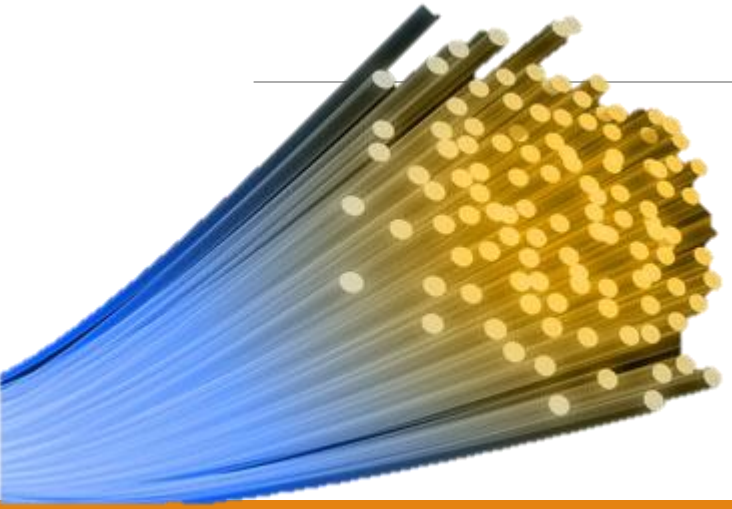
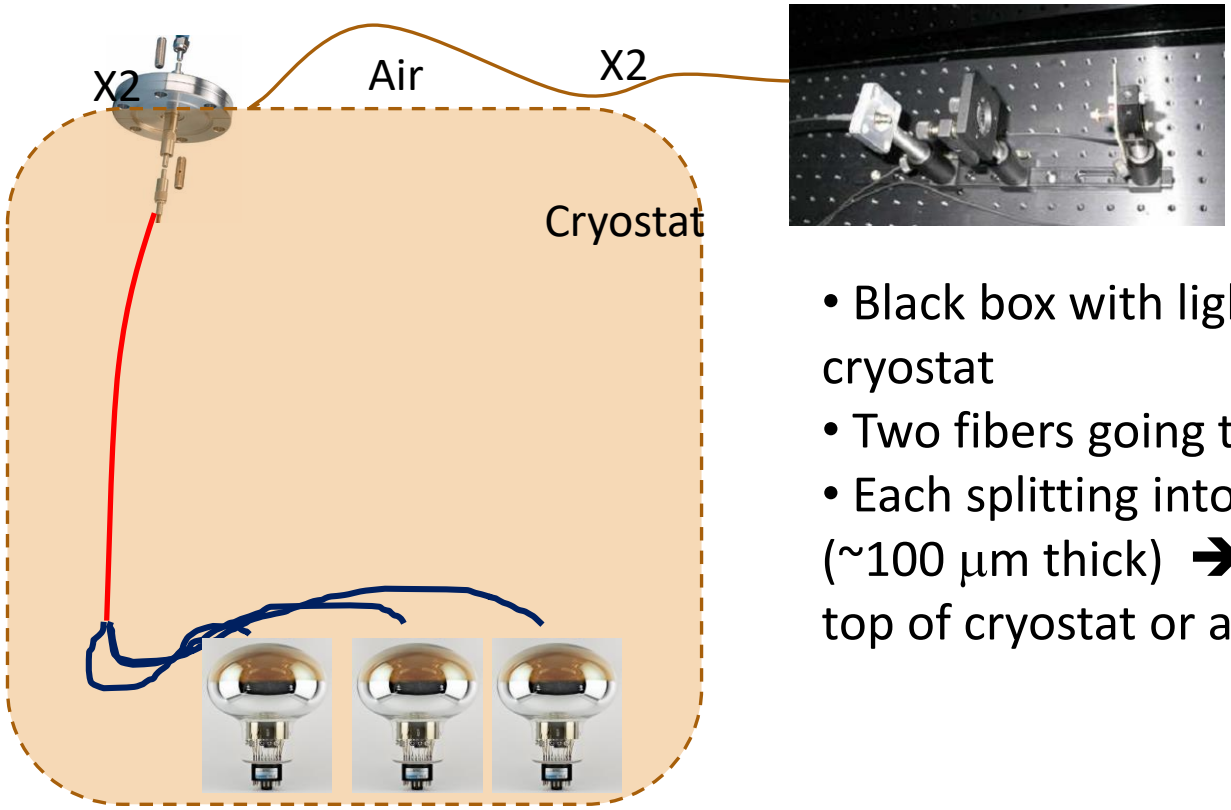
Light Calibration System



