An X-Band Ultra-High Gradient Photoinjector

Sergey V. Kuzikov[1], Sergey P. Antipov[1], Pavel Avrakhov[1,2], Edward Dosov[1,2], Ernest W. Knight[1], Gwanghui Ha[3], Wanming Liu[3], John G. Power[3], Doran Scott[3], Jiahang Shao[3], Chunguang Jing[1,2,3], Philippe Piot[3,4,5], Eric Wisniewski[3,6], Xueying Lu[7,8], Wei Hou[5]

[1]Euclid TechLabs, LLC, Solon, Ohio

[2]Euclid Beamlabs LLC, Bolingbrook

[3]ANL, Lemont, Illinois

[4]Fermilab, Batavia, Illinois

[5]Northern Illinois University, DeKalb, Illinois

[6]IIT, Chicago, Illinois

[7]MIT/PSFC, Cambridge, Massachusetts

[8]SLAC, Menlo Park, California

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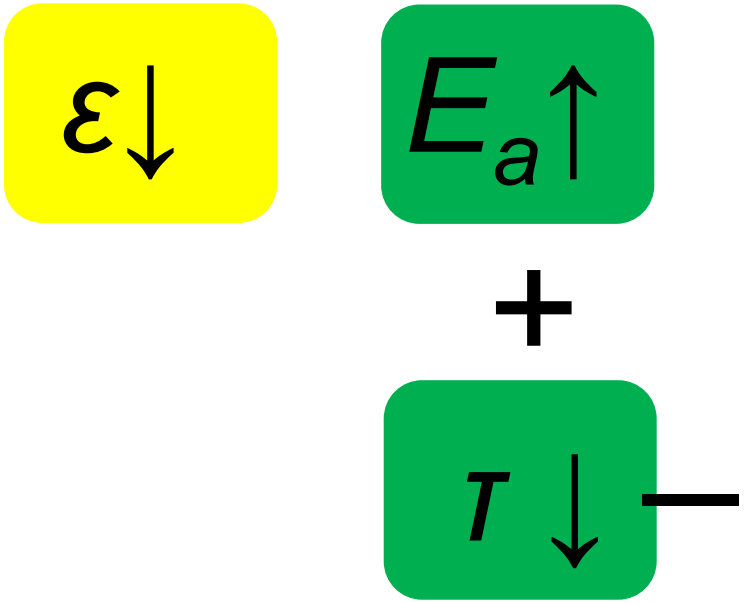
Outline:

1. ***High-gradient photoinjector concept***
2. ***Emittance simulations***
3. ***RF design***
4. ***Beamline engineering design***
5. ***High-gradient tests and measurements of beam energy and emittance***

Abstract: High brightness beams appealing for XFELs and UEM essentially imply a high current and a low emittance. To obtain such beams we propose to raise the accelerating voltage in the gun mitigating repealing Coulomb forces. An ultra-high gradient is achieved utilizing a short-pulse technology. We have designed a room temperature X-band 1,5 cell gun that is able to inject 4 MeV, 100 pC bunches with as low as 0.15 mcm normalized transverse emittance. The gun is operated with as high gradients as 400 MV/m and fed by 200 MW, 10 ns RF pulses generated with Argonne Wakefield Accelerator (AWA) power extractor. We report results of low RF power tests, laser alignment test results, and successful gun conditioning results carried out at nominal RF power.

Concept: e-injector (300 - 400 MV/m @ 10 ns)



For a fixed breakdown rate

$$E_a \cdot \tau^{1/6} = const$$

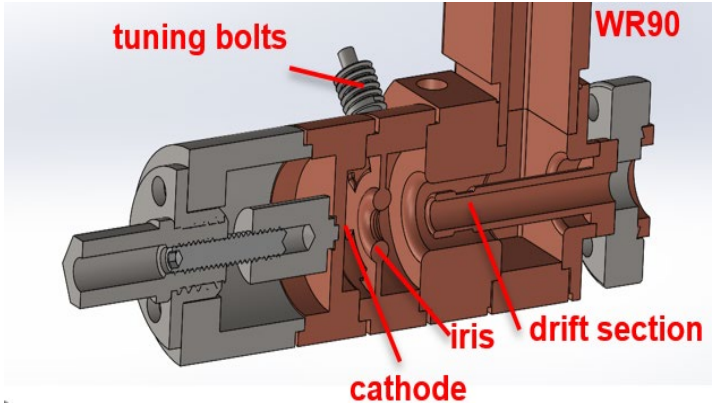
CLIC / SLAC studies

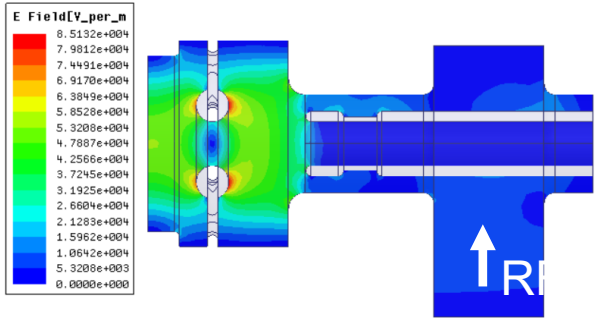
RF design is a subject of this SBIR project

Anticipated Gun Parameters

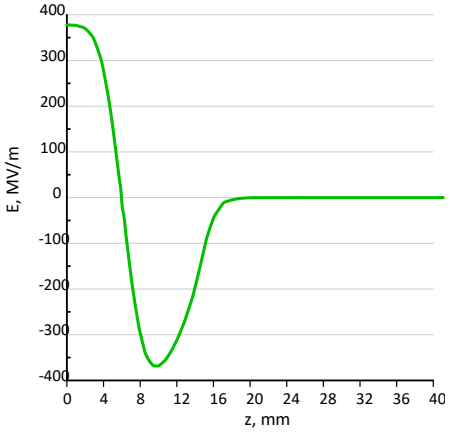
Parameter	Value
Frequency	11.7 GHz
Mode quality factor	180
Mode separation	250 MHz
RF pulse length	10 ns (3 ns flat top)
RF peak power	up to 300 MW
Maximum field at cathode	350 MV/m
Energy of electrons	4 MeV
Bunch charge	100 pC
RMS bunch radius at cathode and at exit	0.07mm, 0.13 mm
RMS bunch length	4 ps
Normalized emittance	0.15 mm×mrad (with linac)
$\Delta E/E$	2.5×10^{-3}

