

## A PULSED SOURCE OF HIGHLY POLARIZED ELECTRONS\*

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In recent years interest in spin effects at high energies has stimulated work on polarized beams and targets.<sup>1</sup> Since 1962 the atomic beam method for production of polarized electrons has been studied at Yale.<sup>2-4</sup> In this method polarized electrons are obtained by photoionization of a polarized alkali atom beam. The first successful experiment was done with an atomic beam of potassium-39 and a cw high-pressure mercury arc as light source, yielding a current of  $10^{-12}$  A and a polarization of 58%.<sup>3</sup> However, these results did not represent the ultimate capacity of this method. In this paper we report experiments which have produced a pulsed source of polarized electrons with high intensity and high polarization, suitable for use with a high energy accelerator.

The polarized electron source consists of a polarized atom source, a uv light source and an ionization region (Fig. 1). The choice of the alkali atom is determined by the following requirements: high photoionization cross section, small hfs interaction energy (for decoupling of the nuclear spin from the electronic spin in a weak magnetic field) and low ionization potential (for operation in a convenient wavelength range). Lithium-6 was chosen because of its particularly high photoionization cross section (Fig. 2) and small hfs interaction (228 MHz). The threshold wavelength for ionization of lithium is  $2300 \text{ \AA}$ . For the pulsed beam a high pressure spark source was developed, since no suitable commercial source was available.<sup>5</sup> For cw measurements a commercial xenon-mercury arc with Suprasil envelope was used.

The atomic beam system is shown in Fig. 3. A conventional oven is used to produce the beam of lithium-6 atoms.<sup>6</sup> The atomic beam is polarized by state selection in a permanent six-pole magnet, and an axial magnetic field of about 100 gauss is maintained in the ionization region. The transition of the atoms from the high field of the six-pole magnet into the relatively weak field of the ionization region is adiabatic. The theoretical value of the electronic polarization of the atoms in the ionization region is shown as a function of magnetic field by the solid curve in Fig. 6.

The uv light source for pulse operation consists of a high-pressure spark chamber (Fig. 4) containing argon or xenon at about 100 psi. The spark is a condensed discharge between tungsten electrodes. A pulsing circuit operating at repetition frequencies up to 20 Hz dissipates about 5 joules per flash. The arrangement of mirrors (front surface, coated with  $\text{MgF}_2$ ) and windows is shown in Fig. 5.

Photoionization occurs through an electric dipole transition, and the electronic polarization should not change in this process. The ionization region is surrounded by cylindrical electrodes to provide a potential of -100 kV and a variable bias voltage of several hundred volts for the extraction of the photoelectrons. The electrons are accelerated to ground potential. The electric field in the acceleration region and the axial magnetic field in the ionization region focus the electron beam and discriminate against background photoelectrons emitted from surfaces. Several coils are placed along the beam system for further focusing and beam steering. The emittance of the 100 keV electron beam is about 1 mrad-cm (aperture angle x radius).

Following the conversion of longitudinal into transverse electron polarization by  $112^\circ$  electrostatic beam deflection, wide-angle Mott scattering from gold foils is employed to measure the electron polarization. For proper elimination of inelastically scattered electrons, surface barrier detectors with an energy resolution of about 15 keV are used. The pulse-height spectra are then recorded with a multi-channel analyzer. Figure 6 presents the results of the polarization measurements in cw and pulse operation. The agreement with the theoretical curve is satisfactory, since the atom polarization produced in the six-pole magnet is somewhat smaller than unity and the electron beam contains a small background of unpolarized photoelectrons from the surfaces, and these two effects are not included in the theoretical curve. The horizontal error bars indicate the uncertainty in the field strength in the ionization region due to the field inhomogeneity. An electron polarization exceeding 90% can be expected if the magnetic field in the ionization region is increased to about 200

gauss.

