Paper presented at the International Conference Real Time Data'94 – Dubna, June 27 – July 1
Moscow (RU)
HP

TRI-PP-94-66
Aug 1994

THE LASER CONTROL SYSTEM FOR THE TRIUMF OPTICALLY PUMPED POLARIZED H⁻ ION SOURCE

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ABSTRACT

The optically pumped polarized H^- ion source at TRIUMF produces up to 100 μA dc of 78% polarized beam within an emittance of 1.0 π mm mrad and is now being prepared for an upcoming experiment at TRIUMF that will measure parity violation in *pp* scattering at 230 MeV. The optical pumping is accomplished by argon laser pumped Ti-sapphire lasers. The laser control system provides monitoring and precision control of the lasers for fast spin reversal up to 200 s^{-1}. To solve the problems of laser power and frequency stabilization during fast spin flipping, techniques and algorithms have been developed that significantly reduce the variation of laser frequency and power between spin states. The upgraded Faraday rotation system allows synchronous measurement of Rb thickness and polarization while spin flipping. The X Window environment provides both local and remote control to laser operators via a local area network and X window terminals. In this new environment issues such as access authorization, response time, operator interface consistency and ease of use are of particular importance.

1. INTRODUCTION

The TRIUMF optically pumped ion source (OPPIS) relies on charge exchange between 2.5 keV protons and electron polarized Rb vapour to produce a beam of electron polarized neutral hydrogen. This is then converted to a beam of nuclear polarized H^- ions and accelerated to 300 keV before injection into the TRIUMF cyclotron.[1] OPPIS produces up to 100 μA dc of 78% polarized beam within an emittance of 1.0 π mm mrad.

The laser control system was significantly upgraded in the last two years to meet the requirements of new experiments at TRIUMF. High spin flip rates up to 200 s^{-1} are specified in the requirements of the E497 experiment to measure the parity-violating analyzing power in *pp* scattering at 230 MeV. In addition, very stringent limits on spin-correlated beam intensity, position and energy fluctuations in the E497 experiment will require precise control of laser power, frequency and polarization.

2. LASER EQUIPMENT SCHEMATIC

Fig. 1 is a schematic of the laser equipment. Two argon (Ar) lasers are used to pump the two Ti-sapphire (TiS) lasers that optically pump Rb vapour in the neutralizing cell. A third Ar laser is used to pump the third TiS laser that serves as a probe to measure the thickness of Rb vapour and Rb polarization. A linear polarizer sets the probe laser intensity and polarization direction. A rotary stage mounted $\lambda/2$ plate along with a splitting prism and a photomultiplier are used to measure the Faraday rotation of the probe laser plane of polarization after its passage through the vapour cells. Partially transmitting mirrors allow the laser light to be sampled for frequency and power measurements. The laser power is monitored using photodetectors.