RF Gun Design

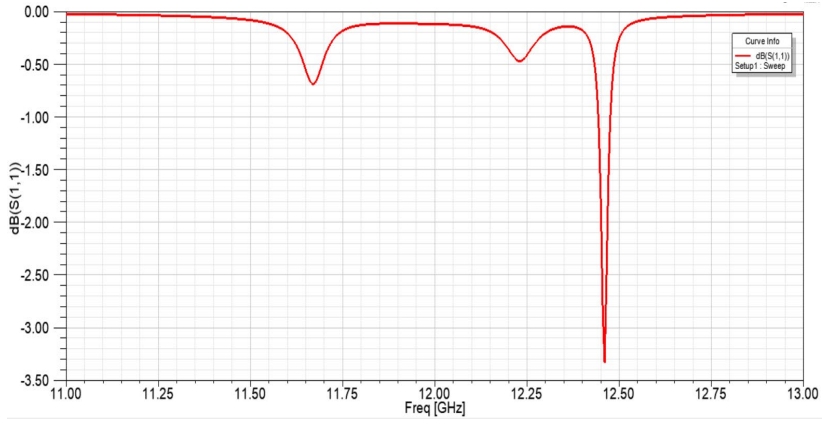




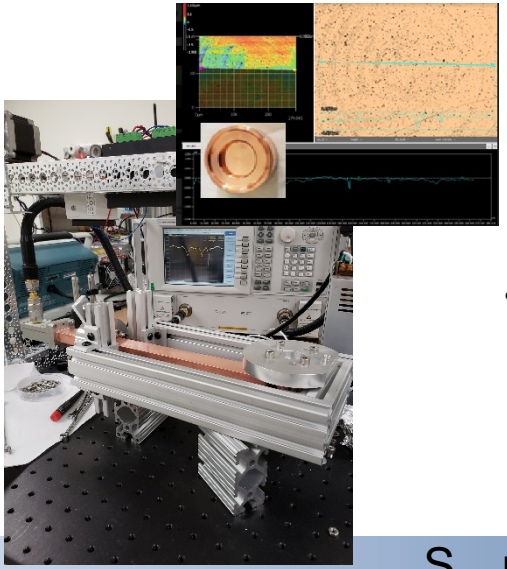
11.7 GHz field structure

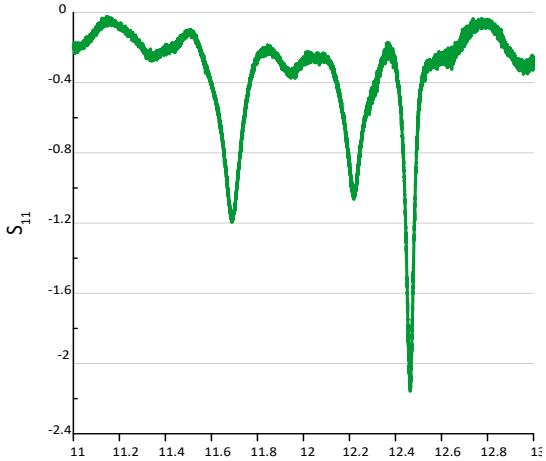


11.7 GHz field structure at axis for 100 MW of incident power



S_{11} parameter (simulation)

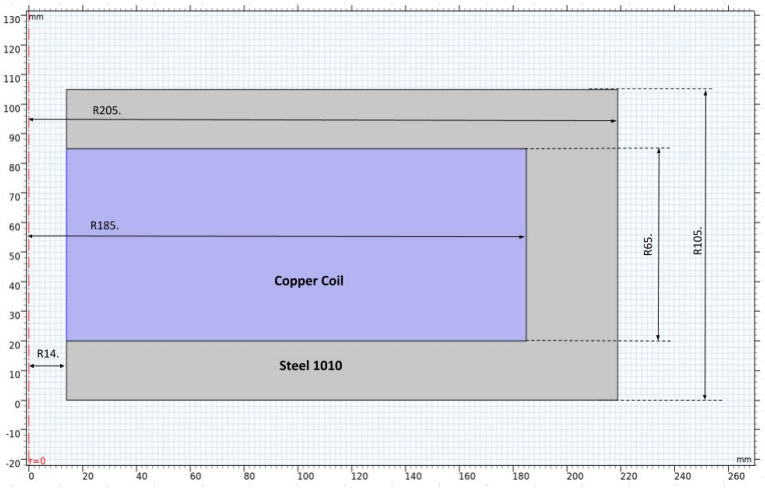


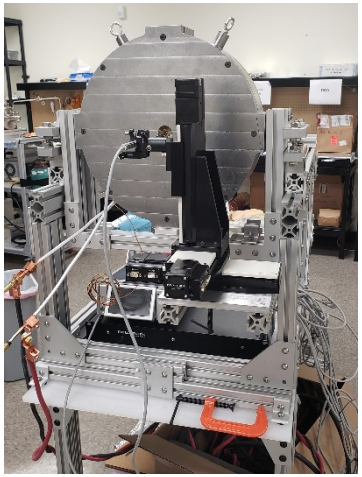


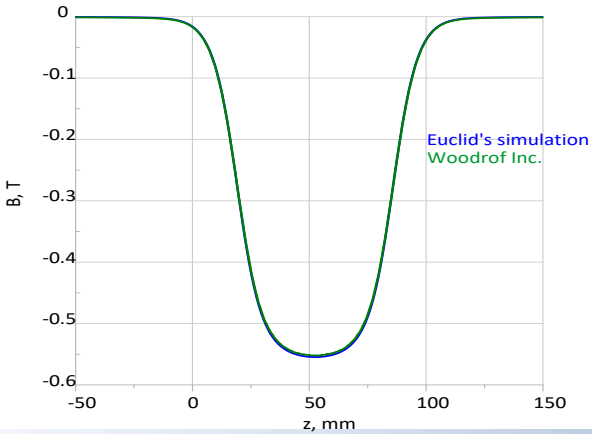
S_{11} parameter (measurement)

