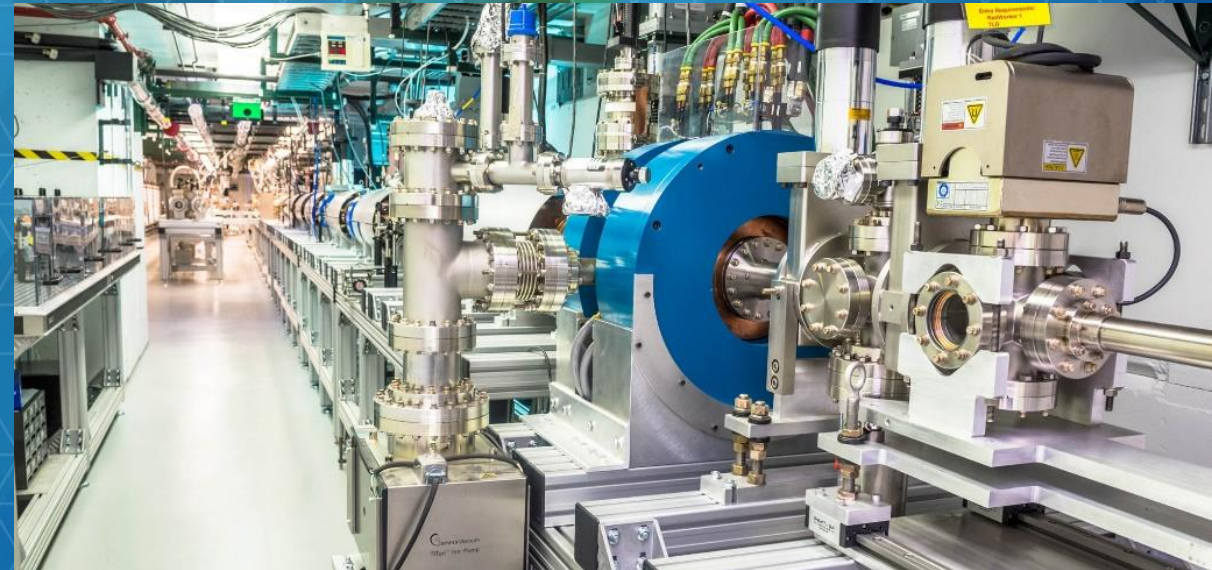


AUGUST 11, 2023

AWA NOW 2023

ELECTRON SOURCES OVERVIEW

ERIC WISNIEWSKI
AWA Facility Manager



AWA RESEARCH THEMES

Long lasting, timeless research themes

APPLICATION



THEME 3

Beam Production

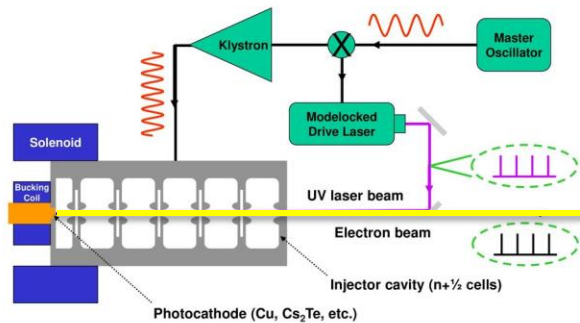
THEME 2

Beam Manipulation

THEME 1

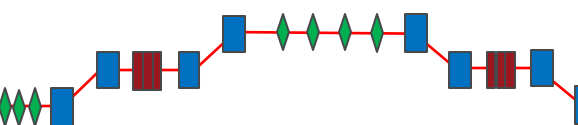
Advanced Accelerator

e.g. RF Photoinjector



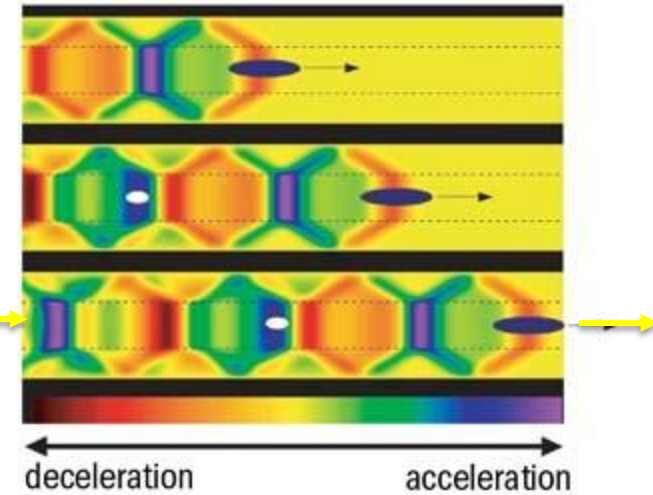
High-brightness and high-charge electron sources, novel cathodes

e.g. Double Emittance Exchange



Beam manipulation and control. Beam Diagnostics.

e.g. SWFA



High-gradient & high-efficiency SWFA & PWFA acceleration

AWA BEAM PRODUCTION/ELECTRON SOURCES R&D CAPABILITIES - CURRENT

- **NCRF gun characterization of photocathodes and field emission cathodes**
 - High gradient RF testing (ACT) --> 100 MV/m
 - Field emission testing and imaging (ACT)
