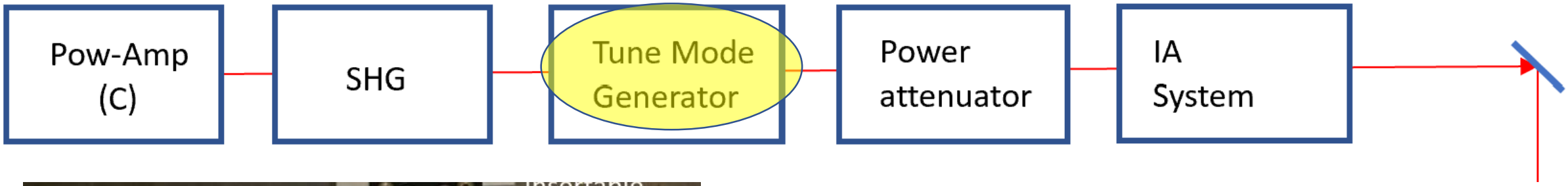
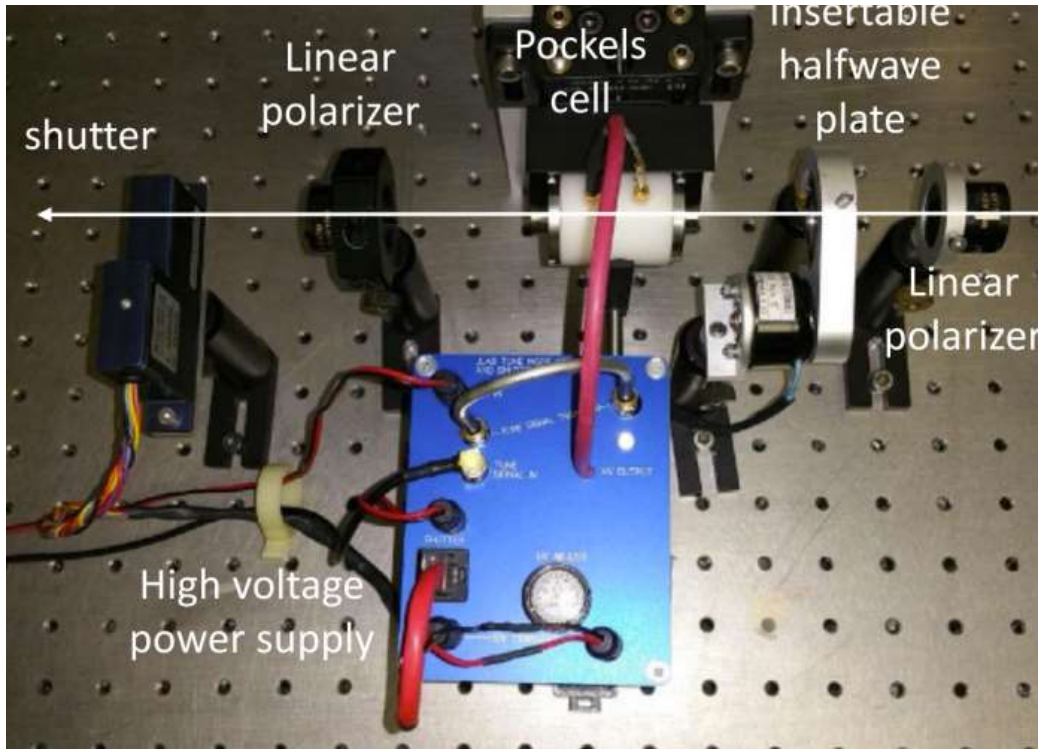
Drive Laser TMG Evaluation Meeting Presentation

Shukui Zhang

April 11, 2024

Tune Mode Generator (TMG)

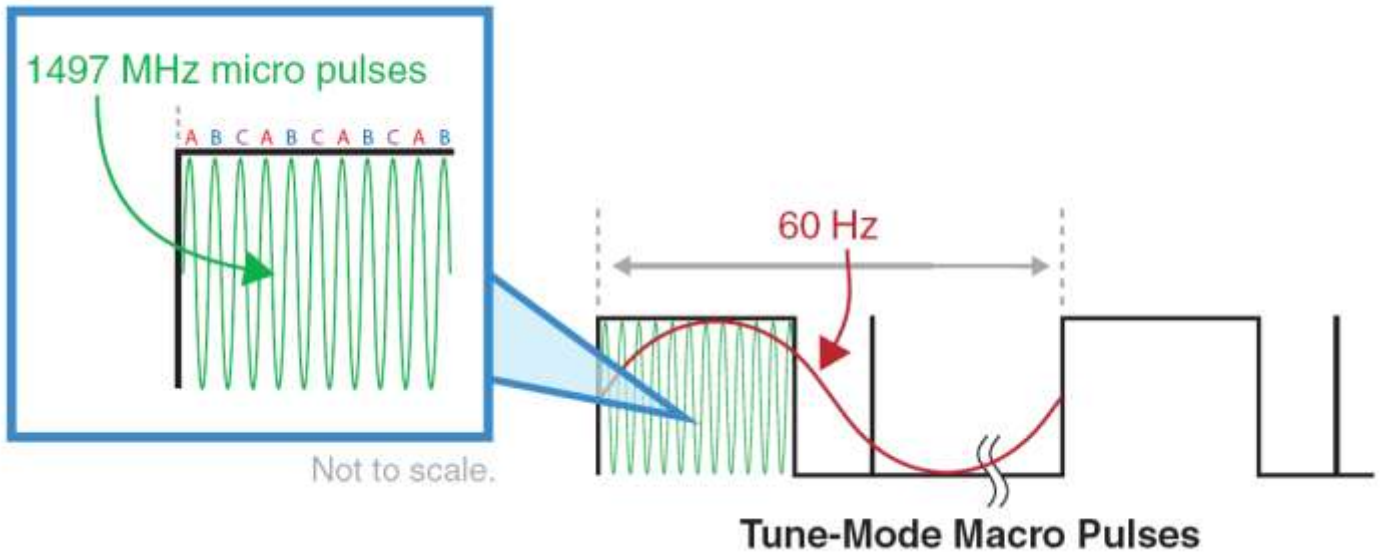


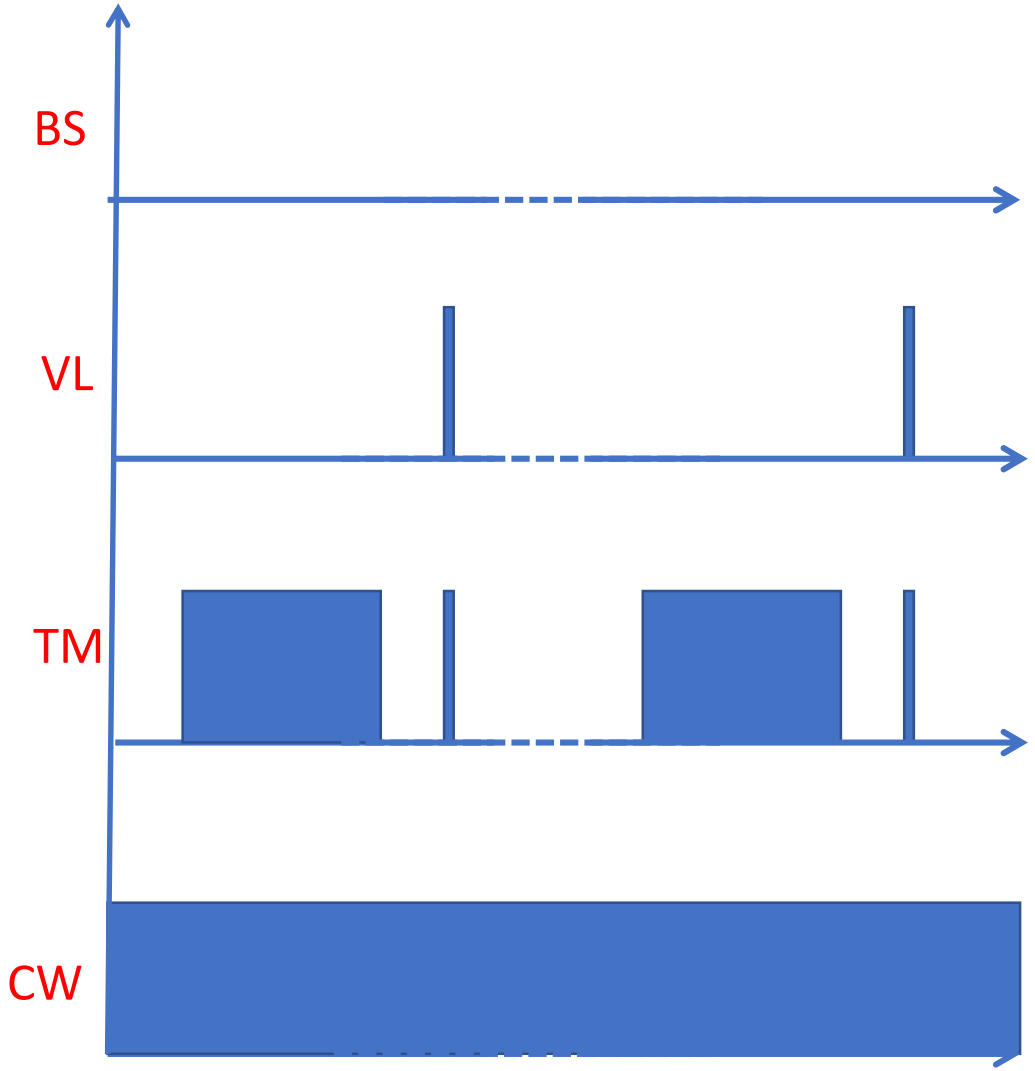


Combination of a Fast EO, polarizing optical elements and a slow mechanical shutter

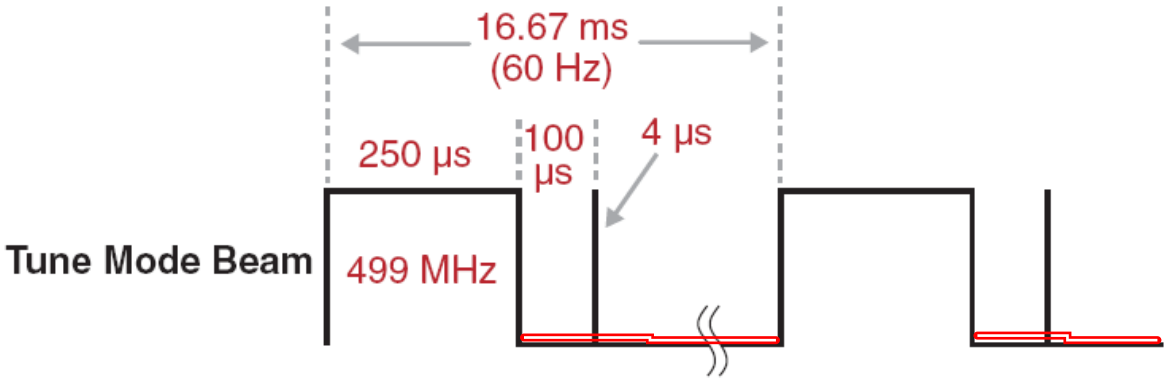
- ***Provide time structures needed by CEBAF operation***
- ***Protect machine***

