First Measurements with a Scintillating Fiber Microdosimeter

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Why make a scintillating fiber microdosimeter?

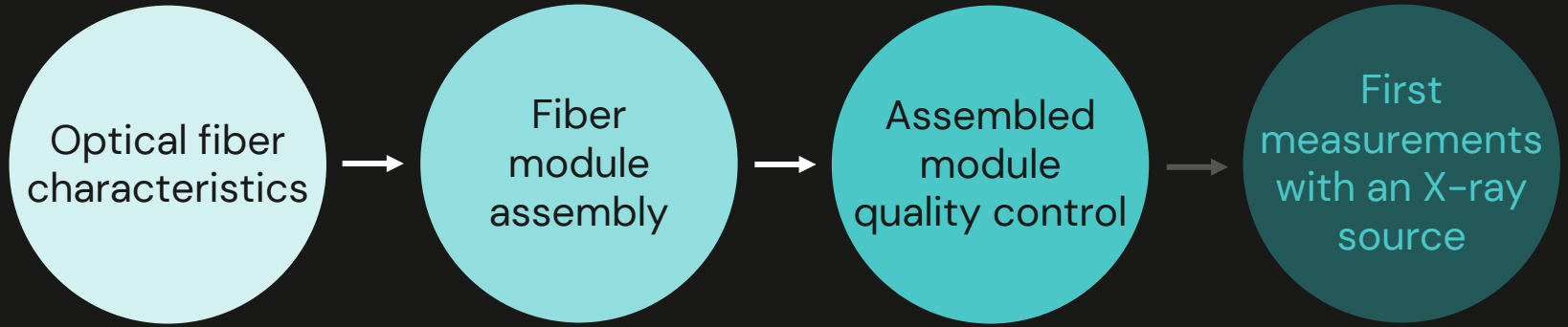
Dosimeter: device that measures the dose (1 Gy = 1 J/kg) of ionizing radiation.

Short term goal: Testing in irradiation facilities

Long term goal: To study the effect of ionizing radiation on living cells

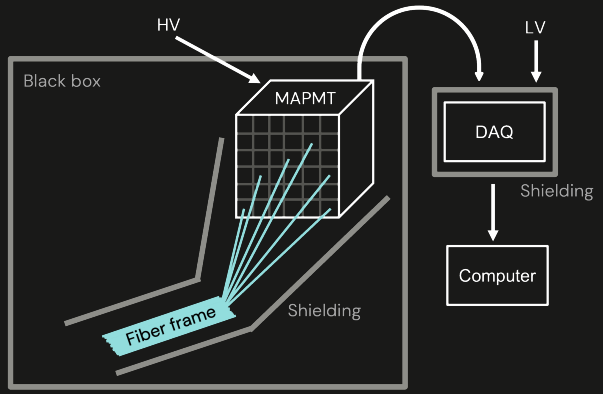
We need a dose distribution map at a submillimeter scale

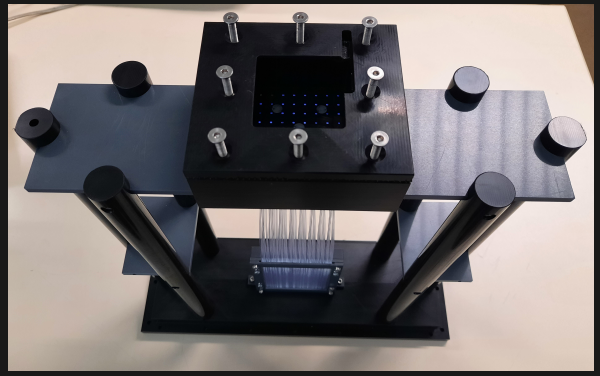
In this internship...



