PULSE SELECTION CONTROL FOR THE IR FEL PHOTOCATHODE DRIVE LASER

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Abstract

The method for current control of a photocathode source is described. This system allows for full remote control of a photocathode drive laser for resulting electron beam currents ranging from less than one microamp to a full current of five milliamps. All current modes are obtained by gating the drive laser with a series of electro-optical cells. The system remotely generates this control signal by assuming a mode of operation with the following properties selectable: Current mode as continuous or gated, micropulse density, macropulse gate width from single shot to 1ms duration, macropulse synchronization to A/C line voltage (60 Hz) or an external trigger, 60 Hz phase and slewing through 60 Hz when applicable. All selections are derived from programable logic devices operating from a master-oscillator resulting in a discrete, phase stable, pulse control for the drive laser. Complete system documentation is available at http://www.jlab.org/fel

1 INTRODUCTION

A Free Electron Laser is under construction in Newport News Virginia. This facility will begin commisioning in the fall of 1997.

1.1 Driver Accelerator

A schematic representation of the infrared demonstration FEL[1] (IR Demo FEL) is shown in Fig. 1. Electrons are produced at 350 keV by a DC photocathode gun[2] driven by a Nd:YLF laser[3] and accelerated to 10 MeV in a superconducting RF (SRF) "cryounit", an accelerator of about 1 m active length. These electrons are then accelerated to 42 MeV by another SRF accelerator, a "cryomodule" (essentially 4 cryounits). The FEL is placed at the exit of the linac, the electron beam is deflected around the two optical cavity mirrors and then has two possible paths. One is straight ahead into a beam dump used for initial commissioning and tune up. The other is into a recirculation loop based on the isochronous achromats used in the Bates accelerator[4]. This latter path allows the electron beam to be recirculated for energy recovery and deceleration in a 10 MeV dump[5,6].

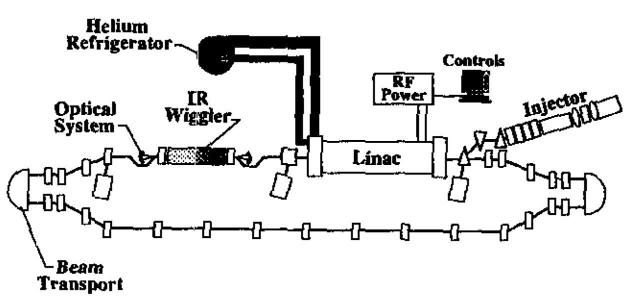

Figure 1. Schematic Layout for IRFEL

Since many of the electron beam properties such as charge/bunch and time structure are a reflection of the laser's beam, some attention has been devoted to its characterization. Equally important has been the development of robust pulse selection techniques capable of delivering the temporal formats (for both micropulse and macropulses) required for commissioning and operation of the FEL. Unlike the usual laser laboratory environment, the drive laser must run unattended for long periods of time, and have remote control and monitoring of its output. As is common in the industry, the pulse selection equipment we purchased was not capable of remote control, so a system was developed and implemented to add that capability. This paper describes our approach and the results.

2 PHOTOCATHODE DRIVE LASER

A schematic representation of the drive laser transport system is shown in Fig. 2. Our drive laser is a frequency-doubled Antares™ mode locked Nd:YLF laser from Coherent, Inc. It differs from the standard product in its operating frequency of 74.85 MHz (1/20th the SRF cavity frequency) and modifications to the laser's optical components to allow insertion of an electro-optic modulator (EOM) before the frequency doubler. The purpose of this EOM is to drop the micropulse repetition frequency to 37.425 MHz, which yields the highest laser gain for our existing machine design. This EOM is a fixed-frequency device and will not be discussed here. Instead, we will concentrate on two EOMs located downstream of the laser, which control the macropulse structure and micropulse frequencies ≤ 37.425 MHz. These EOMs are identical and along with their associated electronics were purchased from Conoptics, Inc. (Danbury, CT). They are of the transverse electric type, using KD*P crystals with a total path length of 160 mm and an aperture of 2.9mm. They are "dry" EOMs, the ends of the crystals are AR-coated, rather than immersed in index-matching fluid. Earlier attempts to use "wet" EOMs were abandoned when we determined the fluid caused thermal blooming for average input intensities exceeding about 25 W/cm^2 (for ~ 45 ps FWHM pulses).

The EOMs require a DC bias and fast-slewing voltage source (~ 160V). This, and the pulse control unit (also known as a synchronous countdown) were purchased from the same vendor (model 25D and 305, respectively).