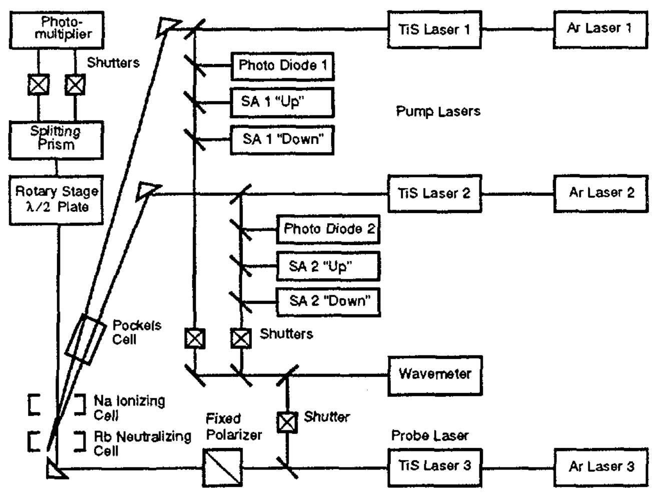

Figure 1. Laser Equipment Schematic

3. LASER POWER AND FREQUENCY STABILIZATION

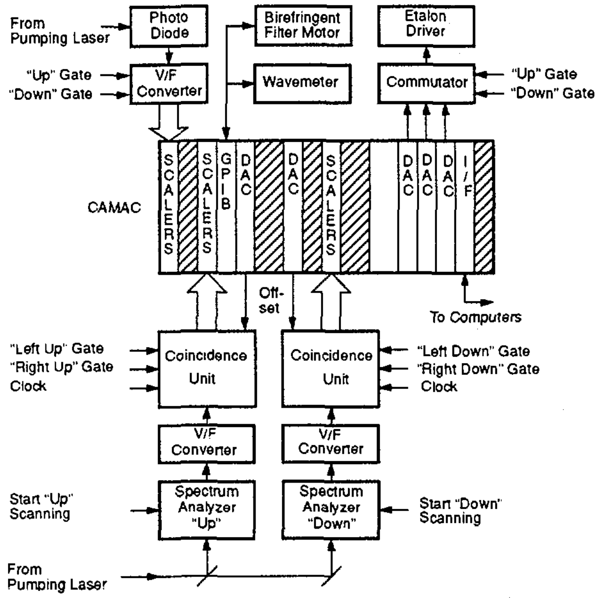

Figure 2. Laser Frequency and Power Control

Laser power stabilization is based on minimizing the power difference between opposite spin states, rather than keeping the absolute power in each state constant. As shown in fig. 2, analog power signals from a photodetector are converted to a frequency, then gated with spin flip and integrated in CAMAC scalers for about ten seconds. The power difference is used for driving the birefringent filter position which affects laser power. This system operates very reliably and reduces the variations in laser power between spin states up and down to less than 1.0% (see fig. 3) while preventing laser mode hops.

A similar algorithm is being used for laser frequency stabilization for each spin state. The 'right-left' frequency difference is minimized. The long term laser frequency stability is estimated to be +/- 100 MHz, limited by the stability of the hermetically sealed, temperature stabilized reference cavities and associated electronics.

To determine the optimum laser frequency an algorithm was implemented that scans etalon position synchronously with polarization measurement. The measured data is then fitted to a curve, the maximum and the minimum values are found, and set for spin state up and down correspondingly. This frequency optimization procedure can be carried out without stopping the spin reversal process.

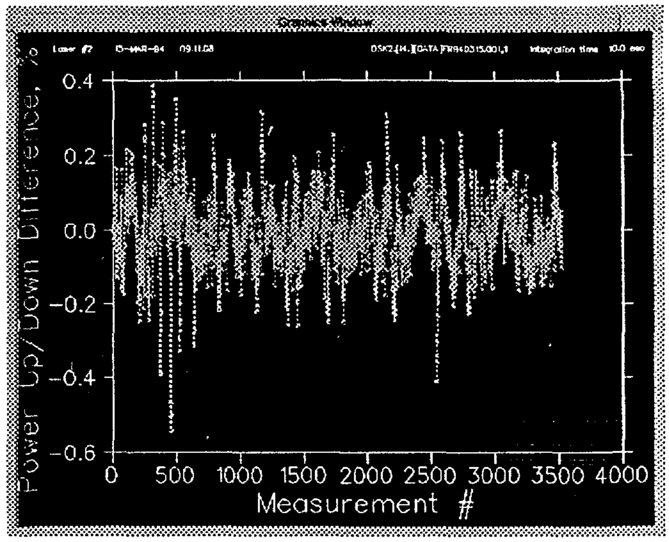

Figure 3. Laser Power Stability

4. FAST SPIN REVERSAL AND RB POLARIZATION MEASUREMENTS

Spin reversal is accomplished by changing the laser light frequency by about 94 GHz at a magnetic field of 2.5 T and reversing the direction of circular polarization. The tilt angle of an intracavity etalon is used to adjust the laser frequency.

The G-120 galvonometers from General Scanning Inc. permit spin reversal rates up to 200 s^{-1} with less than 10% deadtime.

The Faraday rotation system has been upgraded[2)] to give on-line measurements of Rb thickness and polarization. The on-line measurement is well suited to fast spin flip operation, and has permitted us to automate the fine tuning of the laser frequency. As shown in fig. 4, in this technique, probe light is split into two orthogonally polarized beams after passing through the ion source. The intensity ratio between the two beams depends on the input polarization, and can be continually monitored. Appropriate gating of the photodetector signals allows separate measurements for spin up, down and off.

