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ERL17 WORKSHOP, WG1 SUMMARY: INJECTORS

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Abstract

The 59th ICFA Advance Beam Dynamics Workshop on Energy Recovery Linacs, hosted by the CERN was held on CERN campus. The working group (WG) 1 ERL injectors focused on high-brightness, high-power CW electron gun and high QE long lifetime semiconductor photocathode. The working group 1 was separated into two sessions: One is electron gun session, which has eight invited talks; another is photocathode session, which has six invited talks and one contributed talk. This report summarizes the state of the art of electron guns and photocathodes discussed in the ERL workshop WG1.

INTRODUCTION

Energy Recovery Linacs (ERL) enable the generation of high current high brightness electrons beam with high energy and cost saving. The high current, low emittance electron sources are always one of the challenges of ERL. So far, there are several facilities successfully commissioned and operated the electron guns in last a few years. Also, several labs are capable of preparing high QE semiconductor photocathodes for electron guns. These experiences provide an opportunities to push to even higher quality electron source. However, the challenges are still existed such as long lifetime operation cathode, stable operation SRF gun as well as high current operation.

There are total 14 talks in WG1. A large variety of interesting and important topics have been presented in the WG1 sessions. From the number of talks, we identified 4 topics with two separated sessions: Session1 photocathode: i. High QE, long lifetime photocathode: CeC, LEReC (BNL), SHXFEL (SHLS),Mainz Univ. HZB, HZRD. ii. Cryogenic cathode: Cornell, HZB, HZRD Session 2: iii. DC gun: BNL, JAEA/KEK, Mainz Univ.,Cornell Univ., KEK,ALICE iv. SRF gun: BNL, HZDR, PKU DCSC, HZB.

This report concludes with the discussions of cathode and gun operation/commissioning results, concerns, technical issues related to electron source realization and interesting concepts.

SUMMARY OF PHOTOCATHODE SESSION

The photocathode session has seven talks. All talks are discussed alkali antimony based photocathode including CsK2Sb, KNa2Sb, and Cs3Sb. Alkali antimony photocathodes have advantages on visible light sensitive (Green prefer), high QE, low thermal emittance and long lifetime. It could use in DC gun, RF gun, and SRF gun. The presenter Dr. Taro Konomi from KEK, Dr. Triveni Rao from BNL, and Dr. Julius Kuhn from HZD showed the prepared antimony based photocathode can reach 10% QE with the green laser. More discussions brought up in these talks: 1) Using ITO as a substrate to generates transparent photocathode for RF sealing. The cathode QE is almost equalized using reflection mode and transparent mode by a green laser. Transparent photocathode has advantages on simplified the laser transport system and obtaining the low emittance electrons. 2) The cathode routing production system requires very high capacities of alkali source. Conventional SAES sources are not sufficient for continuous cathode preparation. So J-bend effusion cells are developed and used in routing alkali antimony cathode preparation. 3) Using the cathode in cryogenic environments is an open discussion issue for many years. Measure the cathode QE evolution in temperature reducing helps to understand the cathode performance in SRF gun. Besides on high current operation, obtain low transverse and longitudinal emittance electrons beam are very important directions for electron source development. Dr. Monika Dehn From Univ. Mainz compared the multialkali PEA material's longitudinal temporal response with GaAs NEA material and found that the PEA material has significantly short bunch tail. Prof. Ivan Bazarov from Cornell Univ. discussed the cathode in a cryogenic environment and combining with transparent mode operation will generate orders of magnitude lower mean transverse energy electrons. More labs involve the alkali antimony photocathode development. Some labs switch from GaAs photocathode to alkali antimony photocathode for either DC gun or RF gun. The presenter Zhenggong Jiang from SHLS and Dr. Nishimori from KEK presented their new developed alkali antimony deposition systems.

In open discussion, we have two major opening discussion topics, which were recommended to future R&D.