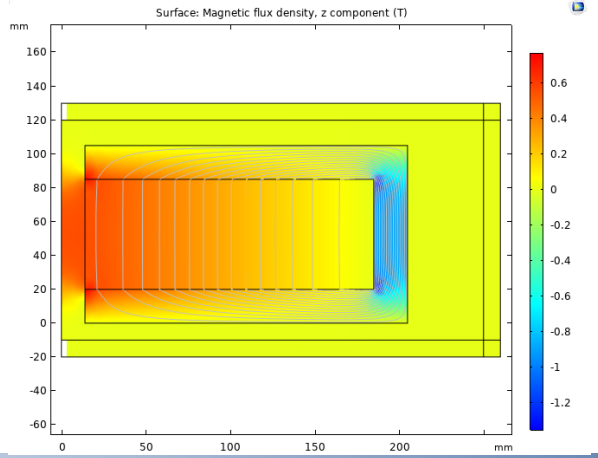
euclid TECHLABS

0.55 T Solenoid for Emittance Compensation







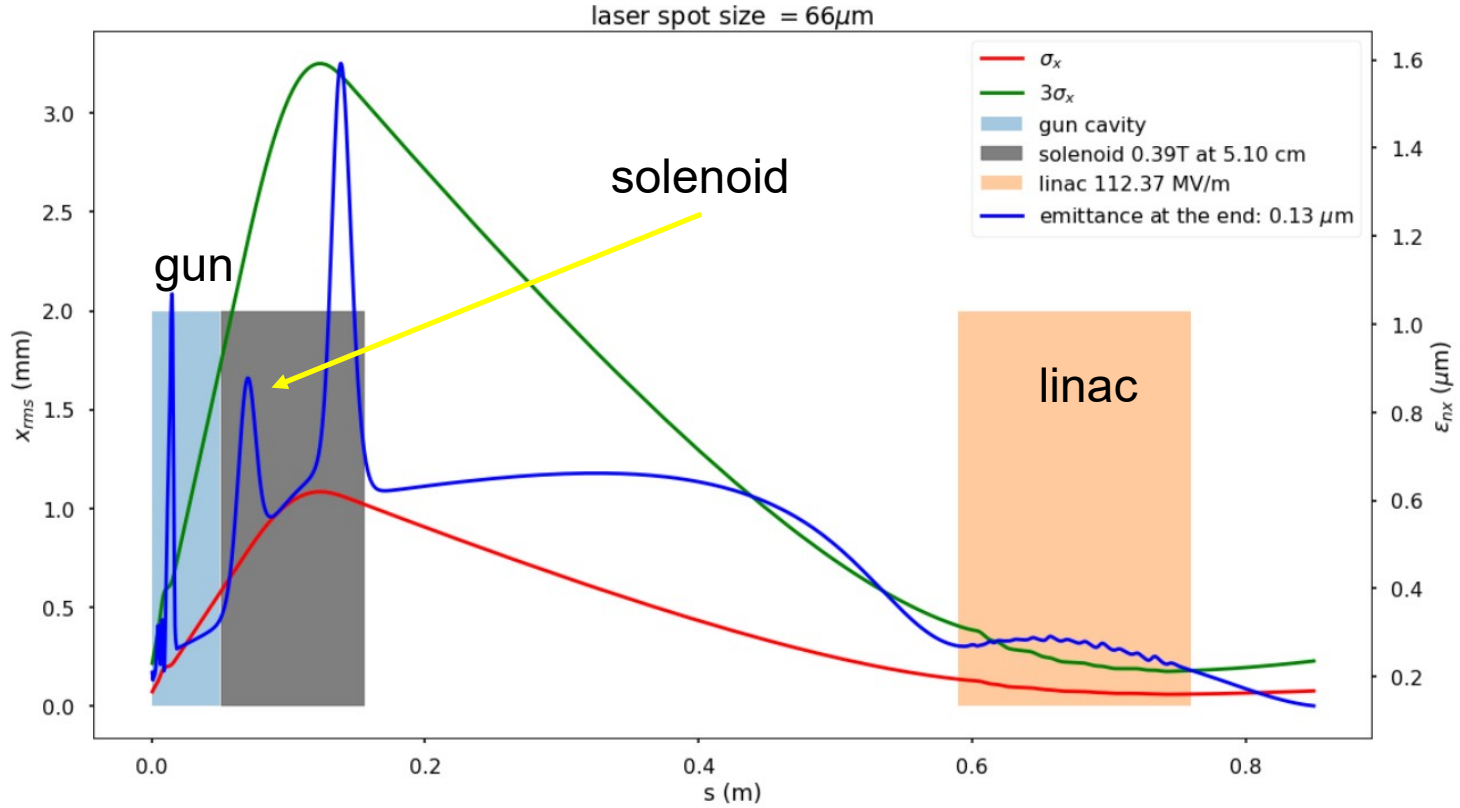


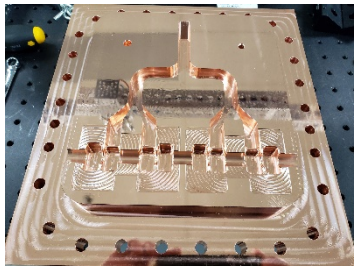
B-field at axis

B-field distribution

Emittance Simulations

For details of gun emittance simulations see also poster **THPAB129.**

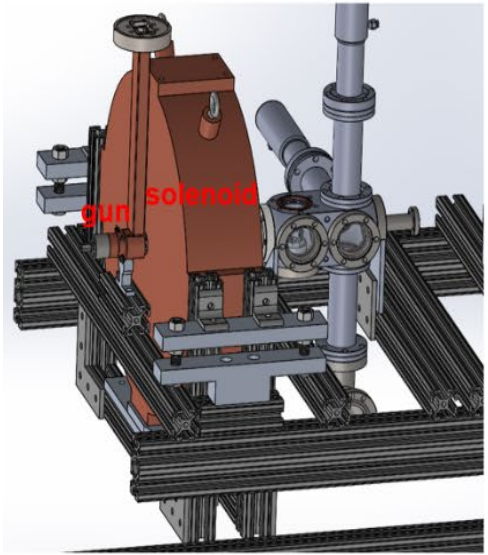


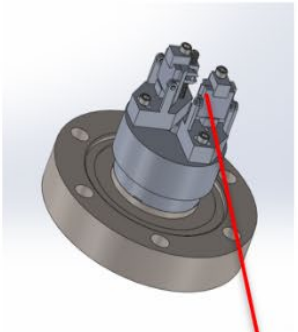


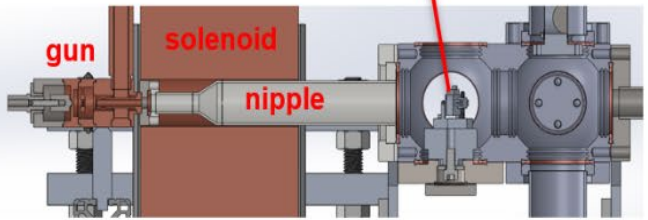
Linac tested at AWA at 180 MW.

