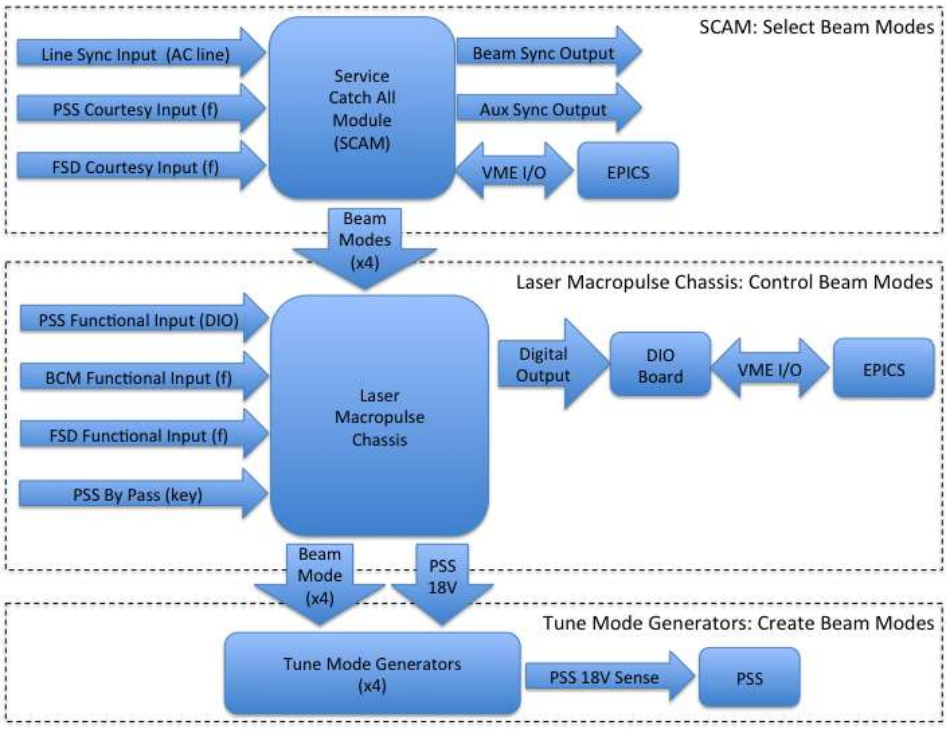
Tune Mode Generator System 2016

John Hansknecht – Jefferson Lab April 2016

This document describes the design goals and final system construction of the tune mode generator system.

Purpose: The CEBAF lasers are pulsed with an Rf microstructure, but this rf pulsing light beam is on all the time. The lasers do not have a provision to turn on and off at a high speed to create the "macro-pulse" structure required for viewer-limited beam or tune-mode beam. In order to create a macro-pulse structure we utilize a high speed electro-optic cell called a "Pockel's Cell". A Pockel's cell has an optical birefringence that can be modified with the presence of high voltage. In other words, it can control the polarization of light based on the amount of voltage present. With this in mind, we place polarization optics on the laser table before and after this cell so the beam will pass through the cell and be diverted to a beam dump when there is no voltage present. When we apply a high voltage, the laser polarization is rotated by the cell and the beam is diverted to the straight ahead mode where is will drive our electron gun.

Electronics Signal flow:



It is assumed that the reader has a basic knowledge of the overall control system shown above, where the SCAM module creates a beam structure, the Laser Macropulse Chassis converts these signals to a drive signal which can be rapidly shut down with a PSS, BCM, or FSD signal. This drive signal is then applied to the Tune Mode Generator described here.

