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POLARIZED LIGHT SOURCES FOR PHOTOCATHODE ELECTRON GUNS AT SLAC*

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ABSTRACT

We describe current and future Polarized Light Sources at SLAC for use with photocathode electron guns to produce polarized electron beams. The SLAC experiments SLD and E142 are considered, and are used to define the required parameters for the Polarized Light Sources.

1. Introduction

Polarized electron sources utilizing photocathodes are currently in use at many accelerators around the world. Two experiments utilizing polarized beams at SLAC are SLD, run with the SLAC Linear Collider (SLC) at the Z^0 resonance, and E142, which is a fixed target experiment running in End Station A. The Polarized Light Source (PLS) requirements for these experiments are summarized in Table 1, where we assume that the photocathode to be used is strained GaAs operating at a wavelength of 830 nm and with a quantum efficiency of 0.1%.

Table 1. PLS Requirements.

	SLD	E142
Repetition Rate	120 Hz	120 Hz
Pulse Energy	25 μJ	250 μJ
Pulse Length	2 ns	2 μs
Helicity Dependent Intensity Asymmetry	$< 10^{-3}$	$< 10^{-4}$

2. The PLS for the 1992 SLD Experiment

In 1992, there was a 5 month SLD run and a 2 month E142 run at SLAC. The Polarized Electron Source used for the SLD run is shown in Fig. 1. The laser used is a flashlamp-pumped dye laser operating at 120 Hz and 715 nm. A current pulse, 15J in 1.5 μs, is sent to each of 2 flashlamps and produces (typically) a 5 mJ laser pulse with a pulse width of 750 ns.

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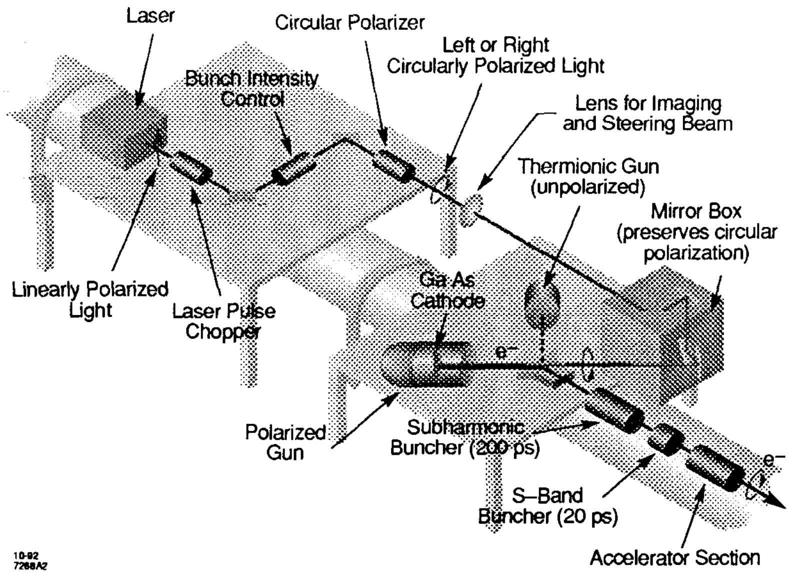

Figure 1. The Polarized Electron Source at SLAC.

A Laser Pulse Chopper (LPC) system consisting of a Pockels Cell between crossed polarizers is used to produce two 2ns pulses separated by 60ns from the initial 750ns pulse. The first of these pulses produces an electron bunch for e^+e^- collisions, while the second laser pulse produces an electron bunch for positron production. Following the Laser Pulse Chopper, a Bunch Intensity Control (BIC) system consisting of a Pockels Cell between aligned polarizers is used to regulate the intensity of laser light on the photocathode.

The laser beam is linearly polarized through the BIC system. A linear polarizer followed by a Pockels Cell operating at its quarter-wave voltage comprise the Circular Polarizer System (CPS) to produce circularly polarized light. A positive HV pulse on the CPS Pockels Cell produces positive helicity light, while a negative HV pulse produces negative helicity light. The sign of the HV pulse is set by a random number pattern generator, which updates at 120 Hz. This effectively eliminates any false asymmetries due to time-dependent behaviour of the accelerator. The absolute helicity of the laser light was determined by a method using total internal relection in a prism to generate a known helicity laser beam.

Following the CPS system, the laser beam enters a vacuum transport line 20 meters long to the photocathode. This transport line contains a 6 meter focal length imaging lens approximately midway between the CPS Pockels Cell and the photocathode. It also contains 4 mirrors to redirect the laser beam to the photocathode while preserving circular polarization.

