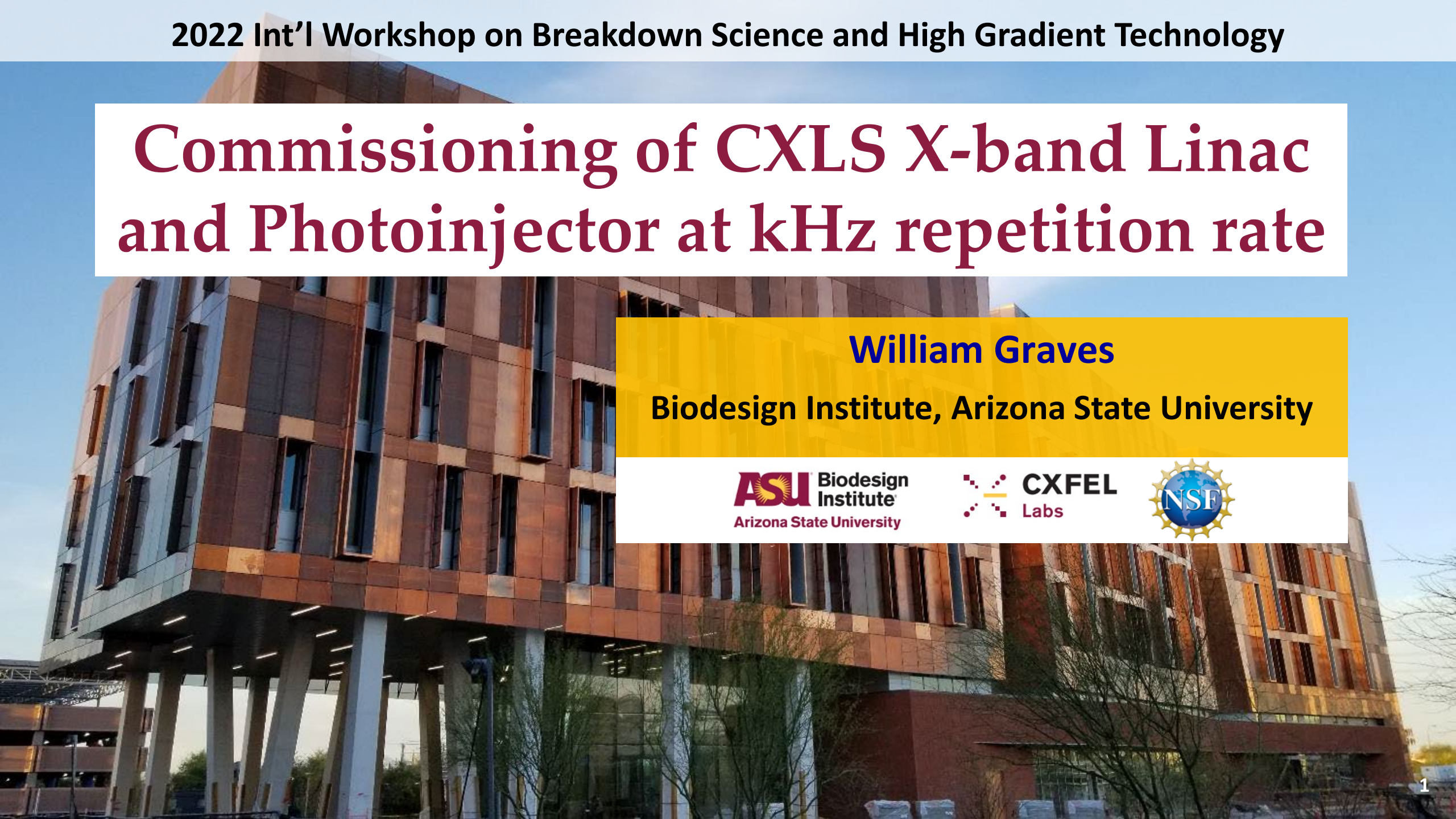
Commissioning of CXLS X-band Linac and Photoinjector at kHz repetition rate

William Graves

Biodesign Institute, Arizona State University

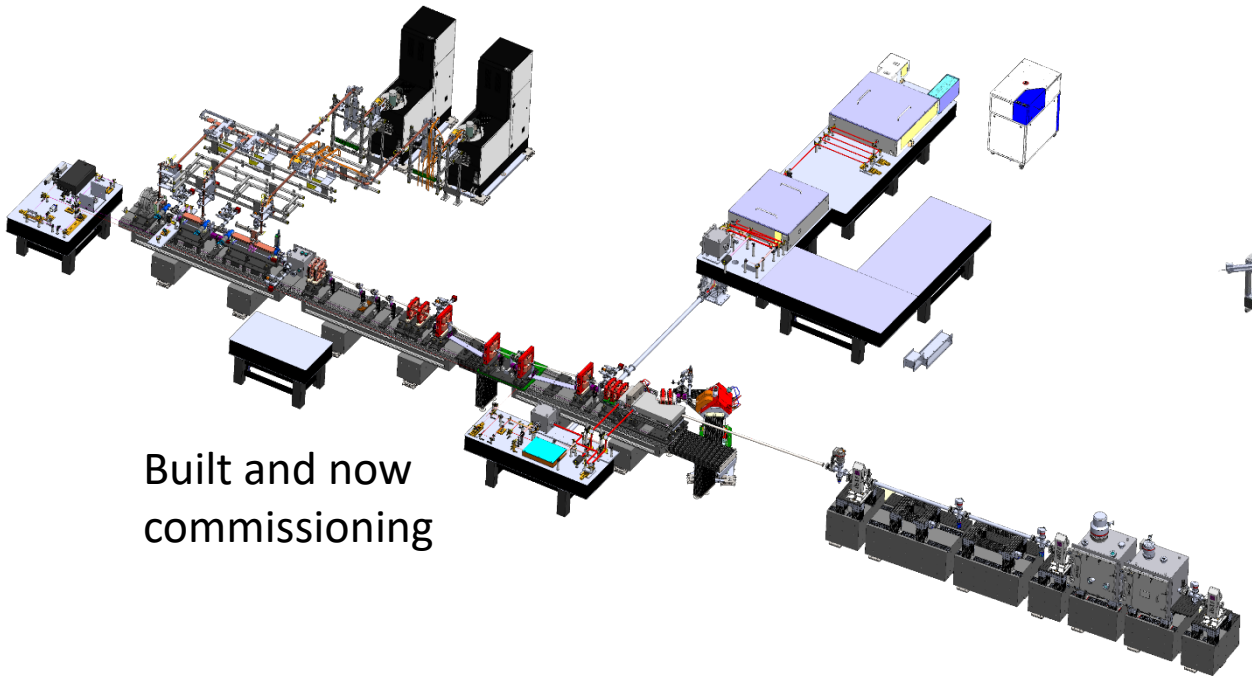


CXFEL Project – What is it?

