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A High Power Gain Switched Diode Laser Oscillator and Amplifier for the CEBAF Polarized Electron Injector

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ABSTRACT

The photocathode in the polarized electron source at Jefferson Lab is illuminated with pulsed laser light from a gain switched diode laser and diode optical amplifier. Laser pulse repetition rates up to 2000 MHz, optical pulsewidths between 31 and 123 ps, and average power > 100 mW are demonstrated. The laser system is highly reliable and completely remotely controlled.

At Jefferson Laboratory, each of three experiment halls receives a 499 MHz electron pulse train. It is advantageous to extract electrons from the polarized electron source with this pulse structure directly rather than shape a DC electron beam using the injector chopper. In this way, all of the extracted electrons are accelerated; electrons are not lost at the chopper. This efficient use of polarized electrons is likely to result in an enhanced photocathode lifetime since lifetime depends on total charge extracted over time [1]. We have developed a gain switched diode laser and diode optical amplifier to illuminate the photocathode with pulsed laser light to create an electron beam with 499 MHz pulse structure and sub-100 ps electron pulsewidths.

Gain switching is a straightforward means to obtain high repetition rate, short pulse diode laser light [2]. The technique is purely electrical in nature; pulse repetition rate and stability do not depend on laser cavity length. The pulse repetition rate is easily locked to an external reference frequency (e.g., the injector chopper frequency). A schematic of the laser system is shown in Fig. 1. The seed laser is biased slightly above lasing threshold. Short electrical pulses are obtained using a step recovery diode [3] and added to the dc

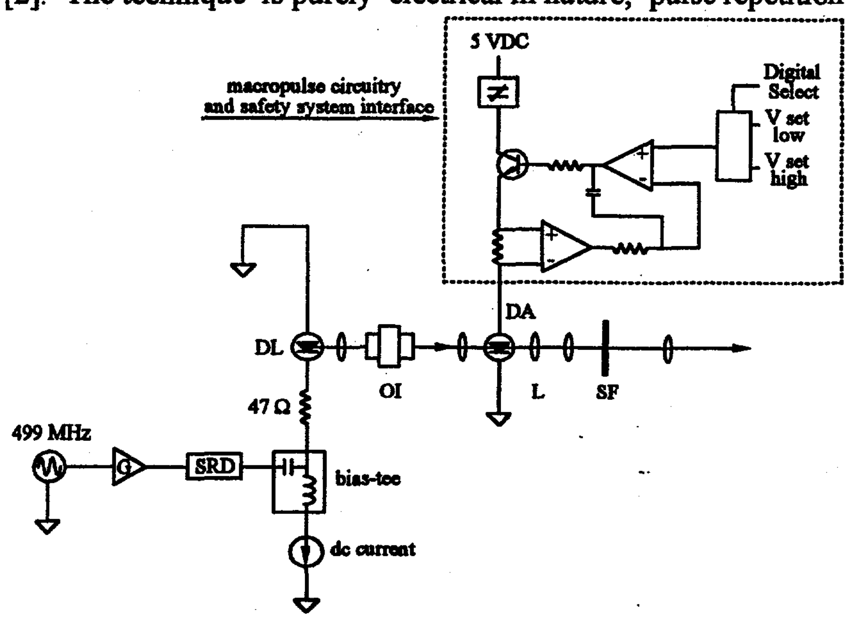

Figure 1 Schematic diagram of the apparatus. DL diode seed laser, DA diode amplifier, OI optical isolator, SF spatial filter, L lens, SRD step recovery diode.

bias current using a bias tee network. Approximately 5 mW of average power is obtained from the seed laser. This light is directed through an optical isolator and focused into a diode optical amplifier (SDL Model 8630E). The amplified output is focused through a spatial filter to remove unwanted dc laser light associated with amplified spontaneous emission from the amplifier. The amount of amplification depends on the amplifier drive current. For a drive current of approximately 1 A, output power exceeds 100 mW.

The laser system can be operated at different pulse repetition rates by merely adjusting the frequency of the drive signal. Pulsed output is shown in Fig. 2 using an SDL 5410-G1 seed laser over a range of frequencies between 500 and 2000 MHz. Pulsewidths were measured using an autocorrelator and found to vary between 70 and 123 ps. Pulsewidths as short as 31 ps were measured using a different seed laser [4]. The average output power increases as repetition rate increases; an output power of 253 mW was measured at the highest pulse repetition rate. (The output power does not increase linearly with increasing duty factor in Fig. 2 because the input seed laser power varied for each repetition rate.)