The PLS ran continuously at 120 Hz for the 5-month SLD run in 1992, with only a 4 hour scheduled downtime every 10 days for dye and flashlamp changes. The efficiency for the PLS to deliver usable beams for SLD running averaged about 95% for the run, including the scheduled downtime. Typically, 5μJ in a 2ns bunch was delivered to the photocathode

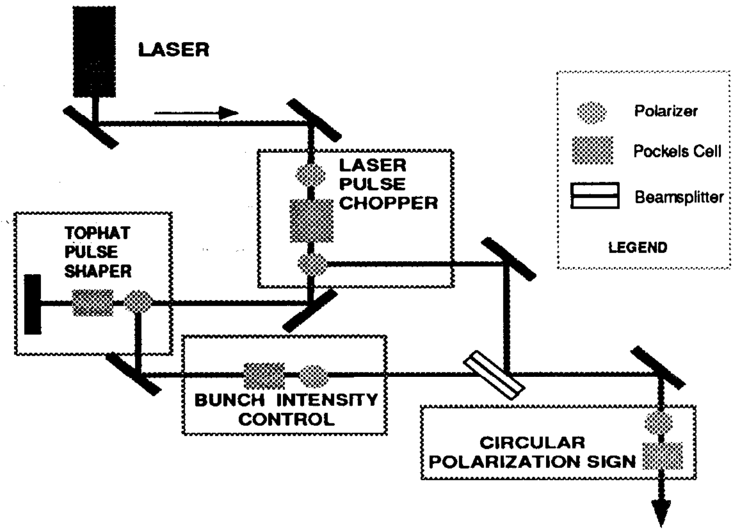

Figure 2. The Polarized Light Source for E142.

with 99% circular polarization. The helicity-dependent intensity asymmetry was determined to be less than $5 \cdot 10^{-4}$ from monitoring of the electron beam. The GaAs photocathode used had a typical quantum efficiency of 5% and produced $6{\cdot}10^{10}$ electrons per 2ns bunch (5A peak current). The electron beam polarization was 28%.

3. The PLS for the 1992 E142 Experiment

Following the SLD run, the PLS was reconfigured for E142 as shown in Fig. 2. For long pulse operation, the dye laser was modified to produce longer output pulses at lower peak power. Two beams from the pulsed dye laser are produced – a 1.2 μs long pulse for the experiment, and a 2 ns short pulse for accelerator diagnostics and tuning. Normal operating conditions during E142 were concurrent running of the long pulse at 119 Hz and the short pulse at 1 Hz.

The Laser Pulse Chopper Pockels Cell system is similar to the one described above for the SLD experiment, except that now the Pockels Cell is between aligned polarizers and only one pulse is produced. The TOphat Pulse Shaper (TOPS) system shapes the dye laser pulse into a 1.2 μs long flattop pulse. A fast feedback system determines a correction voltage to the TOPS Pockels Cell such that a photodiode signal following the TOPS system matches a reference waveform.

Following TOPS is the BIC system which serves the same purpose as for the SLD experiment, which is to regulate the laser light on the photocathode and hence the intensity of the long pulse electron beam. Following the BIC system, the short and long laser pulses are combined and sent to the CPS system, which is identical to that used for SLD. From the CPS on, the PLS for E142 and SLD are identical.

The PLS efficiency for E142 is similar to its efficiency for SLD, with typically 4 hours of scheduled maintenance every 10 days for dye and lamp changes. The PLS delivers about 20 μJ in a 1.2 μs pulse to the photocathode with 99% circular polarization. Helicity dependent

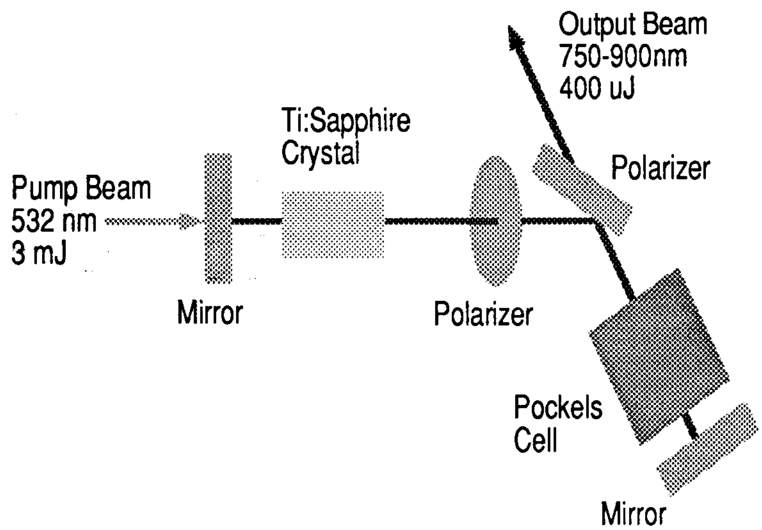

Figure 3. The YAG-TI Laser.

intensity asymmetries as large as $1.5 \cdot 10^{-4}$ have been measured during E142 running. This helicity asymmetry is believed to arise from two effects–residual linear polarization in the laser beam coupled with a small transmission asymmetry in the laser transport optics from the CPS to the photocathode, and steering of the laser beam by the CPS Pockels Cell due to misalignment of the laser beam with respect to the Pockels Cell.[1] For E142, an AlGaAs photocathode was used. It had a typical quantum efficiency of 0.8% and produced $3.5 \cdot 10^{11}$ electrons in a 1.2 μs pulse. The electron beam polarization was 40%.