A two-phase project to build a compact fully coherent x-ray laser

CXLS

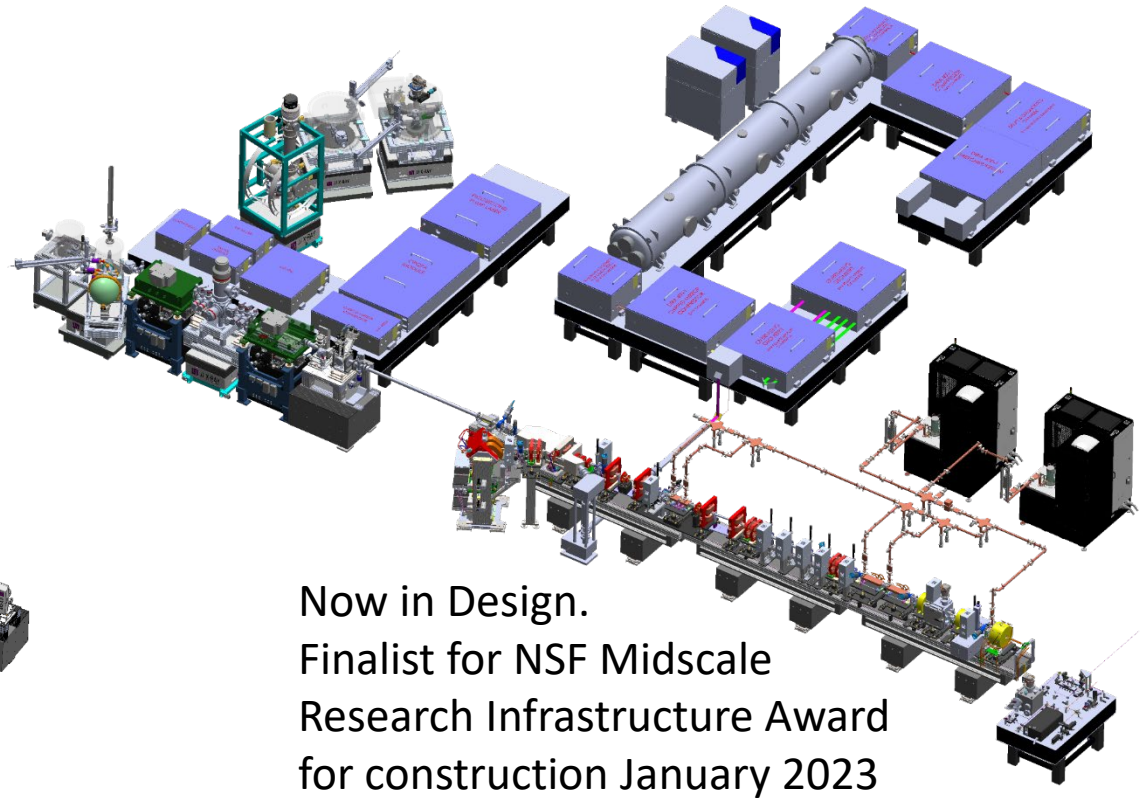
Phase 1 Hard X-ray ICS Source



Built and now commissioning

CXFEL

Phase 2 Soft X-ray Coherent Laser



Now in Design.
Finalist for NSF Midscale Research Infrastructure Award for construction January 2023

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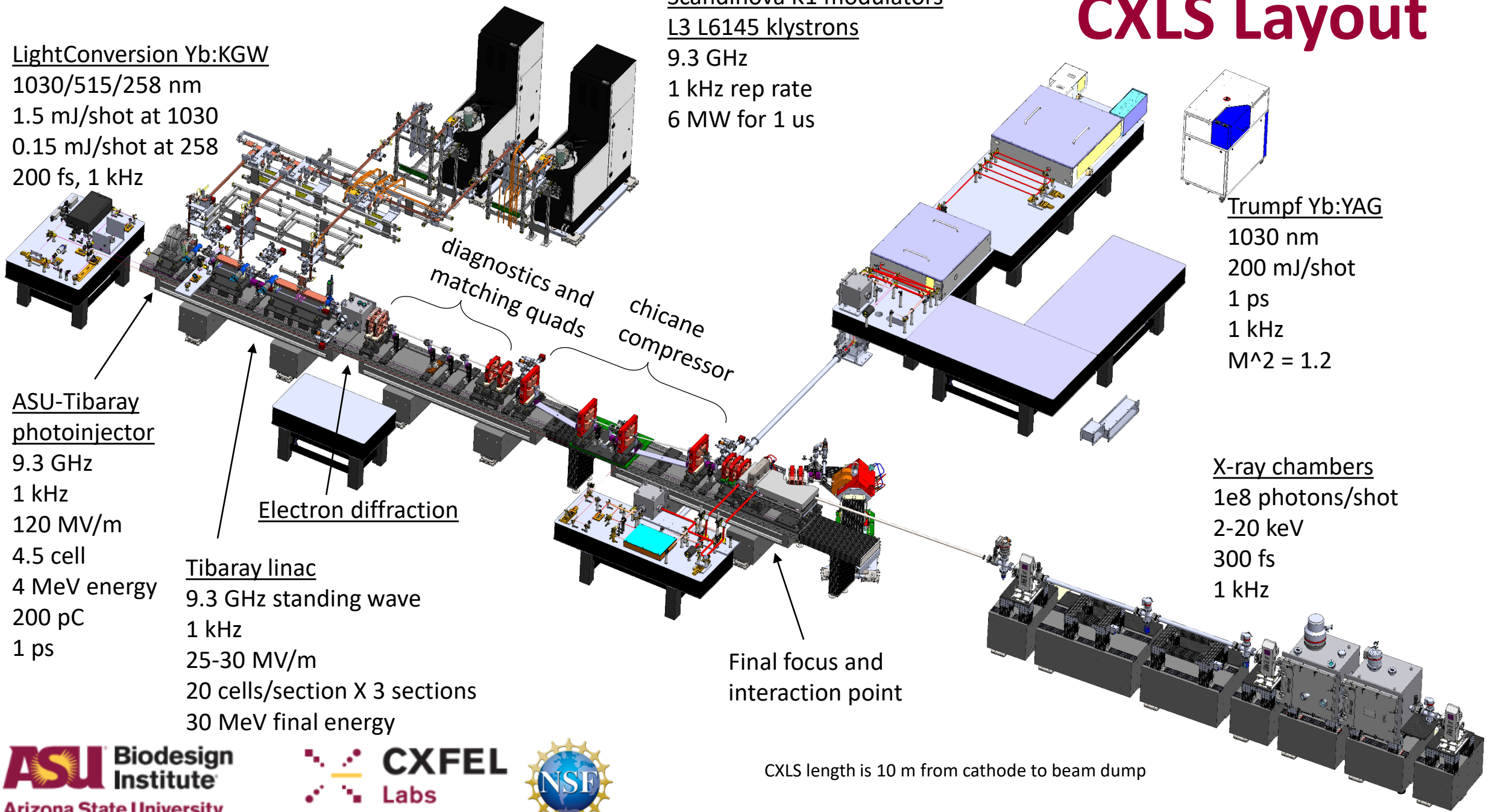
CXLS Layout



LightConversion Yb:KGW
1030/515/258 nm
1.5 mJ/shot at 1030
0.15 mJ/shot at 258
200 fs, 1 kHz

Scandinova K1 modulators
L3 L6145 klystrons
9.3 GHz
1 kHz rep rate
6 MW for 1 us

Trumpf Yb:YAG
1030 nm
200 mJ/shot
1 ps
1 kHz
M^2 = 1.2

ASU-Tibaray photoinjector
9.3 GHz
1 kHz
120 MV/m
4.5 cell
4 MeV energy
200 pC
1 ps

