SRF guns at BNL: First beam and other commissioning

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Outline

- **704 MHz half-cell SRF gun for R&D ERL**
  - Brief introduction of R&D ERL and SRF gun;
  - First beam commissioning with Cu-substrate cathode stalk;
  - Design and commissioning of the new Ta-substrate cathode stalk;
  - Beam commissioning with Ta-substrate cathode stalk.

- **112 MHz QWR SRF gun for Proof-of-Principle Coherent Electron Cooling (POP CEC).**
  - First beam commissioning results

- **Summary**
ERL project engineering construction was completed.
The main mission for ERL is to serve as the test bed for future projects at CAD.
Most of the components will be used for RHIC upgrade project: LEReC.
✓ ERL project engineering construction was completed.
✓ The main mission for ERL is to serve as the test bed for future projects at CAD.
✓ Most of the components will be used for RHIC upgrade project: LEReC.
At the beginning of every regular shift, we use this beamline to check QE and beam parameter measurements.
Cathode stalk: Cu substrate.

Cathode: \( \text{Cs}_3\text{Sb} \) photocathode, 2.75E-3 of QE on the fresh cathode and decayed to 3.5E-4 before inserting into the gun for beam test.

RF: 1.2 MV, in pulse mode.
1 $\mu$A Beam

- Parameters: Laser: 6.08 Watt; RF: 1.2 MV, 500 ms;
- Beam: bunch charge: 7.7 pC, photoemission current 1 $\mu$A, dark current: 38 nA;
- Focusing the beam with RT solenoid.
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Design and commissioning of the new cathode stalk

Three reasons for new cathode stalk:

- Strong multipacting occurred at various field levels in the choke-joint cathode stalk.
  => Design a multipacting-free cathode stalk for reduction of conditioning time.
  => CW operation.

- To replace Cu substrate with Ta.
  => High QE for high charge/current operation.
  => Reserve the cathode lifetime.

- To reduce cathode stalk heat loading
  => Improve the LN2 cooling.
After conditioning for 7 days and average 10 hours per day, the gun reached 1.85 MV with 18% of duty factor.
Within the first 1.5 hours, the cavity voltage goes up to 2 MV in pulse mode without multipacting.
After less than 10 hrs conditioning, it is stable CW operation from 0.4 MV to 1.3 MV CW. Above 1.4 MV, field emission started. We decided to use this cathode stalk for beam test as the field is good enough for initial beam tests.
Beam commissioning with new stalk

- Cathode stalk: multipacting-free cathode stalk with Ta tip.

- Cathode: $K_2CsSb$ photocathode, 3.8% of QE on the fresh cathode stalk and stay the same up before inserting into the gun.

- It was used for beam test since June 1 to present, the initial QE was 1%.

- After that, the QE stays at 0.03%~0.05% for months, which is “good” (safe) for machine tuning.

- No significant additional heatload on the cathode stalk.
Laser: 0.044 W, 5 μsec, 9.38MHz rep rate.
RF: 0.65 MV, 3 ms;
Photocurrent: 17pC per pulse or 159 μA within macro laser pulse.
Dark current: 4 μA
Bunch profile on the YAG screen

Beam profile changes with different RT solenoid current setting (bunch length 23 ps)

Beam profile changes with waving RF phase (bunch length 8.5ps)
New cathode stalk: high QE, long lifetime

![Graph showing QE (%) over time from June 1 to August 31]
QE mapping is still under developing now and it is semi-automatic now.
ERL Commissioning status: GuntoDump

- **SRF Gun**
- **Faraday Cup**
- **SRF Linac off**
- **Beam dump**
- **Beam profile monitor**

Straight section is 7m long

1 MeV
ERL Commissioning status: GunToDump

Beam profile monitor

Straight section is 7m long

SRF Gun

Faraday Cup

Transmission

Beam dump

SRF workshop Sept 13-18 2015

Transmission
Orbit shift and jump: due to ceramic charging and discharging.

Transmission

BPM_X

BPM_y

BPM_sum
Orbit shift and jump: due to ceramic charging and discharging

Double sided flange

Small gap

CF flanges

Insulator

weld

Transmission

BPM_X

BPM_y

BPM_sum

Courtesy @ Bruce Dunham

Wencan Xu  
SRF workshop Sept 13-18 2015
112 MHz QWR SRF gun

- Quarter-wave cavity
- 4 K operating temperature
- Manual coarse tuner
- Fine tuning is performed with FPC
- 2 kW CW solid state power amplifier
- CsK$_2$Sb Cathode is at room temperature
- Cavity field pick-up is done with cathode stalk (1/2 wavelength with capacitive pick-up)
- Up to three cathodes can be stored in garage for quick change-out
- Design gradient 22.5 MV/m

*Thursday’s Poster THPB058*
First beam was observed in June 2015, with integrating current transformer during phase scan. The charge was 0.5 nC.

Found that beam charge is limited by space charge forces.

After 50% laser spot size increase we were able to observe 3 nC charge.

We have increased pulse repetition rate from few Hz to 5 kHz (laser max) and observed 15 μA current.

Were able to see beam on the first profile monitor 2.77 m downstream.

\[ U_{RF} = 1.6 \text{ MV} \]
704 MHz ERL SRF gun observed first beam in Nov, 2014, with Cu substrate cathode stalk.

The new cathode stalk suppresses multipacting, reduces the 2K heat load and provides high QE, long lifetime photocathode.

With new cathode stalk, ERL is under Gun-to-Dump commissioning. We are working on stabilizing the beam orbit first.

112 MHz CEC gun generated the first beam in June, 2015 and demonstrated 3nC (maximum charge) electron beam.

Thanks Igor Pinayev and Vladimir Litvinenko to provide slides on 112 MHz SRF gun.