 - Charge, QE measurement and emitter mapping capability
 - thermal emittance measurement and mapping
- **High-quality photocathode beam generation**
 - Micro-lens array (MLA)-based laser homogenizer provides high-quality UV laser profile
 - Drive gun upgrade will further improve the beam quality (late 2023 -early 2024)
- **Cathode Development Capabilities**
 - AWA operates in-house high-charge large format Cs₂Te cathode deposition system for operating the drive gun
 - Secondary deposition chamber under construction for future R&D use
 - In-situ QE measurement vacuum chamber
 - Kelvin probe work function (CPD) measurement vacuum chamber
 - SEM and other surface studies support available through other ANL divisions ie. CNM, MSD

AWA CATHODE TEST STAND

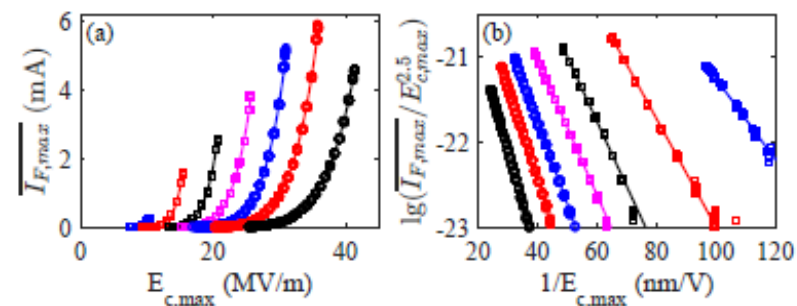
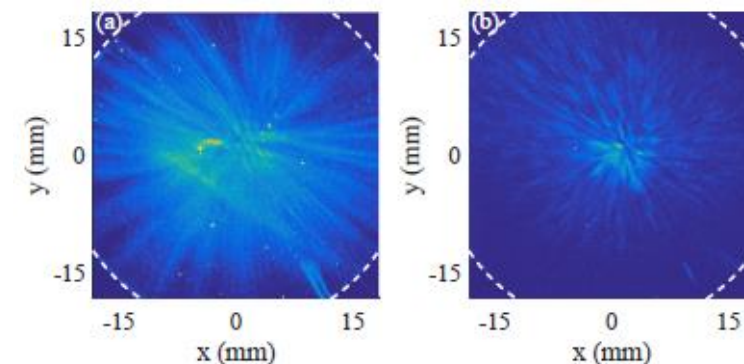
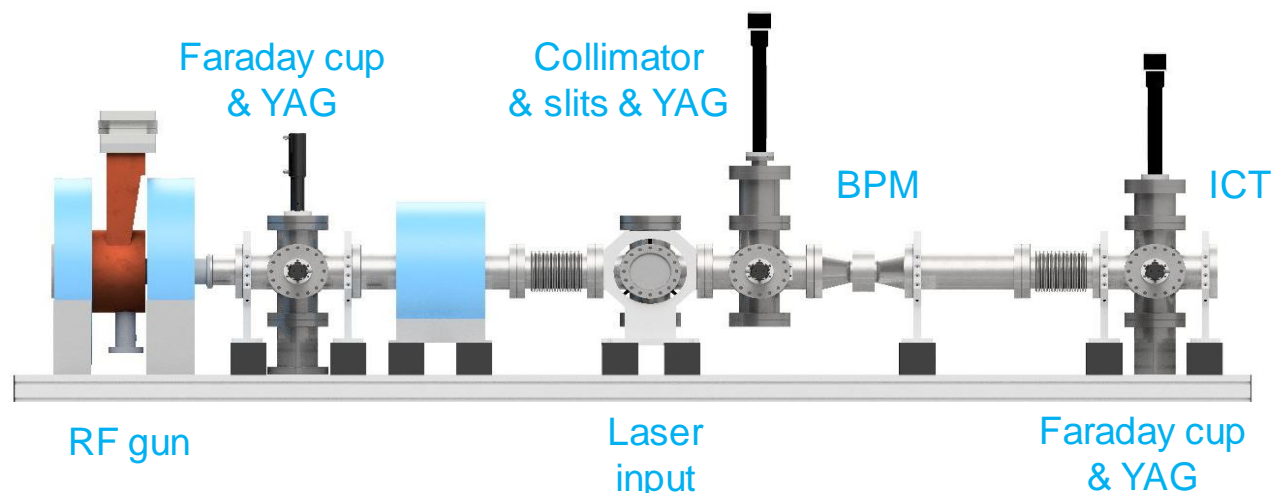