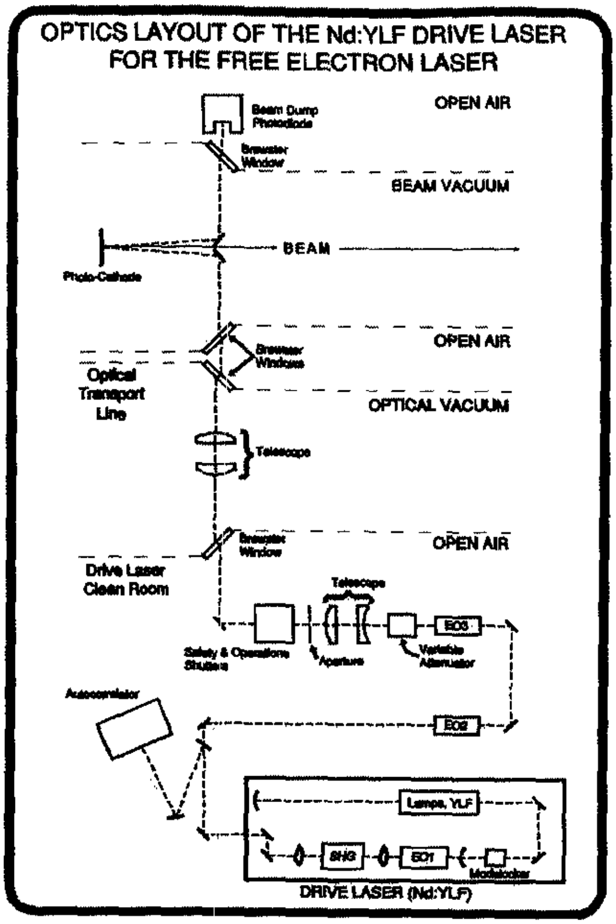

Figure 2. Drive Laser Transport System

2 PULSE CONTROL ELECTRONICS

The pulse control electronics enable full duty cycle control from 100% to less than 0.02% while holding the charge per bunch constant. A system level block diagram is shown in Figure 3. The space charge dominated optics require that the charge per micropulse be between 60pC and 135 pC for clean transmission.

2.1 Pulse mode Gate width

Commissioning of the electron beam will be done beginnning with average electron beam currents of less than 1 µAmp. This minimizes the burn through hazards associated with initial threading of the electron beam. There are 16 choices of gate widths. These gate widths are easily reprogrammed in the Programable Logic Devices (PLDs). The different electron beam diagnostic devices require varying average beam currents. The BPM'srequire a minimum current while the multislit emittance monitor[7] is limited to a fraction of the full beam current.

The rising and falling edge of the gate pulse is preset to occur at the trough of the optical pulses. This enables the system to be setup, once all cables are in place, such that the first and last optical pulse do not get truncated.

2.2 CW Frequency

The electron machine and FEL wiggler are designed to operate with an average beam current of 5 milliamps. The machine optics are designed for bunch charges ranging from 135pC - 60 pC, which in the injector is heavily space charge dominated. The average electron beam current for CW operation is controlled by using a variable attenuator in conjunction with the Conoptics unit to divide the drive laser output frequency by factors of two. This function is implemented in the Conoptics model 305. We have modified this chassis by adding a daughter board with opto-couplers in order to interface to the EPICS control system. This system is able to operate at 40th subharmonic of the superconducting RF cavity frequency 1497MHz and below; 37.425MHz, 18MHz, 9MHz, 4MHz, 2MHz, & 1MHz.

2.3 60 Hz Line Synchronization

The line frequency synchronization system is designed to allow the operation crew to readily check for 60 Hz interference from motors or transformers too close to the beamline. The EPICS interface allows the operator to either single step or sweep the macropulse through 22.5 degree steps of the 60 Hz wavelength. In the sweep mode the operator can optimize the sweep freqency such that the beam, when observed on a beam viewer the spot should appear stable in the absense of any stray 60 Hz fields. In the event that there is excessive 60 Hz magnetic fields in the area of the electron beam transport, the beam spot will appear rhythmically unstable, with an amplitude proportionate to the magnitude and position of the 60 Hz interference.

