Josh’ thesis outline

February 14, 2019

Timeline

2018

* Jun – Started learning about ionization, explore topics ~6 months
* Jul – Analyzed Gun2 lifetime data w/ V-Wien ON/OFF (should be part of thesis)
* Aug – Got a PC, started learning how to run GPT
* Sep – Started weekly meetings w/ Geoff; began calculations for collective ion effects
* Oct – Developed GPT expertise, demonstrated longer-term trapping
* Oct – Got IBSimu installed at JLab, met w/ Erdong discuss collab on GPT
* Nov – Started observing ghost beam, modelling ion collection, ~week of beam studies
* Dec – Worked to get image analyzer statistic live at GTS

2019

* Jan – Learned how to run GPT on farm, analytic trapping conditions, USPAS
* Feb – Oral qualifier scheduled late Feb: discuss a physics topic, present thesis outline…

Thesis Outline

1. Introduction
   1. **Gas in accelerator vacuum channels is rapidly ionized by leading to ‘bad’ effects**:
      1. bombardment of photocathodes => degradation of QE
      2. bombardment of surfaces => further secondaries and gas load
      3. charge neutralization => limits cw operation for high current
      4. bremsstrahlung => generation of x-rays
   2. **Examples**
      1. Storage rings and high current linacs require clearing gaps
      2. DC high voltage guns require precipitators
      3. Polarized GaAs photocathodes require ion mitigation to extend QE/uniformity
   3. Theory & Simulation
      1. **Quantify the effects of ion impact** (sputtering, implantation) that lead to reduction of quantum efficiency. Use analytic calculations and code like SRIM to characterize and calibrate the simulated dose (intensity, energy) that leads to these effects,
      2. **Quantify the dynamics of ionization** (electron impact, of residual gas, secondaries, and x-rays, retroreflections) that leads to generation of ions. Use analytic calculations and codes like IBSimu and GPT to model the dynamics (how these depend upon imposed and self fields) in order to quantify the pathways that result in ion impact at the photocathode.
   4. Stated Goal
      1. **Improve the charge lifetime of polarized GaAs photocathodes producing high current from DC high voltage photogun**
2. Experimental Studies of Ion/Secondary Generation and Effects
   1. Measure the **effect of the gun voltage (ion energy)** on GaAs quantum efficiency [UITF: During non-MeV periods in 2019-2020 e.g. when Booster is replaced with QCM?]:
      1. Measure the charge lifetime and QE surface reduction for a “small” laser spot size and fixed gun voltage vs. different radii to quantify the reduction from a conventional polarized photogun, e.g. reproduces Riad’s PR-AB measurement,
      2. Repeat 2a at three or four additional gun voltages, to measure the dependence on ion damage of a conventional photogun when operated at higher voltage on charge lifetime,
      3. Use GPT and SRIM to assign an expected damage factor (e.g. dose weighted on energy) to the data in 2a-b to corroborate the charge lifetime and QE map reductions,
      4. Collaborate w/ ODU @ ARC lab use surface and profiling to quantify effect of ion sputtering and/or implantation on the GaAs photocathode,
      5. Leak massive gas species X, to repeat 2b-d to differentiate effect of ion velocity vs. energy on QE reduction
   2. Measure the **effect of ions downstream of the gun anode** on GaAs quantum efficiency [UITF: During non-MeV periods in 2019-2020 e.g. when Booster is replaced with QCM?]:
      1. Repeat 2a or 2b for two-three gun voltages, to measure the charge lifetime and QE surface reduction as a function of anode bias voltage, e.g. explore the efficiency and energy threshold for the anode to be transparent to ion,
      2. Consider generating ions downstream of the anode to precisely characterize their contribution to degradation of the QE surface, e.g. repeating the anode bias study in 3a. [UITF: opportunity when 200kV Wien installed for testing?]
      3. Study the collection or limitations of ions downstream of a dc photogun anode; e.g. a) observation of ghost beam at GTS suggests new mechanism for generating unwanted stray beam that may contribute to additional beam loss, [GTS: w/ Xelera gun Spring 2019, or w/ Photogun Summer? 2019 but at different location w/ trapping coils; either case may corroborate with ion precipitator] or b) observation of operating a spin rotating Wien filter as an energy selector to limit ions [CEBAF: PREX summer ’19 with VWien, CREX fall ‘19 VWien+anode\_bias, and during a SAD w/o VWien and anode bias on/off], [one or both topics relevant to a PR-AB paper]
   3. Measure the **effect of laser size** on GaAs quantum efficiency:
      1. Use GPT and/or IBSimu and SRIM to analyze the 2017 CEBAF laser spot size data, evaluate the trend of observed charge lifetime, and limitations increasing the laser size at CEBAF; [generates a PR-AB in 2019],
      2. Repeat the 2017 experiment, but w/ a biased anode to distinguish or demonstrate if the charge lifetime was limited by gun or beam line loss,
      3. Consider measuring beam quality in 4b (e.g. emittance, intensity jitter, QE decay rate) and then comparing w/o a biased anode,
3. Design and long a longer lifetime polarized photogun
   1. Design and test a polarized photogun with reduced sensitivity to ion bombardment [Final stage of thesis, 2020-2021, location of beam test TBD]:
      1. Evaluate parameters beam properties (e.g. laser size for emittance, gun voltage for bunch charge) and photocathode lifetime (e.g. laser size, gun voltage, bias anode) that would be suitable for a 1mA polarized photogun w/ >1000 C,
      2. Design cathode/anode geometry for parameters in 5a, simulate expected performance using GPT and/or IBSimu,
      3. Modify or build a high voltage chamber w/ improved design that can be mated to a beam line, to evaluate charge lifetime.