11.7 GHz 1,5 cell Gun

Beamline Design (experiment #2)



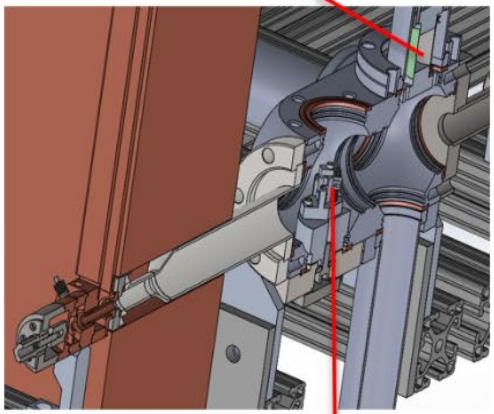




Optical mirrors

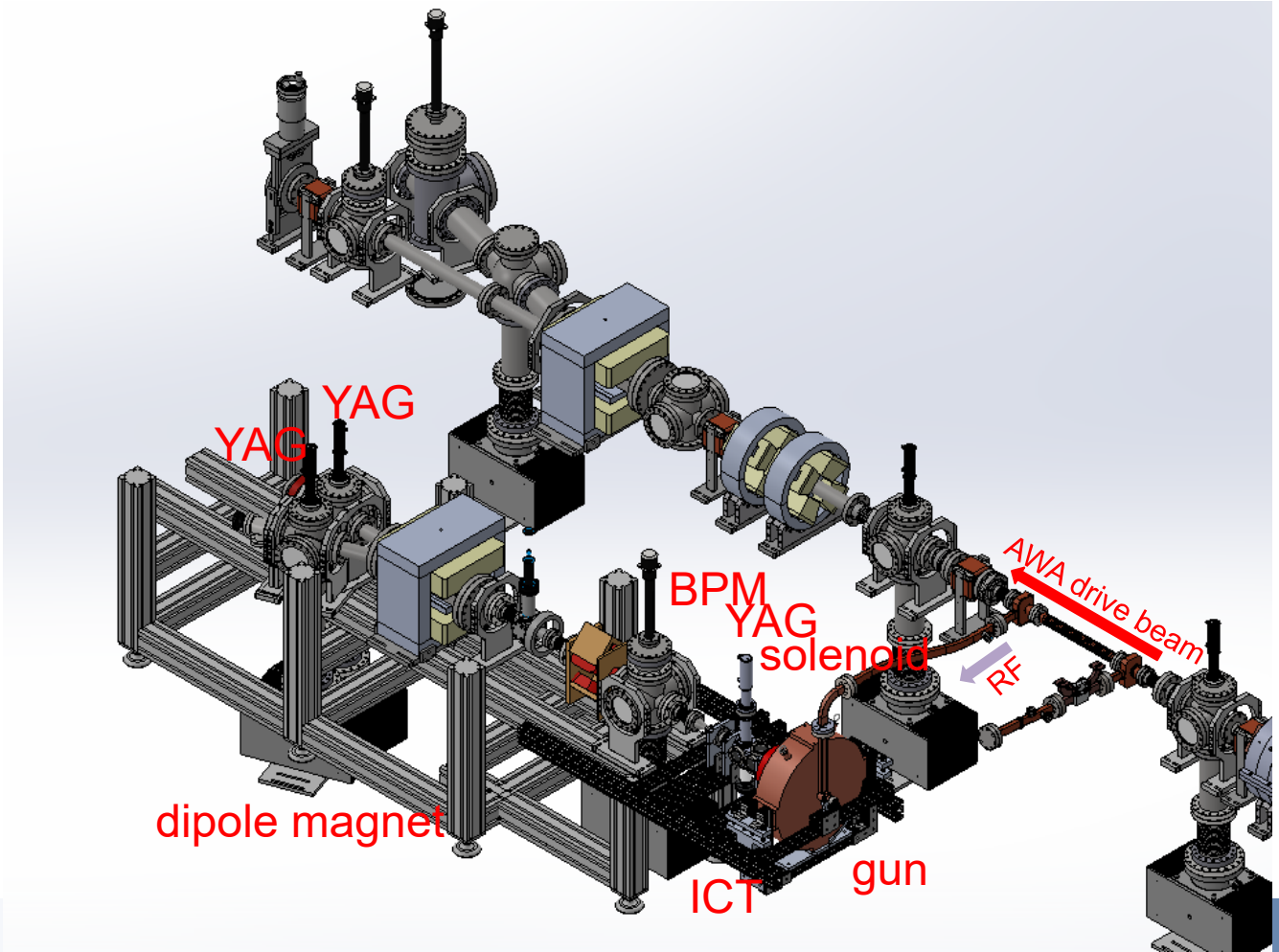
double 6-way cross

Movable YAG screen

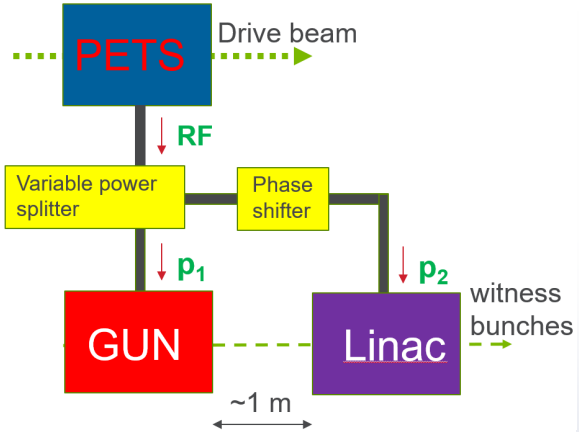