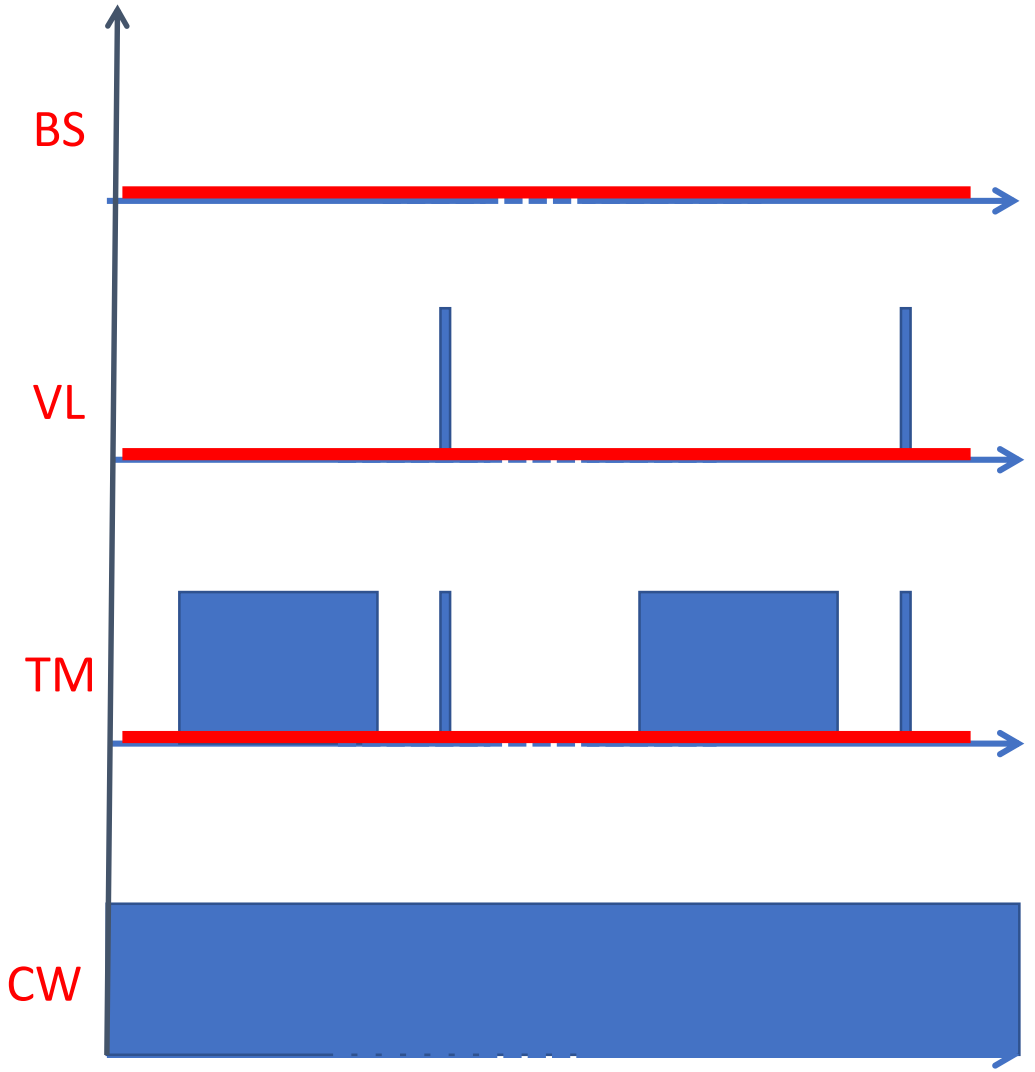
Time structures needed by CEBAF





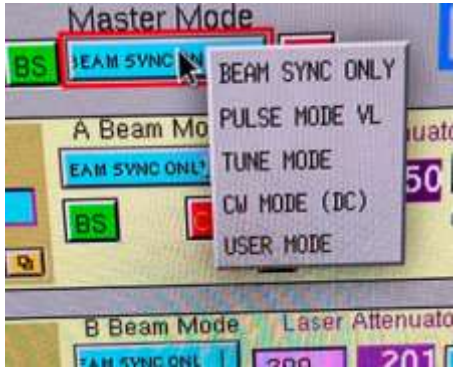
Week background due to limited optical switch contrast

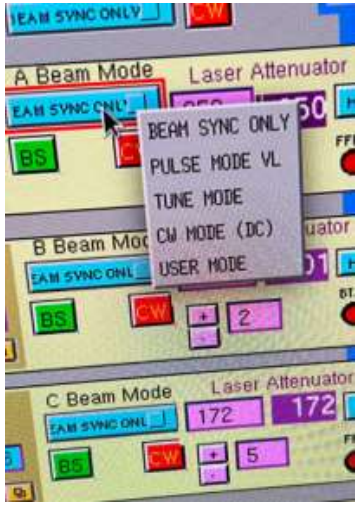




CEBAF Beam/Machine Modes

Beam mode	Macropulse duration at 60 Hz	Duty factor	Tune mode generator Pockels cell	Tune mode generator halfwave plate	Shutter
OFF	N/A	0	ON	IN	CLOSED
Viewer limited	4–10 μs	0.02–0.06%	ON	IN	OPEN
Tune mode	250 μs ON, 100 μs OFF, 4 μs ON	1.52%	ON	IN	OPEN
CW	N/A	100%	OFF	OUT	OPEN





Recent CEBAF beam-strike/Vacuun incident

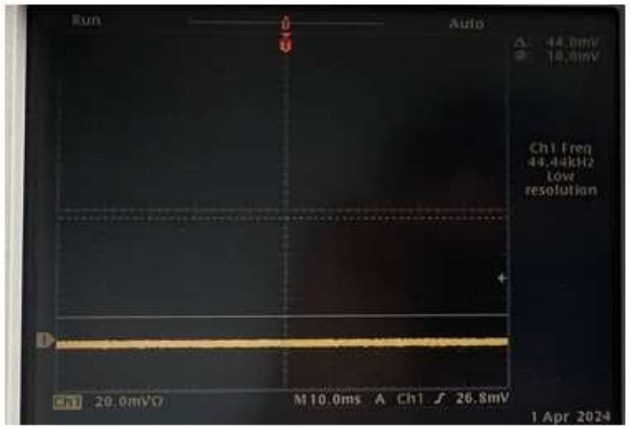
- 3/20/2024, Hall C lost beam.
  - Trouble-shooting showed mechanical shutter is good, the C laser TMG malfunctioning, replaced TMG. Machine resumed operation for a day
- 3/21/2024, vacuum problem in cebaf beam spreader, laser beam /power leak in BS mode. shutter did not seem closed.
- 3/22/2024, more extensive trouble-shooting performed, no
- Extensive trouble-shooting by CIS/SSG/AESCIS

CEBAF Beam Power & Pulse Structure

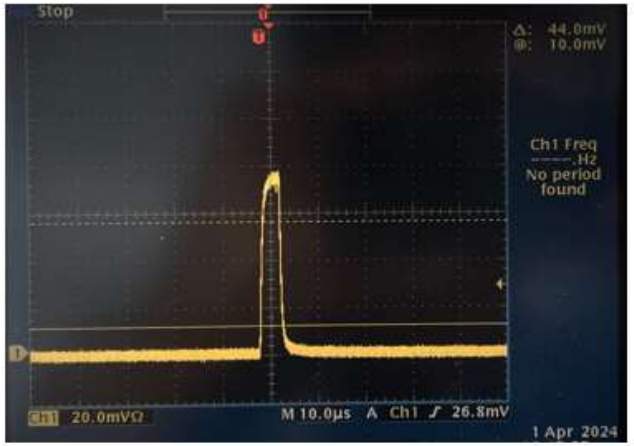
Laser power vs beam mode
Atten@1000

	A (mW)	B(mW)	C(mW)	D(mW)
BS	0	0	0	0
VL	0.55	0.13	1.62	0.018
TM	0.88	0.16	2.1	0.035
CW	77	18.4	198	5.3

