JLAB-ACC-97-26

CONF-970894--
DOE/ER/40150-1187

A Diode Laser System for Synchronous Photoinjection

Matt Poelker and John Hansknecht

Jefferson Laboratory, 12000 Jefferson Avenue, Newport News, VA 23606

Abstract. A laser system, which is composed of a gain switched diode seed laser and a single-pass diode optical amplifier, is used to drive the polarized electron source at Jefferson Lab. The system emits pulsed laser light synchronized to the accelerating cavity radio frequency (rf) at 1497 MHz or the third subharmonic, 499 MHz. The maximum average output power from the laser system is 500 mW and the optical pulsewidth is 60 to 80 ps. The laser system is compact and very reliable operating remotely for many days without attention.

INTRODUCTION

The first nuclear physics experiment requiring polarized electrons at Jefferson Lab [1] was recently successfully completed. An integral component of the polarized injector is a pulsed diode laser system with a pulse repetition rate synchronized to the accelerating cavity rf (1497 MHz or the third subharmonic, 499 MHz). Electrons are extracted from the photocathode only during the portion of the rf phase when they are accelerated through the machine. In this way, few electrons are lost at the injector chopper. This method minimizes the total charge extracted from the photocathode and prolongs the operating lifetime of the polarized source.

The laser system is composed of a gain switched diode seed laser and a single-pass diode optical amplifier along with various optical components used to deliver the laser beam to the photocathode (Fig. 1). The laser system has been operational for nearly two years and has proven to be very reliable. The system is compact (76 cm x 122 cm x 56 cm) and rests beneath the gun in the injector tunnel. It is completely remotely controlled. Early versions of the laser system have been described in other publications [2].

Pulsed laser light is obtained through the technique referred to as gain switching [3]. Gain switching is a straightforward electrical technique; the pulse repetition rate depends only on the frequency of the applied electrical signal. Consequently, it is a simple matter to change the pulse repetition rate and to lock this frequency to the machine. The electrical drive signal is derived from the

DISCLAIMER

Jefferson Lab master oscillator and as a result, the laser output is very stable with respect to amplitude noise and timing jitter.

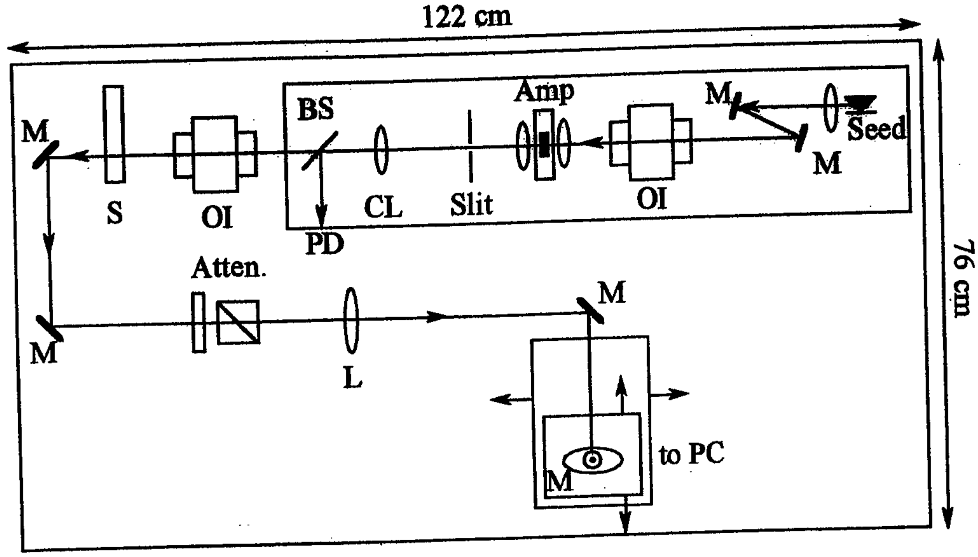

Figure 1. A schematic of the laser system. OI, optical isolator; S, shutter; M, mirror; PC, Pockels cell; CL, cylindrical lens; L, lens; BS, beam splitter.

LASER SYSTEM DESCRIPTION

A seed laser is biased slightly above threshold and driven with approximately 1 Watt of rf at 1497 MHz when delivering beam to three halls, or 499 MHz when delivering beam to one hall. Pulsed light from the seed laser (≈ 5 to 10 mW) is directed through an optical isolator and then focused into a diode optical amplifier (Spectra Diode Labs Model 8630E). Seed laser amplification is a function of diode optical amplifier drive current. Average output power as a function of dc current is plotted for the two different Jefferson Lab pulse repetition rates in Figure 2. The maximum average output power for both repetition rates is 500 mW [4].. The pulsewidth is 60 to 80 ps; pulsewidth increases with amplifier drive current.

