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POLARIZED ELECTRON SOURCE FOR PARITY EXPERIMENT AT BATES*

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ABSTRACT

We are constructing a polarized electron source in order to study parity violation in elastic electron-carbon scattering at the MIT Bates Linac. The source uses a GaAs photocathode illuminated by light from an infrared krypton ion laser. Our design, which uses a multi-chamber vacuum system, meets the special requirements for operation at Bates.

INTRODUCTION

We are constructing a polarized electron source for the MIT Bates Linear Accelerator, an 800 MeV electron linac devoted to studying nuclei with electromagnetic probes. Polarized beams will extend the capabilities of Bates to allow the measurement of parity-violating interference effects between the weak and electromagnetic interactions.[1] These experiments will study in detail the fundamental weak-neutral-current interaction between electrons and quarks. In the future, polarized electrons might be used together with polarized targets or polarimeters to measure nuclear form factors that otherwise would be difficult to isolate.[2,3]

NEUTRAL CURRENT PHENOMENOLOGY

Our polarized electron experiments will measure the parity-violating asymmetry

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

where $\sigma_{R(L)}$ is the differential cross section for the scattering of electrons with right (left) helicity. The parity violation arises because the ordinary one-photon exchange amplitude interferes with the parity-odd amplitude arising from the exchange of the neutral weak boson (Z^o). From the standpoint of a general phenomenological analysis,[4,5] there are four possible parity violating coupling constants as shown in Fig. 1, where the axial vector coupling causing the parity violation may be with either the electron or the nuclear current and the nuclear current may be either isoscalar or isovector. The highly successful Weinberg-Salam model[6] predicts these

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constants in terms of the single parameter, $\sin^2\theta_W$.[7]

At Bates, we plan to measure the asymmetry in elastic electron-^{12}C scattering. The fact that this reaction is a coherent process from a purely isoscalar spinless target causes it to depend only upon the isoscalar, vector hadronic coupling constant $\tilde{\gamma}$.[8] For this target there is only one nuclear form factor, and it cancels out in the asymmetry A. Therefore, the experiment is independent of the details of nuclear structure, and a precise measurement of A provides an important test of the Weinberg-Salam model. The experiment is complementary to the famous experiment in which deep inelastic e-d scattering was studied.[9] There the scattering was incoherent, with the consequence that the result was sensitive primarily to the isovector coupling constants.

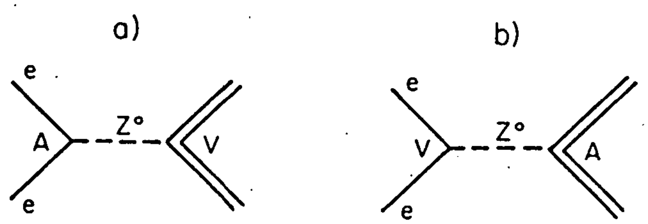

Fig. 1. Feynman diagrams corresponding to the different weak interaction amplitudes. a) Axial electron coupling $\tilde{\gamma}(\tilde{\alpha})$ for an isoscalar (isovector) nuclear current b) Axial hadron coupling $\tilde{\delta}(\tilde{\beta})$ for an isoscalar (isovector) nuclear current. These constants are precisely defined in Ref. 5.

While the study of the parity violation of carbon scattering is unambiguous theoretically, it suffers from the fact that the four-momentum transfer Q must be kept small in order that the form factor remain sizable enough to provide high counting rates and good signal to noise ratios. Since the weak-interaction asymmetry is proportional to Q^2, it is therefore quite small for this process. For our experiment the largest practical Q^2 is about $(150\ \mathrm{MeV/c})^2$, which will be obtained with a 250 MeV beam scattered by ~35°. For these kinematics, the standard model predicts $A \simeq 2\times10^{-6}$, implying that it is desirable to achieve an error in A of $\simeq 2\times10^{-7}$. Although the achievement of this level of sensitivity presents a major technical challenge, it should be recognized that experiments using polarized proton beams have already reached such sensitivities.[10]

DESCRIPTION OF THE SOURCE

Clearly this difficult experiment imposes major constraints on the nature of the source providing the polarized electrons. The intensity and polarization must be high to achieve the required statistical accuracy, and the stability must be sufficient to avoid systematic errors. In addition, the source must be compatible with the accelerator requirements for phase space and injection energy. The design goals of the source are given in Table I. We have

Table I: Design Goals for Polarized Electron Source

Intensity	20 mA peak: 300 μA average
Duty Factor	20 μsec long pulses; 720 Hz
Polarization	0.4
Injection Energy	365 kV
Phase Space	$< 10^{-3}$ π mr-cm
Intensity Stability	< 0.5 % jitter
	$< 10^{-4}$ correlated with helicity

constructed a source based on photoemission from a GaAs crystal,[11] which we believe will meet the listed criteria. Since this general technique has been discussed in detail at this conference and at previous conferences[12] in this series, we will focus on the unique features of our source.

An overall view of the source is given in Fig. 2. The GaAs crystal sits atop a 365 kV acceleration column. The crystal and three associated vacuum chambers including the electron gun, the crystal preparation region, and the insertion air lock, are enclosed by a Faraday cage at high voltage. The outside of the acceleration column is surrounded by several atmospheres of SF_6 to allow a high gradient. At ground potential leading to the accelerator is the beam pipe through which passes the 752 nm laser light producing the photoemission.