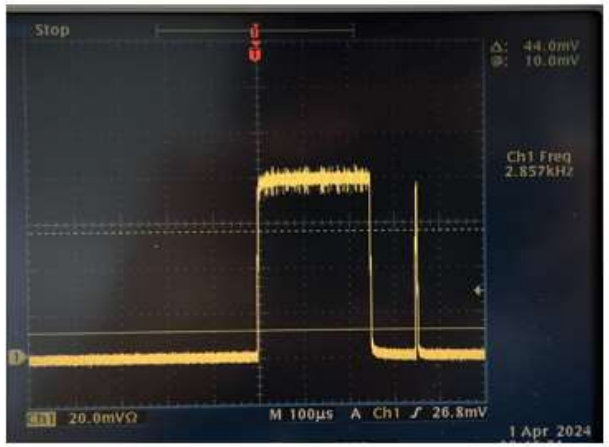
A Laser Pulse traces



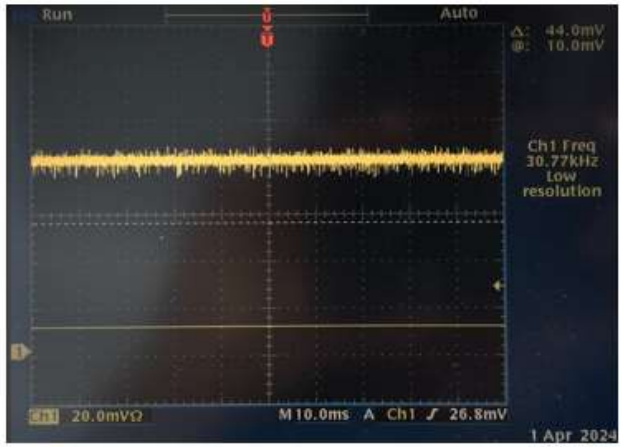
BS



VL

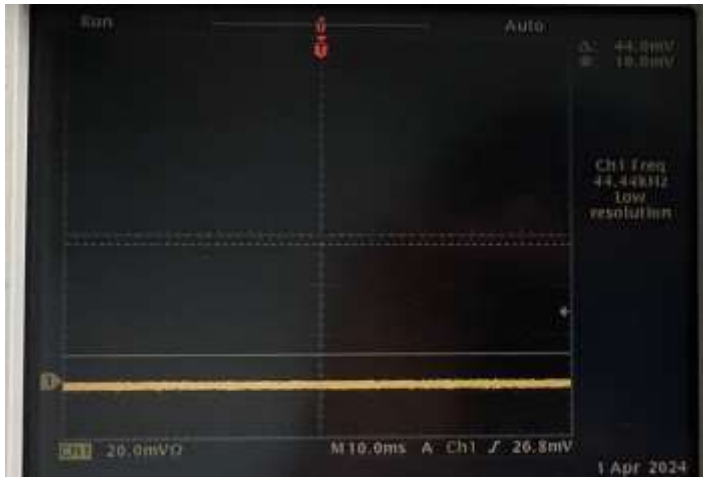


TM1

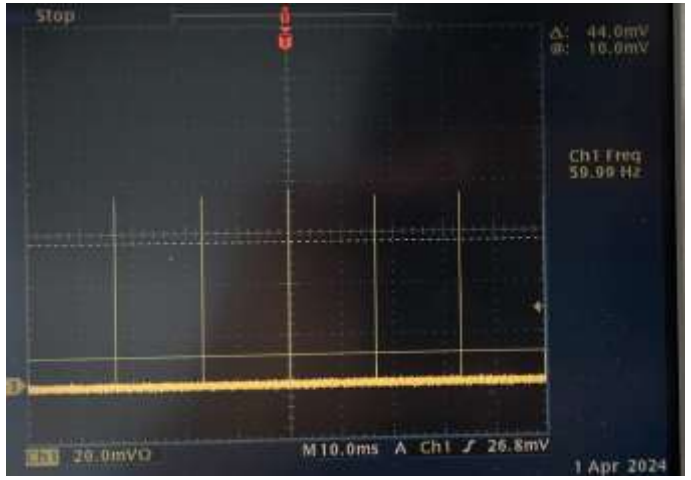


CW

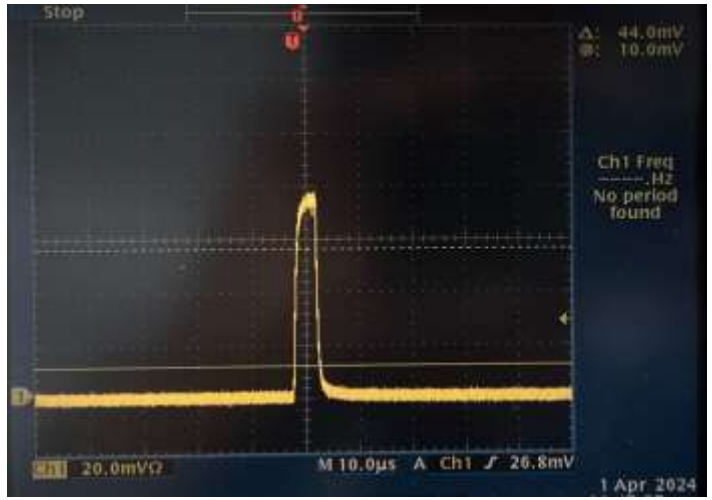
CEBAF Beam Power & Pulse Structure



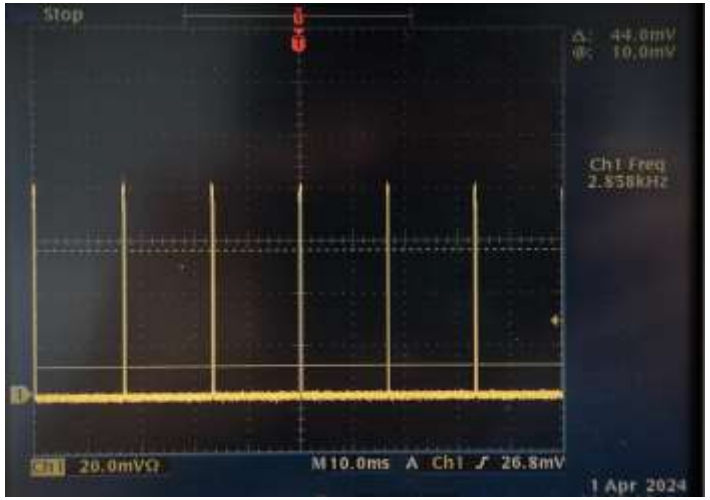
BS



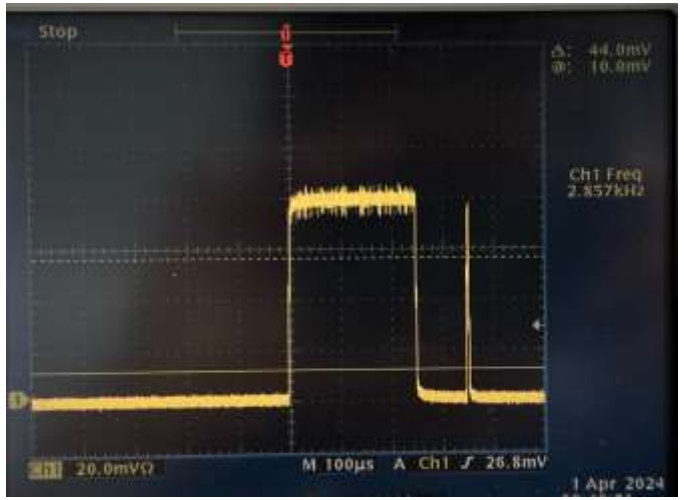
VL1



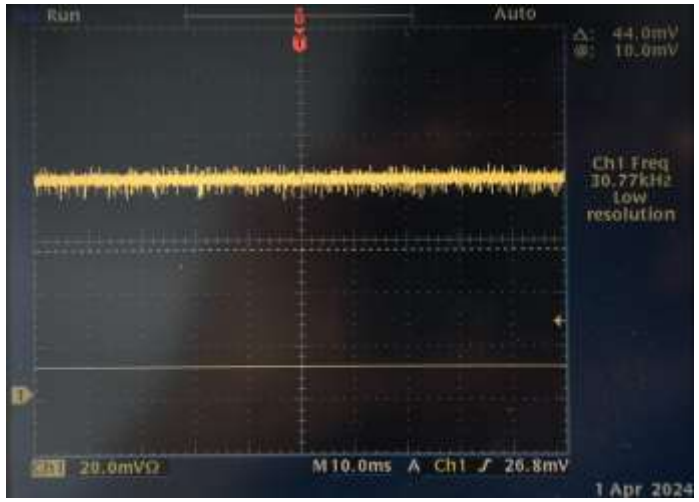
VL2



TM1



TM2



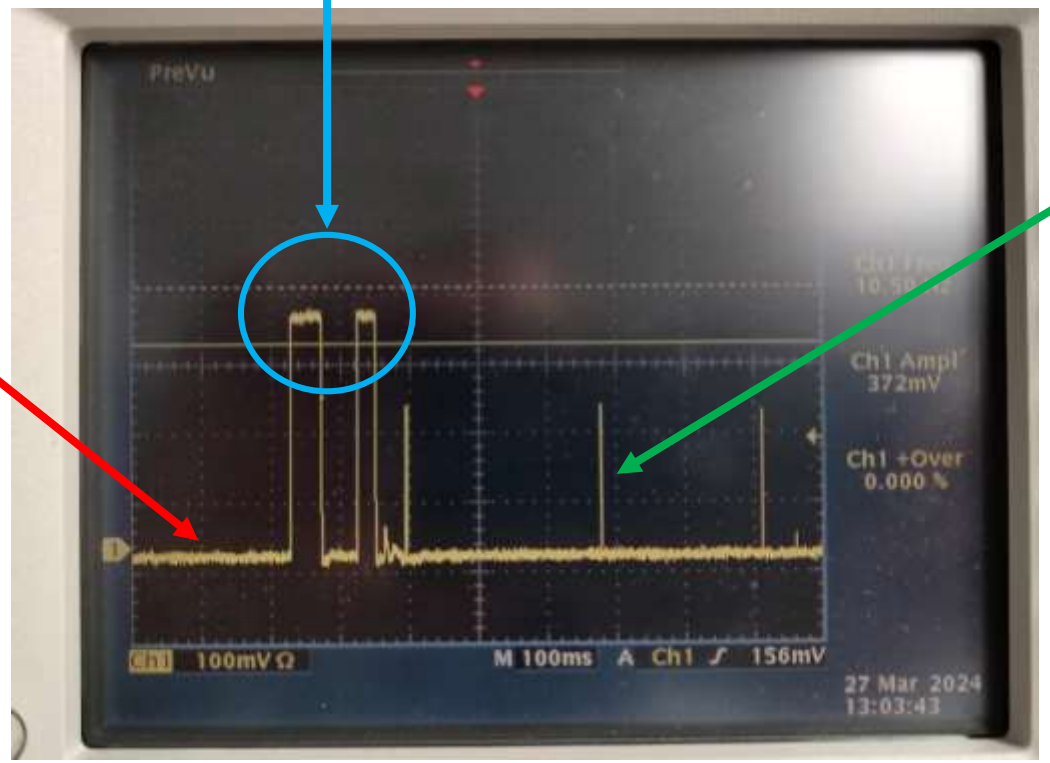
CW

Jefferson Lab

Beam Mode	Pockels cell High Voltage	half wave plate	Shutter
Beam OFF	OFF	Inserted	Closed
Viewer-Limited	Pulsing	Inserted	Open
Tune	Pulsing	Inserted	Open
CW	OFF	Retracted	Open

During transition to Viewer Limited this long (10's msec) would normally be shuttered

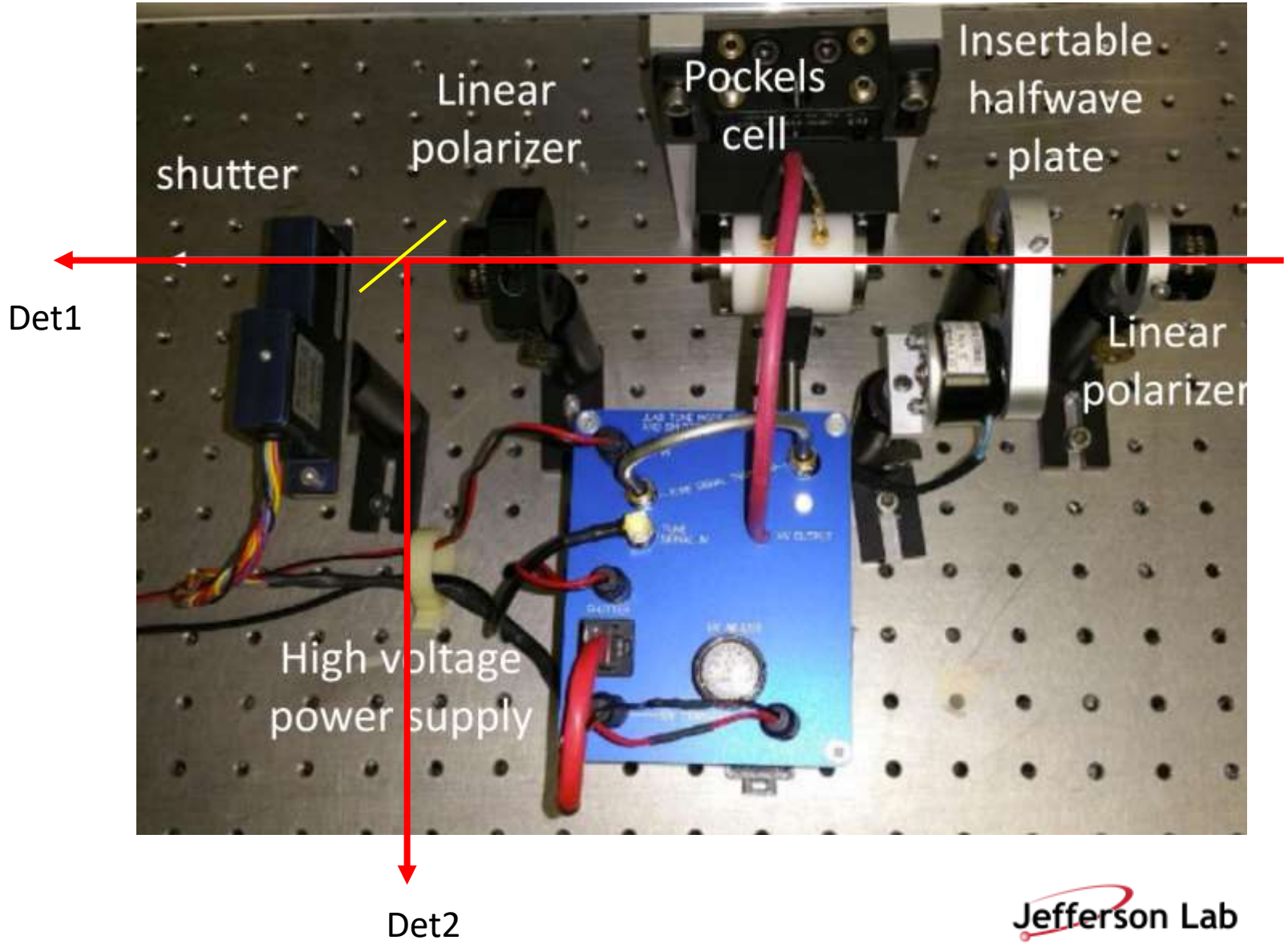
Archiver data shows shutter was **open** during Beam Sync