1) Several labs tested the cathode performance in cryogenic temperature. For the HZB case, the cathode QE at long wavelength side is increased once cathode cool down to LN2 temperature. It is possible caused by the phonon scattering domination in cathode crystal. In the cryogenic environment, the phonon-electron scattering rate decreased, then the QE increase. This may be related to the cathode lattice structure, defects or surface states. The advantage is possible to cool the cathode, generate low thermal emittance electron beams with high QE.

2) Recently, The challenge will be using the alkali semiconductor cathode inside the SRF gun, either caused multipacting or lifetime concerns. It is possible to develop advanced cathodes without any alkali metals or say with superconducting prefered materials such as hydrogen, nitrogen? The diamond amplifier was studied at BNL in a few years before. This is only H_2 terminated on emission source. Recently, the SRF gun has tested with alkali antimony cathode. Test diamond amplifier may solve the issues found in SRF gun test.

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SUMMARY OF GUN SESSION

The gun session has eight talks. Four of them talked DC gun, three of them talked SRF gun and one is about the hybrid DC-SRF gun. DC guns as matured electron source have been used for ERL machines such as ALICE and JLab-FEL. Dr. Lee Jones gave a summary talk of gun operation at ALICE ERL. JAEA/KEK DC gun and Cornell DC gun has been well commissioned. Dr. Nishimori showed the DC gun stable operation range with 1mA average current from GaAs photocathode. The DC gun at Cornell and BNL are explored the new applications on CBETA and LeREC, presented by Karl Smolenski from Cornell Univ. and Dr. Dmitry Kayran from BNL. Two SRF guns from BNL and HZRD showed encourage commissioning results. SRF gun is able to operate in CW mode with a high gradient on the cathode and extremely good vacuum due to cryogenic pumping. Dr. Igor Pinayev reported 113MHz QWR-SRF gun stable CW (26kHz) operation for CeC experiment with 0.32 mm-mrad normalized emittance at half nC. QWR SRF gun has advantages on high gradient, small energy spread, and 4K operations. The K_2CsSb cathodes in this gun have a lifetime more than a month without obviously decay. The multipacting eliminated with new cathode design and RF procedure progresses. Recently, the injector is not the limit of CeC experiment. Dr. Jochen Teichert from HZDR reported that both magnesium and Cs_2Te in 3.5 cell 1.3 GHz SRF gun delivered request beam for users with good lifetime. The issues are focused on increase cathode lifetime in transferring and long time stable operation with Cs_2Te cathode. The HZB gun is approaching to beam test once finish the RF gun. The RF tests show that the peak gradient could achieve 57.3 MV/m. Hybrid DC-SRF gun developed by Peking University has commissioned and delivered the beam for THz and UED experiment. The new design is going on for approaching the normalized emittance to sub mm-mrad.

In open discussion, we have two major opening discussion topics:

1. ERL's for fundamental researches need polarized beams with meaning mA currents with high charge lifetimes. High current polarized electron is useful in the project like future EIC. But there is only very little progress with respect to this topic. More resources should provide to the polarized electron source.

2. Given the fact that it is mandatory to solve this problem if a high average current ERL is to be of use, it seems that efforts should intensify. Even if one group would have the capability to generate 100mA average current for a long time with optimum beam conditions, the respective accelerator managements must understand that mastering the technology requires continuous effort in personnel for example photocathode specialist. Have a photocathode common platform is helpful such as Wiki web page or shared online procedure.

CONCLUSION

The progresses in injectors for ERLs at the last couple years are significant. Many labs start to interested in high QE alkali-antimonide photocathode. Most of the labs reached 10% QE of the cathode in green light and tested in their injectors. The maturity of DC gun technology, and their viability for ERL use has confirmed this year. SRF guns have breakthrough in last two years. Both BNL 113MHz QWR gun and HZDR SRF gun tested semiconductor photocathode with stable CW operation. The cathode lifetime in QWR SRF gun is more than a month without obviously decay. In the future, the injector efforts will push to high current, high brightness and stable operations. The photocathode research should focus on long lifetime, high QE with SRF preferable cathode.

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