Tibaray linac
9.3 GHz standing wave
1 kHz
25-30 MV/m
20 cells/section X 3 sections
30 MeV final energy

Final focus and interaction point

X-ray chambers
1e8 photons/shot
2-20 keV
300 fs
1 kHz

CXLS length is 10 m from cathode to beam dump

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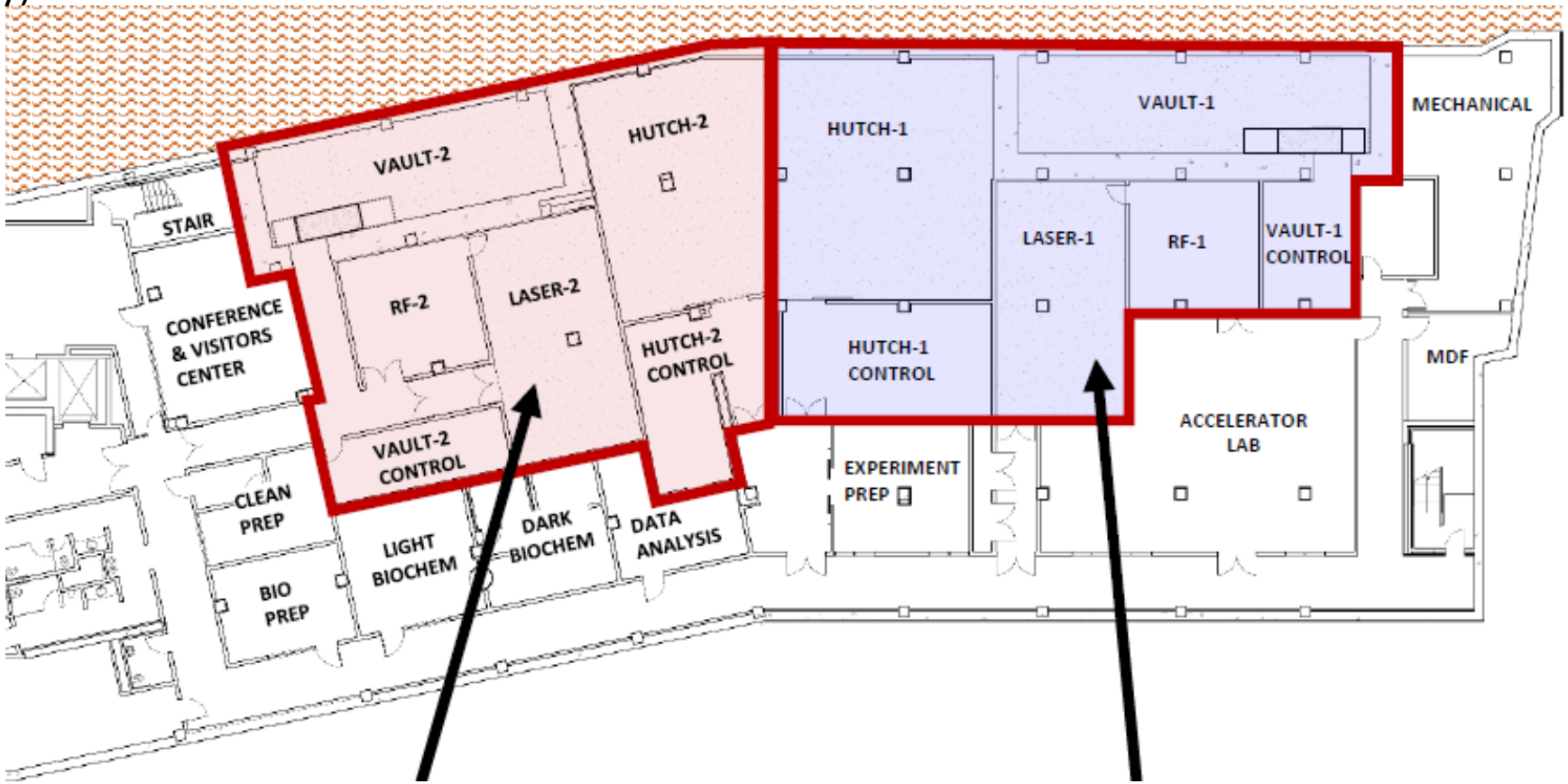
- 2 m thick slab separate from building
- Vibration rated VC-E (TEM quality)
- <0.5 C temperature stability
- <Class 1000 clean room
- Low background B-fields
- Faraday cage RF room

The CXFEL Project includes two lab spaces for independent instruments

- Hard x-ray CXLS is commissioning; prototype of CXFEL technologies
- MSRI-2 award would build soft x-ray CXFEL fully coherent laser



These labs are ready for the proposed **CXFEL**

CXLS is constructed and commissioning in these labs

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CXLS Commissioning Progress

Late 2019

Today

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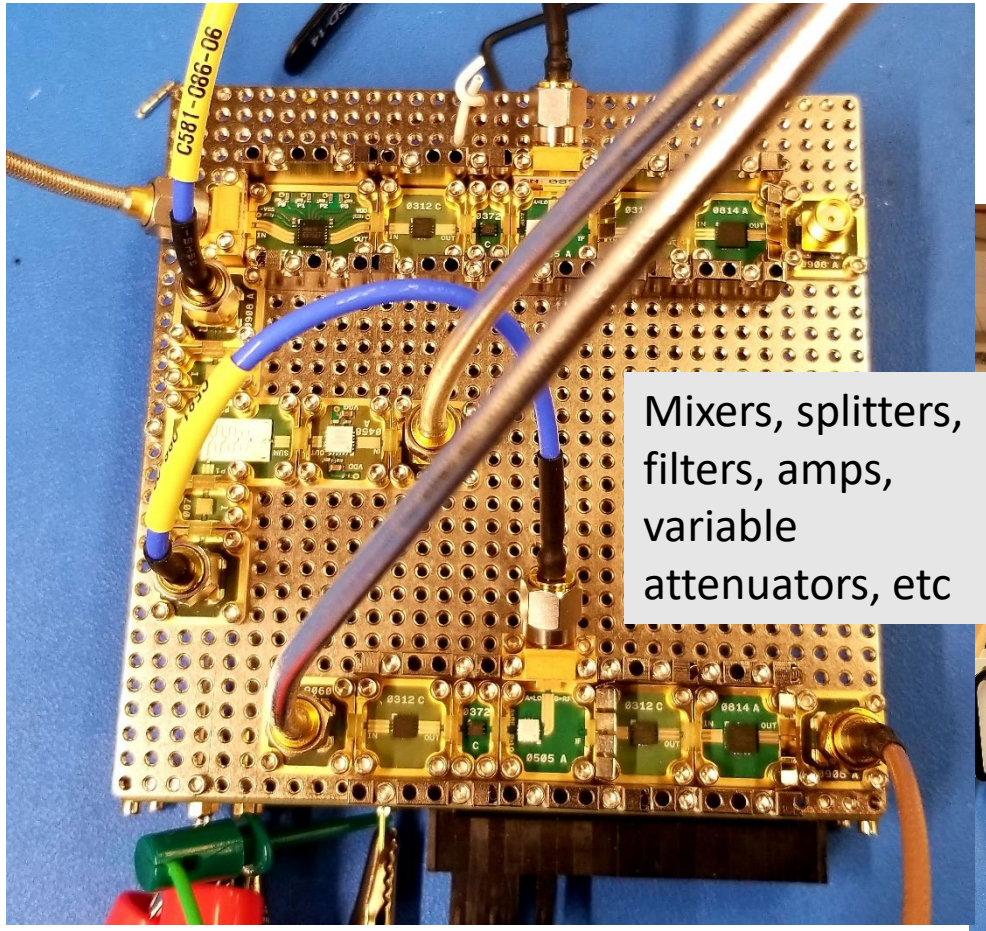
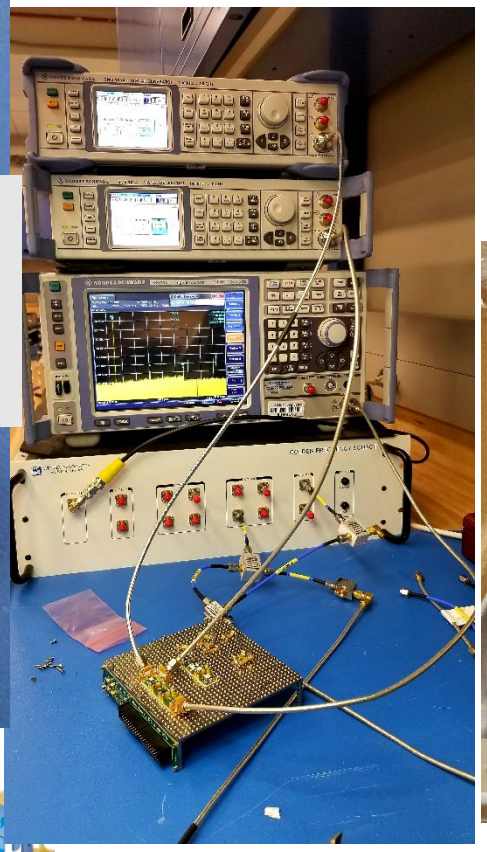
Low Level RF Design with Students