Shutter would then open, allowing Viewer Limited pulses (0.004 msec) to pass

Recent Test: UITF Laser TMG temporal behavior vs beam mode

- Detector 1 (Yellow Oscope traces) located after shutter
- Detector 2 (Purple Oscope traces) located before shutter
- FSD triggered from UITF EPICS



UITF Laser TMG temporal behavior vs beam mode

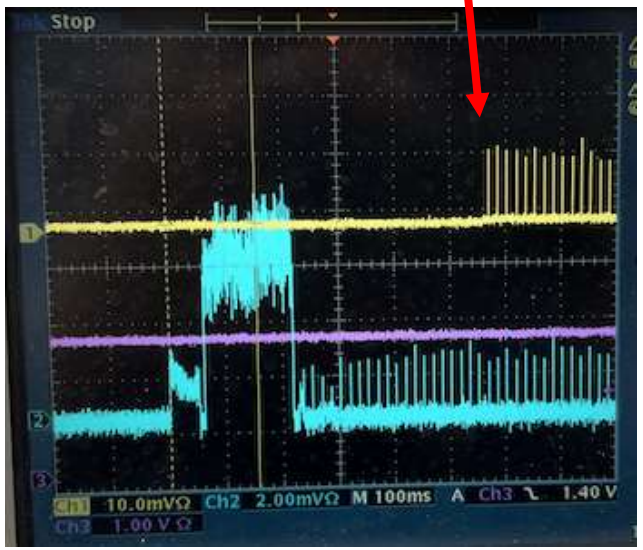
Purple: before shutter
Yellow: After shutter
Date: 4/5/2024

No FSD

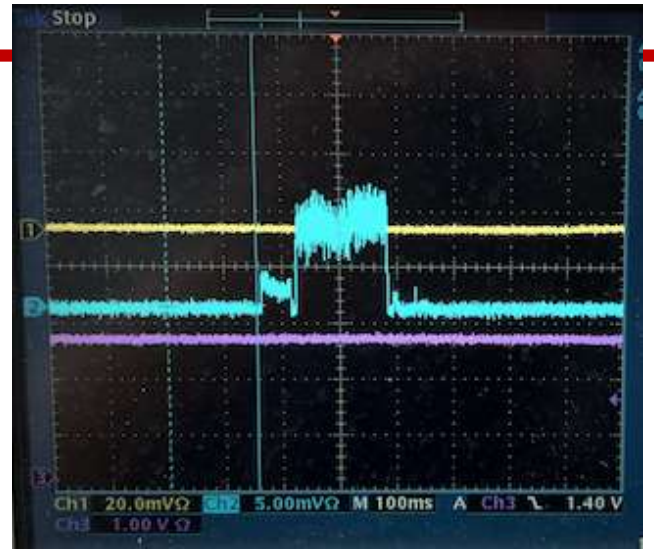
Initial \ Final	BS	VL	TM	CW
BS	n/a	2	3	4
VL	5	n/a	7	8
TM	9	10	n/a	12
CW	13	14	15	n/a

Delay

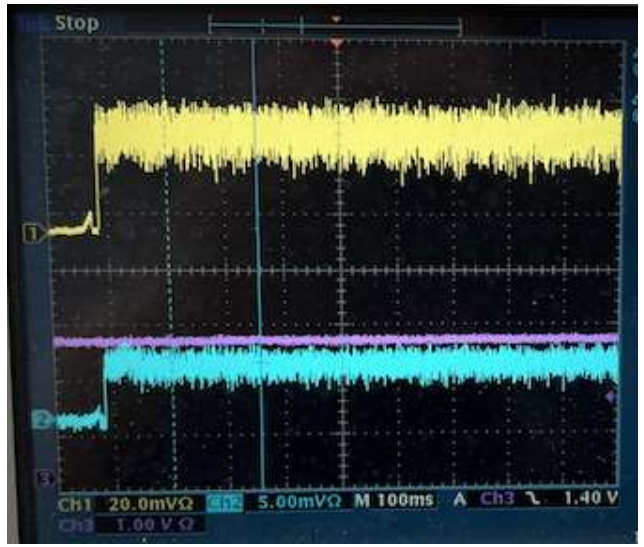
BS-BS



BS-TM



BS-VL



BS-CW

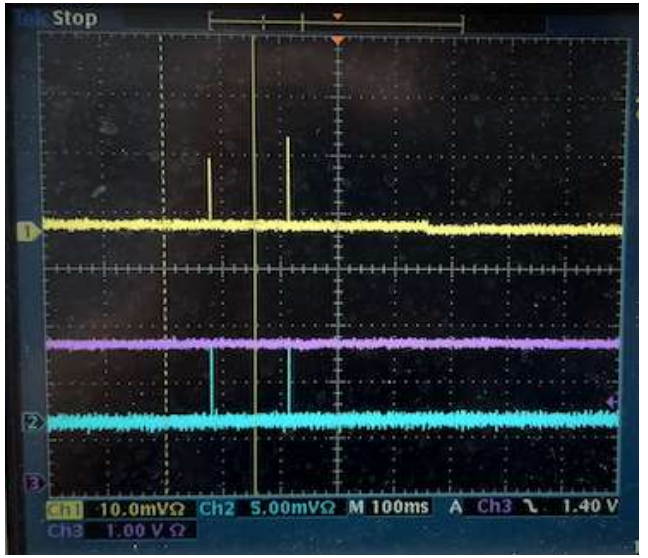
Purple: before shutter
Yellow: After shutter
Date: 4/5/2024

No FSD

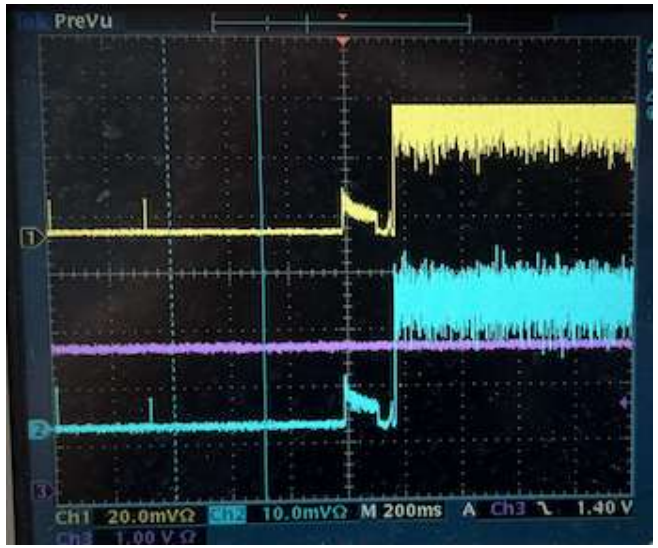
Final

Initial	BS	VL	TM	CW
BS	n/a	2	3	4
VL	5	n/a	7	8
TM	9	10	n/a	12
CW	13	14	15	n/a

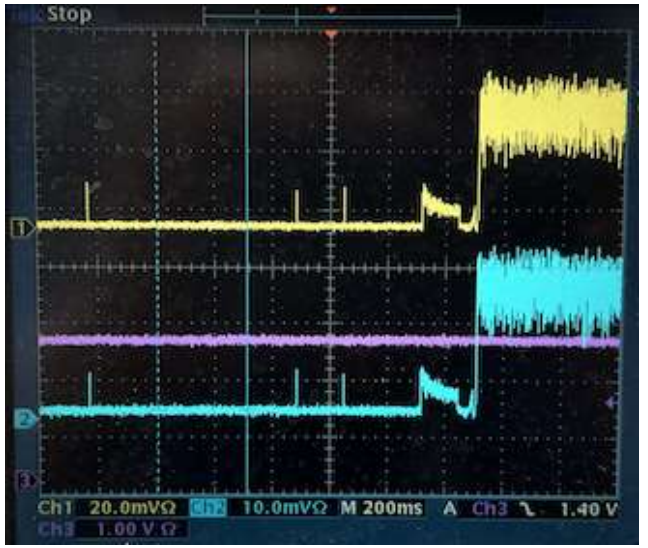
BS-BS



VL-BS



VL-TM



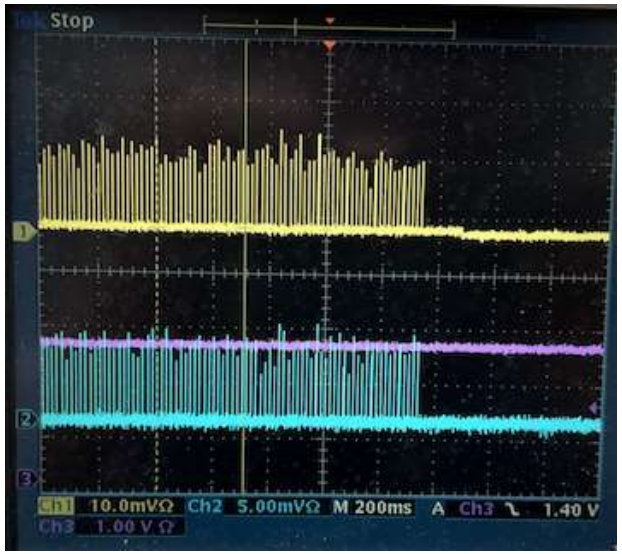
VL-CW

Purple: before shutter
Yellow: After shutter
Date: 4/5/2024

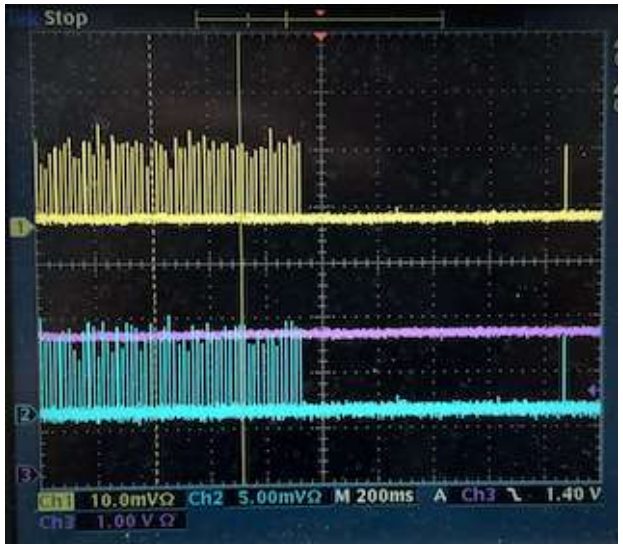
No FSD

Final

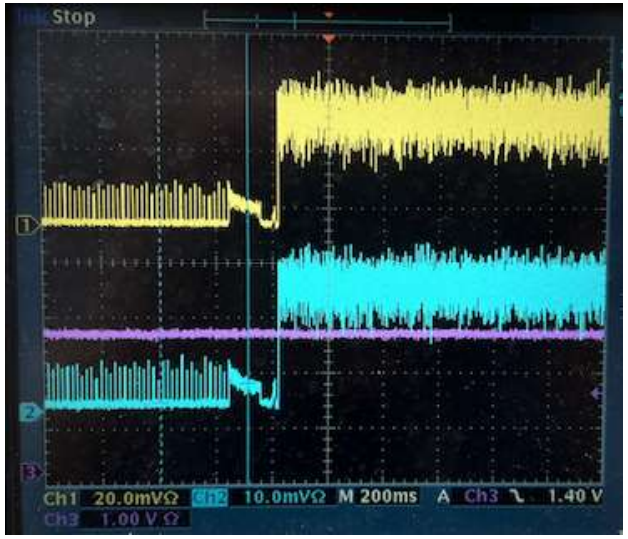
Initial	BS	VL	TM	CW
BS	n/a	2	3	4
VL	5	n/a	7	8
TM	9	10	n/a	12
CW	13	14	15	n/a