WA105

Light Monitor System. First Approach



- Black box with light source outside of cryostat
- Two fibers going to cryostat
- Each splitting into 20 micro fibers (~100 μm thick) ➔Either directly on top of cryostat or at bottom of cryostat

Light Monitor System. Issues to be solved

Light Source:

- Deliver Enough Power.
- Scalability.
- Security requirements. Laser ➔ Different Room and long distance from detector

Fiber System:

- Minimize Attenuation.
- Minimum dispersion values between fibers➔ Measure values.
- PMT receive enough light and each one has enough light range.
- Make it as easy to manipulate and connect as possible.

Studying different light sources

Studying different bundles. Different configuration and different connectors.

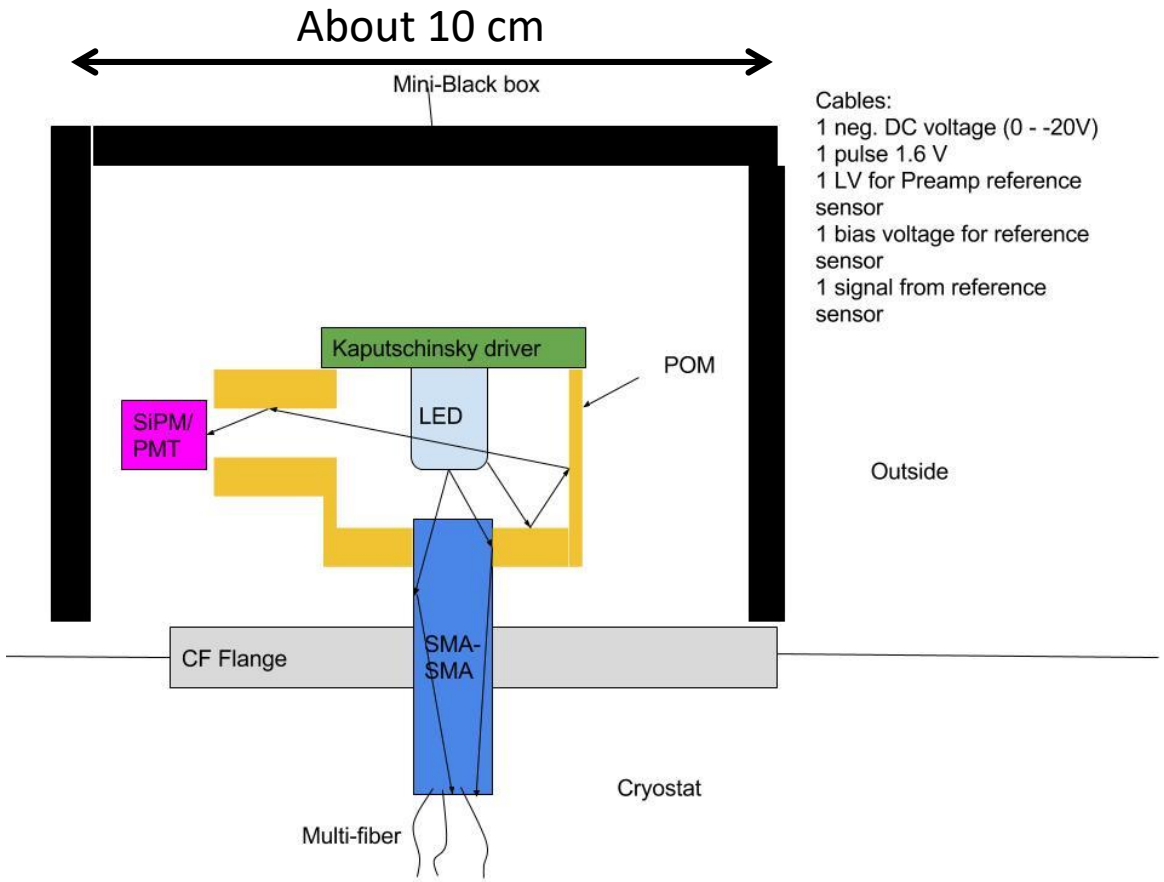
Fiber Connector Tests in Liquid Nitrogen