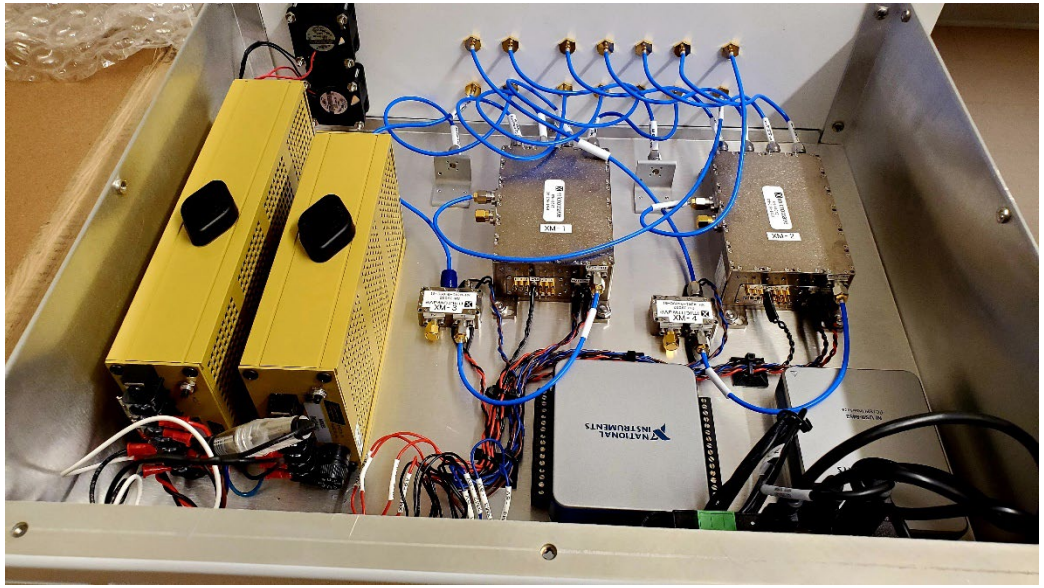


Mixers, splitters, filters, amps, variable attenuators, etc

Rapid and inexpensive prototyping of microwave circuits using modular waveguide components from **X-Microwave**.



Complete IQ Modulator. Similar boxes for downconversion and machine protection



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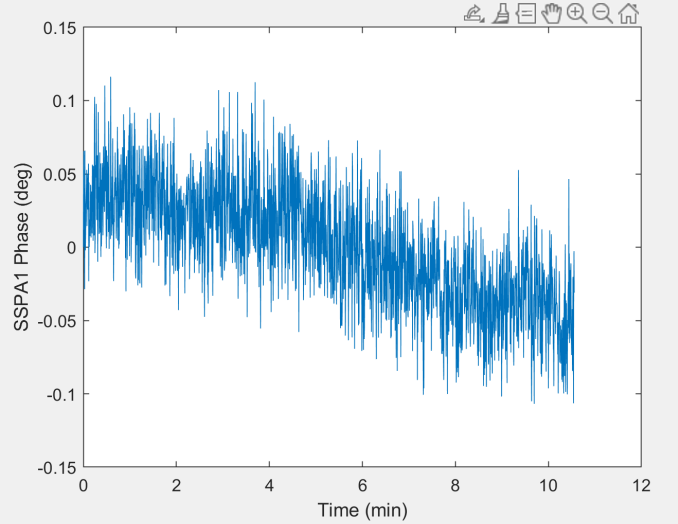
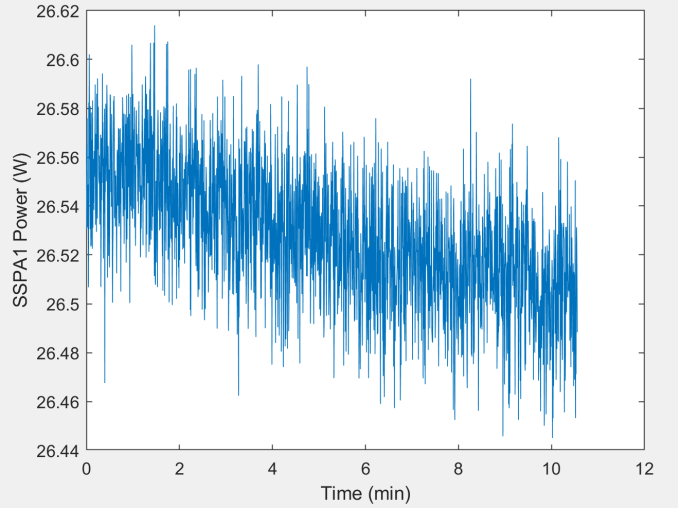
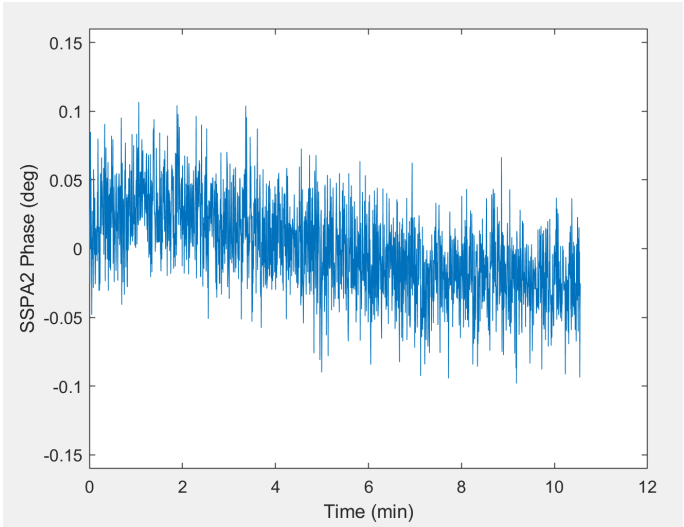
Low Level RF Performance



