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Summary of Polarized e^-/e^+ Source Presentations

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Abstract

The development of polarized electron sources in the 1970s capable of generating beams for injection into electron accelerators has been a major enabling factor for spin physics with electrons during the past quarter century. These sources continue to be refined for higher polarization and better operability. Recent developments were presented at this workshop in both plenary sessions and in 2 separate parallel sessions. The ILC plans to utilize not only a polarized electron source but also a polarized positron source. The current state of two types of positron sources were presented. This paper is a brief summary of all of these presentations.

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Keywords: Electron sources, positron sources, polarized beams
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INTRODUCTION

Accelerator applications of polarized electron sources can be separated into two broad groups: 1) low duty-factor pulsed applications; and 2) high duty-factor cw applications. In addition there are non-accelerator applications for which, at present, cost and operability take precedence over high polarization. At this workshop there were 9 presentations primarily related to accelerator applications and 1 presentation on non-accelerator applications and in addition 2 talks on polarized positron sources for accelerator application.

PHOTOCATHODE ADVANCES

Polarized electrons were first accelerated in 1974 using a Li atomic beam source at SLAC. This was followed in 1978 by a GaAs photocathode source at SLAC and later at Mainz, JLab, Bates and elsewhere. Interesting details of these milestones were summarized by C. Sinclair (Cornell), who was responsible for much of the early development of GaAs sources[1]. Accelerators share a common requirement for high polarization (P_e) and high quantum yield (Y). The former is important because the quality factor for the physics data goes as the square of the polarization. The latter is a practical matter closely related to the state of laser technology. During the past 10 years there have been significant increases in P_e that can be routinely achieved with GaAs while simultaneously maintaining a high Y. Yu. Mamaev (SPbSPU) reported on the latest photocathode results at St. Petersburg using a thin, highly strained AlInGaAs/AlGaAs superlattice photocathode structure: P_e=91-92%, Y~0.5% at the polarization peak[2]. While this yield is substantial, it could in principle be increased by growing a distributed Bragg reflector on the wafer substrate to form a Fabry-Pérot resonant cavity. L. Gerchikov (SPbSPU) reported on the latest resonant-cavity results at St. Petersburg: a factor of 2 increase in the yield at the polarization peak, although it appears likely that a factor of up to 10 is possible with a slight modification of the structure[3].

PULSED SOURCE PROPERTIES

There were 3 presentations directly related to the ILC source, for which a 1-ms, 3 MHz train of 5 nC pulses (at the cathode) at 5 Hz is required. A. Brachmann (SLAC) outlined the expected layout of the injector system[4]. The plan is to utilize a DC-biased gun operating at 140-200 kV. A major challenge is the laser system. A quasi-cw Ti:sapphire cryogenic regenerative amplifier using available high-power Nd:YAG pump sources is being developed that will be used to measure the surface charge limit (SCL) at the cathode under ILC beam conditions. M. Yamamoto (Nagoya) presented the latest achievements with the new high-voltage (HV) gun at Nagoya[5]. After experimental studies indicated that both Mo and Ti should be electrode materials superior to stainless-steel, Mo being especially good at reducing field emission, Ti at reducing secondary enhanced emissions, a Mo cathode and Ti anode were installed in the gun. After careful HV conditioning (dark current <1 nA at 200 kV), the gun was operated at 200 kV for 8 hours while producing an average cw current of 300 nA. Since the average electron current at the ILC gun will be 50-100 μA, ion bombardment is expected to dominate the photocathode lifetime. A possible way to circumvent this problem was described by J. Kewisch (BNL). A superconducting rf gun should provide the extremely low pressures (10^{-12} Torr) required to nearly eliminate ion bombardment[6]. In addition, simulations indicate most of the ions in the gun will not actually hit the cathode or will hit with significantly reduced energy compared to a DC gun.

CW SOURCES

All the improvements in source parameters discussed above will also benefit cw sources. In addition, ion bombardment is of major concern for cw guns. M. Poelker (JLab) discussed some of the research in progress to achieve the 1 mA average current required by ELIC and 25-250 mA for eRHIC[7]. The new JLab load-locked gun has demonstrated 1 mA operation for 8 hours, 250 C lifetime, and initial laser power 160 mW. This result implies 7 days of operation at 1 mA may be possible with a 2 W laser, etc., but it is noted that >0.5 W will require active cooling of the cathode. J. Grames (JLab) reported on additional details of the high current work at JLab, including the interesting demonstration that biasing the anode against ions created in the vacuum pipe immediately downstream of the anode can significantly increase the cathode lifetime[8]. E. Tsentalovich (MIT) discussed the challenges to be faced to build a DC polarized electron gun for eRHIC, especially for the linac-ring version, which is the version with potentially the highest luminosity[9].

One of the more disturbing measurements reported by Poelker shows that the cw current is not linear with laser power despite the fact that this power is orders of magnitude lower than that required to reach the surface charge limit for pulsed systems. This indicates that the SCL may have a serious effect on the operation of future high-current cw sources as well as possibly the ILC source.

OTHER

GaAs polarized electron sources for accelerators are very expensive and require a permanent highly-trained staff to operate. Y. Niu (HKUST) described a simpler field-emission source of polarized electrons (Pe~25%) that utilizes an Fe film on a single-crystal W(100) tip[10]. Beams stable for several days have been demonstrated. R&D continues.

Finally there were 2 talks on polarized positron sources for the ILC. The baseline design generates polarized gammas from an unpolarized high-energy electron beam that passes though a long helical undulator. Compton backscattering from a relatively low-energy electron beam is an alternative scheme, but requires a very powerful laser. P. Schuler (DESY) described the recently completed proof-of-principle experiment at SLAC (E166) that uses the first approach[11]. M. Kuriki (KEK) described advances with the Compton approach[12]. Both approaches generate the polarized positrons by passing the polarized gammas through a thin conversion target.

REFERENCES

1. C. Sinclair, *Polarized Electron Sources*, this workshop.
2. Yu. A. Mamaev, *Record Values of Electron Beam Polarization and Quantum Efficiency for Semiconductor Photocathodes*, this workshop.
3. L. G. Gerchikov, *Highly Effective Polarized Electron Sources Based on Strained Semiconductor Superlattice with Distributed Bragg Reflector*, this workshop.
4. A. Brachmann, *Polarized Electron Source for the ILC*, this workshop.
5. M. Yamamoto, *Development of High-Performance Polarized e- Source at Nagoya University*, this workshop.
6. J. Kewisch, *The Polarized SRF Gun Experiment*, this workshop.
7. M. Poelker, *High Intensity Polarized Electron Sources*, this workshop.
8. J. Grames, *A Biased Anode to Suppress Ion Back Bombardment in a DC High Voltage GaAs Photocathode Gun*, this workshop.
9. E. Tsentalovich, *Polarized Source for eRHIC*, this workshop.
10. Y. Niu, *Spin-Polarized Electrons from Fe Films Coated Single Crystal W(100) Tips by Field Emission*, this workshop.
11. P. Schuler, *The E166 Experiment: Undulator-Based Production of Polarized Positrons*, this workshop.
12. M. Kuriki, *ILC Polarized Positron Source Based on Laser Compton Scattering*, this workshop.