These measurements can be made simultaneously with the spin reversal process without affecting normal ion source operation.

5. LASER CONTROL SOFTWARE

The initial configuration of the control system of OPPIS included an isolated VAXstation running VMS and CAMAC executive crate. The operator interface was the first at TRIUMF to use multiple, graphical win-

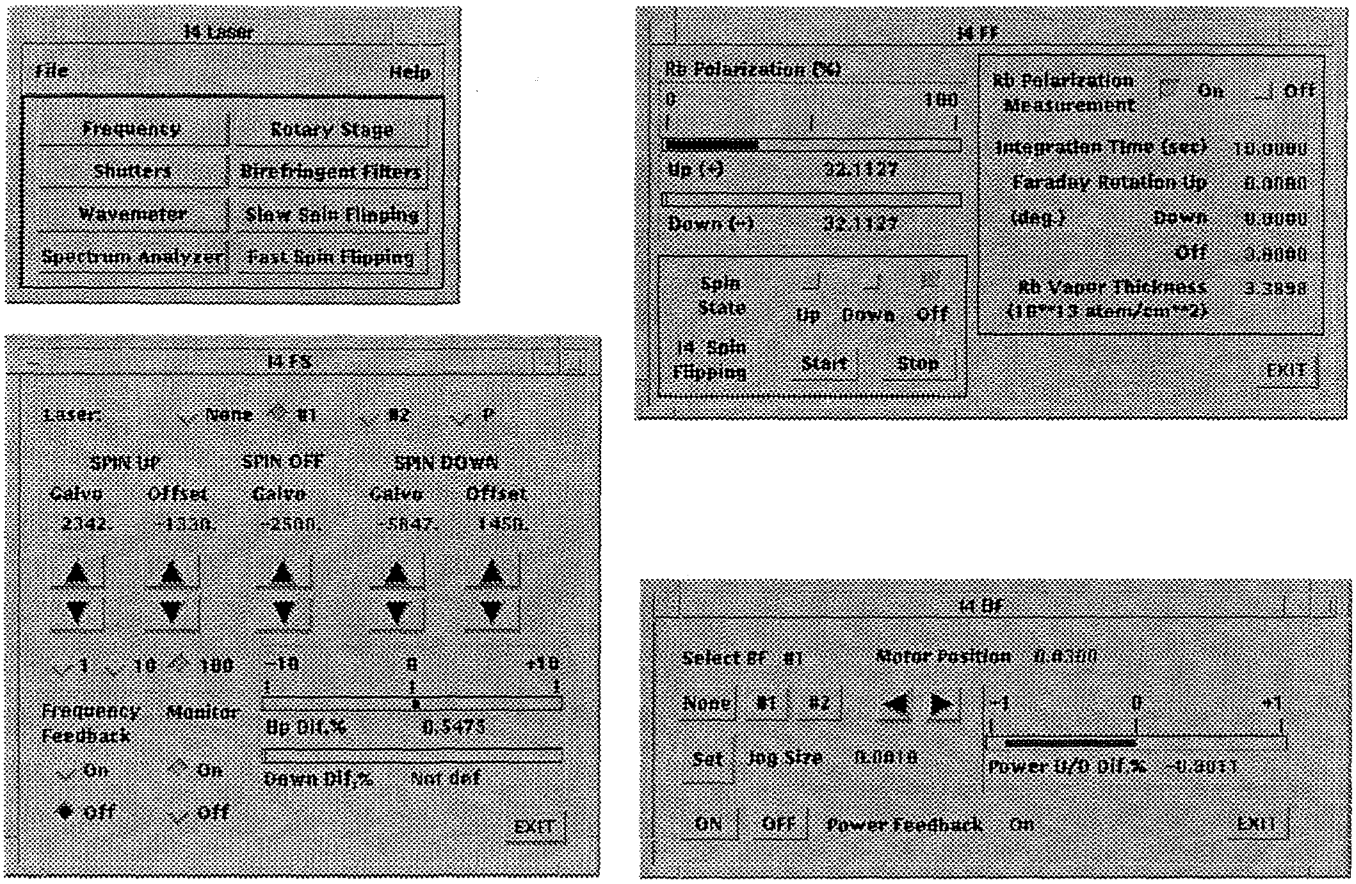

Figure 5. Laser Control Program Windows

dows and a mouse. The software in this user interface pre-dated most of the open graphical protocols and window managers such as the X window protocol and the Motif window manager. As a result, the application software was dependent on graphical components that were soon unsupported as standards emerged. In 1992 the graphical user interface (GUI) was changed[3] to use DECwindows/Motif. The controls hardware configuration has changed to be more tightly integrated into the cyclotron's Central Control System. The changes allow multiple computers to access to the laser control equipment and provide hot-standby support in case of computer failure.

The new DECwindows/Motif version of the control program provides the X window environment and, in particular, both local and remote control to laser operators via a local area network and X window terminals. In this new environment issues such as access authorization, response time, operator interface consistency and ease of use are of particular importance. The new version supports the additional features including fast spin flip mode control, laser frequency and power stabilization, and the new Faraday rotation measurement techniques.

The control program is implemented as a set of VMS subprocesses invoked by the master process. Each subprocess as well as the master process creates its own application window (see fig. 5).

The main application window is used to call the specific windows, to display the help page and to quit the program. The Frequency Stabilization (FS) window serves to modify and monitor galvo and offset values for the selected laser and different spin states, switch stabilization monitor and frequency feedback on/off, and monitor the frequency 'right-left' difference that reflects the laser frequency stability. The Birefringent Filters Window (BF) is used to monitor and to control the birefringent filters' motor position and laser power stabilization.