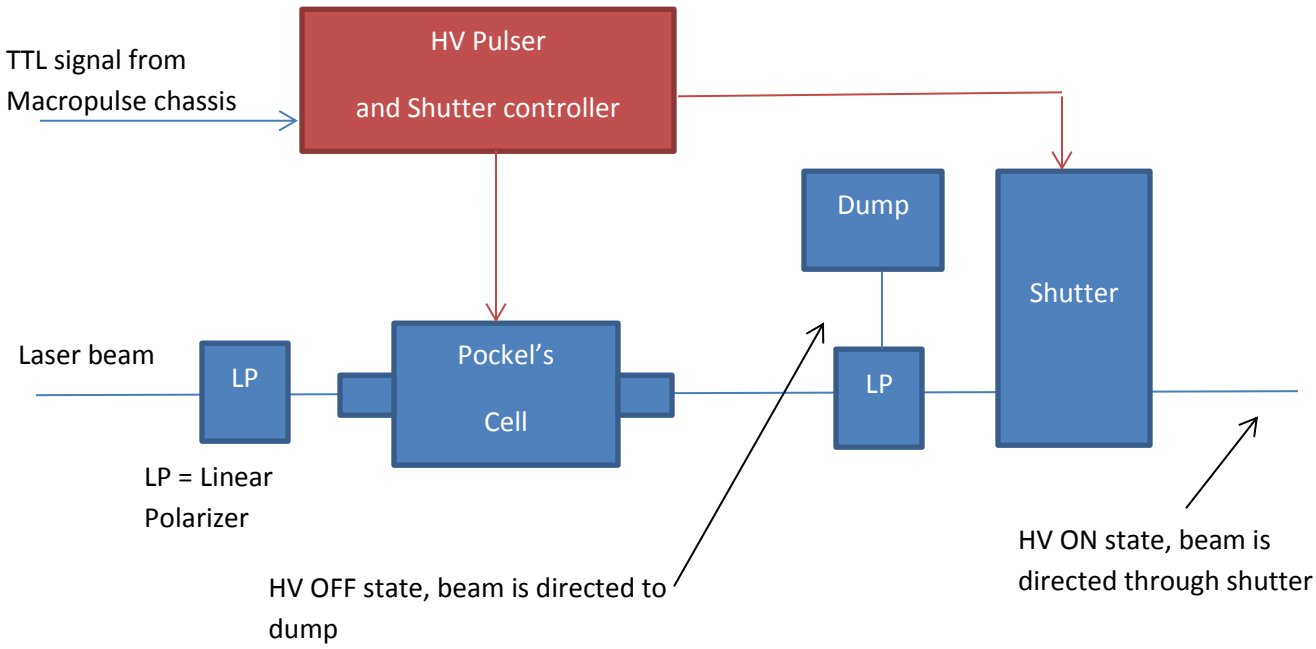
In a perfect world, the Tune mode generator would only need a Pockel's cell driven with the tune structure to turn the beam on and off completely. In reality, the Pockel's cell is not a perfect optic and it "leaks" a tiny amount of light even when it has been driven to the "off" state (500 times lower). In order to completely turn off the light we must also include a mechanical shutter in the system for each laser. The TTL beam mode applied to the Tune Mode Generator goes to the Pockel's cell driver and a shutter controller. The chart below shows the operational status:

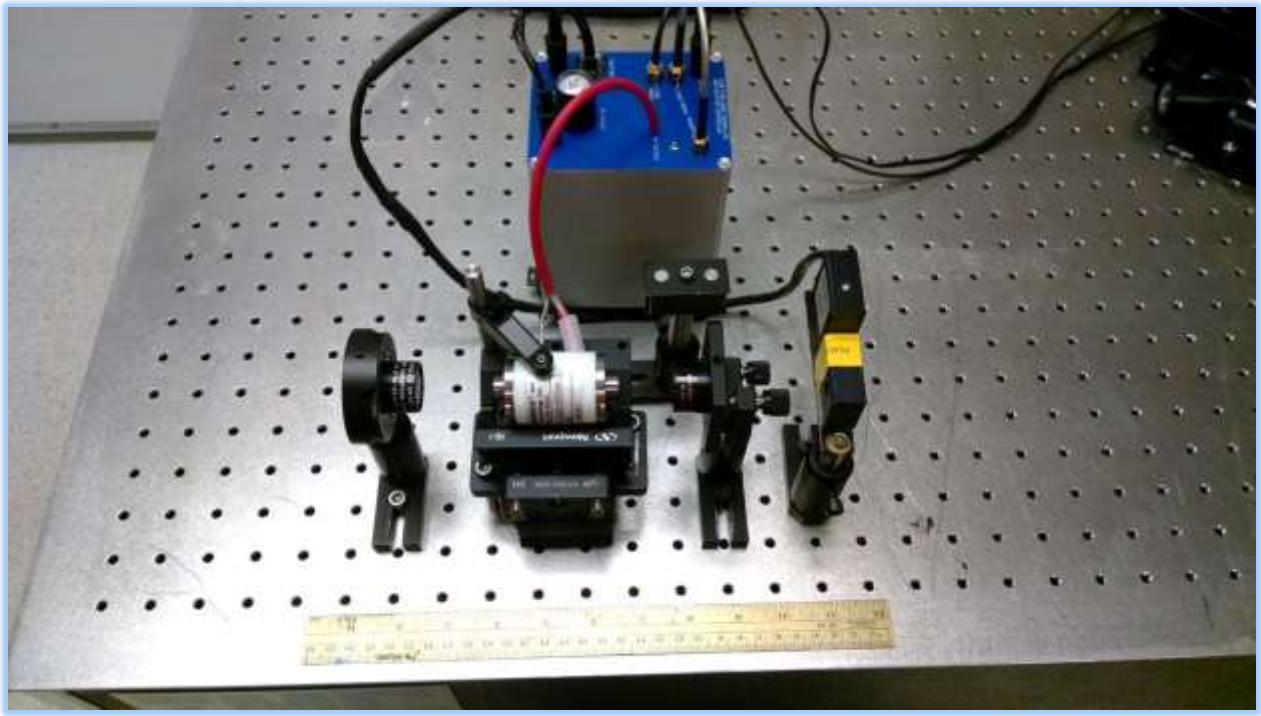
Beam Mode	**Pockels cell High Voltage**	**Shutter**
Beam OFF	OFF	Closed
Viewer-Limited	Pulsing	Open
Tune	Pulsing	Open
CW	On continuously	Open

