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2020 snowmass Letter of Interest: High current high brightness SRF gun

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The initial brightness of electron source determines the brightness of electron beam which is useful in many future facilities such as X-FEL, UEM and strong hadron electron cooling for electron ion collider (EIC). Study the photocathode and how to use the advanced cathodes in the RF electron gun are must in my personal view of the step to pursue the required electron beam.

The initial brightness of electron beam is determined by the photocathode properties and electric field gradient on photocathode at the moment of emission Therefore, a photocathode with low MTE operating in a high gradient gun offers a clear path towards high brightness electron beams.

Using SRF gun**, with a modest frequency of ~ 100 MHz**, has several advantages including operating with **high gradient** at cathode at the optimum emission phase approaching the crest of the accelerating field. It can also operate at **CW mode** generating stable and high average current electron beam [1–4]. Such SRF gun operates with much higher gradient and generates much higher beam energy when compared with the DC guns [5,6].

The bialkali antimonide photocathodes, which have high electron yield at the green light, can produce electron beams with smaller emittance than other semiconductor photocathodes (such as Cs_2Te) and metal photocathodes driven by UV lasers. For the same accelerating gradient, at typical photon energies used with semiconductor cathodes as electron sources, bialkali antimonide photocathode shows smaller thermal emittance than Cs_2Te photocathode [5,7].

The successful combination of low thermal emittance cathode with high gradient low frequency SRF gun is **the best candidate for the future high current high intensity electron source**.

The proposed EIC needs an electron cooling facility to maintain the luminosity up to 10^{34} $cm^{-2}s^{-1}$. The cooling requires the electron beam average current above 120 mA with less than 2 mm-mrad normalized transverse emittance. Recently only high voltage DC gun can generate 10s mA average current, high brightness beam with several days' lifetime. However, due to low electrical field gradient on the photocathode, the initial bunch must be beer-can shape, typically with bunch length in 100s ps. To boost beam's energy up to 150 MeV for ecooler, the bunch has to be compressed to 10s ps for fitting into ultra-high frequency RF LINAC. However, the strong hadron cooling using coherent signal needs low shot noise electron beam. Any beam compression may enhance the shot noise, resulting large noise signal in amplification. Generating high intensity beam with short bunch length initially will be very attractive.

Thus, developping SRF gun based high average current high intensity electron source is one of the R&D topic should be in considering.

Considering the success of the SRF guns operation at HZDR and BNL for low current operation [3], the next step should explore SRF gun capability of the high average current operation.

To get success of SRF photoinjector of high current high intensity source, the following R&D topics are worthwhile to study:

- The QWR SRF gun high power coupler.
- High QE long lifetime multialkali photocathode
- Cathode insertion system
- Multipacting elimination when turn on RF power.

Develop a reliable, stable operation high current high intensity SRF gun may need 10 million US dollars. 3-5 years fabrication and commissioning are needed. Upgrade the existing SRF gun or operational SRF gun is a cost-effective choice.

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