For the first measurements performed with Suprasil windows an intensity of  $3 \cdot 10^7$  electrons per pulse was obtained. During the time of the polarization measurements the intensity decreased as the result of the formation of uv-absorbing films on the windows. Current work is aimed at reducing the film formation. Furthermore, lithium fluoride windows will be used, and with the LiF transmission to wavelengths of  $1200 \text{ \AA}$  an intensity exceeding  $10^8$  electrons per pulse is expected. A further intensity increase may be possible with the use of a jet atomic beam.<sup>7</sup>

Measurements of the electron-pulse length were performed with a plastic scintillator, electron multiplier and fast oscilloscope. For argon or xenon in the spark chamber an electron pulse length of about 1 microsecond was observed. With the use of a different power supply and the installation of water cooling in the spark chamber, repetition frequencies of 60 Hz or higher appear technically feasible.

Reversal of the polarization of the electrons is easily achieved by reversal of the magnetic field direction in the ionization region. An unpolarized electron beam similar in intensity and emittance to the polarized beam can be obtained by photoemission from a metal mesh moved into the ionization region. A transversely polarized electron beam for injection into an accelerator can be obtained from the longitudinally polarized beam by use of crossed electric and magnetic fields.<sup>8</sup>

In summary, the performance characteristics achieved with our polarized electron source thus far are close to those predicted in the design.<sup>9</sup> As discussed, it seems reasonable to expect that we can now readily produce a polarized electron source with a polarization of greater than 90%, with an intensity exceeding  $10^8$  electrons per pulse, and with a repetition frequency of 60 Hz.

\* This research has been supported in part by the U.S. Atomic Energy Commission and the U.S. Office of Naval Research.

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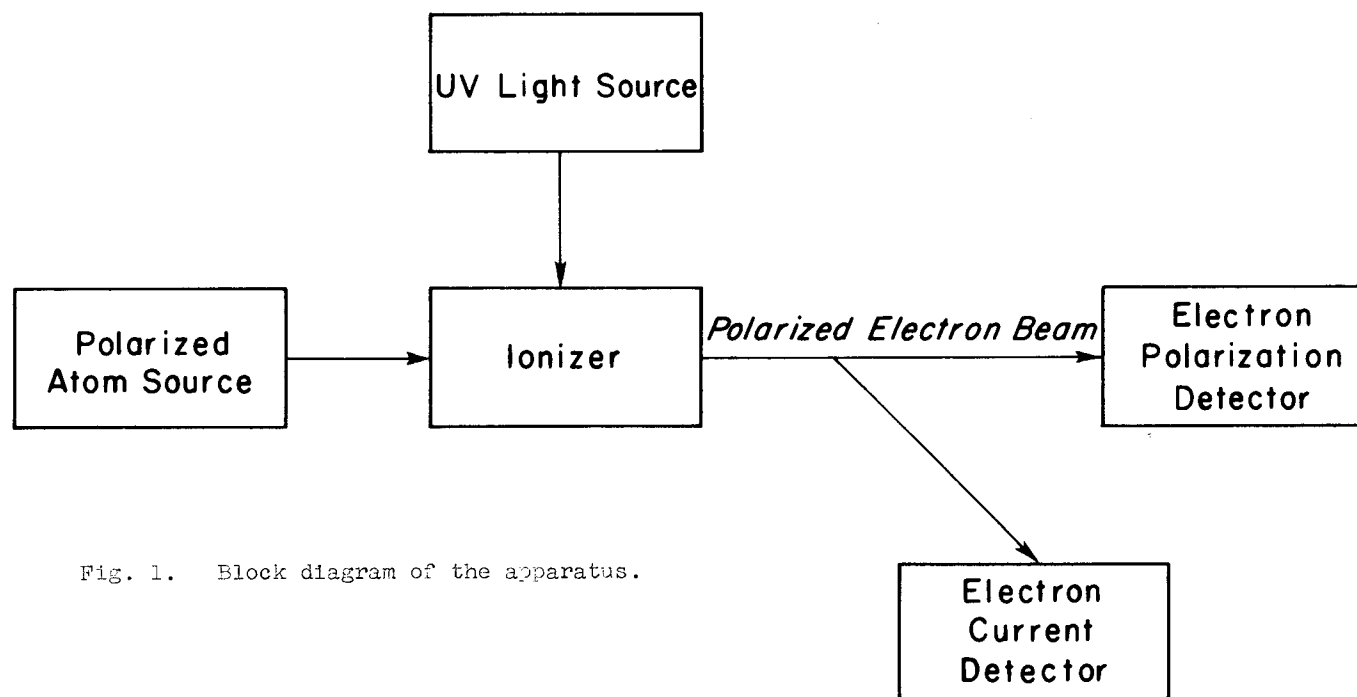


Fig. 1. Block diagram of the apparatus.