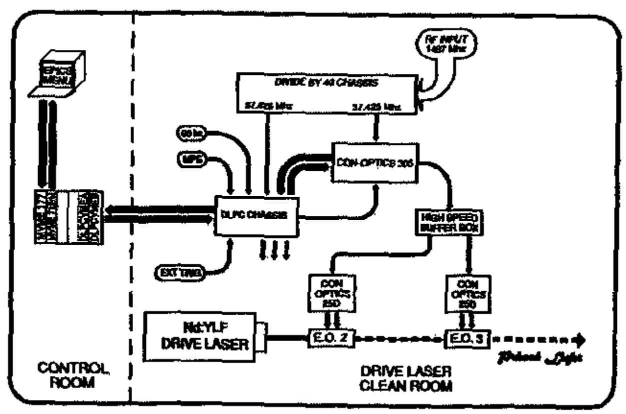

Figure 3. Block Diagram of Pulse Control Electronics

2.4 Machine Protection Interface

The electron accelerator has four distinct beam modes for comissioning and operation: 1. Injector startup; this is average current limited by a ceramic beam viewer (cromox) to less than 100nAmp. 2. Multi-slit Emitance measurement; this device is average power limited to dissipate 100 watts or less. 3. Tune-up beam; For general beam startup the macropulse is set to 250 microseconds at a CW fequency of 18.7125 Mhz. This is the minimum beam for reliable operation of the beam position monitors. 4. Unlimited; All protection systems are active and the beam is allowed to run at any current up to the design value of 5 milliamp at an energy of 43 MeV.

A single fast shut down interface now exists; when any of a number of faults occurs, the system sets the laser to pulsed mode and removes the gate pulse shutting down the drive laser and hence the electron beam in a few microseconds. In addition to the EOM shutter a mechanical shutter also closes.

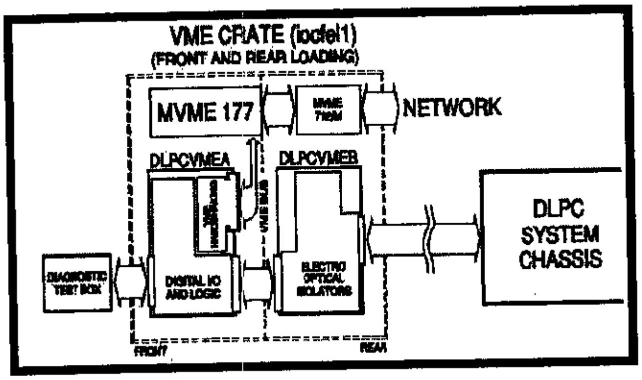

Figure 4: Simplified Diagram of Remote Inteface System

2.5 Remote Interface

The Drive Laser Pulse Control System (DLPC) is operated remotely from a VME based microcontroller located in the FEL Control Room (Area 7). This VME crate is fitted with two custom built VME modules which bridge the gap between the DLPC system and the VME system (see figure A). The DLPC control cable connects to a board fitted in the rear plane of the crate (DLPCVMEB). The function of this module is to optically isolate all electrical connections from the DLPC chassis and rout them through the user-defined pins of the P2 connector of the VME Bus. These control signals are driven by a simple VME slave module (DLPCVMEA), which is fitted into the front plane of the VME crate. The DLPCVMEA module is classified as an A16:D16:D8 device. The DLPCVMEA also has the ability to display all of it's current setting to a Diagnostic Test Box which is easily inserted and removed at any time. The two boards (DLPCVMEA and DLPCVMEB) working together empower all functions of the Pulse Control System to be governed by the IOC of the VME crate (iocfel1). The IOC is made accessible to the network using a standard Ethernet adapter, and can be communicated with from any number of locations. From this point, all command functions and status readback items can be observed and/or modified by other systems if and when appropriate, such as the Machine Protection System and Instrumentation and Controls by the Operators.

3 FUTURE DEVELOPMENTS

This system as described is operational in the Injector Test Stand (ITS) for the FEL. Beginning in June of 1997 the ITS will be moved to the new FEL building. Commisioning will begin in the new facility in early fall 1997. Also, the system described is the first attempt at fulfilling the design requirements for a pulse control system for the FEL. It was designed and built around other key devices involved with the operation of the drive laser. In some regaurds, the functionality of the Pulse Control System is limited by these devices. The primary example of this effect is the lack of communication between the DLPC Chassis and the Con-Optics 305 Chassis. More specifically, the DLPC synthesizes the signal used by the C/O-305 to gate the micropulse stream. The problem arises when low frequencies are chosen for the micropulse stream. In this condition, if the operator chose a gate width less than the period of the drive laser output no light would be emitted. This can easily be resolved in either PLD code or software.

4 ACKNOWLEDGEMENTS

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