TM-BS



TM-VL



TM-TM

TM-CW

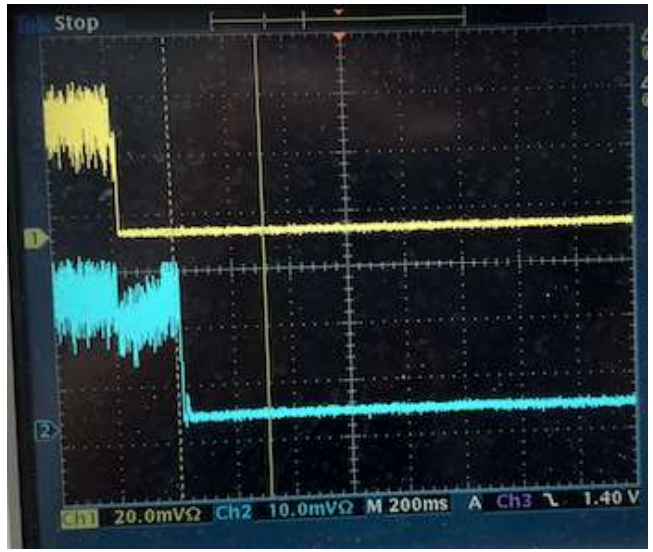
Purple: before shutter
Yellow: After shutter
Date: 4/5/2024

No FSD

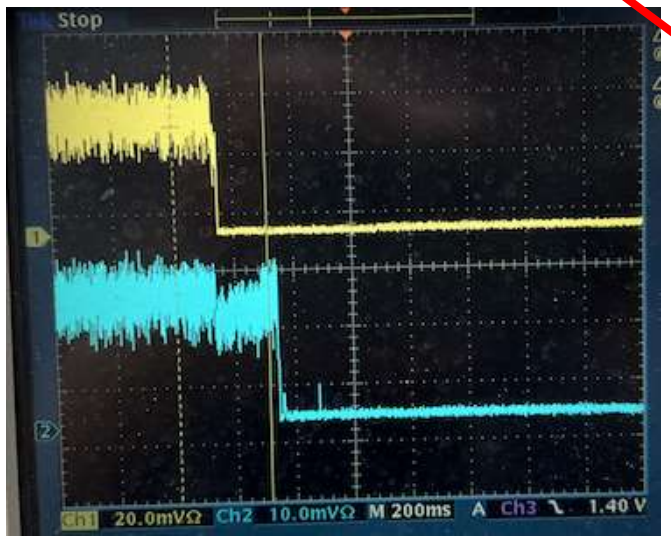
Final

Initial	BS	VL	TM	CW
BS	n/a	2	3	4
VL	5	n/a	7	8
TM	9	10	n/a	12
CW	13	14	15	n/a

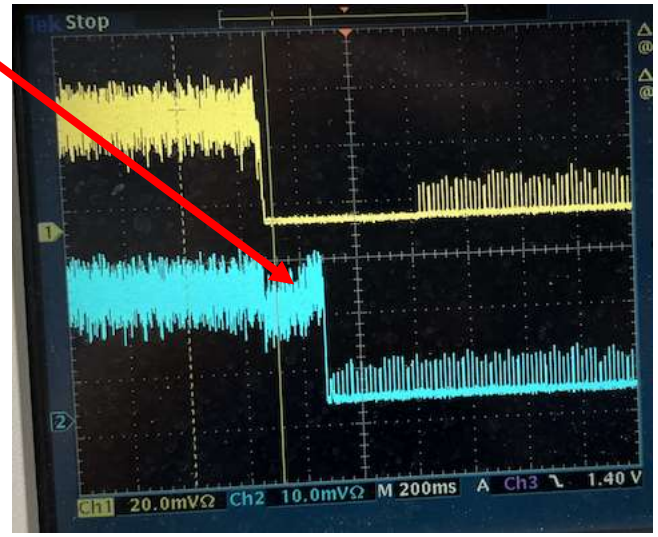
Delay



CW-BS



CW-VL



CW-TM

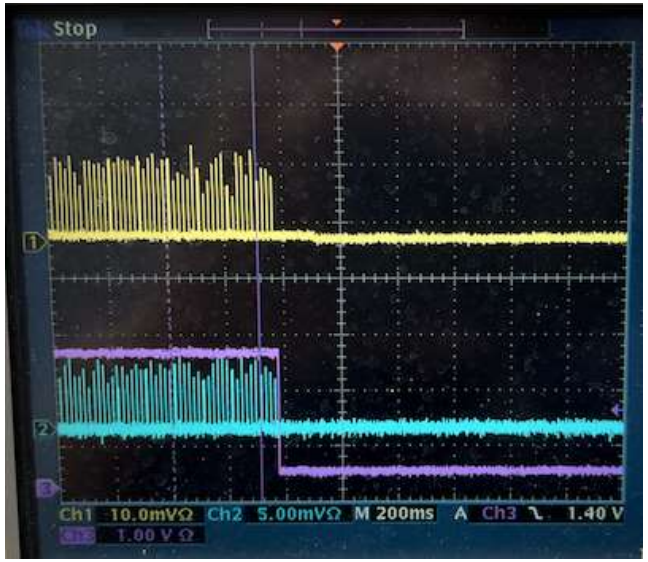
Purple: before shutter
Yellow: After shutter
Date: 4/5/2024

FSD from Static mode

Initial	BS
BS	n/a
VL	5
TM	9
CW	13

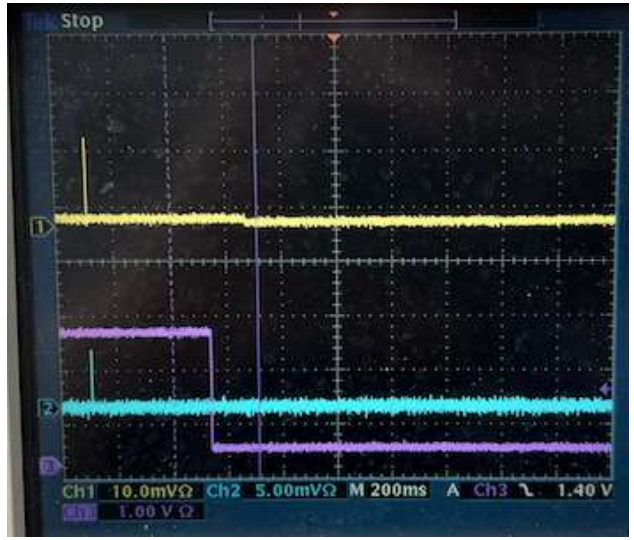
Delay

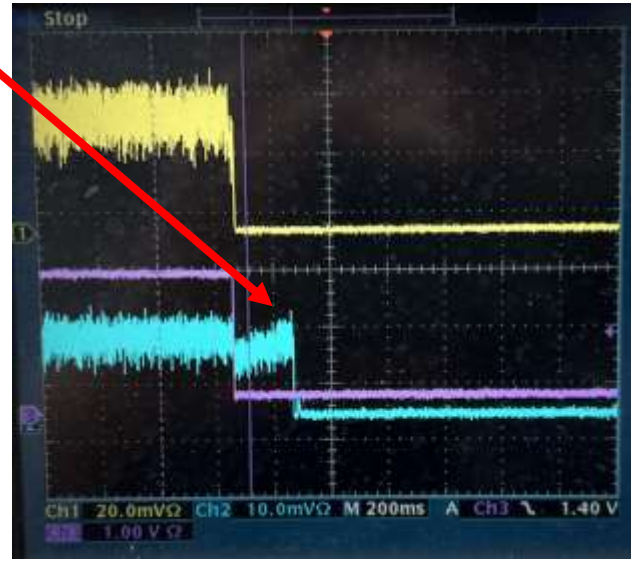
BS-BS



TM-BS

VL-BS





CW-BS

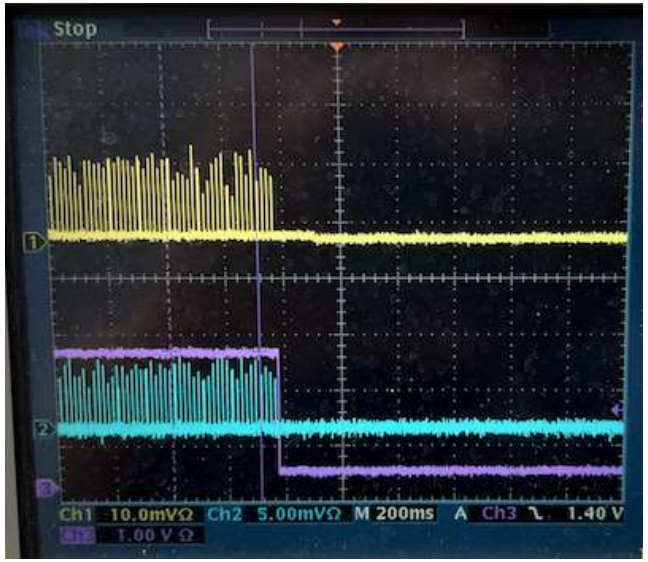
Purple: before shutter
Yellow: After shutter
Date: 4/5/2024