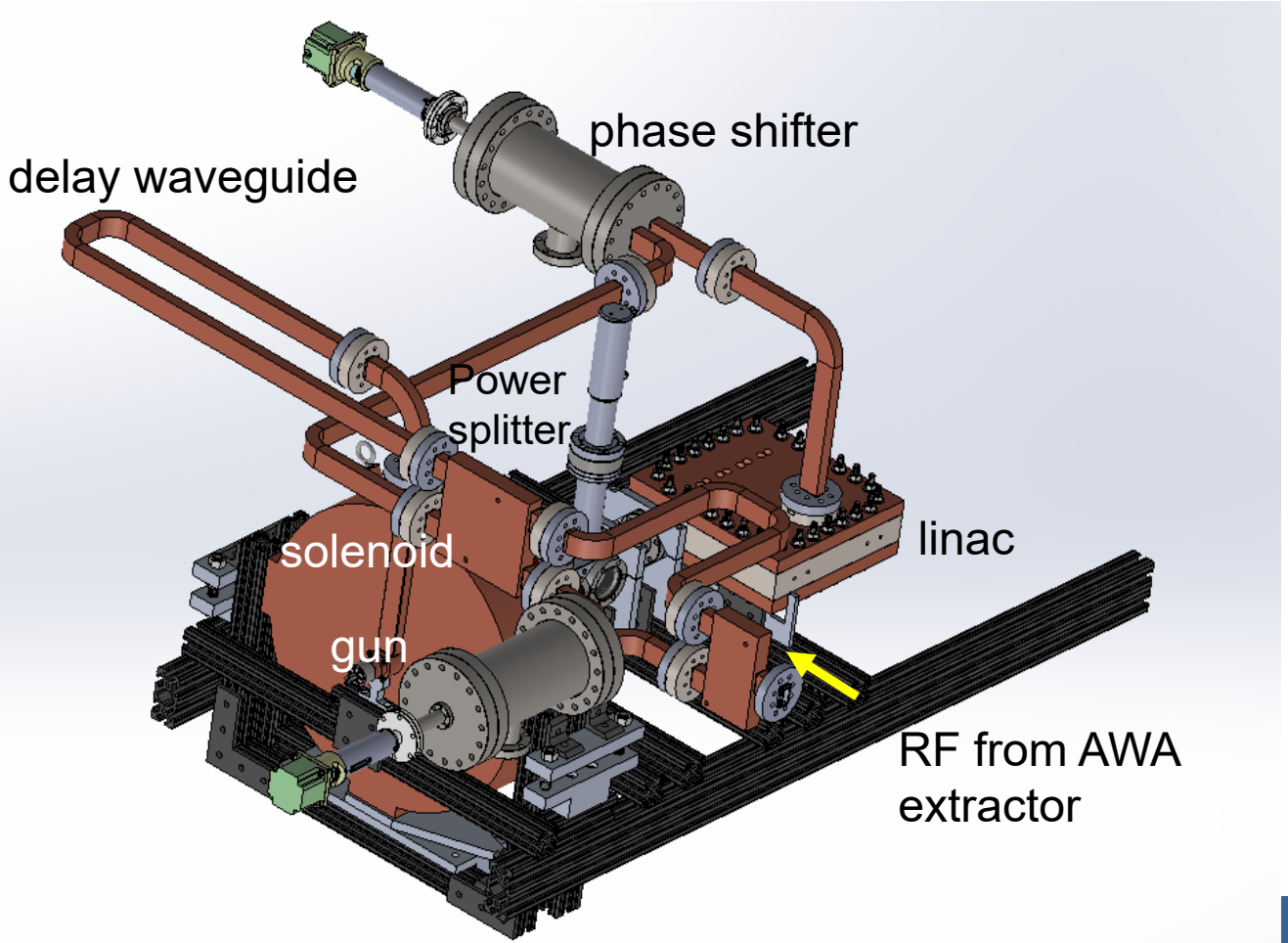
Optical mirrors

Beamline Design (experiment #2)

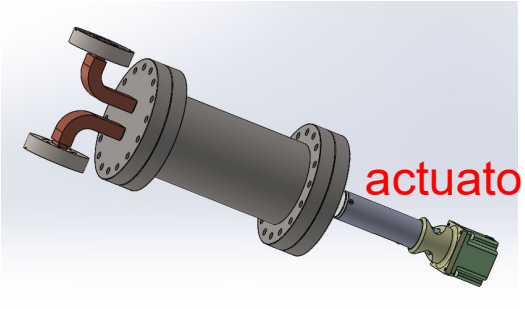


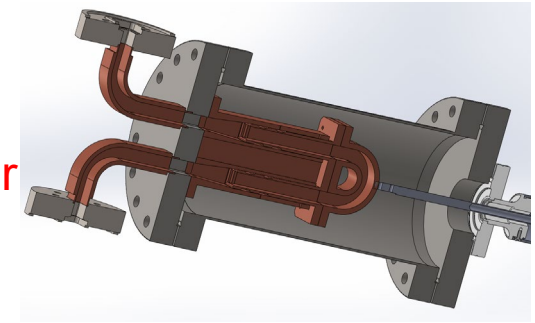
Experiment #3: RF Feeding of Gun and Linac from the Same Power Source