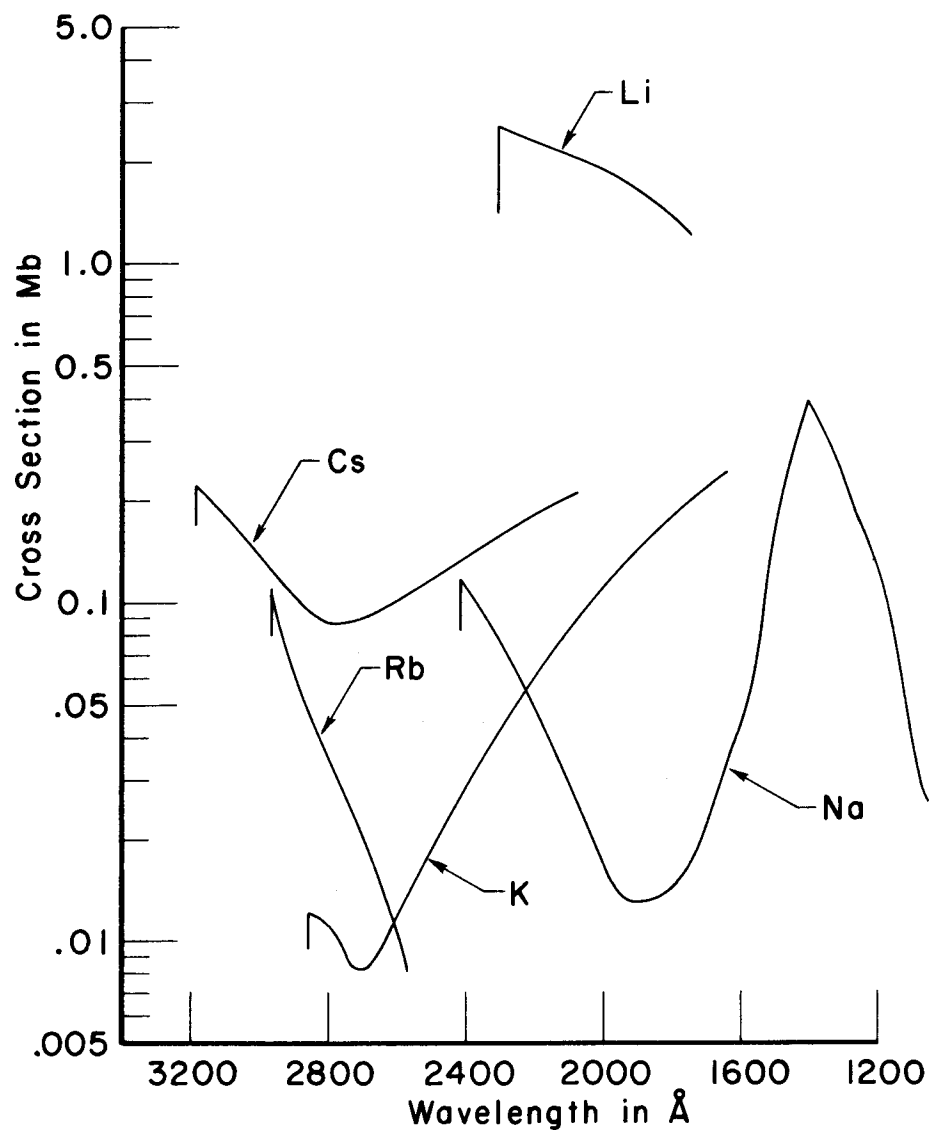


Fig. 2. Photoionization cross sections of alkali atoms. (from ref. 10).