The light from the diode optical amplifier passes through a shutter, an attenuator (i.e., mica halfwave plate and stationary linear polarizer) and a focusing lens before passing through a Pockels cell used to obtain left and right circularly polarized light. The Pockels cell is the last optical component the laser beam encounters before passing into the vacuum chamber that houses the photocathode. The focused laser spot can be moved across the photocathode using two stepper motor-controlled translation stages. Light from the diode optical amplifier is nearly diffraction limited; the 3 mm diameter laser beam is focused to a spot on the photocathode with a diameter between 250 to 400 μm (FWHM).

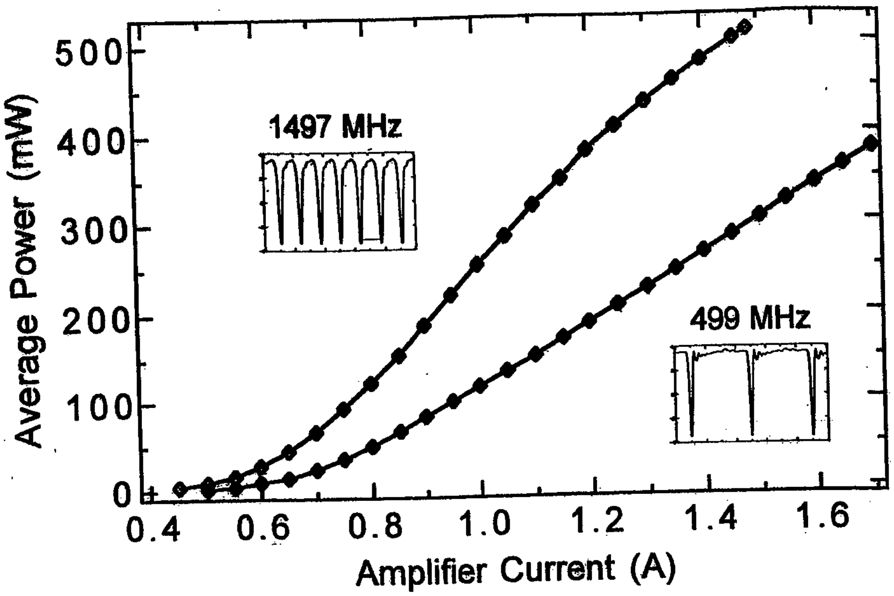

Figure 2. Average output power as a function of diode optical amplifier drive current (dc). The insets show fast photodiode signals for the two different Jefferson Lab repetition rates, 499 and 1497 MHz.

In addition to modulating the seed laser drive current to create rf microstructure on the extracted electron beam, the amplifier drive current can be modulated to create "macropulse" modes of operation for machine tune-up. The amplifier current can be pulsed with a risetime/falltime as short as 500 ns. This allows operators the ability to create specific electron beam time structures similar to those used when operating the thermionic electron gun. The diode amplifier current supply is also interfaced to the machine/personnel safety system to allow rapid termination of electron beam delivery.

ELECTRON BUNCH LENGTH MEASUREMENTS

Electrons travel from the photocathode (at -100 kV) through a Z-style electron spin manipulator, an emittance filter and then the RF chopper which deflects the beam in a circular path across three chopper slits separated 120 degrees in phase. The maximum slit aperture is 60 degrees of rf phase at 1497 MHz which corresponds to a temporal width of 111 ps. The total electron beam path from the photocathode to chopper is approximately 11 m. For a more complete description of the photoinjector, please refer to C. Sinclair's paper in these proceedings.

To determine electron bunch length, two slits were completely closed. The third slit aperture was adjusted to be 10 degrees of rf phase at 1497 MHz which corresponds to a temporal width of 18 ps. The phase of the rf signal applied to the seed laser was adjusted so that the electron bunches at the chopper are swept across the narrow, open slit. The transmitted beam was detected with a Faraday cup downstream of the chopper. Electron bunch length can be determined from a plot of the Faraday cup signal versus laser rf phase. Electron bunch length profiles are shown in Fig. 3 for three different beam currents; 2, 28 and 80 μA. Clearly, electron bunch length increases with increasing beam current. For 2 μA beam current, the electron bunch length is approximately equal to the laser pulsewidth (≈ 50 ps) and beam transmission through the fully-open injector chopper slit is high. At 80 μA however, the electron bunch length has roughly tripled and approximately 60% of the beam is lost on the fully open chopper slit. Based on this observation, a prebuncher was added to the polarized source beamline. For recent operation during the nuclear physics experiment E89033, 75 μA was delivered to the Halls (through three slits) with 100 μA extracted from the gun. It is believed rf settings of various injector components can still be further optimized to provide considerably improved beam transmission. It should be noted that this is work-in-progress. A more detailed account of these measurements and attempts to model the photoinjector will be presented in a future publication.