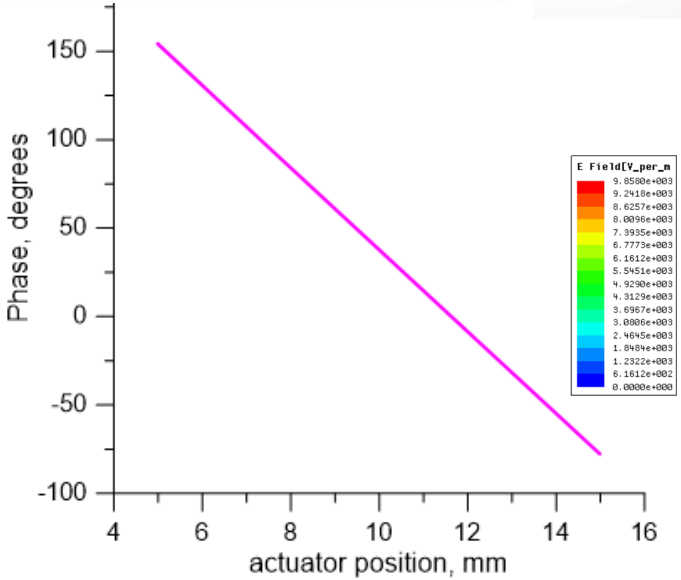


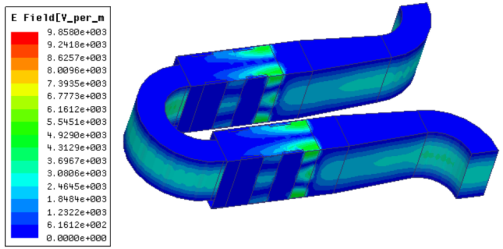


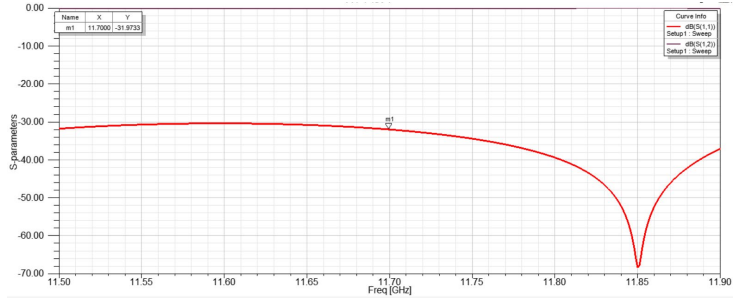
RF Phase Shifter

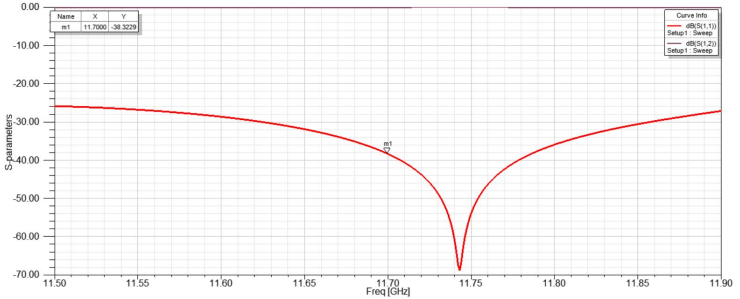


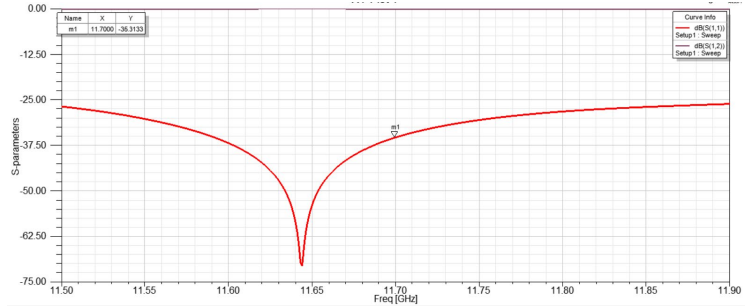




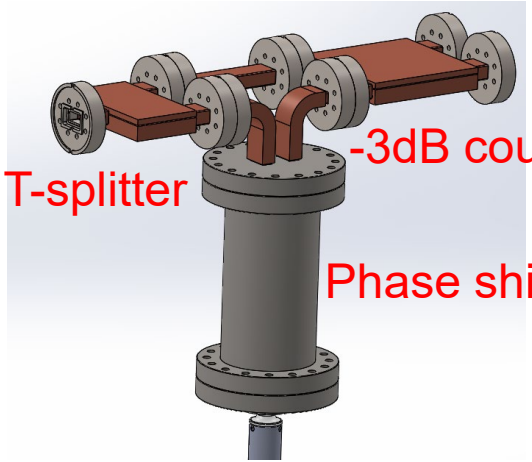


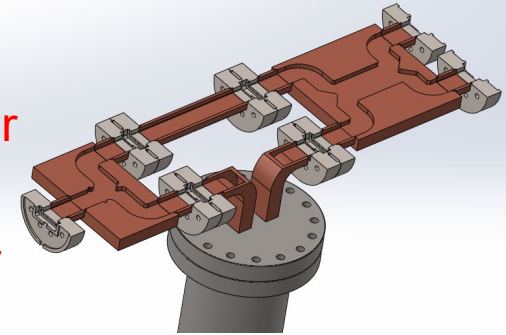


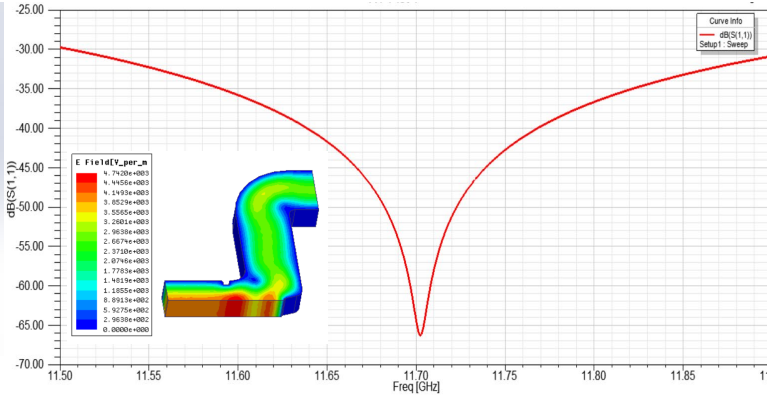


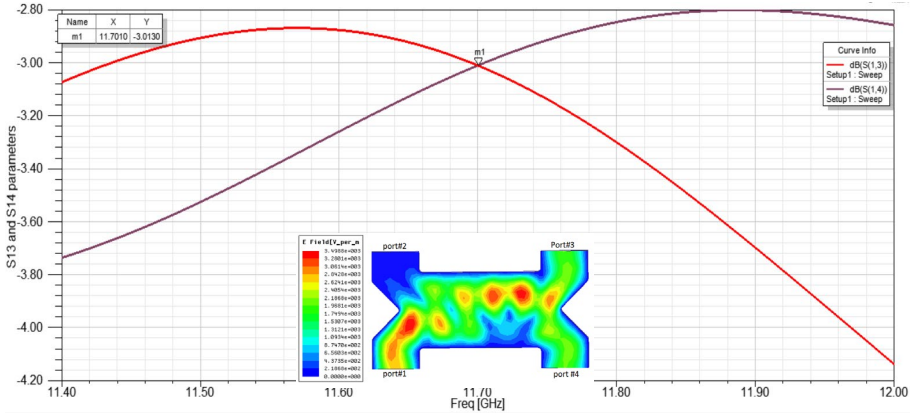


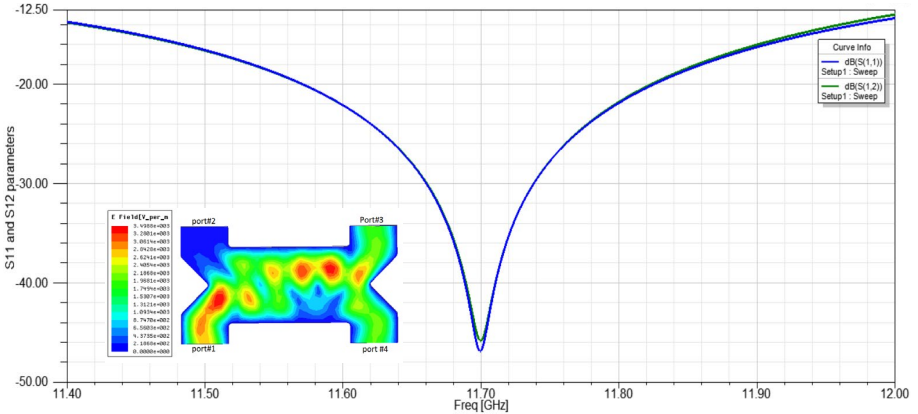
RF Power Splitter