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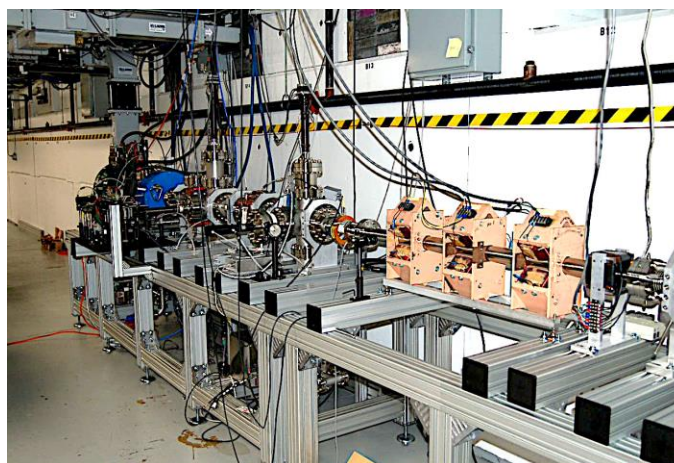
ARGONNE CATHODE TEST-STAND (ACT)

Standalone beamline dedicated to fundamental R&D on Field Emission and RF breakdown, novel cathodes, and low energy beam applications



○ Capability

- - FE/BD study: BD location, FE imaging
- Cathode study: QE, charge, transverse profile
- Application: low energy beam (field emission/photoemission) delivered with quad triplet focusing to the ample space at the end of the beamline



ARGONNE CATHODE TEST-STAND (ACT)

Details

- L-band half-cell gun
- 1.3 GHz 2.5 MW
- 2 MeV/c electrons (max)
- Typical Vacuum: 5×10^{-9} Torr
- Rep rate : 2 Hz
- Duration: 6 μ s flat top
- Typical gradient for DFEA experiments: 10-35 MV/m
- Typical fie for breakdown studies of flat cathode: 0-100 MV/m
- Protruding tip cathode: max gradient 700 MV/m
- Accessible waveguide port for RF measurements and tuning