PicoQuant D-C-405M Laser
Power Meter Ophir PD300UV

SMA to SMA mating sleeve: 1.5dB Loss @ Room Temperature. Measured 4dB loss in LiN respect Room Temperature Values. SMA Vacuum connectors ordered for testing.
FC/PC to FC/PC: 0.5 dB @ Room Temperature. In LiN both mating sleeve and fiber connector survived. Measured 0.5 dB loss in LiN respect Room Temperature Values

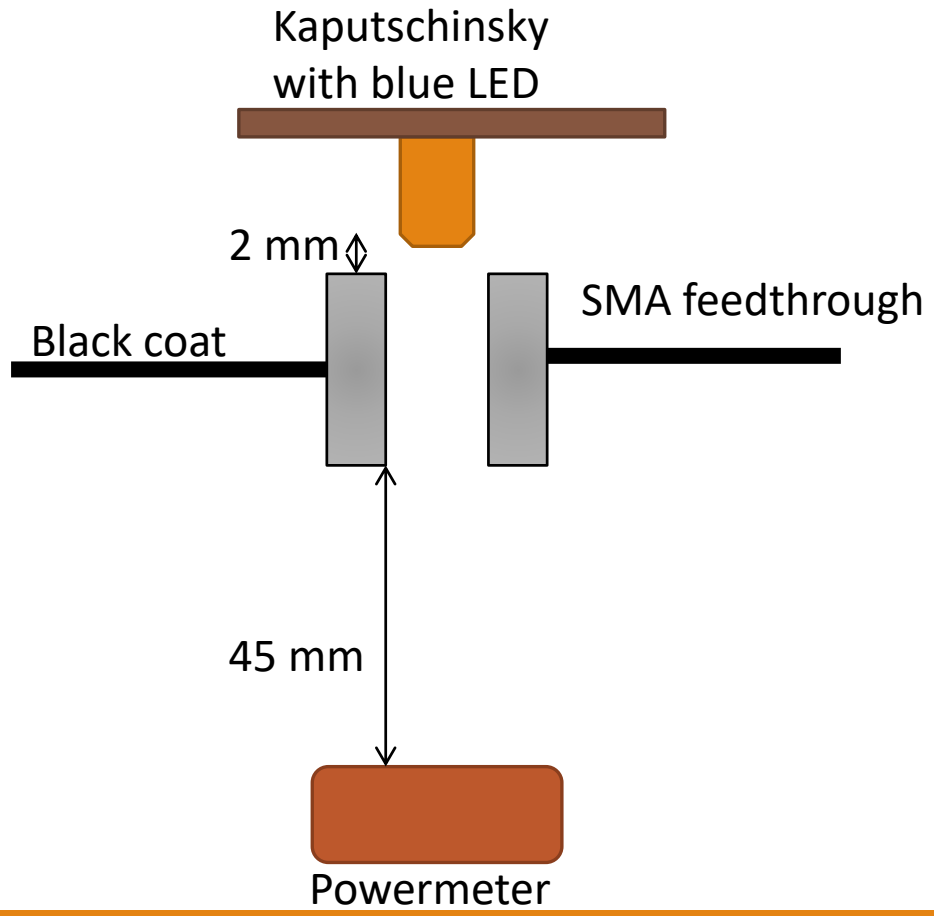
FC/PC aperture much smaller

Light Source. Alternative Idea



Put LED with Kaputschinsky driver directly in front of SMA feedthrough to shine on fibers inside the cryostat