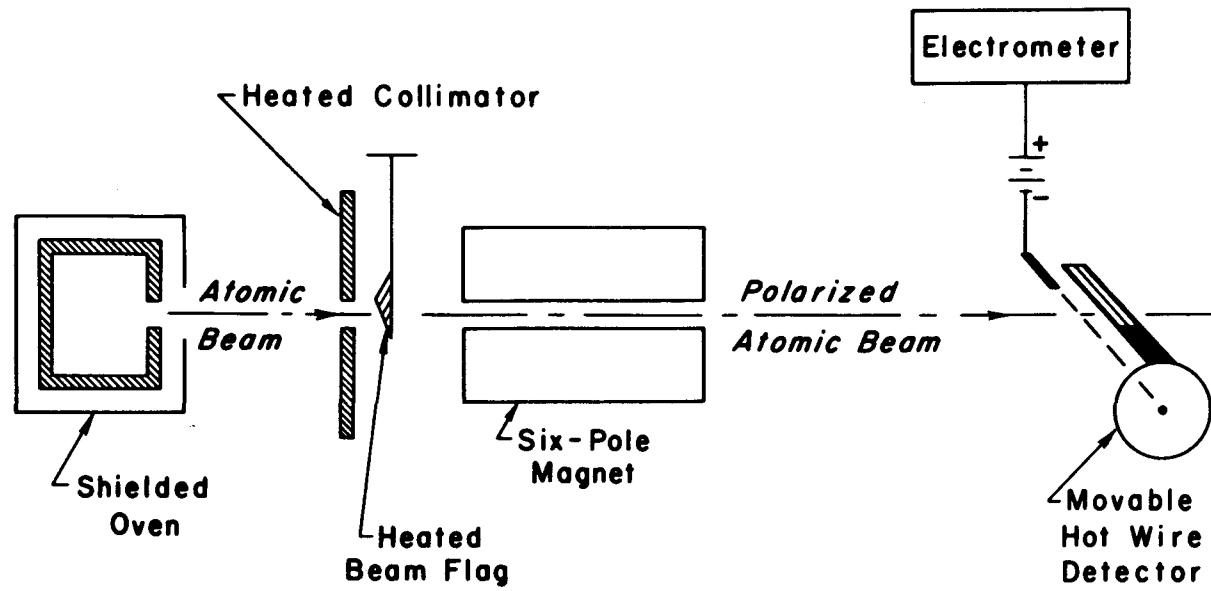


Fig. 3. Schematic diagram of atomic beam system.