The dosimeter

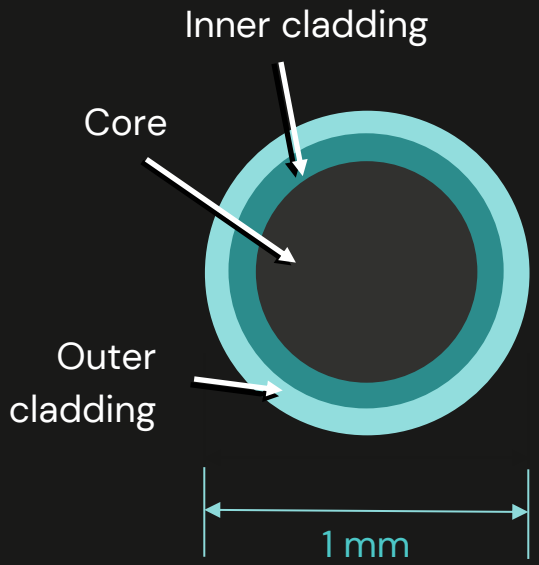
- 64 scintillating aligned top-end aluminized fibers
- 8x8 channels MAPMT H8500
- POM and PVC rigid and light-tight structure
- HV source
- DAQ system





Plastic scintillating fibers

Kuraray SCSF-78



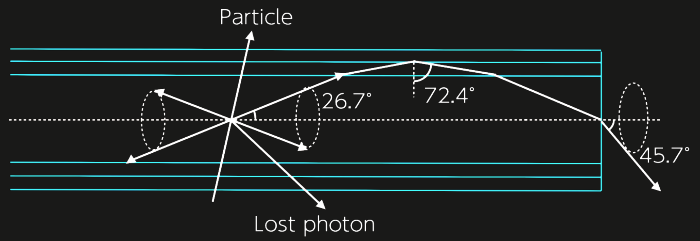
	Material	Density (g/cm^3)	Refractive index	Atoms
Core	Polystyrene (PS)	1.05	n_o = 1.59	C, H
Inner cladding	Polymethylmethacrylate (PMMA)	1.19	n_o = 1.49	C, H, O
Outer cladding	Fluorinated polymer (FP)	1.43	n_o = 1.42	