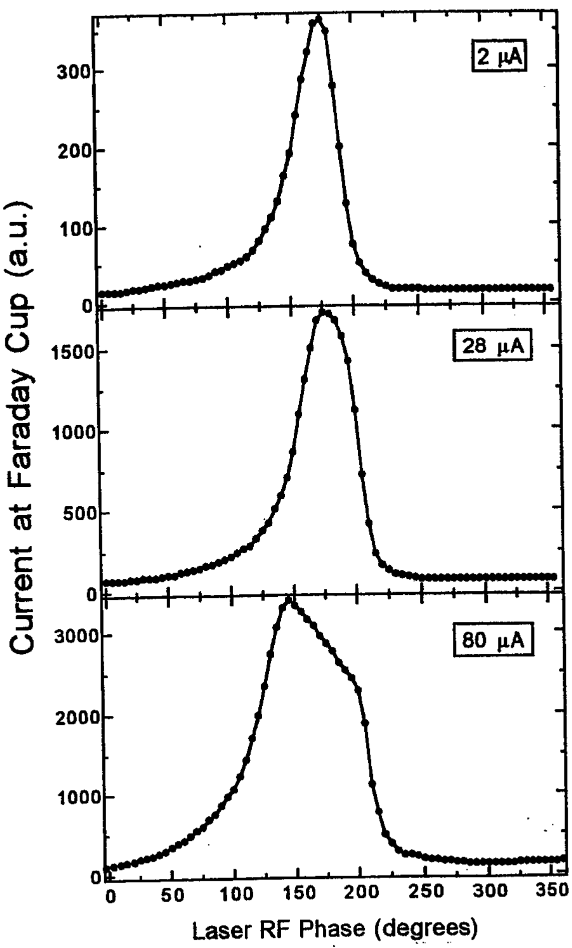

Figure 3. Electron bunch profiles for three different beam currents; 2, 28 and 80 μA.

It is particularly noteworthy that, to a large extent, the laser truly "turns off" between rf pulses. There has been concern expressed that the Jefferson Lab laser system suffers from unwanted amplified spontaneous emission (ASE). That is, the rf pulsed light is contaminated with dc light that results from ASE from within the diode optical amplifier. The bunch length plots in Fig. 3 show that this is not the case. At most, the rf pulsed light is contaminated with 2 to 3 % dc laser light.

FUTURE PLANS

There are a number of improvements planned to further enhance laser system performance. In particular, a remotely controlled mirror mount will be added to the system to provide remote alignment of the seed laser beam into the diode optical amplifier. Despite choosing stable mirror mounts, the seed laser mirrors sometimes require adjustment to obtain maximum laser system output power. (Misalignment may be a result of temperature changes that occur when the laser enclosure is dismantled for system check-out, spring relaxation in various optics mounts, etc.) A remotely controlled seed laser mirror will allow laser power optimization throughout a nuclear physics experiment without requiring access to the injector tunnel.

In the near future, three independent seed laser/optical amplifier laser systems will occupy space on the laser table beneath the gun; one laser system for each hall. The laser power from each of the three laser systems can be adjusted independently to precisely provide the required beam current to the hall, without beam loss at the injector chopper. Three laser systems also means there is more laser power available for each hall (500 mW rather than 500 mW divided by three as is presently the case). This means the gun can operate longer without intervention required to restore the photocathode quantum efficiency. And finally, three independent laser systems may increase machine availability to the nuclear physics users by allowing cw electron beam delivery to one or two halls while providing pulsed beam delivery for machine tune-up from the beam switchyard to the other hall(s).

The present laser systems at Jefferson Lab emit light at 776 nm and 862 nm. To operate at other wavelengths, new laser components must be purchased. Experiments will soon be performed to determine if the present laser systems can be modified to provide 10 to 15 nm of wavelength tunability. Such a modification will be highly useful when operation with high polarization strained-layer photocathode materials begins. A promising technique involves "seeding" the seed laser with light from an external, wavelength tunable source using a partially reflecting mirror. In a recent publication [5], researchers were able to tune the wavelength of a gain switched diode laser over a 40 nm range using a variation of this technique.

ACKNOWLEDGMENTS

The following people made significant contributions to the material in this proceeding; Philip Adderley, Jim Clark, Tony Day, Bruce Dunham, Curt Hovater, Reza Kazimi, Hongxiu Liu, Scott Price, Bill Schneider and Charlie Sinclair. This work was supported by the U. S. Department of Energy Contract No. DE-AC05-84ER40150.

REFERENCES

1. E89033; Polarized electrons on ^{16}O. C. Glasshauser spokesperson.
2. M. Poelker, Appl. Phys. Lett. **67**, 2762-2764 (1995); M. Poelker and J. Hansknecht, Proc. of the 12th International Symposium on High-Energy Spin Physics, edited by K. Jager et.al., (World Scientific, Singapore, 1997).
3. See for example, P.T. Ho, in *Picosecond Optoelectronic Devices*, edited by C. H. Lee (Academic, New York, 1984).
4. The manufacturer of this device, Spectra Diode Labs, recommends that average output power not exceed 500 mW from the output facet of the diode amplifier. The maximum laser power deliverable to the photocathode has been limited to approximately 440 mW as a result of lossy optical components within the laser beam delivery system (eg., optical isolator, Pockel's cell. etc.,).
5. Y. Matsui, et al., IEEE Photon. Technol. Lett. **9**, 1087-1089 (1997).

DOE

(18) DOE, XF
(19) UC-900, DOE