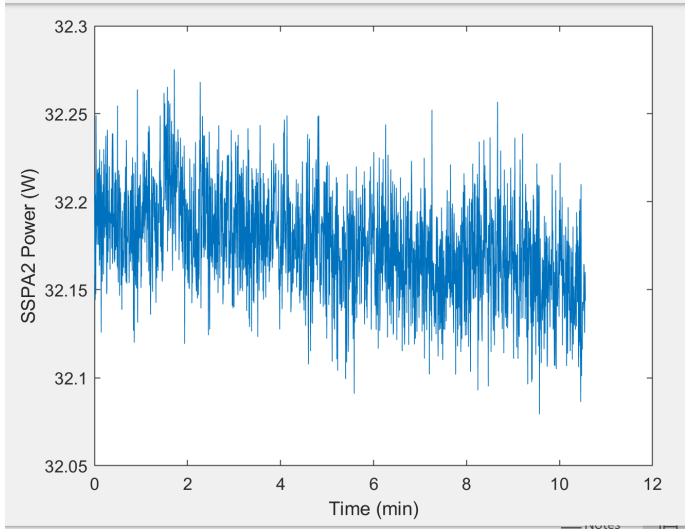
Solid State Power Amp #1
RMS **Δphase = 0.040** deg
over 10 minute period



Solid State Power Amp #1
RMS **Δpower = 0.1%**
over 10 minute period



Solid State Power Amp #2
RMS **Δphase = 0.034** deg
over 10 minute period



Solid State Power Amp #2
RMS **Δpower = 0.09%**
over 10 minute period

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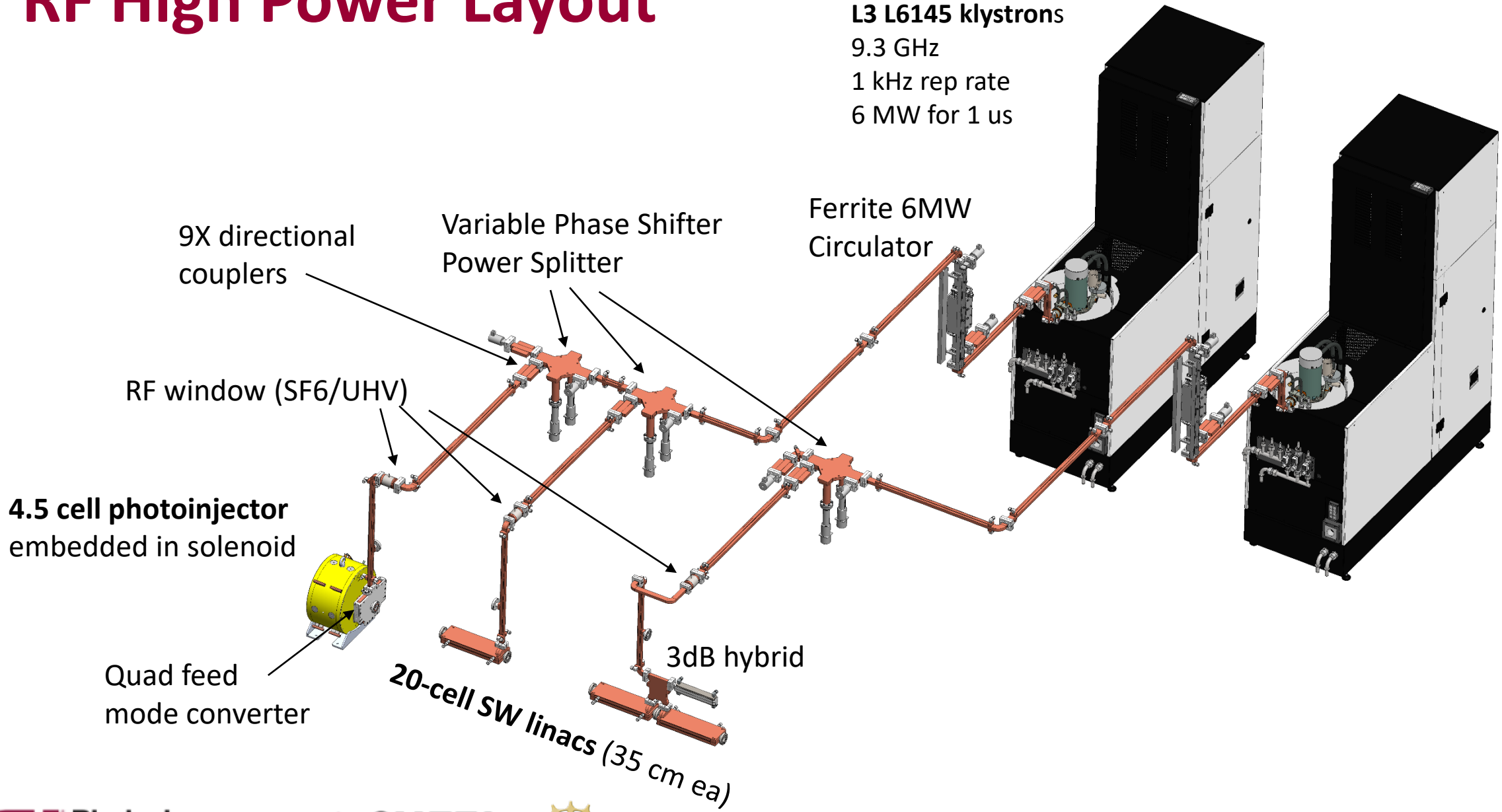
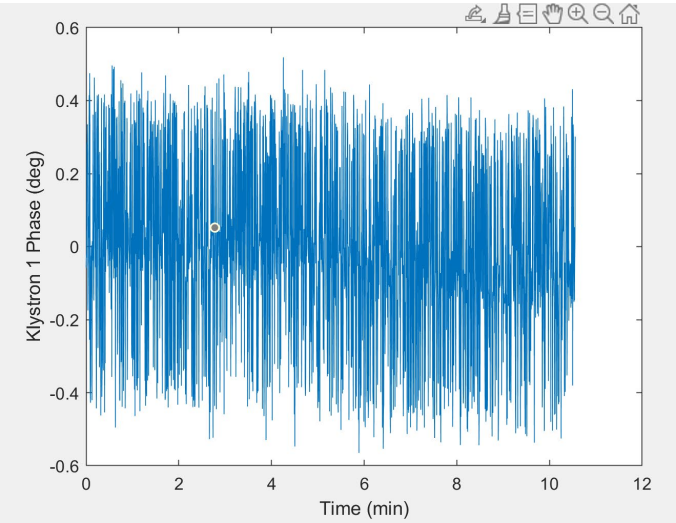
RF High Power Layout

