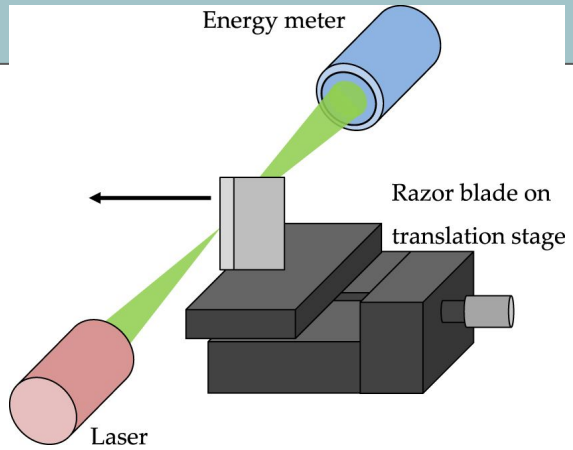
Analog Optical Link Development at APC

DUNE VD-PDS meeting
24/03/2021

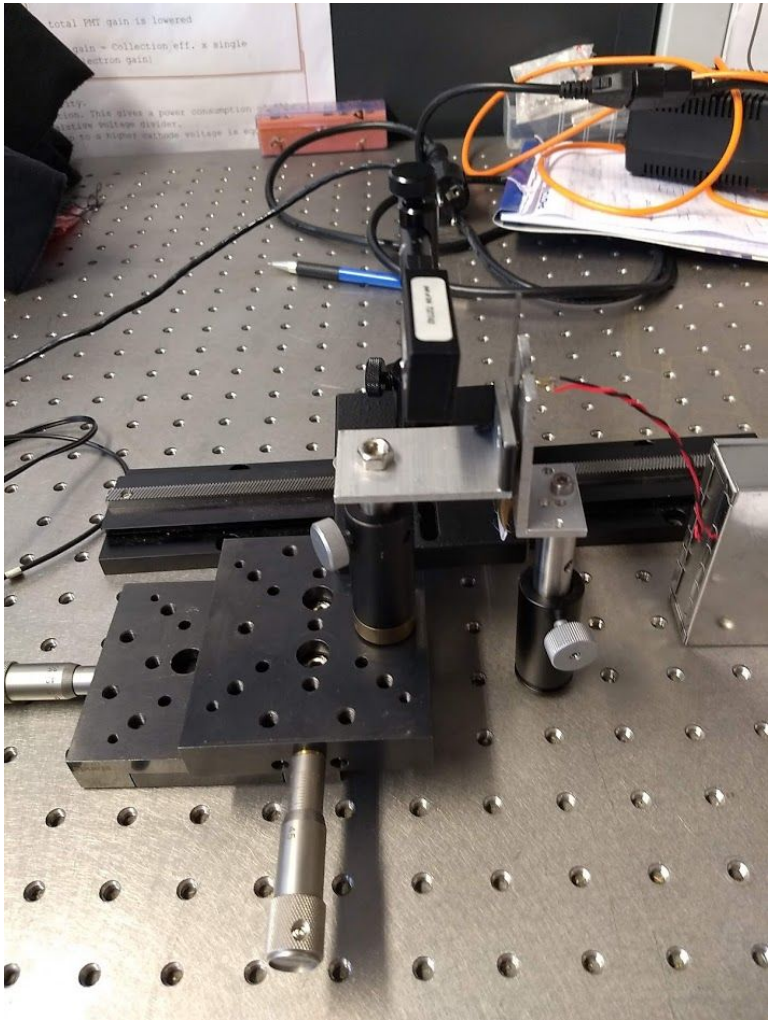
Optical tests at room temperature

- P vs I characterisation
- beam size/profile estimation
- No fiber options yet, some ideas:
  - quartz won't shrink
  - tefzel cladding does well in cold
  - Multimode
  - as thick as possible (~500 microns core)
- fiber alignment options:
  - with/without ferrule?
  - DS-style connector
  - from FreedomPhotonics: bare module diode and fixed fiber, investigate cryo epoxys



Sensors for tests :

- Ophir Photonics PD300-UV: 1x1cm^2 10pW-300mW sensor
- PDA36A-EC: Si detector, allows mounting of pin-hole



Components to test:

VCSELs: low power, ~800 nm so far. Will evaluate moving to 1310 nm (to avoid interference with signal in case of light leakage).