Design goals:

1. Make a failsafe circuit that uses "off the shelf" components.
2. There shall be no microcontrollers or programmable logic in the device, so any technician can reproduce the item anytime in the future.
3. Make the circuit board relatively compact.
4. System should operate on 18VDC and removal of 18V will physically stop the laser beam from striking the electron gun.
5. System must be able to chop the beam on and off with a rise and fall time of 50ns. The shutter shall close to back up the Pockel's cell within 30ms of any "beam off" request.

A physical schematic diagram of the laser table components is shown below:





The image above is the actual tune mode generator with placement of optical components exactly as represented in the previous schematic layout. This layout consumes about 12” by 8” of table space for each laser, and can be made more compact if desired.

From a standpoint of any PSS interface, it should be obvious that removing the incoming power feed (18VDC) will secure the beam with two methods.

1. The pockel’s cell high voltage will be off and the cell will not be able to rotate polarization. The two crossed linear polarizers will divert the beam to the dump.
2. The shutter drive circuit will not have power to open the shutter. The shutter is spring loaded to close and will stop beam.

Shutter drive Circuit:

The shutter drive circuit board watches the incoming TTL signals and makes a determination to open or close the shutter based on that signal. When TTL is high, the shutter opens. When TTL is pulsing greater than 50hz, the shutter opens. When TTL is low for longer than 30ms, the shutter closes.

The physical layout of the board allows it to mount within the internal slide rails of a Hammond 1455 Series electronics box. The schematic for this circuit is described later in this document.

Pockel's Cell driver circuit:

The Pockel's cell driver circuit board also slides into a Hammond 1455 series electronics enclosure. The circuit board has a small 2kV regulated DC-DC power supply and a pair of fast Insulated Gate Bipolar Transistors (IGBT's) in a half-bridge configuration that allows the Pockel's Cell output line to be rapidly driven between positive high voltage and ground. The half-bridge allows the output to rest indefinitely in either output condition. The schematic for this circuit is described later in this document.

Assembly:

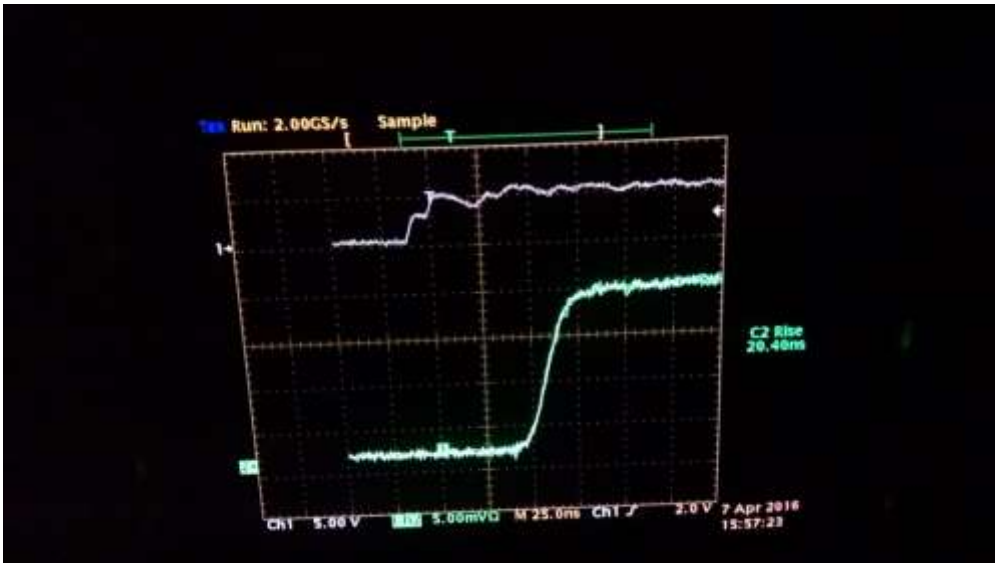
The Pockel's cell switch is placed in the larger Hammond 1455N1201 box (120mmX103mmX53mm). The shutter drive is placed in a smaller 1455L1201 box that is bolted to the side of the larger box. This are separated so the EMI produced by the high voltage switch will not affect the shutter control.