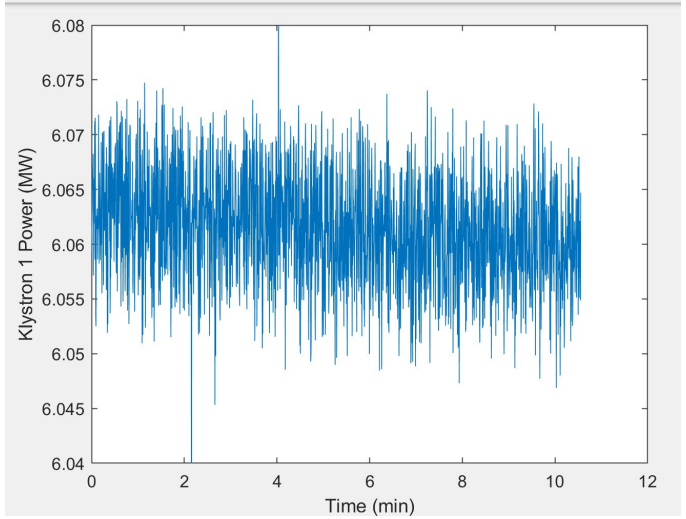
Scandinova K1 modulators
L3 L6145 klystrons
9.3 GHz
1 kHz rep rate
6 MW for 1 us



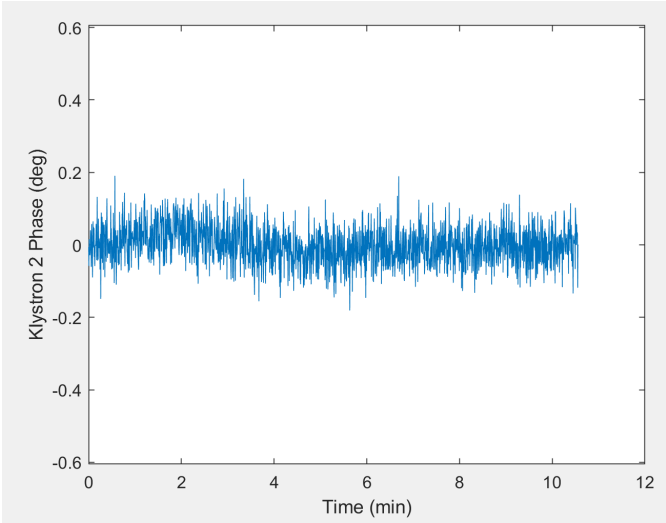
High Power RF Performance



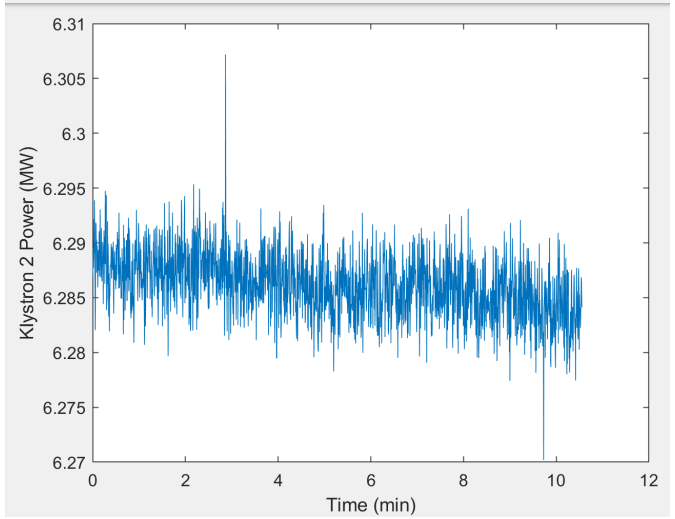
Klystron #1
RMS **Δphase = 0.25** deg
over 10 minute period



Klystron #1
RMS **Δpower = 0.08%**
over 10 minute period



Klystron #2
RMS **Δphase = 0.053** deg
over 10 minute period



Klystron #2
RMS **Δpower = 0.04%**
over 10 minute period

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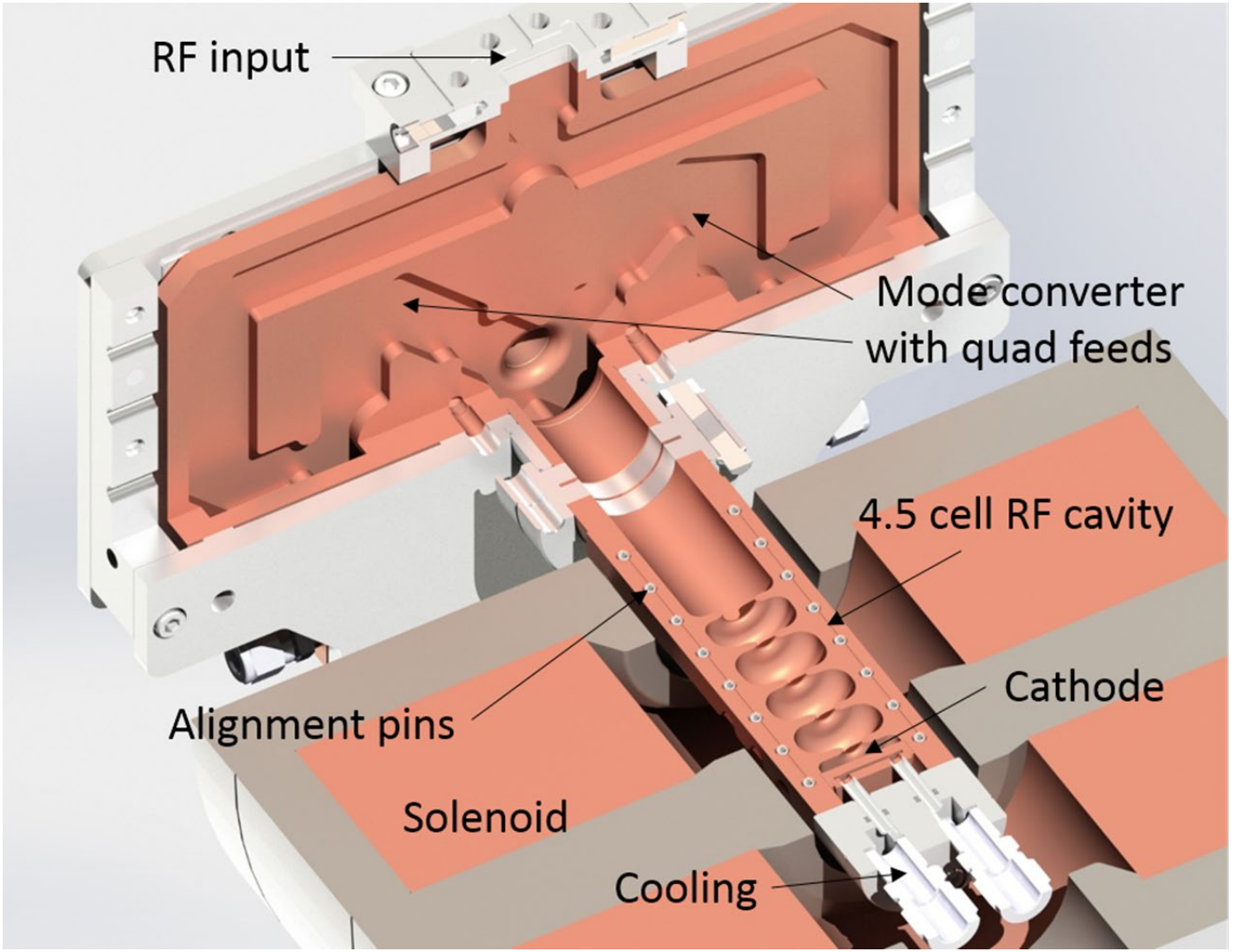
Novel X-band kHz Photoinjector