tissue equivalence

Plastic scintillating fibers

Kuraray SCSF-78

Total internal reflection

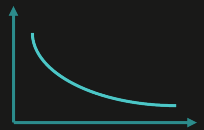


Main fiber characteristics

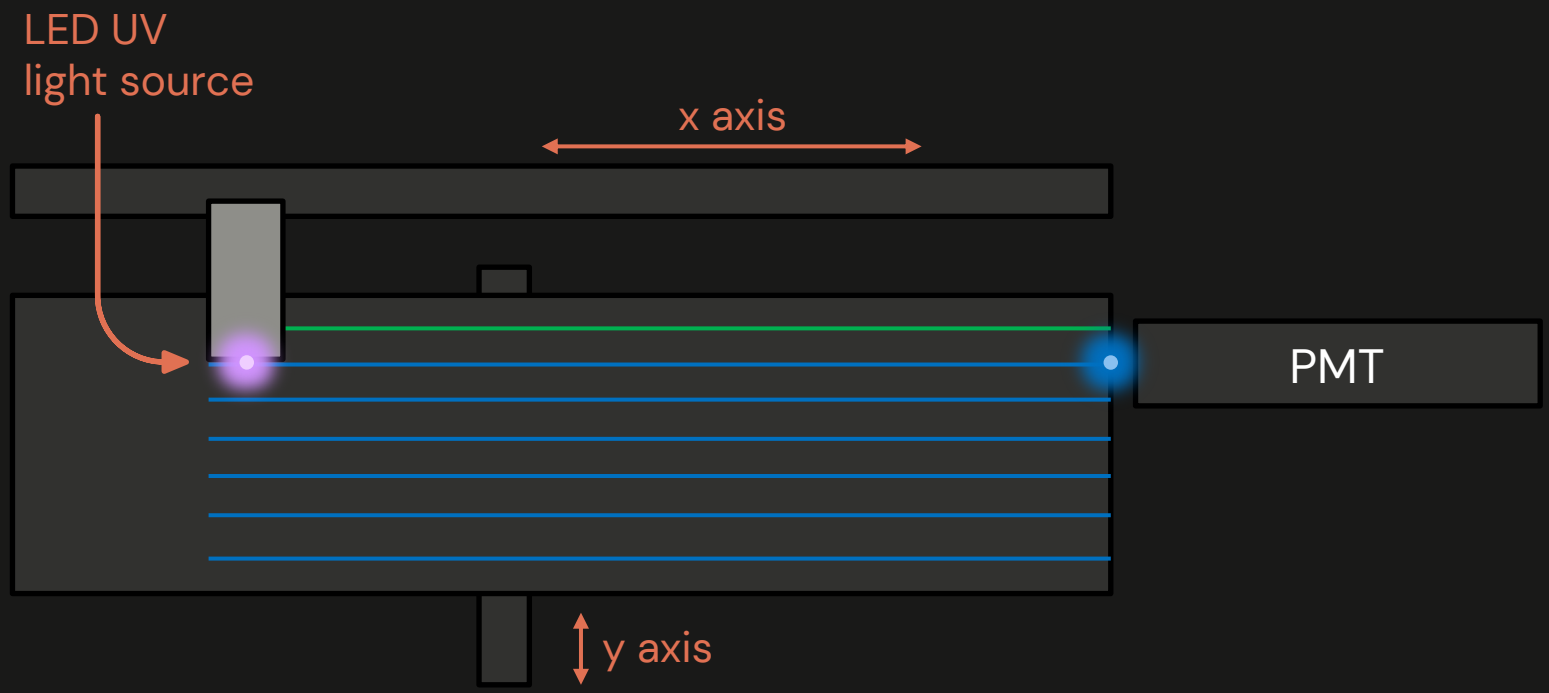
Light yield

Aluminum mirror reflectivity

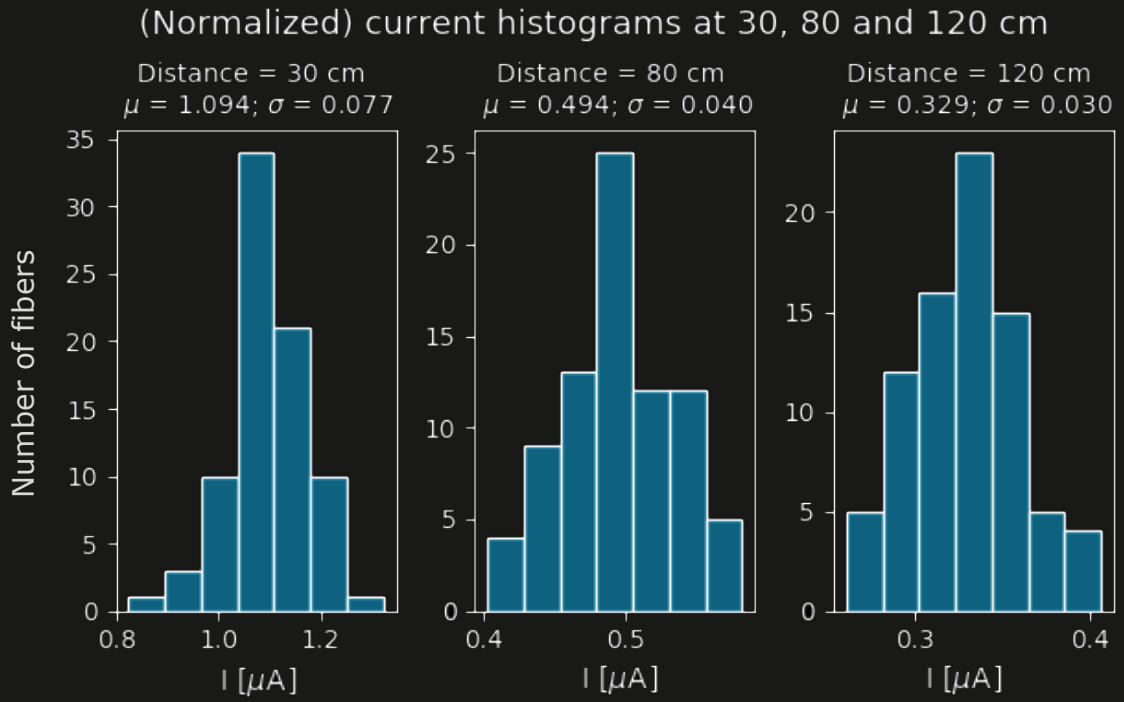
Attenuation length



Fibrometer



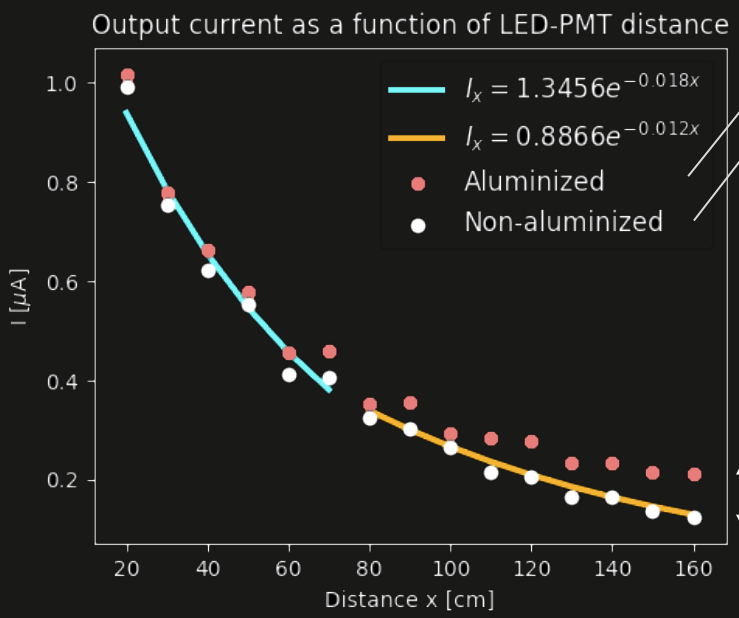
Light yield – aluminized



Sample size: 64 aluminized fibers.

The graphs on the left are 3 out of 15 LED-PMT distances covered (20 to 160 cm, with a 10 cm step)