FSD from Static mode

Initial	BS
BS	n/a
VL	5
TM	9
CW	13

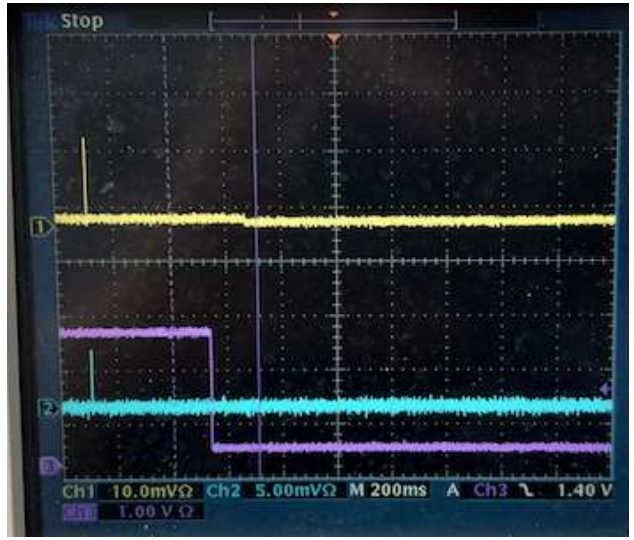
Delay

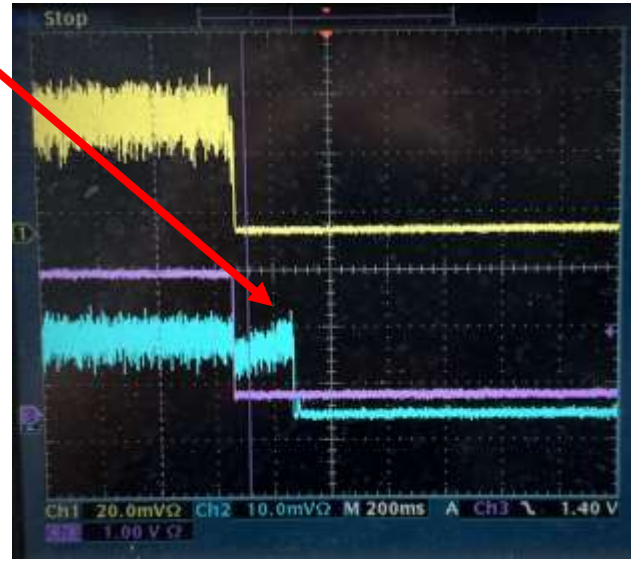
BS-BS



TM-BS

VL-BS



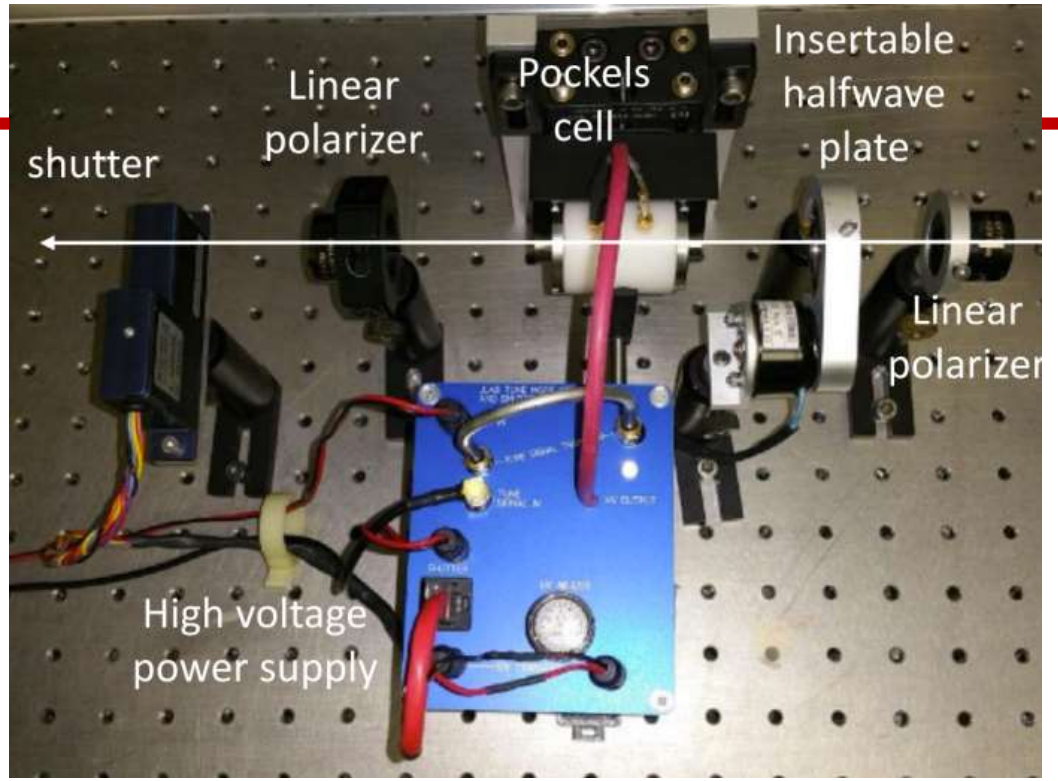


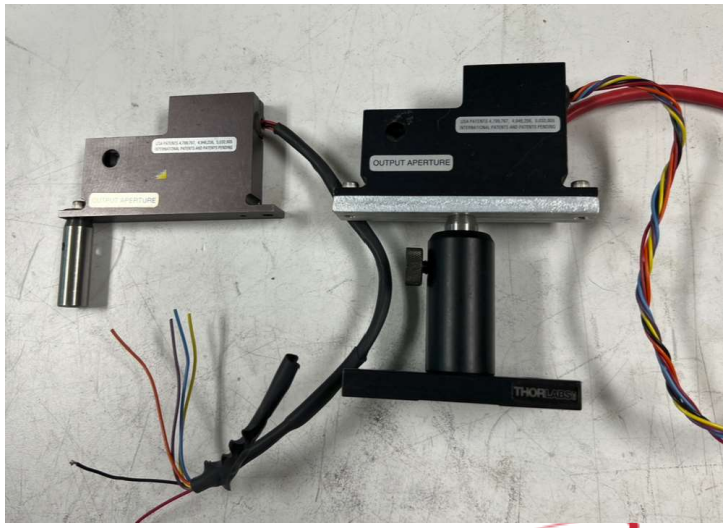
CW-BS

What may go wrong?

- Attenuator setting too high (280), laser power 10s x more than routinely set value

- Shutter open?
  - Triggers – controls to TMG seem fine
  - Shutter needs DC voltage to keep open
  - Mechanical?
    - Shutter has been on its holder
    - A chance that laser beam may go above the shutter due to loosen screw





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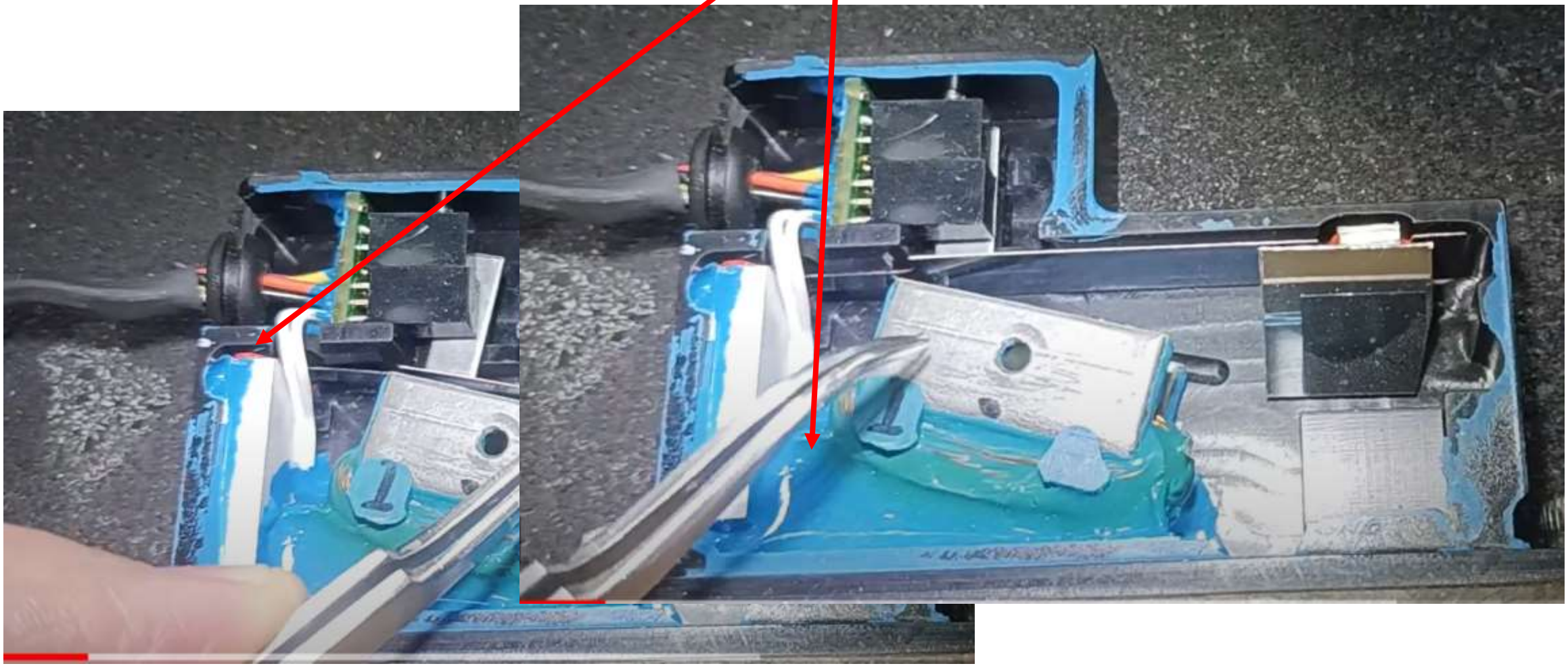
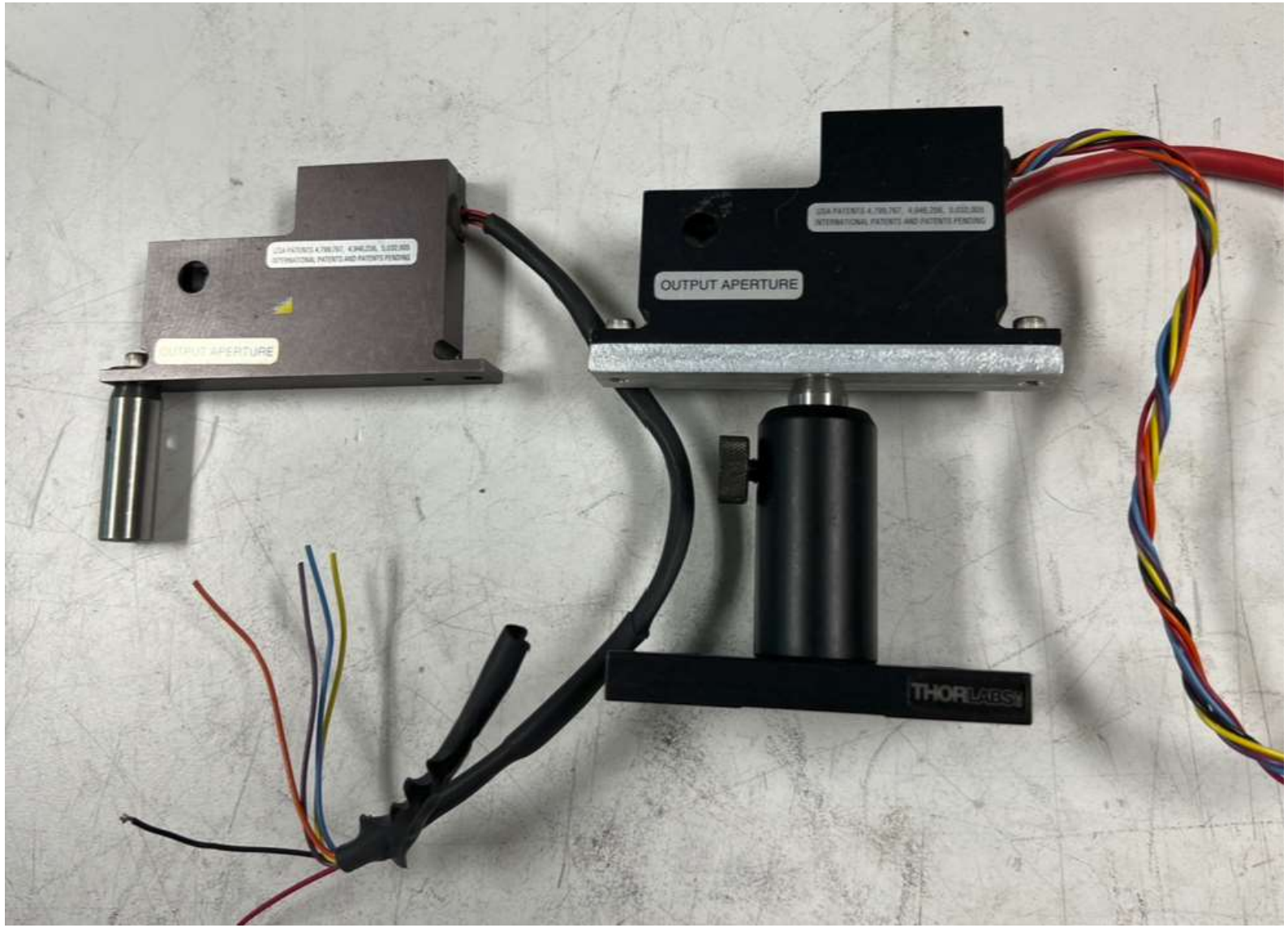
Nothing can be 100% safe,
Fail Safe May not Be Safe!

