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Jefferson Lab injector development for next generation parity violation experiments

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Abstract To meet the challenging requirements of next generation parity violation experiments at Jefferson Lab, the Center for Injectors and Sources is working on improving the parity-quality of the electron beam. These improvements include new electron photogun design and fast helicity reversal of the Pockels Cell. We proposed and designed a new scheme for slow helicity reversal using a Wien Filter and two Solenoids. This slow reversal complements the insertable half-wave plate reversal of the laser-light polarization by reversing the electron beam polarization at the injector while maintaining a constant accelerator configuration. For position feedback, fast air-core magnets located in the injector were commissioned and a new scheme for charge feedback is planned.

Keywords Parity violation · Inverted Photogun · Wien filter · Helicity reversal · Position feedback · Pockels cell

1 Introduction

In the coming few years, two very demanding parity violation experiments are scheduled to run at Jefferson Lab: PREx [1] and QWeak [2]. These experiments will measure very small parity-violating asymmetries (A_{PV}) of the order of few hundreds parts-per-billion (ppb) with unprecedented accuracy. The beam requirements of these two experiments are listed in Table 1. To carry out these measurements, the Center for Injectors and Sources is working on improving the parity-quality of the electron beam. The goal is to minimize the helicity-correlated charge asymmetry and position differences and to provide for a new scheme to cancel systematic errors. The statistical errors are also minimized by providing the required beam current and reducing the target density fluctuations.

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Table 1 Upcoming parity violation experiments at Jefferson Lab

Experiment	Beam current	Target	A_{PV}	Maximum charge asymmetry	Maximum position differences
PREx	50 μA	^{208}Pb (0.5 mm)	500±15 ppb	100±10 ppb	2±1 nm
QWeak	180 μA	^{1}H (35 cm)	234±5 ppb	100±10 ppb	2±1 nm

2 Injector development

2.1 Higher gun voltage and new photogun with inverted ceramic insulator

At high beam currents, the space-charge increases the emittance of the electron beam in the injector. The increase in beam emittance (and size) results in beam loss at two emittance defining apretures which results in an increase of charge asymmetry width.

To be able to deliver high beam current to QWeak experiment, the gun high voltage will be increased from 100 kV to higher voltage. A new 150 kV power supply has been installed. To achieve this and eliminate field emission in the gun, a new gun with inverted ceramic insulator has been installed in the injector [3]. Field emission degrades vacuum and reduces the lifetime of the photocathode. The new gun helped overcome field emission problems of the previous gun design that used a conventional large-bore cylindrical ceramic insulator common to most DC high voltage GaAs photoguns.

2.2 Slow reversal of the electron polarization

Parity experiments at Jefferson lab have been using the insetable half-wave plate for slow reversal of the laser circular polarization. This slow reversal cancels the electronic cross-talk and optical steering from the Helicity Pockels Cell (HPC). However, helicity-correlated effects from residual linear polarization do not cancel. Electron polarization reversal cancels all helicity-correlated beam asymmetries from laser and photocathode including spot size.

The photogun produces longitudinally polarized electrons. A Wien Filter rotates the spin by 90° in the vertical direction. Then two solenoids rotate the spin back to the horizontal plane transverse to the beam motion. By changing the current direction in these two solenoids, the spin is rotated either to right or left of beam. Then a second Wein rotates the spin in the horizontal plane to account for the spin precession in the accelerator such that the experiment receives fully longitudinal polarization.

During beam delivery, the settings of the two Wiens will not change while the slow polarization reversal is achieved by changing only the direction of current flow in the two solenoids often, e.g., once a week. Focusing from these solenoids will not change, however, phase advance will. To address this issue, new beamline design has been implemented and more diagnostics are added to commission and operate the new injector: quadrupoles, beam profile scanner, viewer, vacuum gauges, UHV ion supplies, and beam position monitors. The new beamline will be installed and commissioned before the start of PREx experiment.

2.3 Fast helicity reversal

All previous parity violation experiments at Jefferson Lab ran with 30 Hz helicity reversal where the helicity changes every 33,533 μs. The experiment vetoes the first 500 μs, allowing for HPC settling, and collects data during the remaining 33,330 μs. Since the data taking period contains two 60 Hz cycles, this scheme exactly cancels the 60 Hz line noise. However, there are other sources of beam noise at low frequencies and the noise from target density fluctuations is biased to low frequencies.

Previous studies showed that faster reversal rate reduces target density fluctuations [4]. More recent studies have shown a reduction by a factor of 4 in the width of charge asymmetry with a reversal rate of 1 kHz: 60 μs for HPC settling and 980 μs for data taking. Fast helicity reversal of the HPC was possible using newly designed optically-driven fast high voltage switch. A new Helicity Control Board has been installed to provide wide range of helicity reversal rates.

2.4 Fast magnets for position feedback

There are four fast air-core magnets in the 5 MeV region in the injector that can be used to implement a feedback to correct both position and angle at the helicity reversal rate. Previously, a piezoelectric transducer (PZT) mirror on the laser table was used in position feedback. Since moving the laser on the photocathode affects the charge asymmetry, the position feedback was coupled to the charge feedback. No coupling was measured when using these magnets. Position feedback was successfully commissioned during a previous parity violation experiment. The magnets are powered by electrically isolated controls. To check for helicity pickup, the HPC was turned off and one magnet was powered to 1,000 times its operational current; no position differences were measured upstream of this magnet.

2.5 Other developments

Other developments include the ability to do charge feedback to correct for HPC electro-optical hysteresis and the ability to move the HPC remotely (X and Y) to minimize electron beam position differences caused by optical steering. Also, with the load-locked gun, we can now zero the offset term in the charge asymmetry caused by the vacuum window birefringence by rotating the photocathode.

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References

1. Horowitz, C.J., et al.: Parity violating measurements of neutron densities. Phys. Rev. **C63**, 025501 (2001)
2. Van Oers, W.T.H.: The QWeak experiment. Nucl. Phys. **A790**, 81–87 (2007)
3. Adderley, P.A., et al.: A load-locked DC high voltage GaAs photogun with an inverted-geometry ceramic insulator. Phys. Rev. ST Accel. Beams **13**, 010101 (2010)
4. Armstrong, D.S, Moffit, B., Suleiman, R.: Target density fluctuations and bulk boiling in the hall a cryotarget. JLab Technical Note JLAB-TN-03-017 (2003)