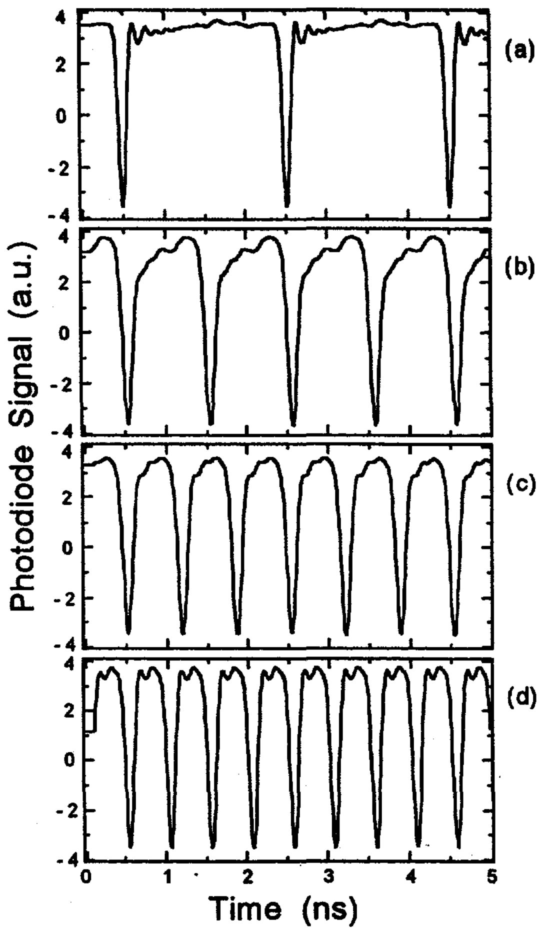

Figure 2 Operation at different pulse repetition rates. a) 500 MHz, 115 mW, 70 ps, b) 1000 MHz, 200 mW, 123 ps, c) 1500 MHz, 230 mW, 109 ps, d) 2000 MHz, 253 mW, 93 ps. (frequency, average output power and pulsewidth)

The laser system along with beam steering mirrors, attenuators, beam translating stages and a Pockel's cell has been installed beneath the polarized electron source in the Jefferson Lab injector. The complete optics system fits on an optics table with dimensions 76 cm x 122 cm. The laser system and associated optics are completely remotely controlled and highly reliable, operating continuously for days without attention. Dry nitrogen is used to prevent condensation on the diode laser and amplifier facets. To demonstrate the stability of the laser system, the average output power is plotted versus time in Fig. 3 for the system operating unattended over a period of 62 hours with a pulse repetition rate of 500 MHz. Fluctuations in output power are less than 1%. In addition, the laser system requires no water cooling or high voltage. It is relatively inexpensive (< 25K $ US). The amplifier drive current can be pulsed to create an electron macropulse time structure for machine tune-up modes of operation with macropulse pulsewidths as short as 1 μs. The diode-laser current supplies are interfaced to the machine safety system to provide a means for fast electron beam shutdown.

Measurements have been made to determine the transmission of polarized beam through the injector chopper when the photocathode is illuminated with pulsed laser light

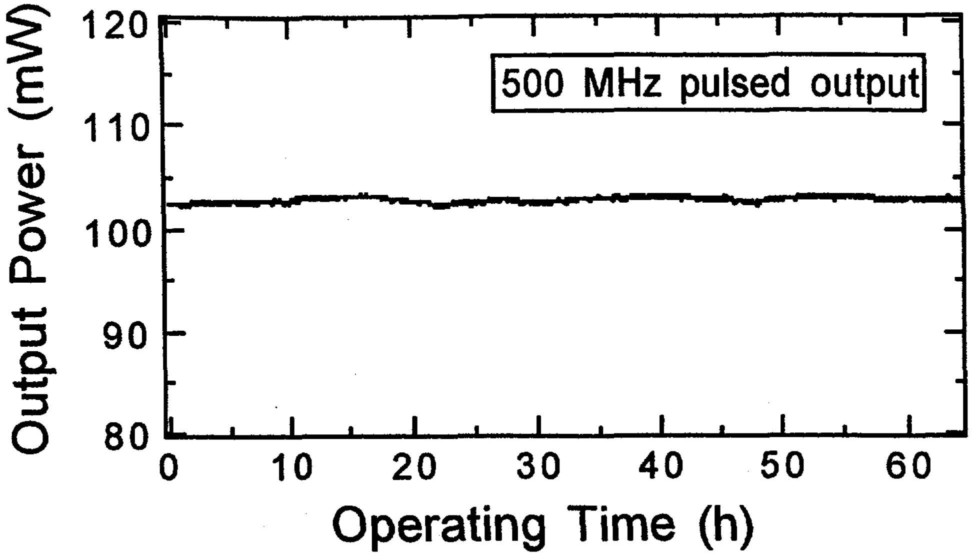

Figure 3 Average output power versus time. Continuous unattended operation with a pulse repetition rate of 500 MHz.

having a pulse repetition rate equal to the injector chopping frequency, 499 MHz. For low average beam current (< 10 μA), the electron bunch length is approximately equal to the optical pulsewidth and as a result, there is nearly 100% transmission of the polarized beam through the injector chopper into the machine. As beam current increases however, bunch length increases indicating that over the 11 m distance between the photocathode and the injector chopper, space charge effects become significant. The injector group at Jefferson Lab is considering two modifications to the polarized injector to ensure that in the future there is 100 % transmission of high average current, pulsed polarized beam through the injector chopper. One possible change to the injector involves adding a prebuncher to the polarized source beamline just downstream of the Z-style spin manipulator. Another possibility is to decrease the distance between the photocathode and the injector chopper from the present 11 m to approximately 3 m by replacing the Z-style spin manipulator with a smaller Wein filter spin manipulator. Modeling is in progress to determine the optimum solution.

In conclusion, a diode-laser based system has been constructed to drive the polarized electron source at Jefferson Lab. The system meets Jefferson Lab requirements for optical pulse repetition rate, pulsewidth and output power. The system operates reliably with a minimum amount of attention. Such a system provides an alternative to more sophisticated modelocked laser systems.

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[1] K. Aulenbacher, Proceedings of the Workshop on Photocathodes for Polarized Electron Sources for Accelerators, Stanford (1993), SLAC-432.

[2] P. T. Ho, in *Picosecond Optoelectronic Devices*, edited by C. H. Lee (Academic, New York, 1984).

[3] Recent work indicates that the step recovery diode shown in Fig. 1 is unnecessary. Pulsed output is obtained with comparable results when the step recovery diode is removed from the circuit and a 1 Watt sine wave is added to the dc bias current through the bias tee network.

[4] M. Poelker, Appl. Phys. Lett. **67**, 2762 (1995).