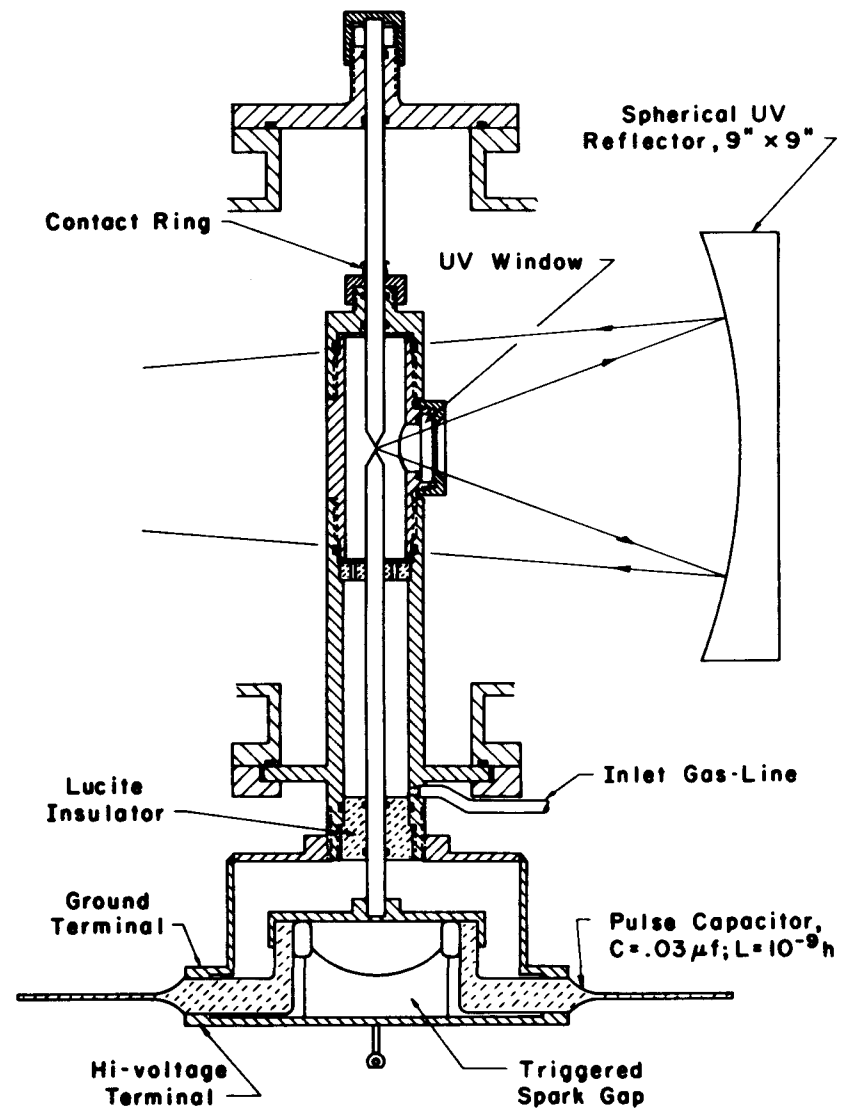


Fig. 4. Spark light source.

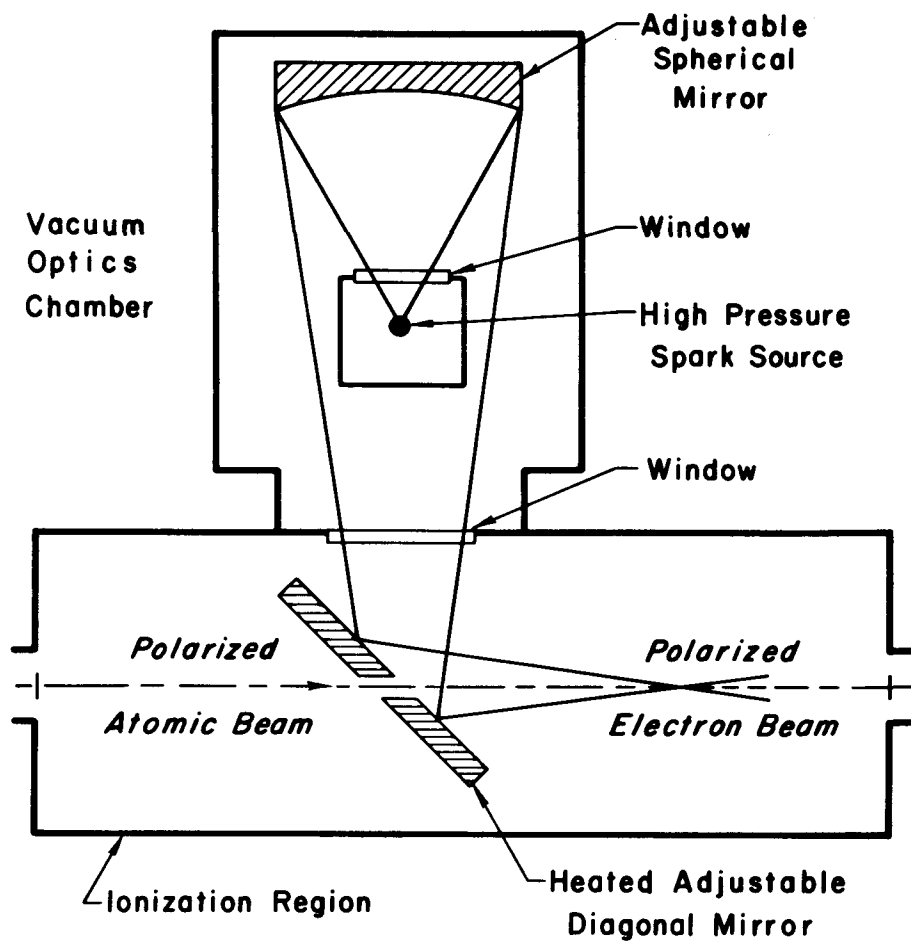


Fig. 5. Schematic diagram of optical system.