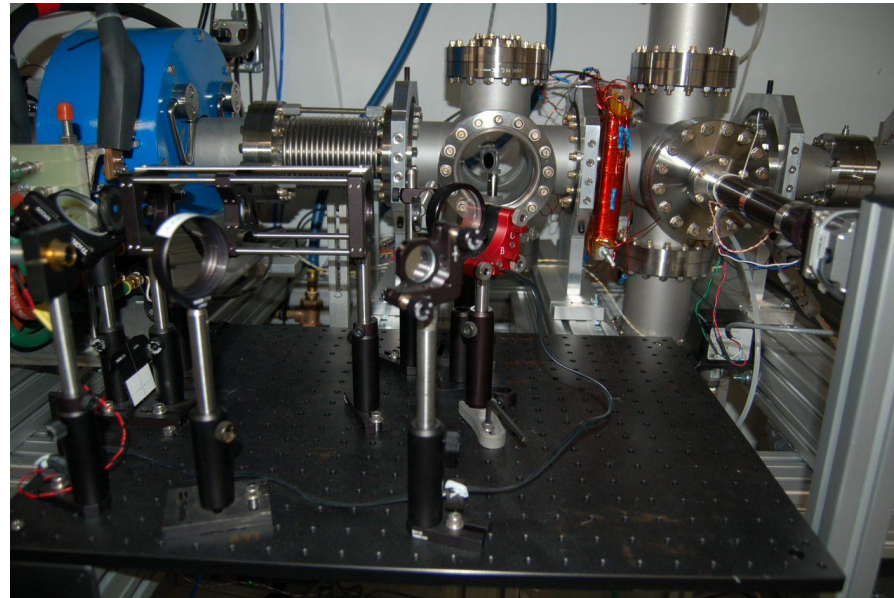


261 nm, 0.3-6 ps laser

1 m Space Available for expansion

ACT UTILITY AND CAPABILITIES

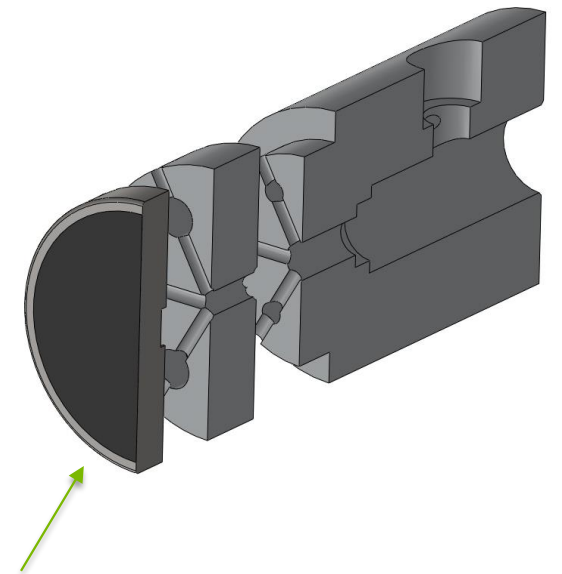
- RF testing at high gradient
 - RF testing high gradient 0-100 MV/m with flush-mounted flat cathode
 - RF testing high gradient up to 700 MV/m with a protruding pin cathode
- Dark current imaging capability: features include
 - solenoid focusing
 - selectable collimator beamline
 - imaging optics with 2" YAG(Ce) scintillator screens
- Laser input system
 - 262 nm laser
 - 1 mJ per pulse
 - 0.4-6 ps variable pulse length
 - 2 Hz rep rate
- Future upgrades/add-ons:
 - Load-lock system
 - MLA based laser homogenizer
 - Dipole Spectrometer



3-PIECE SAMPLE HOLDER - PUCK STYLE

Custom re-usable cathode sample holder

- Some details
 - aluminum or stainless, other material possible, puck can be of different material
 - surface study friendly design
 - Provides good electrical contact
 - Proven robust design
- Features:
 - Cost-effective: replace or recoat only the puck, re-use the cathode cartridge.
 - Efficient: AWA can pre-assemble cartridges and reduce the turn-around time