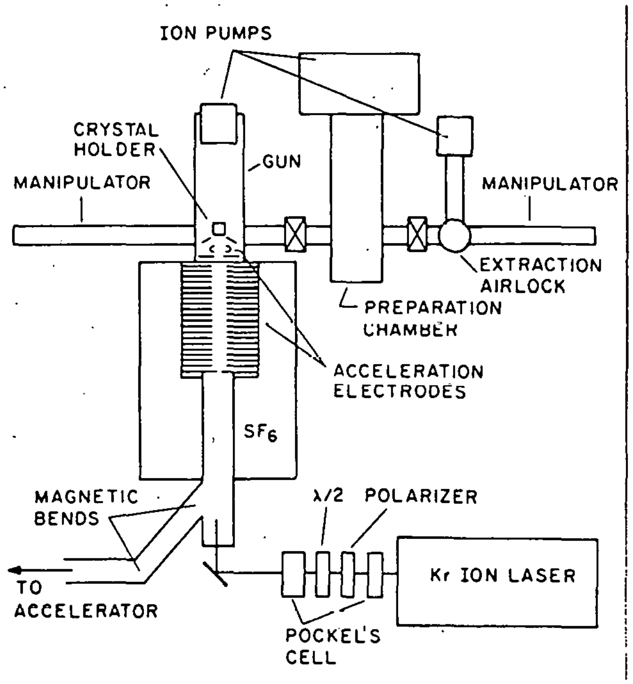

Fig. 2. Schematic of the polarized electron source.

A detail of the gun chamber is given in Fig. 3. The electrode assembly was designed to be similar to that of the thermionic gun presently in service at Bates. Provision is made to cool the crystal as well as the electrodes near the crystal to liquid nitrogen temperature. The high vacuum required (~ 10^{-10} Torr) is provided by two 20 ℓ/sec ion pumps and a Ti sublimination pump.

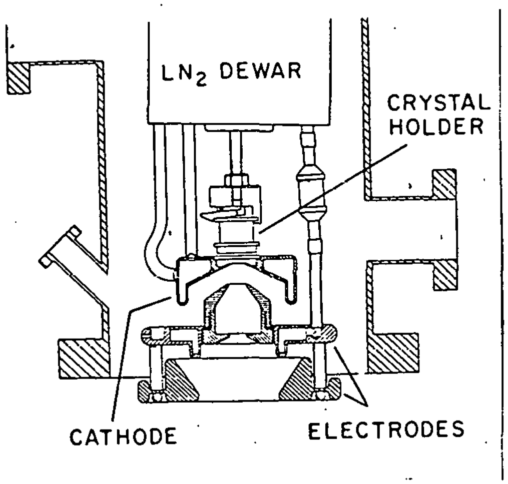

Fig. 3. Detail of the gun chamber.

The preparation chamber, in which the GaAs crystal is heat cleaned, coated with cesium and oxygen, and tested for quantum efficiency, is shown in Fig. 4. The performance of these functions in a separate chamber protects the critical gun chamber from contamination and also allows several crystals to be available for use during a run.

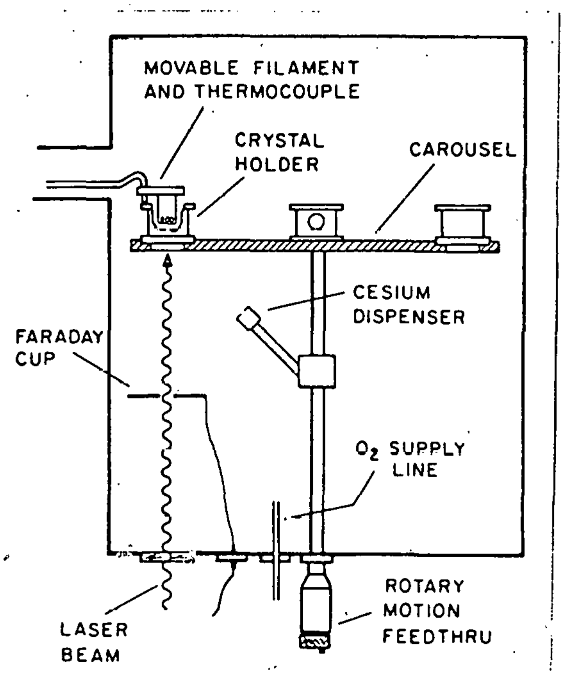

Fig. 4. Schematic of the preparation chamber.

A continuous-wave Kr ion laser provides the 752 nm light to produce the polarized electrons. A Pockels cell chops the light to provide the ~20 μsec long pulses to match the accelerator time structure. A second Pockels cell randomly reverses the helicity of the laser beam (and hence the electron beam) on a pulse to pulse basis. Our chopped laser is ideal for this sensitive experiment because it produces a beam of much more uniform intensity than would be possible with a pulsed laser.

PRESENT STATUS

We have recently begun studying the properties of GaAs in our preparation chamber as a function of the method of surface preparation. Thus far we have been able to obtain quantum efficiencies in excess of 2% with light from a helium-neon laser. We plan to study the polarization of the beam obtained with our Kr ion laser in the next few months before installing the source at Bates. By that time the high energy apparatus, including magnetic spectrometers, detectors, and beam monitors, should be fully tested and ready to use the polarized beam.

FUTURE PROSPECTS

I would like to jump ahead and mention that there is considerable interest in the nuclear physics community in constructing a continuous, high current, 4 GeV electron facility. At least three institutions, Argonne National Laboratory, MIT, and the Southern Universities Research Association, have included in their detailed designs the capability of using polarized electron beams. Such a facility would be ideal for continued studies of parity violation. Elastic scattering from hydrogen is a particularly exciting possibility because of the high precision that can be obtained.[2] Of course, we are hoping that a photocathode capable of producing electrons with nearly 100% polarization will be available for that experiment.

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