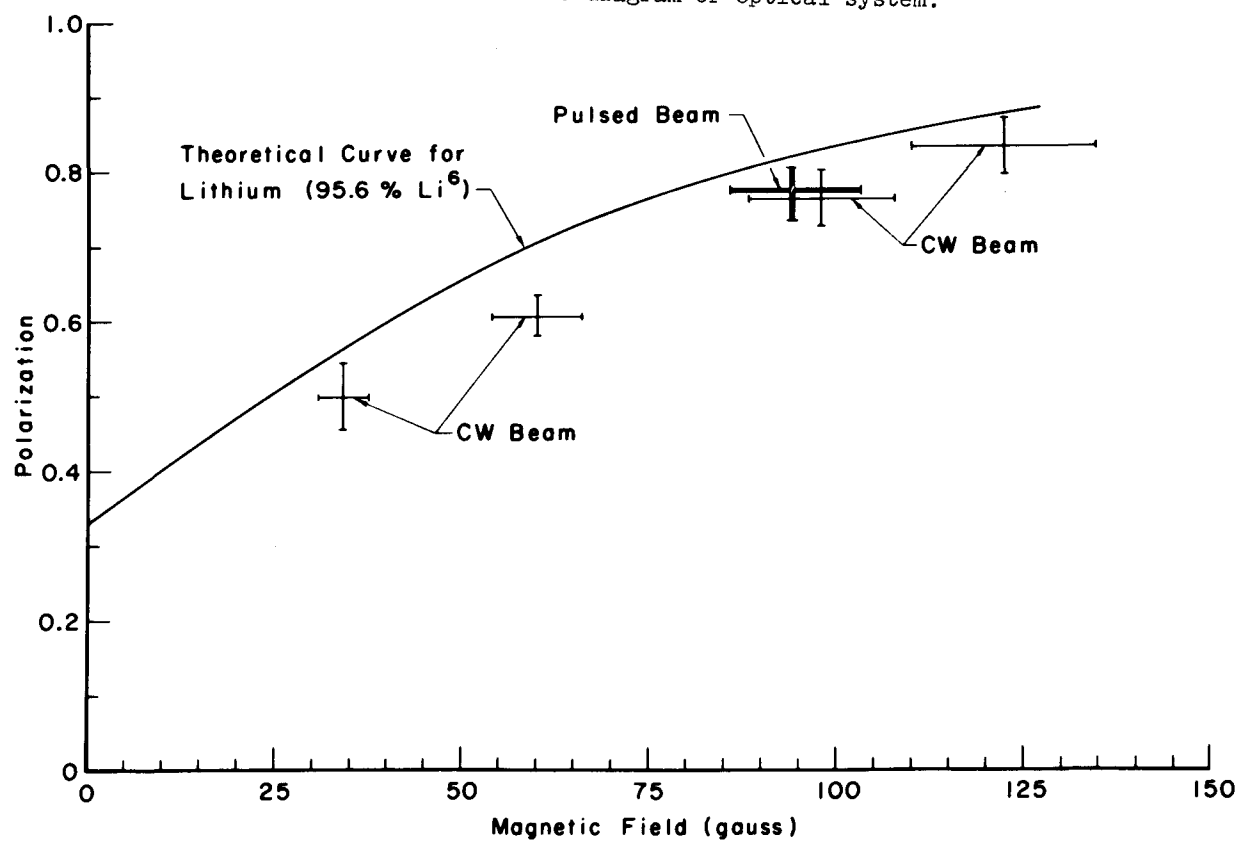


Fig. 6. Electron polarization as a function of magnetic field in the ionization region. Measured points are shown with error bars. The solid curve gives the calculated values.