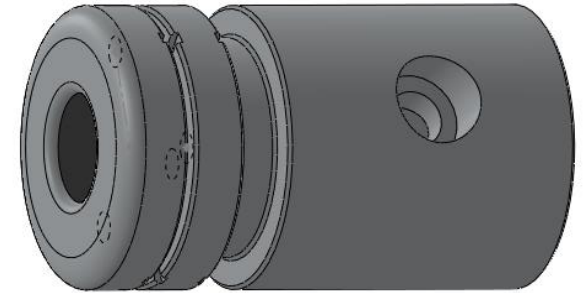


Interchangeable puck

3-PIECE SAMPLE HOLDER -CAPTURED THIN DISK

Custom re-usable cathode sample holder

- Some details
 - developed in conjunction with G. Chen's UNCD studies
 - Provides good electrical contact
 - Designed to test thin disk photocathode samples
 - Proven design
- Features:
 - Cost-effective: no expensive machining pucks; replace only the thin film, re-use the cathode cartridge.
 - Efficient: AWA can pre-load additional cartridges and reduce the turn-around time
- Practical Info
 - Cathode sample load time 30 minutes
 - Beamline is vented with dry nitrogen
 - Pump time is 3-5 days to achieve high 10^{-9} torr
 - load-lock system is in the planning phase



AWA CATHODE RESEARCH PROGRAM

– Selected highlights



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CATHODE RESEARCH

In-house: The AWA group & **Collaborators:** IIT + LANL + NIU

PHOTOCATHODES

Selected Research Highlights:

- **(in-house) Halavanau**, et al., Tailoring of an electron-bunch current distribution via space-to-time mapping of a transversely shaped, photoemission-laser pulse, Phys. Rev. Accel. Beams. 22, 114401 (2019).
- **(in-house) L. Zheng**, et al., Rapid thermal emittance and quantum efficiency mapping of a cesium telluride cathode in rf photoinjector using multiple laser beamlets, Phys. Rev. Accel. Beams 23, 052801 (2020).
- **(IIT) Gongxiaohui Chen**, et al., "Demonstration of nitrogen-incorporated ultrananocrystalline diamond photocathodes in a RF gun environment", Appl. Phys. Lett. 117, 171903 (2020)
- Note: Chen is now on the AWA staff

ARGONNE WAKEFIELD ACCELERATOR FACILITY
ELECTRON SOURCES RESEARCH OVERVIEW

THANK YOU FOR YOUR ATTENTION



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BACKUP SLIDES



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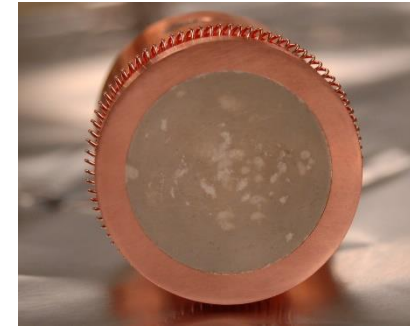
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BRIEF HISTORY OF AWA'S PHOTOCATHODE R&D

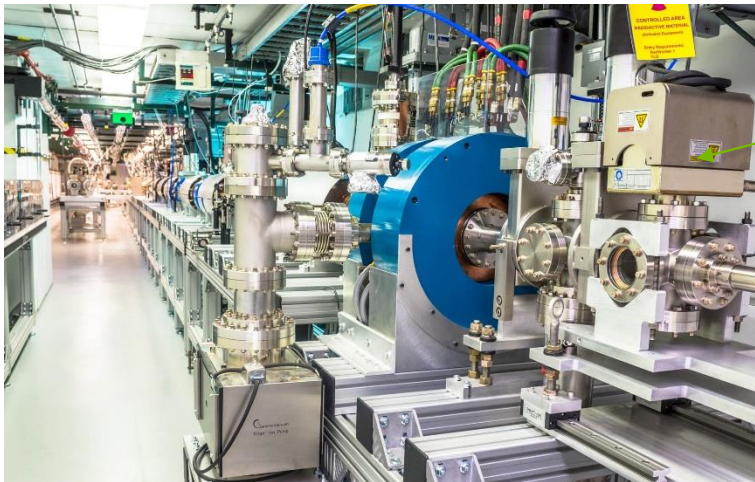
- **Witness gun (~2001-present)**

- Mg photocathode, conical slug set in a copper plug, designed for low to moderately high charge