A DIN rail clip is attached to the rear of the assembly. This lets it quickly snap down to a DIN rail mounted on the laser table.

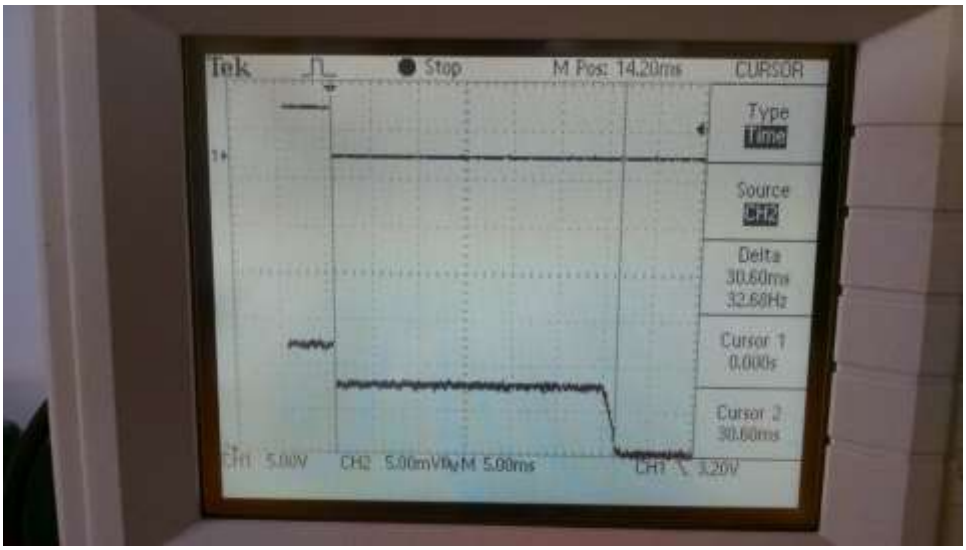
The boards are slipped into their respective boxes.

A custom cover plate from Front Panel Express ties it all together from the top.

Operation:



Trace that shows the high speed response of the circuit to an “ON” command. Rise time is 20.4ns from 0 to 1800V. The fall time is identical. The white trace is the TTL input, and the green trace is a fast photodiode response of the laser light passing through the Pockel’s cell.



Trace showing the shutter closure time. In this image the top trace is the command for “beam off”. The bottom trace is the laser beam passing through a purposely misaligned Pockel’s cell and the shutter before striking a photodiode to create this trace. Notice the Pockel’s cell immediately drops the power within 20ns to an intermediate level. This level would normally be so low that we cannot discern the shutter closure. 30ms later, we see the shutter close to completely block the beam.

The laser shutter we are presently using is the LST400.

Datasheet of the LST400 from nmlaser.com

Model LST400 Series Specifications

This model is designed for use as a safety interlock and for some processing applications. For high activity processing, consider the LS055W8 model. The LST400 provides TTL output position sensors for the open and closed states as standard equipment. The thin body style and 8 mm aperture accommodate many popular laser sources. The –IR suffix replaces the over-coated aluminum mirror with gold, for use in the IR, including CO2. This option must be used for CO2 lasers.

Compatible system controllers include user built capacitor discharge, PWM current drivers, and our controller models CX3000B, CX1100, and CX2450B.

Options are available using a suffix code system. Many options cannot be installed after manufacture, so choose carefully. Choose the –IR suffix for CO2 and IR use, starting at about 700 nm. The standard over-coated aluminum mirror is good from deep UV to about 4 microns. Special mirrors are not currently available, except for OEM applications. Cable options are available, call for details.

See the "Mechanical Drawing" tab for dimensions. Also see the "Application Notes" tab on the home page menu for important operational issues including: thermal mounting, user-built circuits, polarization, lifetime, jitter, vacuum operation, and contamination. See the "Accessories" tab for useful system components.

Special Considerations for this model include damage threshold assessment. The shutter is not designed for high energy, low repetition rate Q-switched lasers. See LS055W8 and LSTXY-W8 for these applications. Thermal mounting must be given strong attention if optical power dissipation is near the upper limit of the rating.

Restricted use for this model is only limited to damage threshold and wavelength considerations. It can be used in any orientation w/r to gravity.