- Shutters may get heated up to high temperature
- High Temp may melt the glues
- The cantilever may fall, leave the shutters open




OUTPUT APERTURE
OUTPUT APERTURE
THORLABS

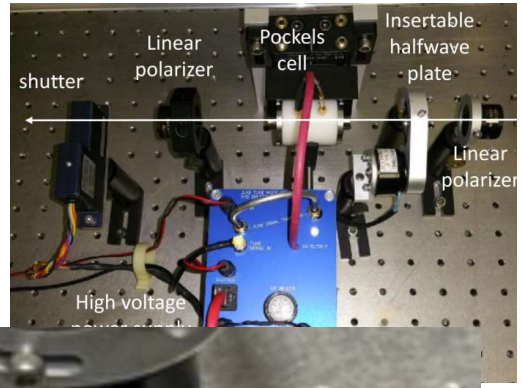
A deeper look into TMG

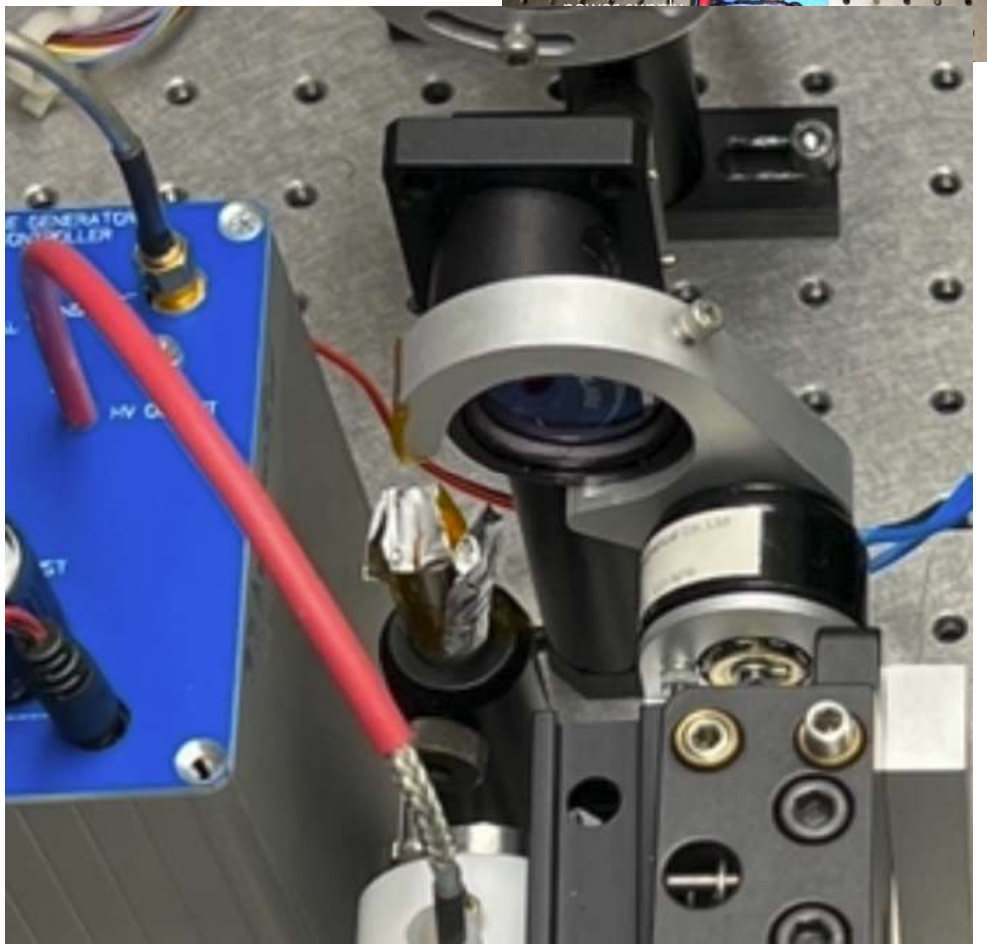
An even worse scenario, assuming the HWP fails, then what would happen

- BS mode – 100% power, shutter closed
- VL/TM mode– >99% laser power going thru, shutter open
- CW mode – 100% power going thru, shutter open

✓ *It's necessary to monitor HWP position*

✓ *Control follows if needed*

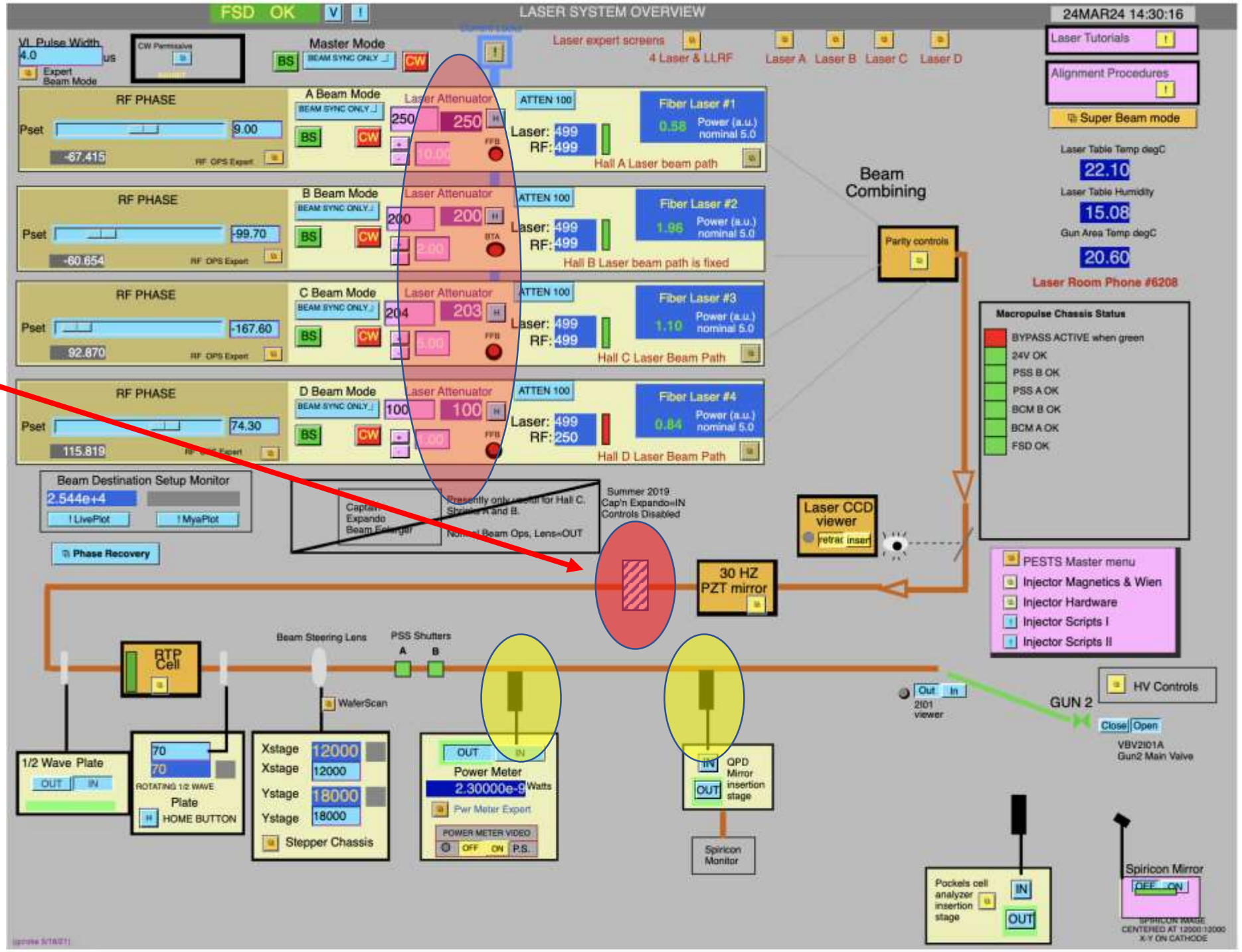




Risk Mitigation

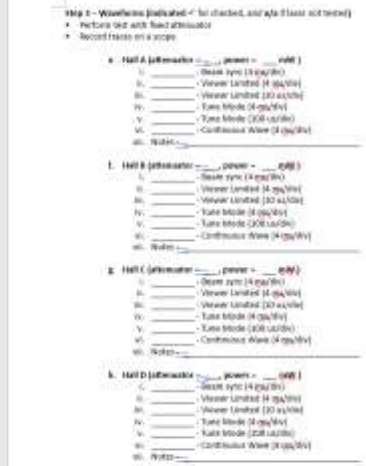
Near terms: this additional shutter could be the simplest and most reliable approach to prevent similar incident to occur.