4. The PLS for Future SLD Running

The SLD experiment has an 8-month run beginning in January 1993. Current plans for the polarized source are to begin this run with a thin epitaxially grown GaAs cathode (0.3 μm active layer). The PLS will operate at 765 nm, and this is expected to give an electron beam polarization of 49%. Later in the run, or perhaps for the 1994 run, it is hoped that we can switch to a strained lattice GaAs photocathode, which will be operated at 830nm to give an expected electron beam polarization of 80%.

A new PLS laser is being installed in January for the 1993 run. It has significantly higher power than the existing dye laser, and it has the capability to operate in the wavelength range from 750–900 nm. The laser consists of a Ti:sapphire laser cavity, which is end-pumped by a frequency doubled Nd:YAG laser as shown in Fig. 3.[2] The Ti:sapphire cavity is Q-switched and cavity-dumped by appropriate pulsing of the cavity Pockels Cell to produce a 3.5ns output pulse. To achieve the 2 bunch time structure at 120 Hz needed for SLD, 2 Ti:sapphire cavities are used. Each cavity runs at 120 Hz and their output pulses are separated in time by 60ns. The new laser system uses two 60 Hz Nd:YAG lasers, which are frequency doubled to operate at 532nm. Their output beams are combined and then split to produce two 120 Hz beams for pumping the Ti:sapphire cavities.

We have gained a lot of operating experience with this YAG-TI laser over the last 15 months. It is currently running in 2-bunch mode at 120 Hz at a wavelength of 765 nm. The energy per bunch is about 400 μJ with less than 3% rms jitter. The excess pulse energy available will be used to saturate the cathode and reduce the rms intensity jitter in the electron beam to the 1% level. In addition to having more power and a longer wavelength capability than the dye laser, this laser is also expected to require less maintenance. We anticipate a scheduled four hour downtime every 8 weeks for replacing flashlamps in the Nd:YAG lasers.

5. The PLS for Future E142 Running

Future fixed target experiments at SLAC will require an electron beam with 80% polarization at intensities of up to 80 mA from the photocathode (see Table 1). To achieve this, we expect to use a strained lattice GaAs photocathode operating at 830 nm. The laser system we are developing for this uses a flashlamp-pumped Ti:sapphire laser to replace the existing dye laser. This laser system is very similar to the existing dye laser system, and we plan to reuse much of the existing laser support hardware (flow systems, power supply controls, modulator).

In a test lab, we have been operating a prototype Flash-Ti system. This system is operational at 120 Hz and gives an output pulse 15 μs long, from which we can slice a 2μs pulse using the TOPS Pockels Cell system. Running at 785 nm, this gives 8 mJ in the 2μs pulse. The laser was run in this mode for 100 million pulses, demonstrating that the expected maintenance time interval for flashlamp changes is about every 2 weeks. Recently, the laser has been tuned to 830 nm. We are also Q-switching the laser cavity to produce higher peak power pulses of about 100ns duration. We are evaluating this configuration for possible use of the laser for SLD.

6. Conclusions

We have described the Polarized Light Source used for producing a polarized electron beam at SLAC. PLS operation for the 1992 SLD and E142 experiments was very successful, having an uptime efficiency of 95% averaged over 7 months of running. A new YAG-TI laser is being installed to replace the existing dye laser for the 1993 SLD run. This, together with new GaAs photocathodes, is expected to give close to 50% polarization for the electron beam early in the '93 run, and hopefully 80% polarization later in the '93 run or for the '94 run. For fixed target experiments at SLAC requiring electron beam polarizations of 80%, we have developed a flashlamp-pumped Ti:sapphire laser. This laser is also being evaluated for short pulse operation for SLD.

7. References

1. These effects are described in detail in G. Cates et. al., Nucl. Inst. Methods in Phys. Res. **A278**, 293 (1989). This article points out that the transmission asymmetry in the optics transport line can be minimized by using pairs of phase compensating mirrors, such as is done in the SLAC PLS Mirror Box. The article also points out that steering effects from the helicity Pockels Cell can be minimized by 1:1 imaging of the laser beam from the helicity Pockels Cell to the cathode. This is approximately accomplished in our setup with the 6m imaging lens between the CPS and photocathode.

2. For a more detailed description of this laser, see Frisch et al., SLAC–PUB–5950 (1992).