- V. Dolgashev (SLAC) RF design
- Mode converter with quad RF feeds
- 4.5 cells
- 9.3 GHz RF
- 3 MW peak power
- 4 MeV final energy
- 120 MV/m on cathode
- 1 kHz repetition rate
- Embedded in tape-wound solenoid

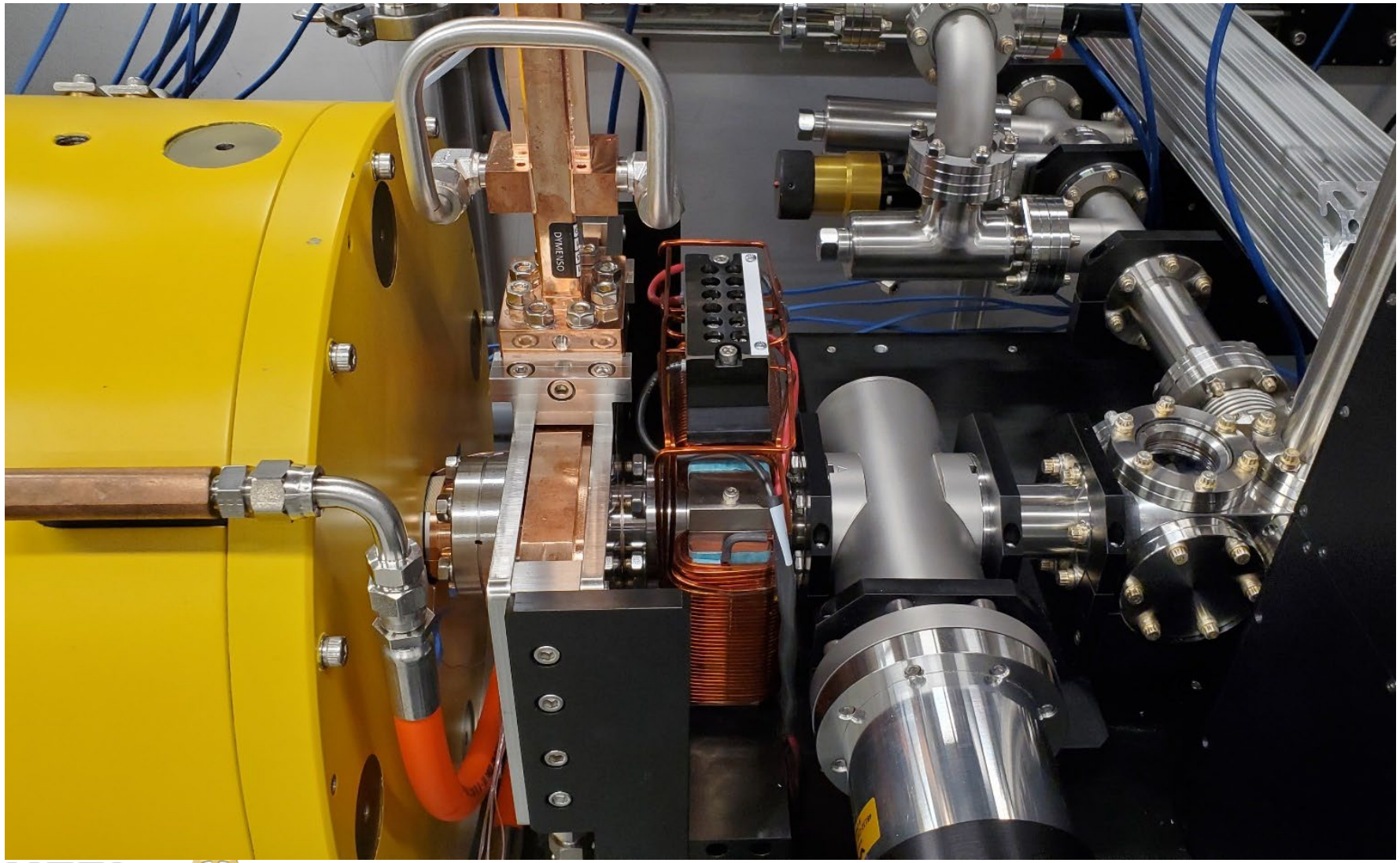


Graves et al
IPAC 2017 TUPAB139

CXLS Photoinjector Commissioned

Commissioned to

- 3.6 MW delivered
- 117 MV/m gradient
- 3.8 MeV energy
- 1000 Hz rep rate
- 700 ns pulses
- Conditioning time ~3 days
- Zero breakdowns/day