Only need to be synchronized with the 4 shutters, i.e. open/close with any of them



Risk Mitigation

Enhanced Procedure: multi-point check out



Tune Mode Generator Hot Check-Out (HCO) checklist (version 2, 4/2/24)

Staff performing HCO: _____

Date: _____

Step 1 – Visual inspection (indicate n/a if laser not tested)

- Indicate pass (✓)/fail(✗) for each function.

a. Hall A (Serial #s TMG/TMG-, Waveplate/, Shutter/)

i. _____ - Beam Sync (shutter closed, waveplate in)

ii. _____ - Viewer Limited (shutter open, waveplate in)

iii. _____ - Tune Mode (shutter open, waveplate in)

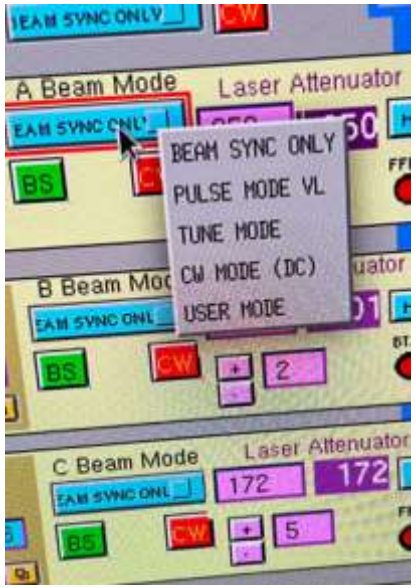
iv. _____ - Continuous Wave (shutter open, waveplate out)

v. Notes

Risk mitigation

Immediate/short-term

- Laser power automatically go to minimum Ops setting such as “Atten/100” when switching mode
- Additional shutter

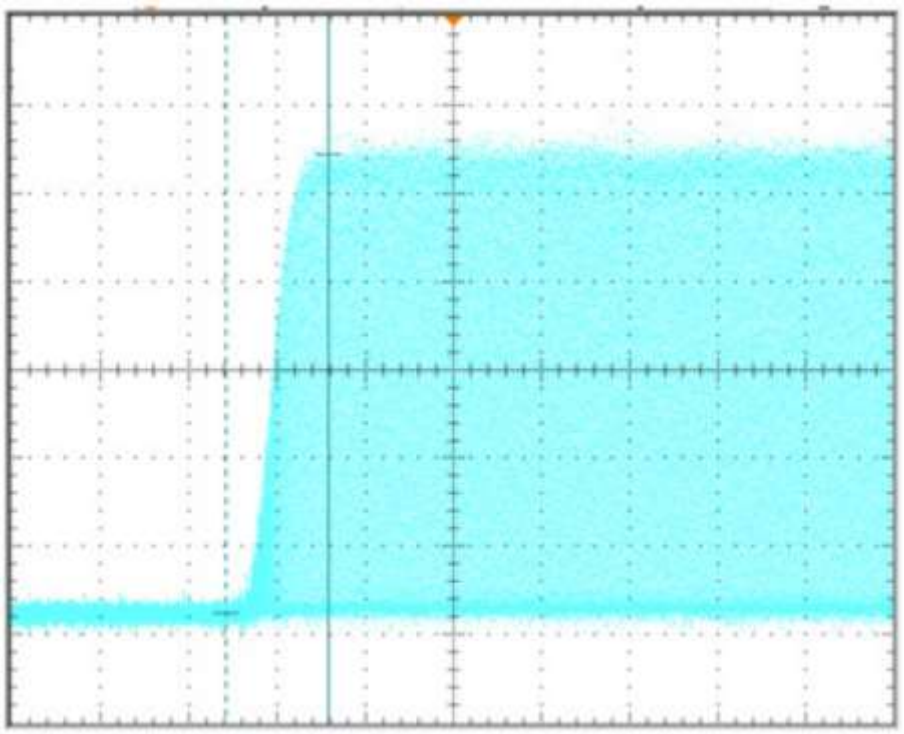


Long-term

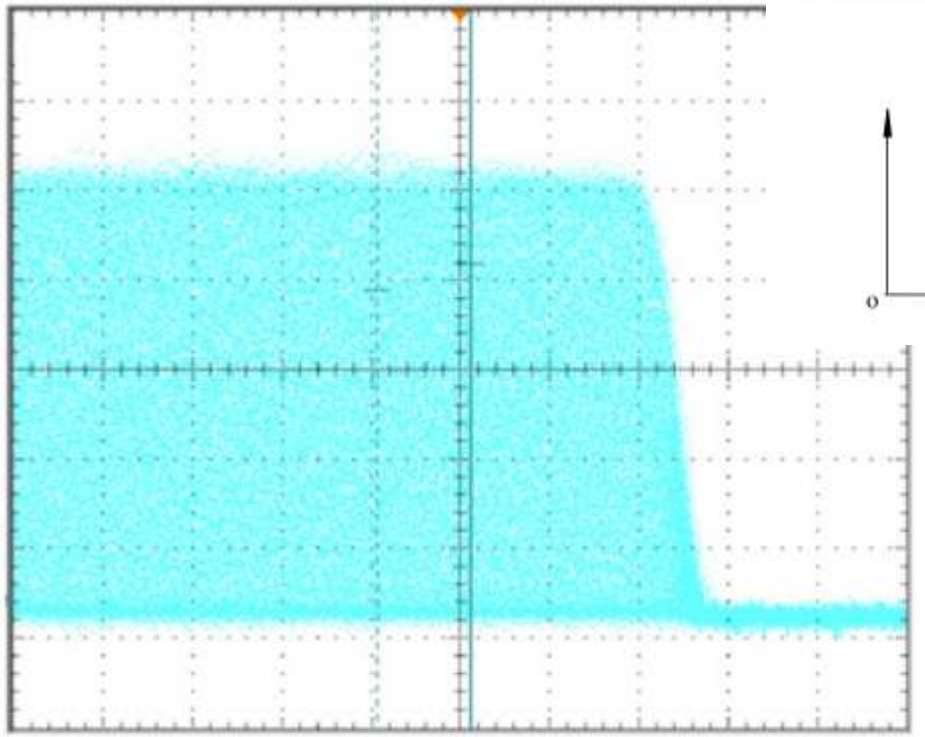
- Implement ***variable rep rate***, 1, 15, 30, to 60 Hz (existing, fixed)
- Go to “**B. Sync**” mode and the **lowest rep rate** (1Hz) whenever beam mode/machine status changes. Laser power detector goes in prior to “Beam Permit”
- Increase **pulse contrast**, new crystal
- Shutter open/close status signal-**position sensors**
- Realtime beam mode monitoring / **Oscope signal** to MCC
- More frequently **check up** on system parameters
- Faster shutters
- Improve procedures

Rename the attenuator? The attenuator reading scaling (0 up to 1000) may cause confusion, max attenuation is x1000, which actually gives the max laser power!

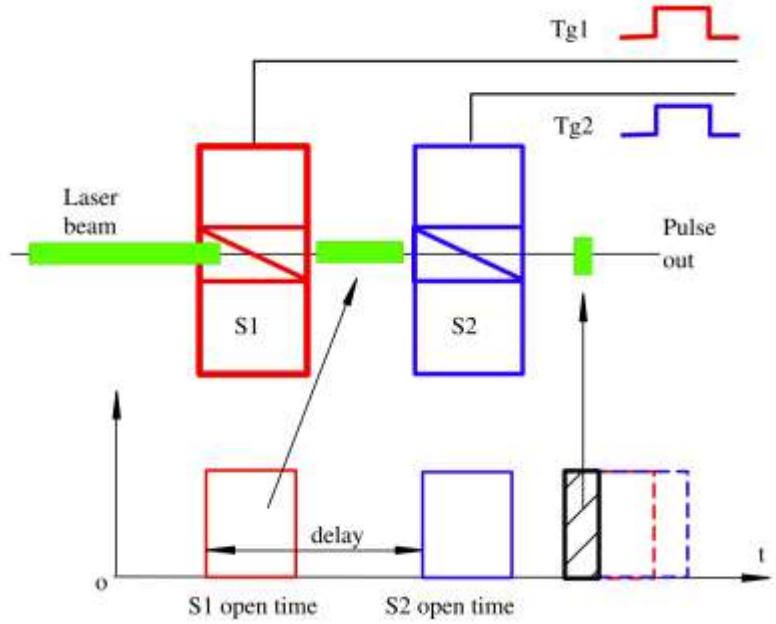
Safer – Use of much faster shutter



Vertical 5mV/Div Horizontal 100µs/Div

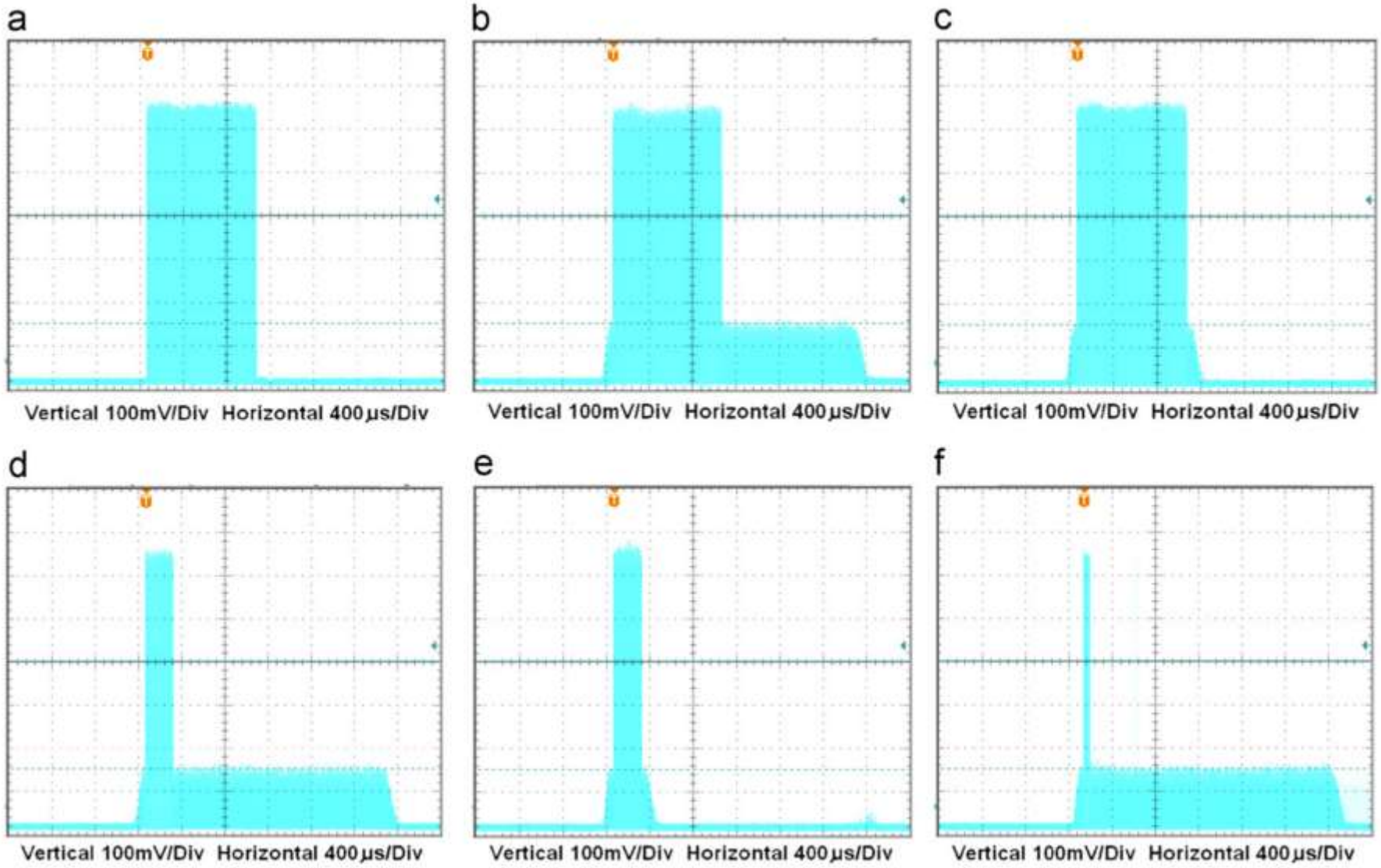


Vertical 5mV/Div Horizontal 100µs/Div



S. Zhang, etc., "A simple gating technique for high-average-current photo-injectors", Nuclear Instruments and Methods in Physics Research A 629 (2011) 11–15

Safer – much faster shutter



S. Zhang, etc., "A simple gating technique for high-average-current photo-injectors", NIMA 629 (2011) 11–15