- L808P010: 808 nm, 10 mW
- L808P200: 808 nm, 200 mW
- L785P090: 785 nm, 90 mW

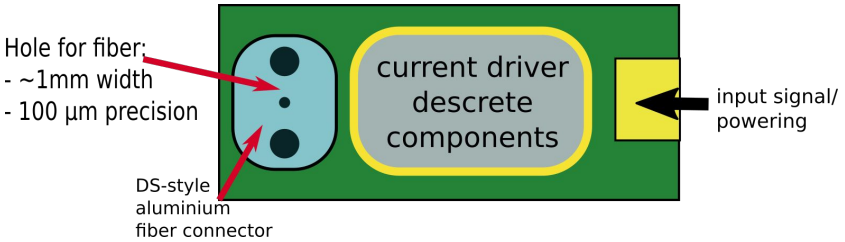
To investigate: equilibrium between power budget and needed light to properly transmit the signal.

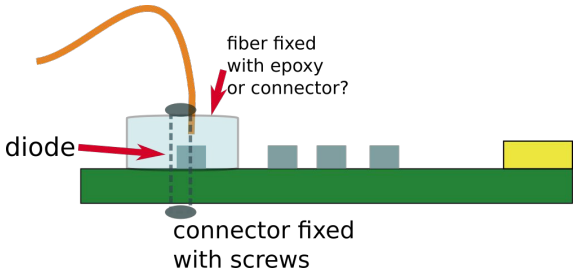
OPV314YAT: 850 nm, 1.4mW
VCSEL with ST connector

Considering LED testing:

- lower power and faster turn-on
- DarkSide reported issues with non-linearities when in cold,
- which are a bit unpredictable (batch/handling dependant)
- investigate possibility to find non-kink LEDs to test or
- use calibration to circumvent non-linearities

Emitter design idea

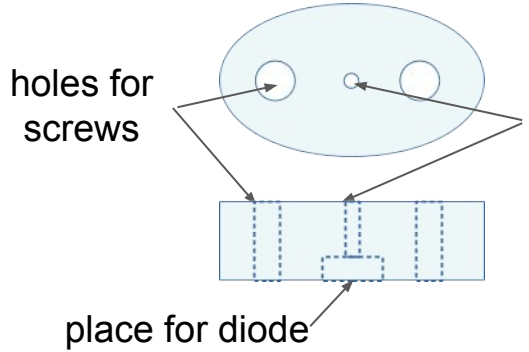




DarkSide transmitter

Idea for connector:

based on info from DarkSide



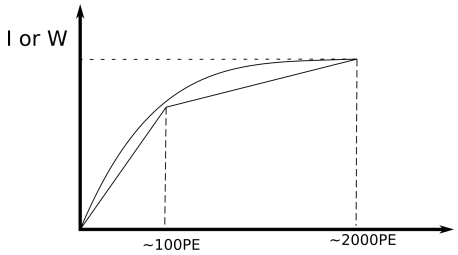
- in aluminium
- first "hand-made" prototype soon
- then properly machined at the lab's workshop
- fiber held in place by epoxy
- investigate if it would be possible to have additional screws for adjusting the fiber position

Design of an in-house cryo laser driver

Target:

