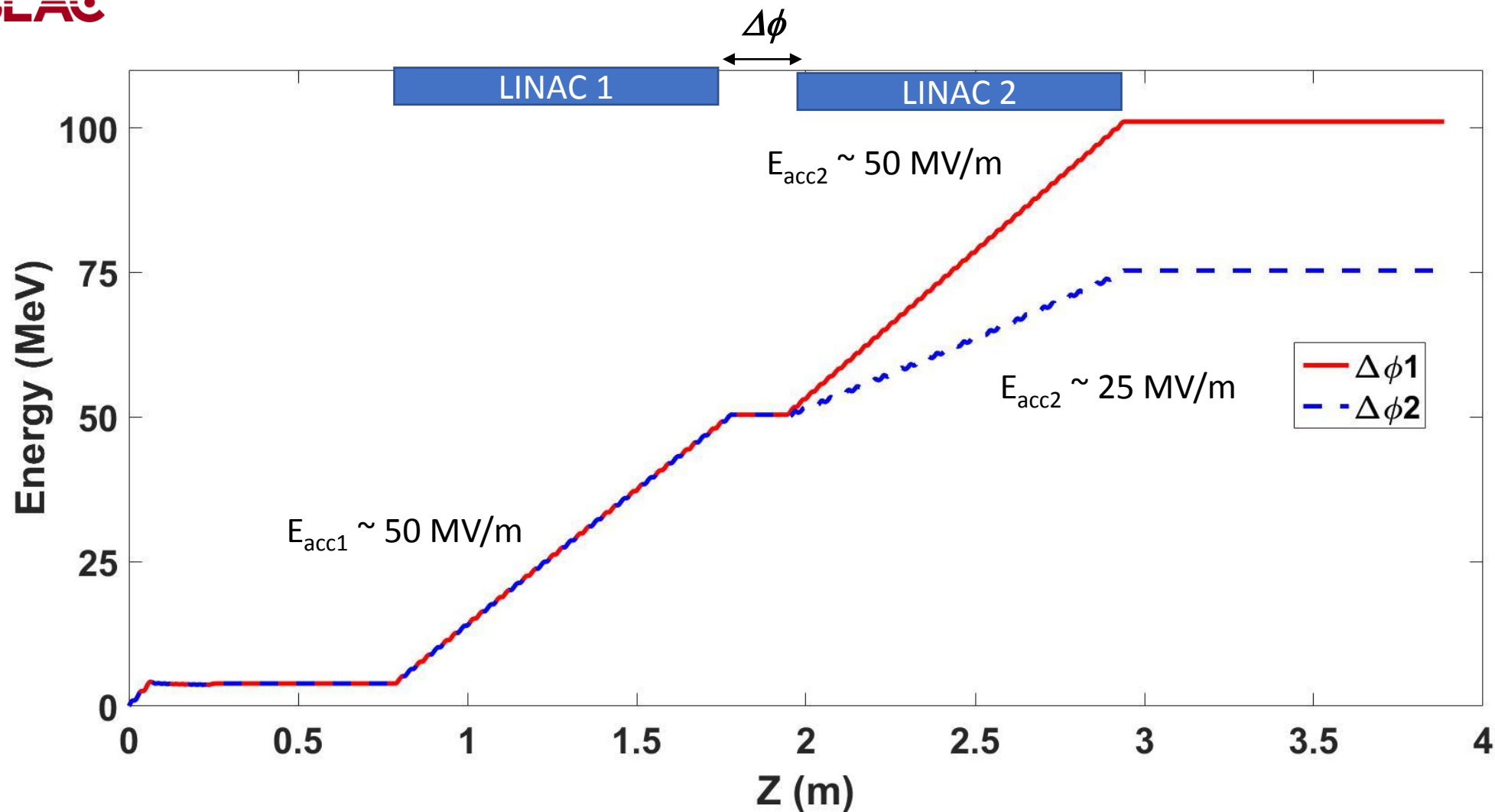
Input Parameters	Value
Beam Charge	250 pC
Sigma x (cut@1-sigma)	500 μm
Laser Pulse Length	0.5 ps
E-field at cathode	120 MV/m
Peak Bz	0.27 T
Linac Gradient	50 MV/m
# particles	50,000

- Beam Dynamics simulation carried out with GPT;
- 1-m long distributed-coupling linacs (S. Tantawi) at 50 MV/m;
- **Emittance compensation** and **bunch compression**, simultaneously;
- Beam spot focused down to about 200 μm rms;
- Beam peak current > 600 A;
- The unique beam envelope dynamics and the wake-field effects inside the hybrid photoinjector was also investigated with analytical methods (see Fabio Bosco's and Martina Carillo's presentations, respectively).





Multiple Energy Operation



Versatile system

- Multiple energy operation.
- Adjustment of Phase-shift between first and second linac e.m. fields.



Conclusions

- A new class of a hybrid (SW/TW) photoinjector in C-Band: extension and evolution for this new class of device.
- Optimized SW and TW sections in order to obtain 120 MV/m at the cathode with < 20 MW RF input power;
- Optimized beam dynamics shows 6D phase space compensation at 250 pC;
- Proper beam shaping at the cathode yields a 0.5 mm-mrad transverse emittance.
- A beam waist occurs simultaneously with a longitudinal focus of < 400 fs rms and peak current >600 A.
- Successfully investigated operation with two 50 MV/m linacs for an ICS source but can be used for FEL applications as well;
- Suitable for cryogenic operation → higher accelerating gradients;
- Work supported by DARPA GRIT under contract no. 20204571.

Thank you very much for your attention!