The power stabilization algorithm is based on the symmetry of laser power between spin up and down states for the optimal birefringent filter position. The stabilization process calculates the power difference and,

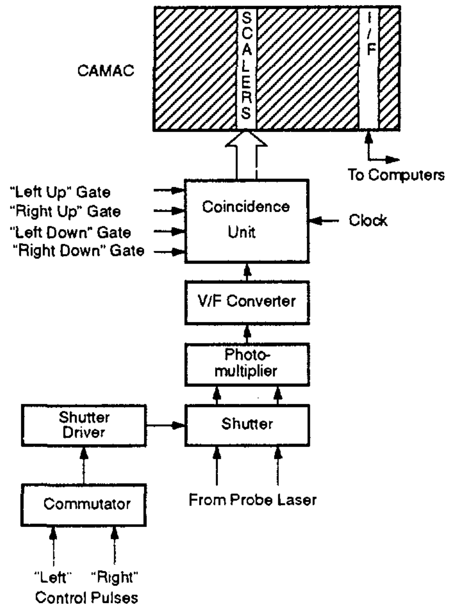

Figure 4. Laser Faraday Rotation Polarization Measurement.

if power feedback is on, corrects the corresponding birefringent filters position respectively.

The Fast Spin Flipping (FF) window controls and monitors the fast spin flipping mode. It also displays the current results of the Rb polarization measurements, if the measurement process is on. This includes Rb polarization, integration time, Faraday rotation, and Rb vapour thickness.

Two types of 'software interrupts' are served for each window. First one is time interrupts used for updating a window. Second type is interrupts caused by operator manipulations with the mouse or keyboard. Window update rates are usually set to a few times per second.

The Kinetics 3388 GPIB Controller is used to talk to GPIB devices from CAMAC. The 0655 Time Out Module (TOM) is used to share access to GPIB devices through the bus.

A DEC product called VUIT was used for building the operator interface but because the product is being discontinued, another package, most likely BX[4)] will be employed for new development.

6. SUMMARY

The upgraded laser control system has proven to be extremely reliable. It reduces the variations in laser power between spin states up and down to less than 1.0% while preventing laser mode hops. The high spin flip rates have increased the accuracy of all the laser diagnostic systems. Laser frequency switching times are 0.5 ms or less. The frequency tuning algorithm has been implemented that scans etalon position synchronously with polarization measurement.

The Rb polarization measurements, power and frequency stabilization and optimization can be made simultaneously with the spin flipping without affecting the running experiments.

7. ACKNOWLEDGEMENTS

We would like to thank K.Jayamanna and P.W.Schmor for assistance in preparation of this paper.

8. REFERENCES

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