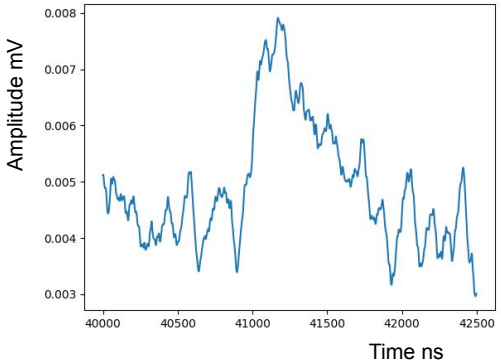
- keep S/N from ganged SiPMs in ARAPUCA modules
- transmit rise time →50 MHz?
- Dynamic Range:
  - 1 SPE
  - max signal ~2k*SPE

→ non-linear mapping



Filtering:
DC: >1Hz,
HF noise:<?? Hz

Example input signal: Ganged Hamamatsu SiPMs
(file from Maura/Andrea)



- SiPMs in LN_2
- SPE seems to be an 8mV signal
- with 1μs duration
- and S/N ratio ~3.
- 100 ns rise time (?)

Test input signal:
Function generator (50 Ω)
SPE: ~10mVpp,
rise time: 20ns
fall time: 100 ns
max signal: 2 Vpp, ~µs long
~4 S/N?

Design of an in-house cryo laser driver

Starting with the choice of the components of a standard current source:

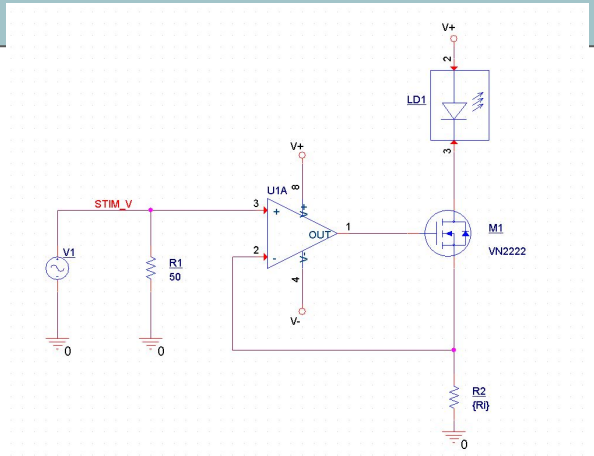
- that fit our speed requirement (~50 MHz)
- that have chances of working in cold

From experts in our lab:

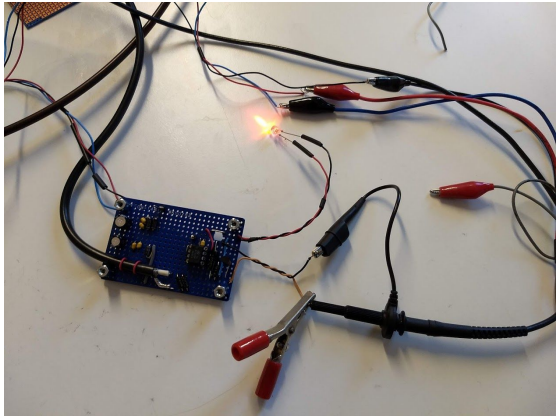
- **Bipolar** components
  - in silicium → loose gain in cold
  - in **SiGe** could work (difficulty: finding this info in specs)
    opamps: LMH6629 (DarkSide), LTC6252
    transistor: BFP640
- **MOSFETs** should all work since they are CMOS
- **JFETs**: tested in cold (next slide) but fabrication dispersion is high

→ will be testing some components that we already have at the lab

- **HEMTs:** often used at low temperatures (~few K), many possibilities available, also possibly at the needed speed but more expensive
  - GaAs, and other 3-5 components