RECOMMENDED CONTROLLER =	USER CIRCUIT — OUR CONTROLLER
Aperture Diameter =	8.0 mm
Typical Beam Diameter used for Specs =	6.0 mm
Maximum Shutter Repetition Rate =	3 Hz
CW and Quasi-CW Optical Power Handling =	25 W (OEM to 50 W
Typical Damage Threshold, Aligned Polarization =	300 mJ/cm
Delay to Begin Opening after Command Open =	10 ms
Opening Time Switching Speed =	20 ms
Delay to Begin Closing after Command Close =	10 ms
Closing Time Switching Speed =	20 ms using CX3000B
Minimum FWHM Exposure Capability =	30 ms using CX3000B
Thermal Power Dissipation Holding Open =	4 W
Thermal Power Dissipation, Repetitive Cycling =	8 W @ 3 Hz
Nominal Magnetic Winding Impedance =	15 Ohms
Cable/Wire Type and Length =	18 inch, 6 leads 22 g.
Mounting Surface for Thermal Sinking =	Base Plate
Position Sensors =	Logic TTL, Require 5 VDC @ 20 mA
Weight =	4 Oz.
Size (see mechanical drawing) =	3.80 x 2.06 x .64 Inches

Parts list of shutter board: (refer to system schematic)

Part	description	Source and part number
IC3	Solenoid driver chip	TI DRV102F (digikey 296-15964-1)
U2,U3	Configurable multifunction gate	SN74LVC1G97DBV (digikey 296-15581-1)
X1,X3	Power connector 2.5X5mm	CUI corp PJ-102BH (digikey CP-102BH)
R7	100 ohm resistor	Any 805 type
IC1	74LS122D in SO14 package	74LS122D
R4	100K resistor	Any 805 type
R3	82.5K resistor	Any 805 type
X2,X4	SMA board edge connectors	Digikey 931-1175
S1	DIL switch	Digikey GH7135-ND
Diodes D1,2,	SMC package Schottky diode	ON semiconductor MBRS3100T3G (or equiv)
C3,C6,C8,C10	.1uf capacitor	Any 805 size rated >24V
R8	40K resistor (+/- 5%)	Any 805 size
IC4	5V regulator type 7805TV	On Semi MC7805CTG or equiv
C1,C4	1000uf 35V capacitor	Nichicon UHE1V102MHD6 or equiv
J1	8P8C RJ-45 connector	Amp 54602-908LF or equiv
Enclosure	Hammond Manufacturing 1455 series	1455L1201 (digikey)

Parts list of Pockel's Cell driver board: (refer to system schematic)

Part	description	Source and part number
X3	Power connector 2.5X5mm	CUI corp PJ-102BH (digikey CP-102BH)
IC2	15V switcher type voltage regulator	Digikey 945-1048
U$5	3kV HV iso 15V DC-DC converter	DCH010515SN7 (Digikey 296-20642)

U2,4	2500V IGBT IXGT2N250	Digikey IXGT2N250
U2,3	SI82394BD gate driver IC	Digikey 336-3383-5
U$6	0-2KV 2.5mA regulated supply	PICO Electronics HVP2P
LED	High effic Amber LED	Digikey 516-1779-1
R7	100 ohm resistor	Any 805 type
R4	100K resistor	Any 805 type
R3	82.5K resistor	Any 805 type
R3	Not stuffed- can be used if 50ohm matching desired in future.	
R1,2	7K resistor (+/- 5%)	Any 805 size
X2	SMA board edge connector	Digikey 931-1175
C2,C4,C7,C8	.1uf capacitor	Any 805 size rated >24V
C1,C3,C6,C9	1uf capacitor	Any 805 size rated >24V
C5,C12	100pf capacitor	Any 805 size rated >24V
C11,13,14	10uf 35V capacitor	package C050-.025 by .075
C10,15,16,17	220pf 3KV capacitor	DEA1X3F221JA3B (jlab stockpile)
IC1	5V regulator type 7805TV	On Semi MC7805CTG or equiv
Enclosure	Hammond Manufacturing 1455 series	1455N1201 (digikey)
DIN rail clip	Optional mounting method for box	Hammond HM1361-ND (digikey)
Barrel plug for power and jumper between boards		(3 per system) Digikey 839-1166

Custom front panel from Front Panel Express

Also attached to this package are the following attachments:

GERBER files zipped and ready for manufacture

Eagle board and schematic files (Pockels cell driver is called rtp01)

Board schematics in DXF format.

Front Panel Express – front panel layout (.fpd file) and bitmap images of panel and purchase.

Front Panel Express file exported as DXF

Schematics of printed circuit boards in PDF format.