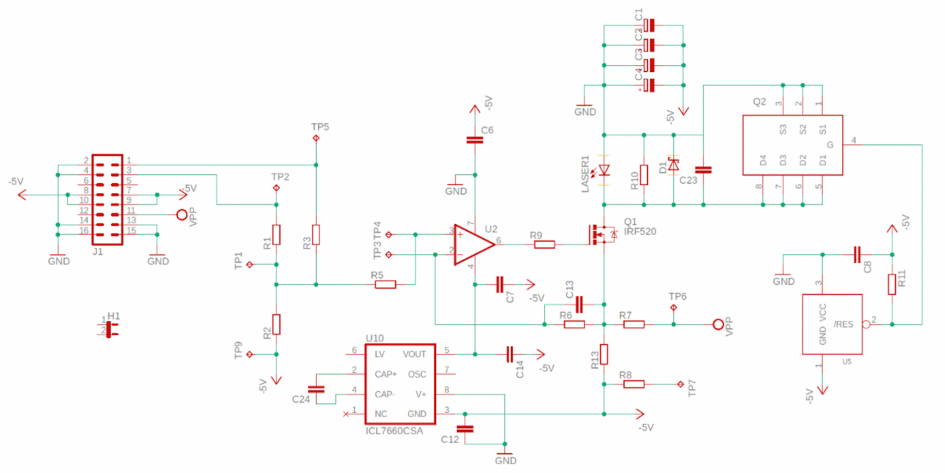
FY2024 KA25 - Power over Fiber

Intro

Today, power is transmitted over copper in most High Energy Physics (HEP) experiments. This is a classical and well understood solution; however, it has many limitations. First, copper is sensitive to electric and magnetic fields, which are present in future colliders and liquid noble Time Projection Chambers (TPCs). In colliders, this translates into Lorentz force exerted on the powering cables in a power pulsed system. Until now, the optical instrumentation in TPCs has been located at the anode plane or outside the TPC to prevent a HV ground return within the electric field. Accommodating light sensors reduces the charge-readout coverage and active volume. Power over Fiber (PoF) would enable optical instrumentation within the TPC, maximizing charge-readout coverage and active volume. Optical readout inside the TPC provides a local trigger; improving trigger efficiencies. Maximizing active volume is vital for any statistics-limited experiment.
PoF completely solves the above-mentioned problems. In such a system, the power is carried by a laser source through optical fibers, which are insensitive to electric and magnetic fields. An optical power converter (receiver) is placed near the sensor (ASIC, SiPM, …). In addition, ground loops are eliminated, thus reducing the total system noise floor. Moreover, we have a material budget gain, as we replace thick copper cables with thin optical fibers. This is of particular interest for e+e- colliders.

The present project proposes to study the feasibility of PoF in extreme conditions, using commercial components. In the first phase, we will set up a lab space with the necessary engineering controls to lower the safety classification of the required class 4 laser to a class 1. Then the receiver will be characterized at cryogenic temperatures (down to 77 K). By adding a power storage capacitor and an LDO regulator, this setup can be used to power an ASIC with a power-pulsing scheme, or a low-power digital SiPM. We will collaborate with universities for the aforementioned. Finally, we will work with national and international collaborators, and will investigate the possibility of characterizing the photodiode with respect to different irradiation doses compatible with e+e- colliders (> 100 krad).

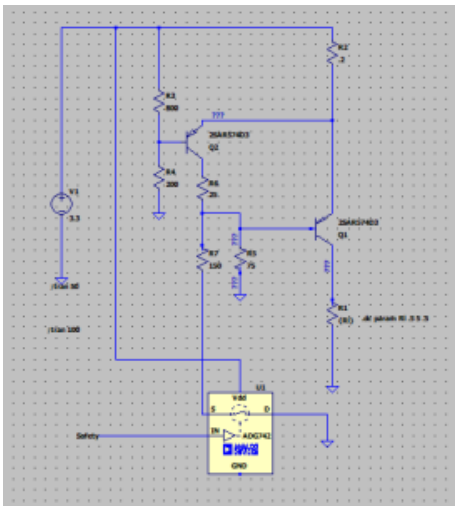
Specifications - Laser



Laser User Manual

laser with housing: https://www.digikey.com/en/products/detail/broadcom-limited/AFBR-POMEK2204/15928069?s=N4IgTCBcDaIIIDEBCAlAtABQPIFkCiA0mGAAwAsIAugL5A

laser diagram from Bill Pellico:



Specifications - System

material for laser enclosure: SF41465161 (1).pdf

folders with drawings for laser enclosure and clamshell design: https://slac-my.sharepoint.com/:f:/r/personal/alexhab_slac_stanford_edu/Documents/Documents/KA25/PoF/PoF_Shared_Folder/Other%20groups?csf=1&web=1&e=Q1ECHF

Specifications - Safety

general safety slides: https://slac-my.sharepoint.com/:p:/r/personal/alexhab_slac_stanford_edu/Documents/Documents/KA25/PoF/PoF_Shared_Folder/Safety/231130%20first%20laser%20safety%20meeting.pptx?d=w54504c00ea944ea2aac367bb4decd4db&csf=1&web=1&e=JEAlFu

FPD/TID general safety form: https://slac-my.sharepoint.com/:w:/r/personal/alexhab_slac_stanford_edu/Documents/Documents/KA25/PoF/PoF_Shared_Folder/Safety/240125%20power%20over%20fiber%20FPD%20Form%20-%20Experiment-Eqpt%20Design%20Review%20and%20Approval%20.docx?d=w2350952e08fe48269e954e062ed8fa63&csf=1&web=1&e=VrapGV

https://slac.sharepoint.com/sites/ESH/laser/lso/facilities/LCLS-fibertiming.aspx (Fiber-coupled power meters and fiberscopes, Charlie Xu and Sam Eisenberg. They're responsible for the laser fiber timing system for NEH lasers for LCLS experiments. Documentation for the associated Fiber Timing Lab)

Presentations

PoF Shared Folder

Initial Proposals

20-FY242_KA25_PoF_Proposal.pptx

KA25 FY24_Synopsis_PoF.docx

Other talks about PoF

CPAD_2023_Ajib_Paudel (1).pdf

EIC_R_D_2023_Mandal.pdf

CryoPof_TIPP23.pdf

Meeting Minutes

Minutes

- We have a box enclosure
  - Pietro and Sander need to look into key, led control and interlock
- Students:
  - We have a SULI Electrical Engineering undergrad coming during the summer (Jack)
  - We have a Physics grad student from Michigan
- Pietro presented the laser driver reverse engineered PCB
  - the test needs to continue

Minutes

- Students:
  - We have a SULI Electrical Engineering undergrad (Around June - August '24)
  - We have to look for a Physics grad student
- Discussion about the 80/20 cutting
- Marty found a nice ppt from TIPP2023 about a group that used our same laser
- We will buy also another "naked laser" without driver and ask for Bill Pellico about his design
- We will go for a very simple OPC Board design, as simple as possible

Business of the day:
Zoom: https://stanford.zoom.us/j/6723568666?pwd=eGxoSEs0ODc2UDdjL0NWR3RNSUZ3dz09
after discussing with Alex, my suggestion for the agenda is:
1. Thanking Alex for his work!, discussing new PI role, discussing what we need for the smoothest transition
2. Information gained from talk to Bill Pellico from Fermilab
3. Information gained from attending POF Fermilab meeting (David Martinez Caicedo)
4. Updated idea on cryogenic setup (reusing open LN2 duwar)
5. Discuss proposal for redistribution of hours
6. Discuss possible summer student opportunities: SULI UG, Stanford UG, direct hire from University grad, GEM fellow grad
7. Quick prep for safety meeting this afternoon
8. Any other updates/business? (edited)

-drawings received from Dune on their laser enclosure box and feedthrough clamshell design.

-Example quote received for laser enclosure material (walls and 8020)

Minutes

- a new small testing TPC is being constructed by James for the DUNE project with delivery for June. This is a light-tight open dewer. This can be used as our cryogenic setup.
- Possible summer students, probably a good number would be 2 grad students, one physics and one engineering
  - There is a promising MSU grad student through James
- Should we change vendor for the laser? let's create a set of questions for Bill Pellico
- drawings received from Dune on their laser enclosure box and feedthrough clamshell design.