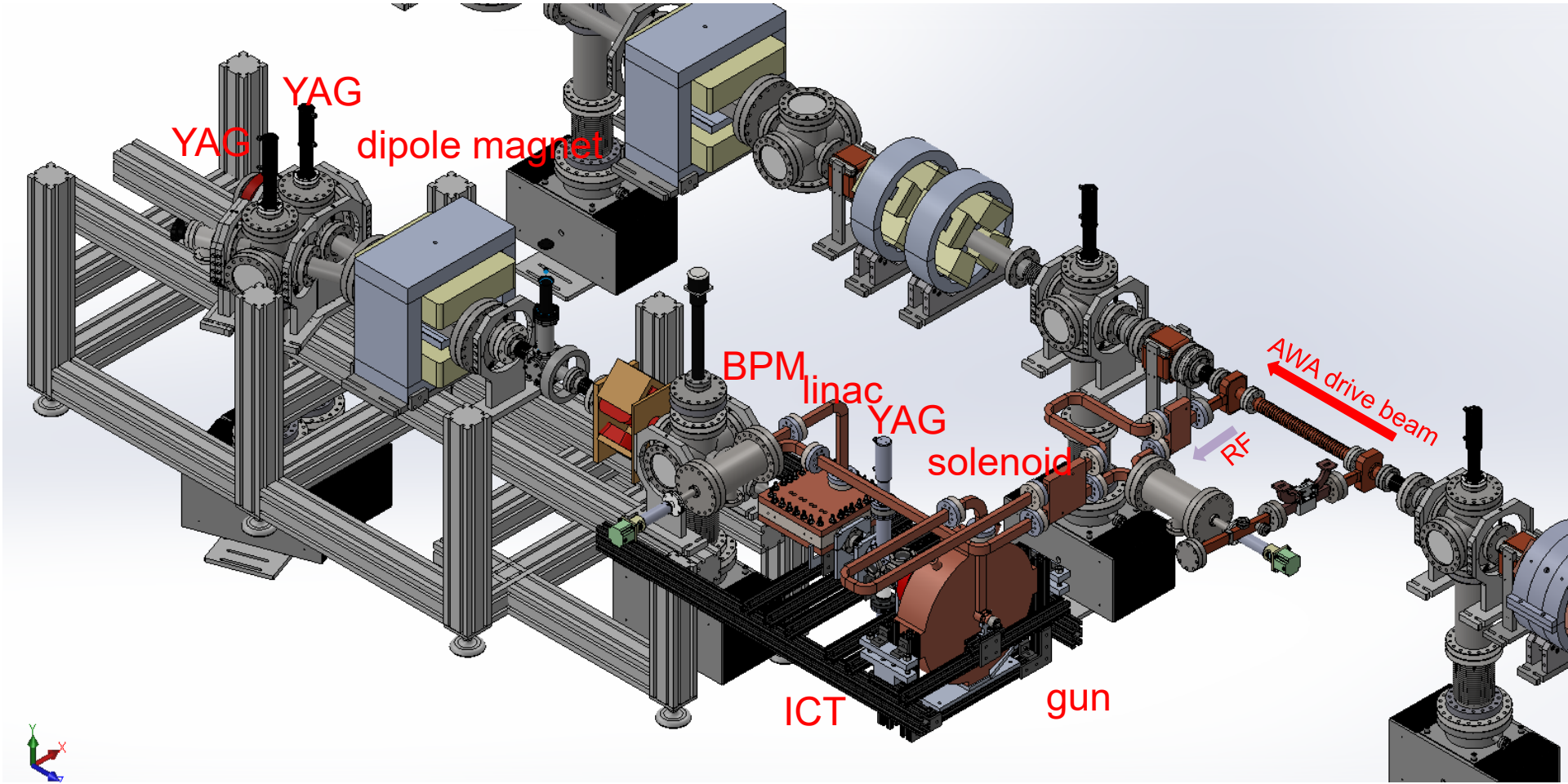








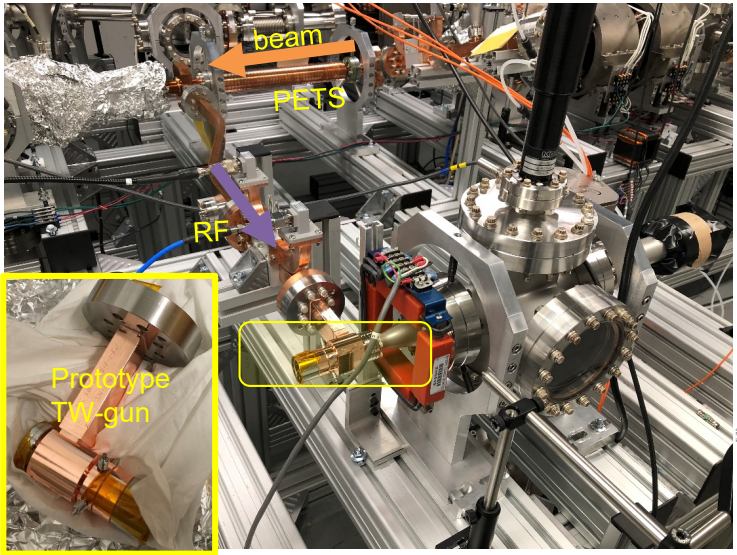
Beamline Design (experiment #3)

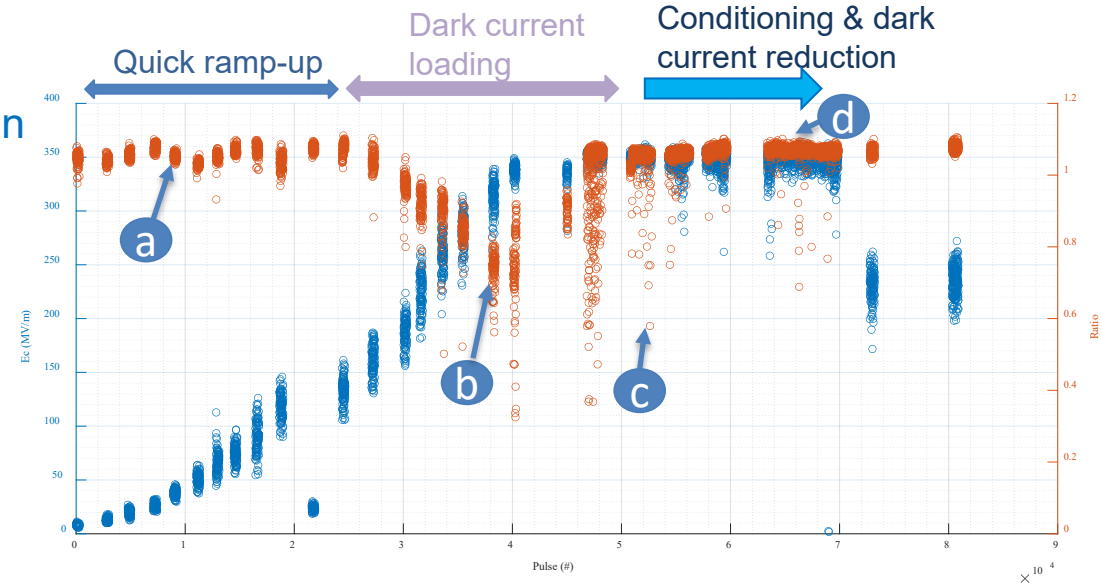


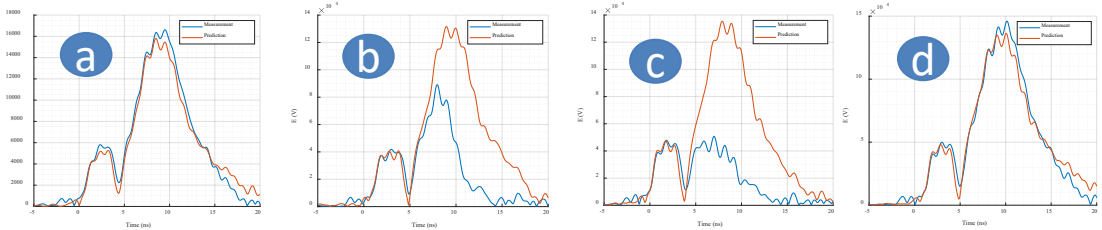
BREAKDOWN TEST OF A PROTYPE GUN AT AWA (2020)

- Achieved 350MV/m on cathode
- Observed strong dark current loading regime but quickly conditioned away
- It only took 70k pulses for a full condition
- Back to 200MV/m to 250MV/m region, no breakdown, no measurable dark current.