Alternative Idea. First Tests without Fiber



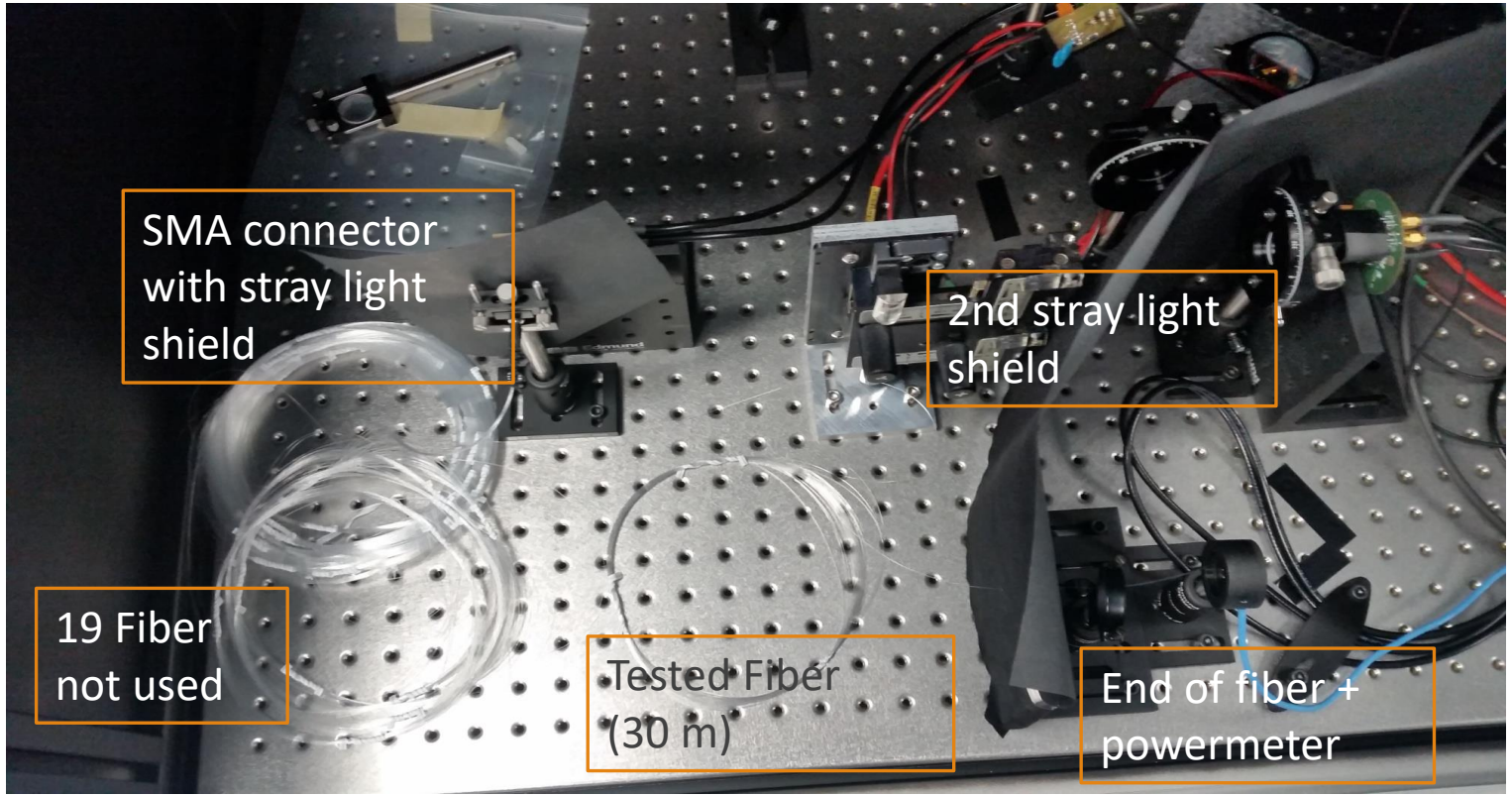
Measured power released with Kaputschinsky