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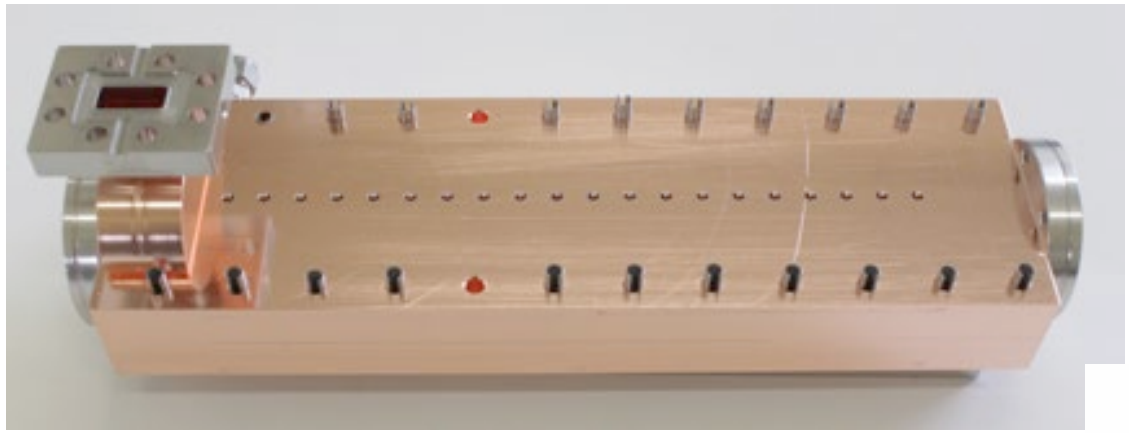
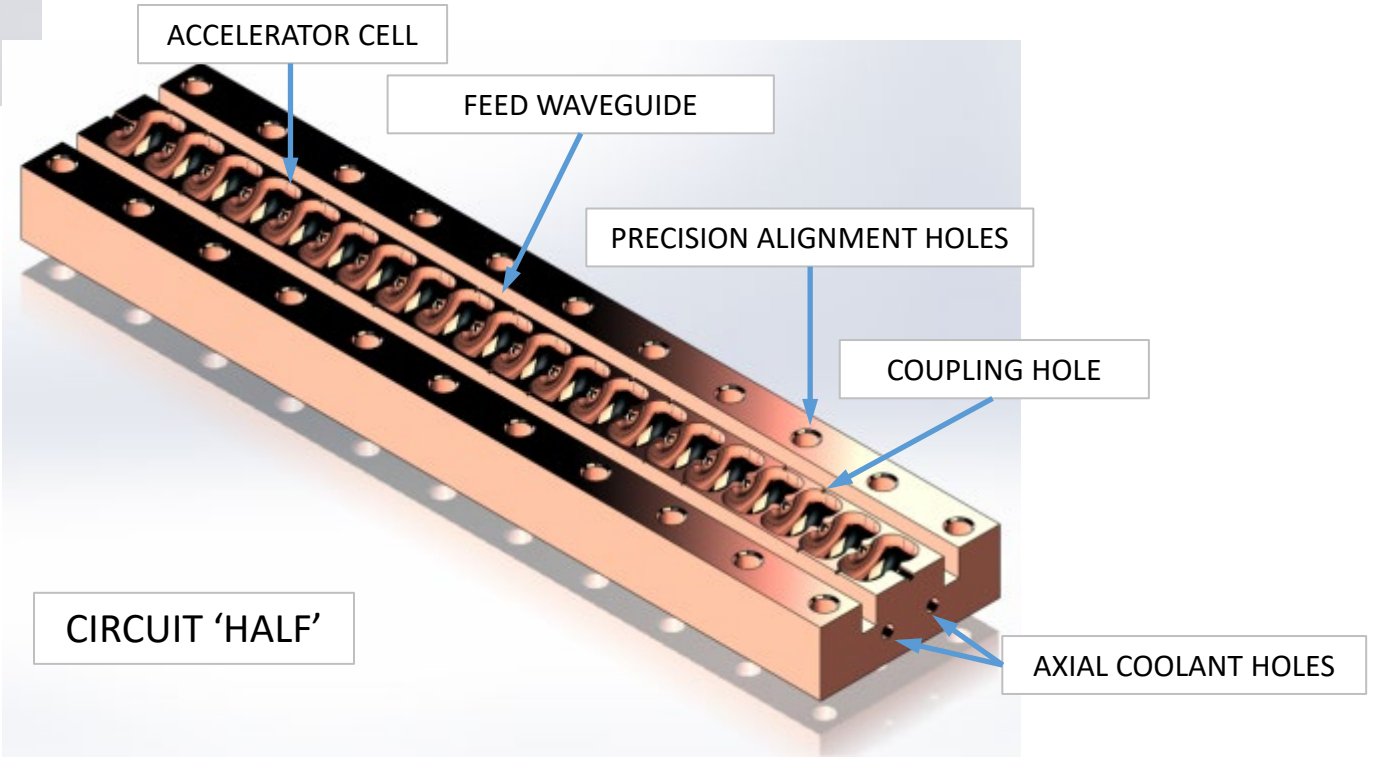
Novel 9.3 GHz SW Linac Structure

Tantawi and Li (SLAC)



Tantawi et al, Phys Rev Accel and Beams 23, 092001 (2020)

- 9.3 GHz 20-cell structure 32 cm long
- 165 MOhm/m shunt impedance
- 170 ns fill time
- 3 mm apertures
- $E_{surface}$ to E_{accel} = 4:1
- 1 kHz rep rate
- Distributed coupling to each cell
- Inexpensive



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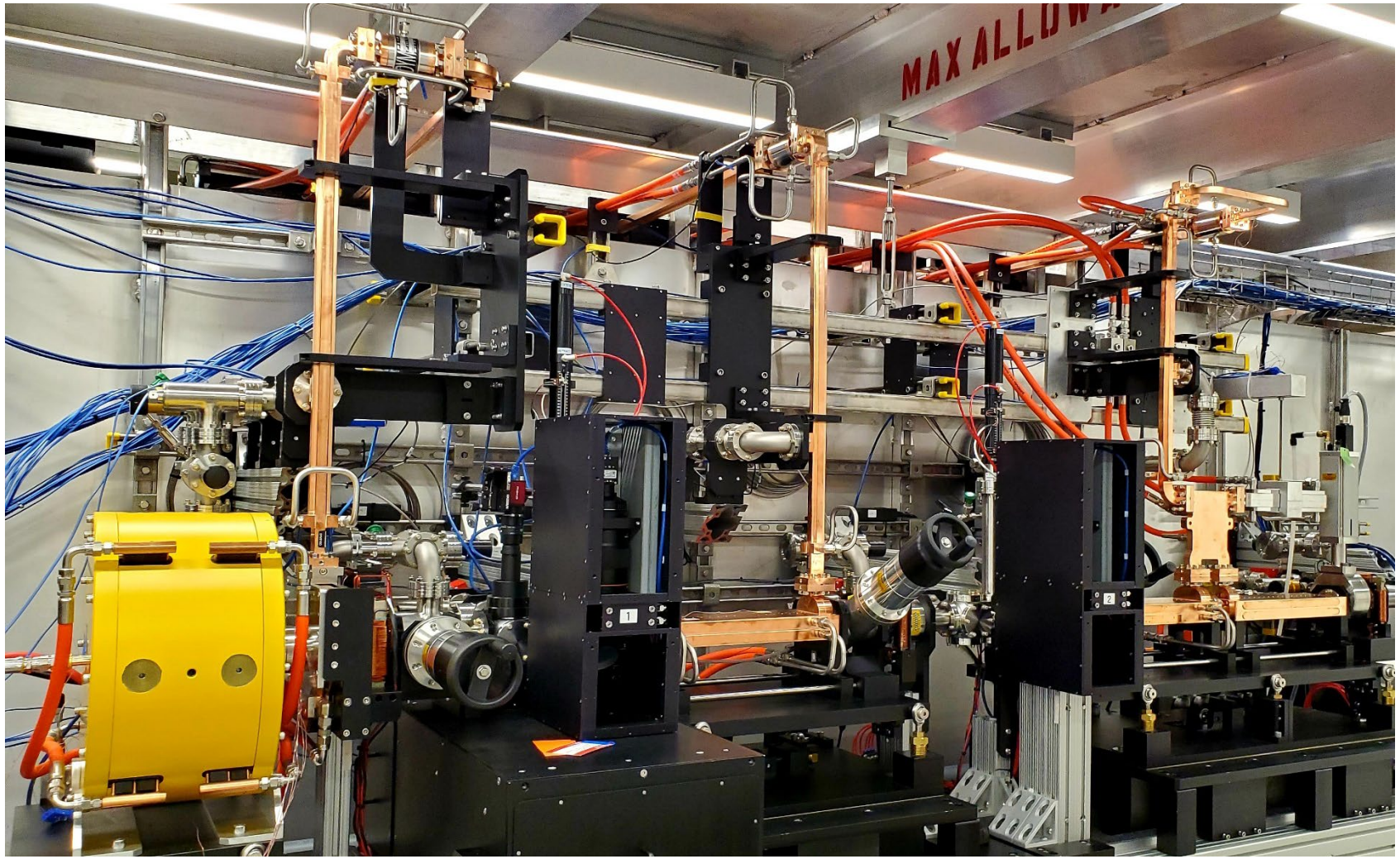
CXLS Linac Commissioning

Commissioned to

- 27 MV/m gradient
- 108 MV/m surface field
- 1000 Hz rep rate
- 700 ns RF pulse
- 2 MW delivered to each structure

- ~10 pC per 700 ns RF pulse dark current
- 28 MeV final beam energy (still tuning)
- RMS dE/E = 0.005 – 0.03%



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