For gun high-power test see also poster THPAB331.

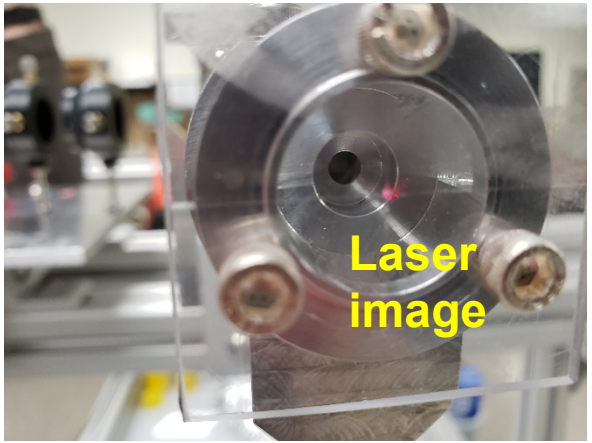


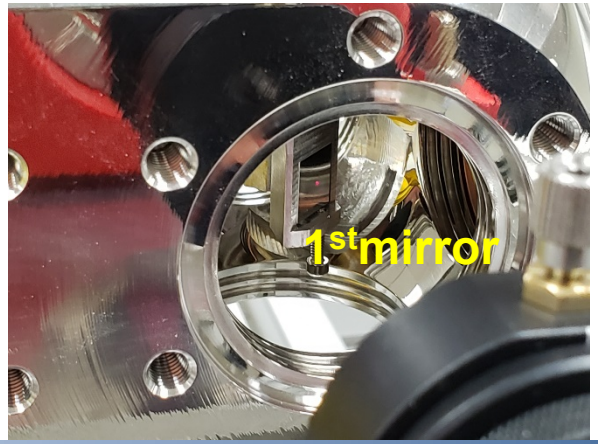




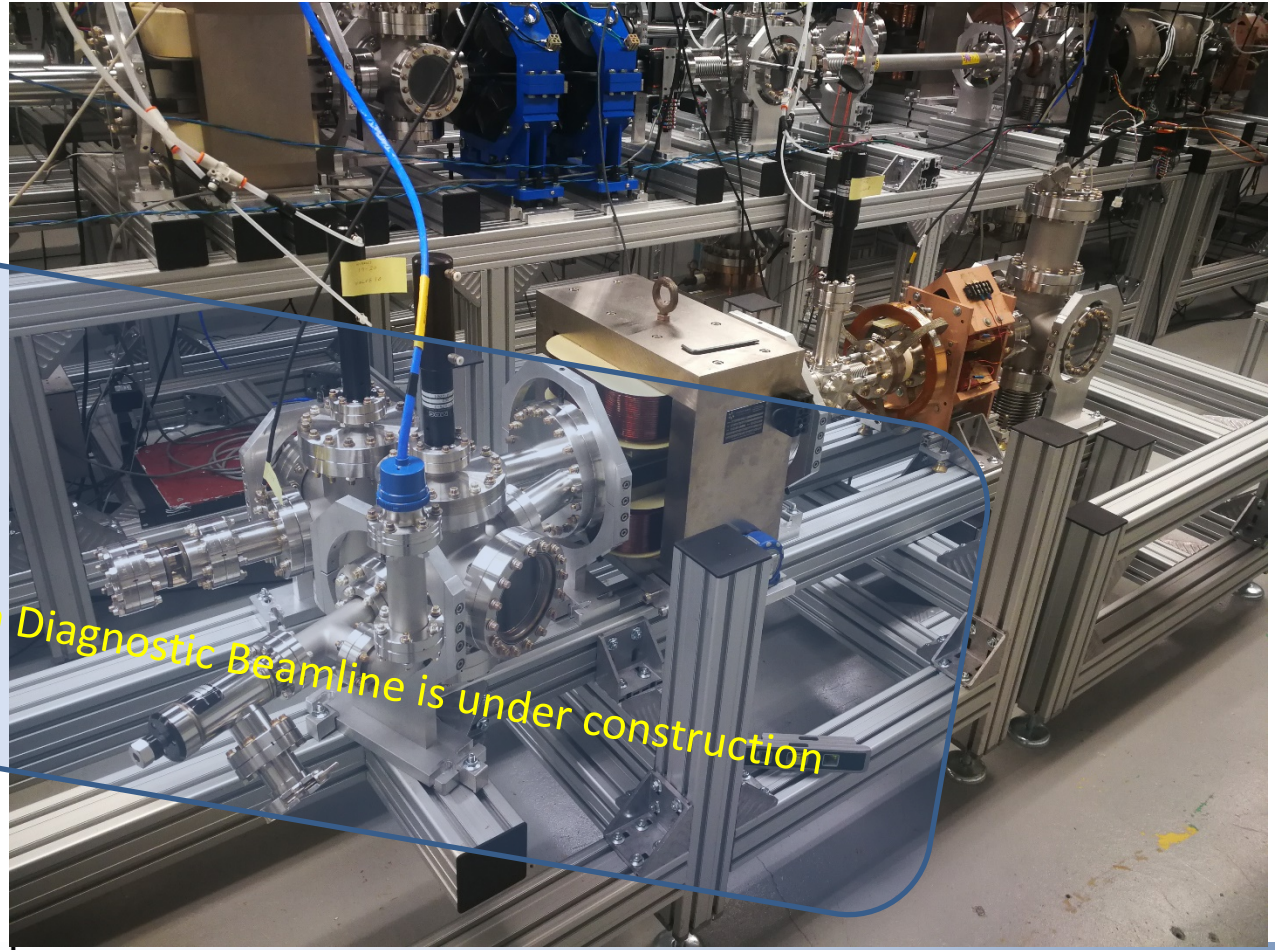
Reflection signal from bi-directional coupler

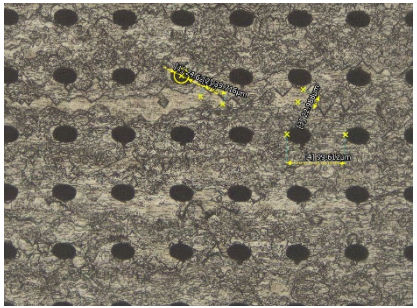
Adjustment of Optical Mirrors at Mockup





Full-Scale High-Power Experiment





Tungsten pepper pot

Conclusion

1. High-gradient gun design promises a very low beam emittance (less than 0.15 mm×mrad).
2. An operation with a very hort RF pulse (9 ns full duration, 3 ns flat top) preserves from breakdown and large dark current. This was confirmed at AWA experiment with 300 MW power extraction structure.
3. Lots of the components designed, fabricated and tested.
4. Full-scale high-power experiments scheduled for this Spring (experiment #2) and fall of this year (experiment#3).