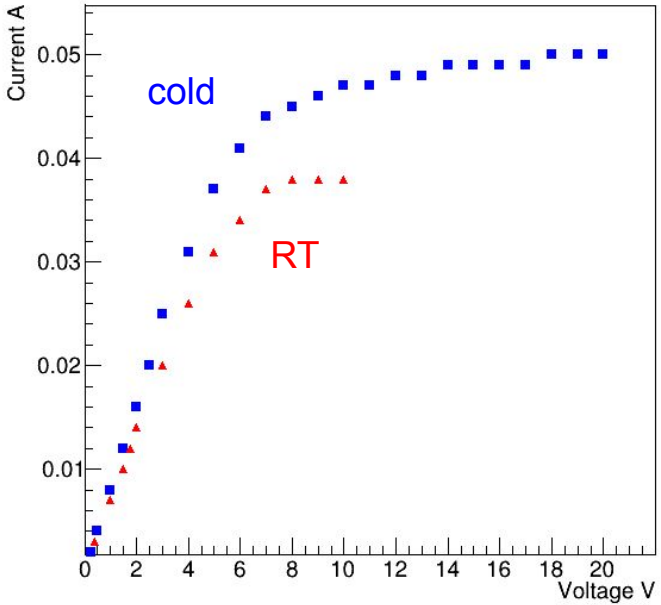
Basic current source for RT tests

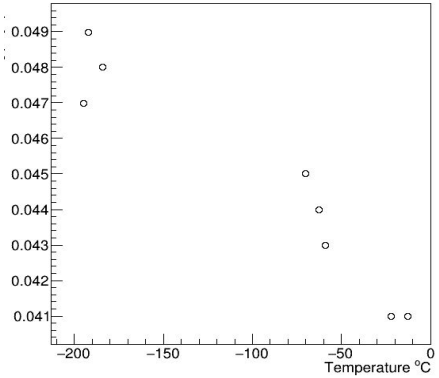


First cold test of current limiter

Circuit with a JFET transistor:

- survived multiple temperature cycles
- not too carefully handled (and it still worked)
- current only slightly higher





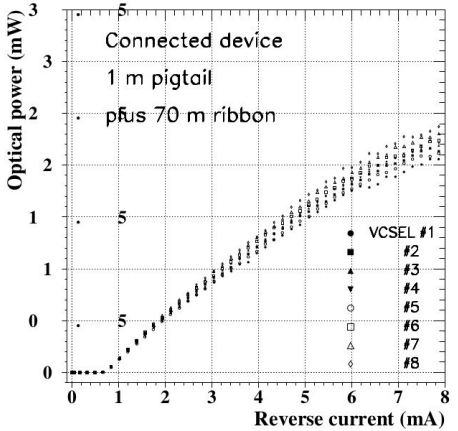
Current change with temperature:
(temperature control is a bit hard)

Receiver

- We might have tens of μW to few mW of optical power at receiver end, according to ATLAS papers
- example: S5972 Hamamatsu pin diode
  - 1GHz max speed
  - 0.1 nA max dark current
  - ~0.5 A/W @ 800 nm
  - for 10 μW signal (assuming acceptable S/N ratio at emmitter)

    → 5μA is safely larger than receiver noise

(but optimal for λ~800nm)



Upcoming activities

Near Future:

- Next 2 weeks:
  - choice of single components
  - individual tests in LN_2
- In ~1 week first full circuit board to test (first at RT and then in LN_2)
- In parallel, during the next few weeks, diode characterization and test of connector concept

Planning ahead:

- Should have a full transmitter-receiver chain to test in cold in.. mid May
  → seems unlikely to have the necessary information for integration in time
  → will try to adjust as requirements/constraints are set
- Bottleneck: we estimate we'd need ~3 weeks per prototype iteration
  (test + design change + fabrication)
- 3rd week of June: deadline for almost final prototype, allows one more iteration before September installation

Our minimum expectations:

- Current drivercomponents : LDO, opamp,transisor
  - input handling: a func generator: 20-100ns full signal rise time? s/n~4, 50 ohms
  - fast enough (50 Mhz?)
  - doesn't die in LAr (capable of turning on and off)
  - doesn't kill my laser
- Optics:
  - choice between 850nm or 1310nm/1500nm?
  - laser-fiber coupling that doesn't break and yields enough light towards receiver end
  - fiber that performs well in cold
  - receiver with decent fiber coupling
- readout: a scope? / our ADC card?