- Result: 11.5 nW
- Amazing result: E(465 nm)=430*10**-21 J => 11.5 nW correspond to 27 billion photons
- 1 kHz pulsing => each pulse 27 million photons which will directly go to fiber bundle

Advantages of this approach:

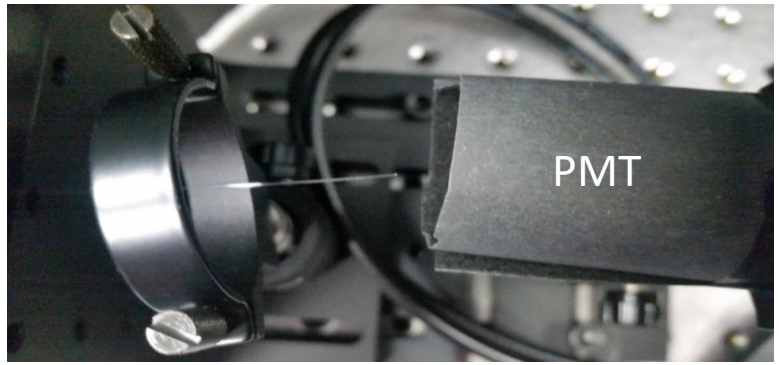
- much cheaper than laser approach
- no safety issues at CERN
- Scalability

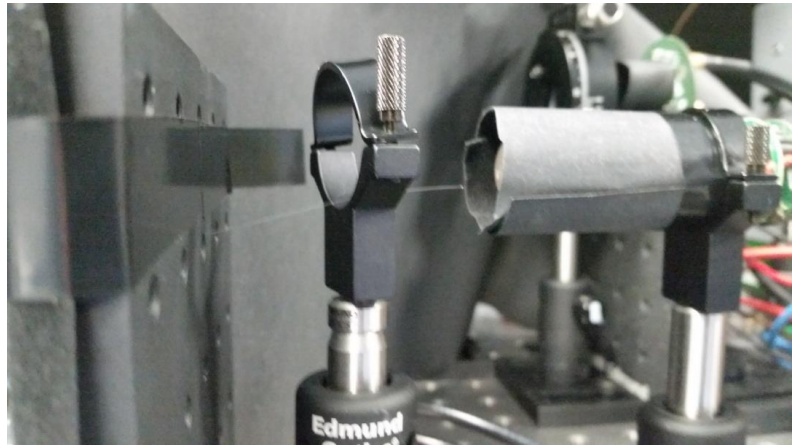
Alternative Idea. Tests with Fiber and Powermeter



- Measured power should correspond to about 30.000 photons per pulse (10 ns) assuming 0.01 nW
- reduction by factor 1000 compared to direct pulsing without fiber
- Seems Still a factor 100 reduction possible and needed to get photon range of 0 to about 250 photons per pulse

Alternative Idea. Tests with Fiber and PMT





- PMT sees clearly the light from the end of the fiber
- Single photons at around 6.9 V bias voltage on the LED
- With powermeter was necessary to go to 18 V to get a signal
- Signal at 18 V smaller than expected, probably of the order of 1000 pe
    - electronic effect?
    - difference in Qeff powermeter and PMT?
    - mistake and photon estimation?
    - mis-calibration of powermeter?
- delay of 220 ns between trigger and PMT pulse expected (60-80 ns delay without 30 m fiber and fiber should add roughly “100 ns * n” from the refractive index of the fiber
- pulse width at end of fiber around 12 ns