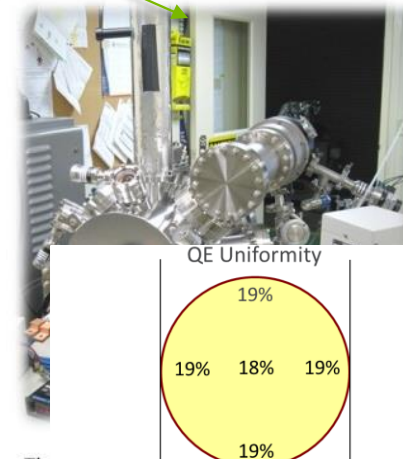


- **Drive gun (~2013-present)**

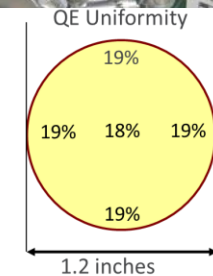
- Cs₂Te on Mo plug, 30 mm diameter, 60-75 MV/m
- World's highest charge photocathode: up to 600 nC with bunch train



Photocathode Fabrication Chamber



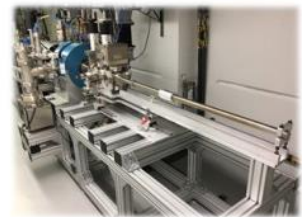
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Photocathode load-lock UHV transfer system



Deposition Configuration

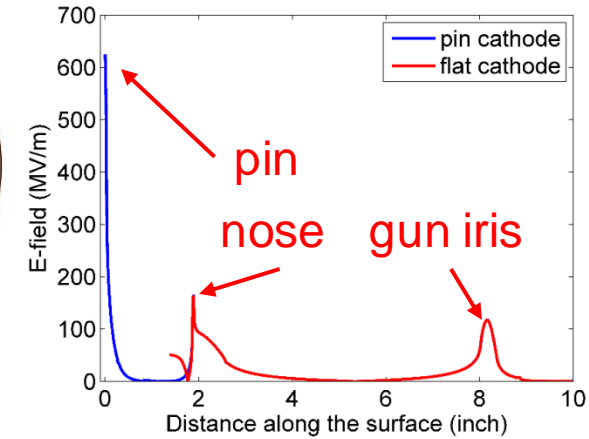
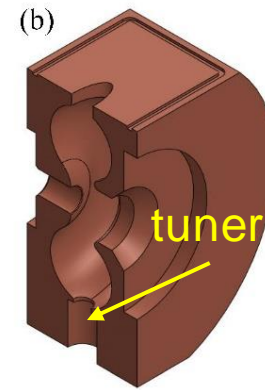
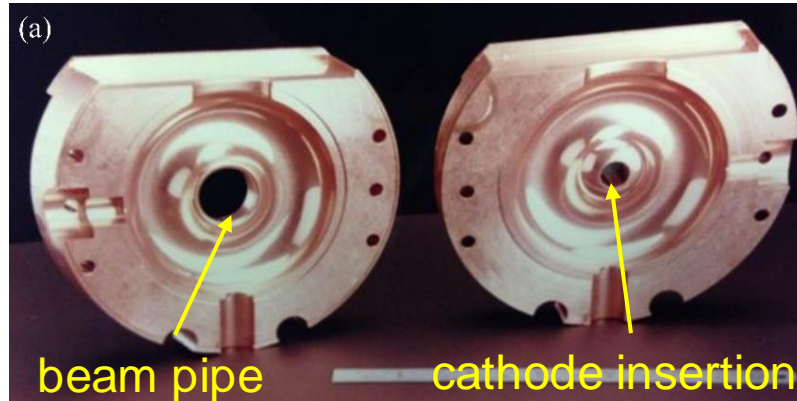


Operating Configuration

ARGONNE CATHODE TEST-STAND (ACT)

- **L-band single-cell rf gun**

- High gradient (100 MV/m) with modest rf power (2.5 MW)



- **Detachable cathode**