- Sander is progressing on the safety procedures. He had some technical questions that were answered by the group.
- Marty has some technical questions regarding the diode. Alex should check the MAPS excel sheet and propose a technical meeting with Marty.
- Pietro made a first design for the PCB. The group made the following suggestions:
  - The diode should be off the board, inside the sealed box. We could have a connecter that allows us to easily connect/disconnect the diode
  - We should foresee a power pulsing scheme with a MHz range. More precisely: the load consumes most of the stored power within 1 us, with a 120 Hz repetition frequency. To be foreseen: power storage capacitor, switches controlled at 1MHz, and deal with the case where the average input power is not equal to the average consumed power.
  - Provide probing pins for easy monitoring on oscilloscope
  - Think about the case where the diode would operate on a floating ground for TPC operation (not necessarily implemented in this iteration)
  - Provide key, interlock, light diode (green/red) for the sealed box
- We need to design the 80/20 box (James would sketch one?)
- Alex showed the initial Smartsheet planning, which was modified according to the group's suggestions. Objective: Have a first laser by April 1st, with Safety Ok, and PCB ready. For a more detailed planning please visit the Smartsheet page:

  Meeting Minutes:

  We had our first laser safety meeting with Mike Woods and these slides were presented: 231130 first laser safety meeting.pptx

  - We should look at commercial products to see how they are doing interlocks
  - Important things that our system should have:
    - Key
    - Emission Indicator (red/green)
    - interlocking
    - (optional) Emergency OFF button
  - The box should have 2 redundant interlocks in series
  - If the box is made up to specs we will not need a separate laser area and will not need eye protection to operate
  - Box material can be 80/20 Aluminum

- For the feedthrough we should think of having an elbow to avoid direct line of sight
- We have to take into account the fiber bend radius
- **SOP is not enough, we will need a separate approval to operate**
- People working on the assembly of this will need:
  - 253
  - 131
  - T53
- People only operating will need only a simpler laser safety basic course
  - ???
- **Mike gave us permission to buy the laser**

Next Steps:

- **Mike Woods asked for a component list**
- **Norman Picker asked us to start a Hazard list with Mitigation (All the risks will be Extremely low)**

Meeting Minutes:

- Alex presented a summary of bibliography. Presentation can be found in the shared folder here:blocked URLPoF_Shared_Folder
- Sander presented about laser safety. Presentation in shared folder
- Laser safety takes approx. 4 months. We need to start asap
- The cryo measurement has been done by DUNE, what is our target?
- DUNE group at FNAL has favored connection with Broadcom, for customized products for cryo.
- MSU and CU reached out to James about the status of the project.
- We can lend setups to partners. One Broadcom setup is around 2k

Next Steps:

- Sketch of lab space in 113 (James)
- Ask Ryan about Lab space in building 84 (Sander)
- Contact Mike Wooks for a meeting (Sander)
- Redefine Scientific goals (everybody)
  - Verify if it can power 1 reticle (min) and 16 reticles (max) (Alex)
- Contact DUNE at FNAL (Sander)
- Can we/ Will we take a SULI Student? (Caterina)
- Draft of PCB board (Pietro)

Meeting Minutes:

- Marty talked to Michael Woods (Laser Safet Officer at SLAC), and he seems understanding of our need. General recommendations: laser always connected to a receiver, laser in a box,...?
- Mengqing at Nikhef has a set of lasers. A possible collaborator.
- Sander has been to the laser safety event at Stanford.
- We need to think about the system level for safety, and for practical reasons (where to dissipate power in a power-pulsed system). We either have to control the laser, or tune it to deliver the 'average' power that is stored on a capacitor, and regulated with an LDO
- We need to start with a generic system, with LDO, and a set of variable loads (resistors) with a way to monitor the ouput voltage and current, to characterize the system before connectiong it to any real load (ASICS, SiPM).

To Do list:

- Start ES&H Process on laser safety (Sander)
- Literature study on solutions/competitions (Alex)
- create a list of possible laser and diode providers (Alex and James)
- Concept design of PoF board (Pietro)
- Start setting up a lab space (James)
- Reach out to collaborators, with a potential meeting before winter break (Sander and James)
- Keep an eye for relevant talks at CPAD and NSS (everybody)