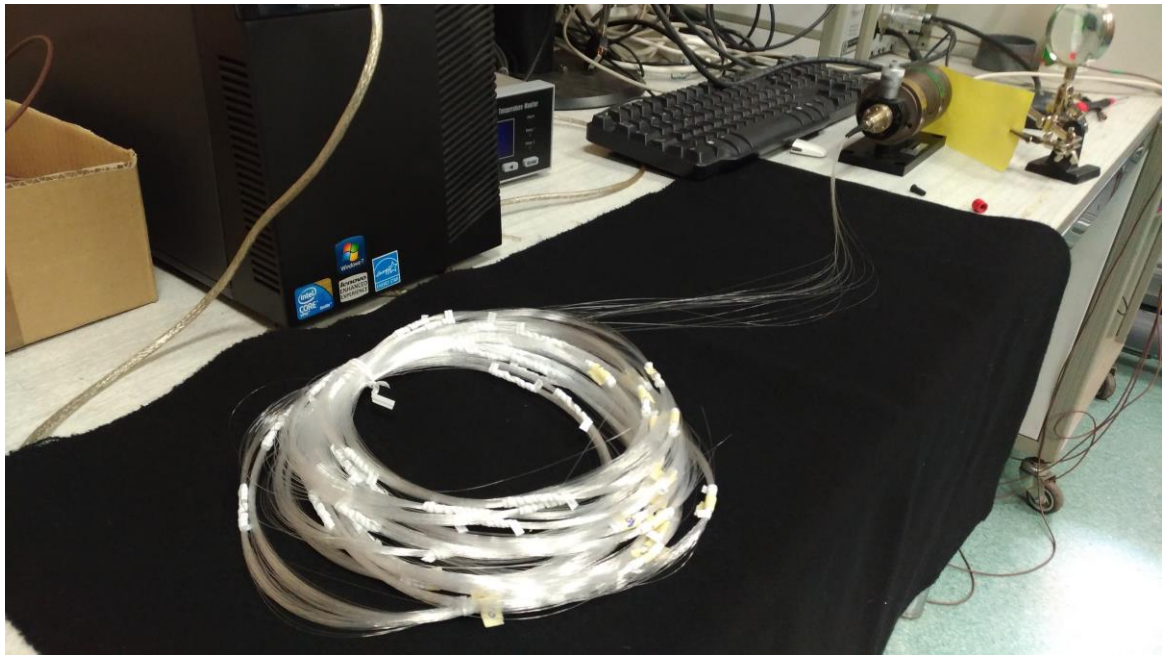
Light Source. Alternative Idea. First conclusions.

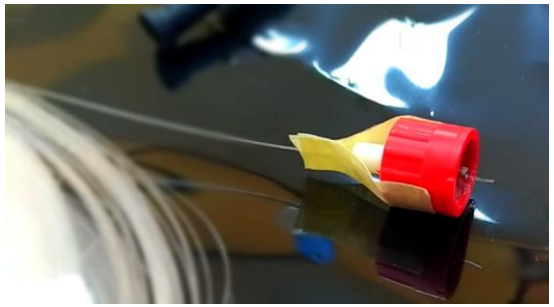
- Preliminary test results give hope => clear signal after coupling of LED directly to SMA connector with fiber bundle and 30 m of light path in fiber
- Observed signal at 18 to 20 V bias voltage lower than expected but many possible explanations
- Alternative idea seem to be possible (and probably better scalable for a DUNE far detector with at least 1000 PMTs which possibly could increase to 2000 to 4000 PMTs at the end)
- Does not mean laser approach is dead, missing pieces for tests should arrive soon and then tests with laser will be done, hopefully in Semana Santa but do not expect miracles in amount of light gain
- Also improvements with LED possible: better geometry coupling, more luminous LED, …
- For both approaches many tests to be done equally:

  Light distribution over fibers?
  Larger/smaller loses in liquid N2?
  Adding 10 m (?) SMA-SMA fiber from top to bottom of cryostat and shortening fine fibers?
  Reflective shielding of fibers or bare fibers?

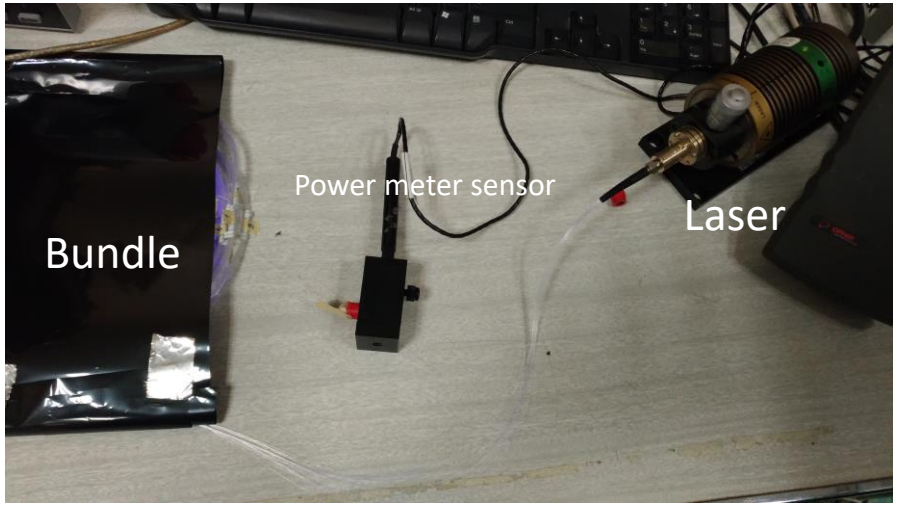
Fiber Bundle Test @ CIEMAT. Setup

20 Naked fibers bundle. SMA Connector, no termination.





Custom made
FC/PC connector



Measuring Setup

Fiber Bundle Test. Results

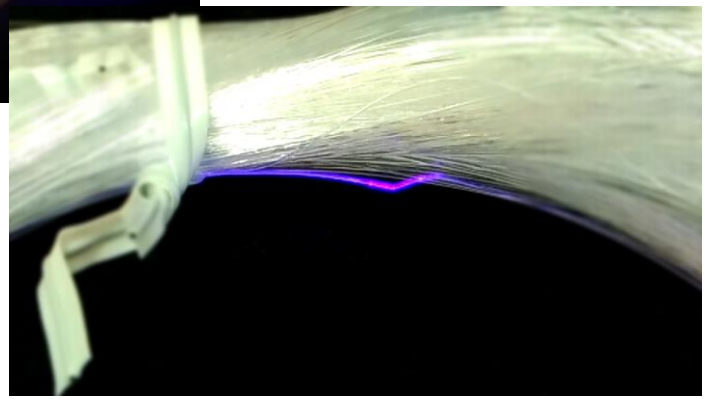
Fiber	Measured Power	Attenuation	Attenuation
	nW		dB
1	1.1787	5.21E-08	-72.83
2	4.13	1.83E-07	-67.38
3	4.19	1.85E-07	-67.32
4	2.045	9.04E-08	-70.44
5	127.44	5.64E-06	-52.49
6	577.94	2.56E-05	-45.92
7	0.983	4.35E-08	-73.62
8	429.94	1.90E-05	-47.21
9	929.94	4.11E-05	-43.86
10	649.94	2.87E-05	-45.41
11	245.94	1.09E-05	-49.63
12	187.44	8.29E-06	-50.81
13	5.6	2.48E-07	-66.06
14	249.94	1.11E-05	-49.56
15	5.43	2.40E-07	-66.20
16	0.605	2.68E-08	-75.73
17	3.01	1.33E-07	-68.76
18	0.283	1.25E-08	-79.03
19	115.14	5.09E-06	-52.93
20	0.62	2.74E-08	-75.62

$$Att = {}^{P_{out}}/_{P_{in}}$$

Laser gives us 22.61mW being pulsed at 80MHz with a Duty Cycle of 66.6.%

Three orders of magnitude from one fiber to another

Fibers extremely delicate.
Connector not uniformly built
Laser opening oval shape



- IFAE obtained 1000 attenuation while at CIEMAT , even in the best case, are of the order of 100.000. ➔ Only measured one fiber with different wavelength.