Attenuation length and mirror reflectivity



70% gain

$L_{at_1} = (56.65 \pm 3.21)$ cm; $L_{at_2} = (119.50 \pm 7.56)$ cm

$L_{at_1} = (54.16 \pm 0.77)$ cm; $L_{at_2} = (79.35 \pm 1.47)$ cm

$$I_x = I_0 \times e^{-x/L_{at}} + I_0 \times e^{-(L-x)/L_{at}} \times \mathbf{R} \times e^{-L/L_{at}}$$

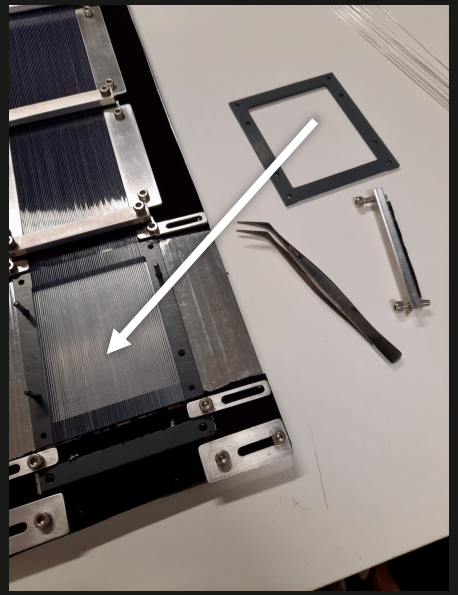
Reflectivity

$$R = \left(\frac{I^{al}}{I^{nal}} - 1\right) \times e^{\frac{2(L-x)}{L_{at}}}$$

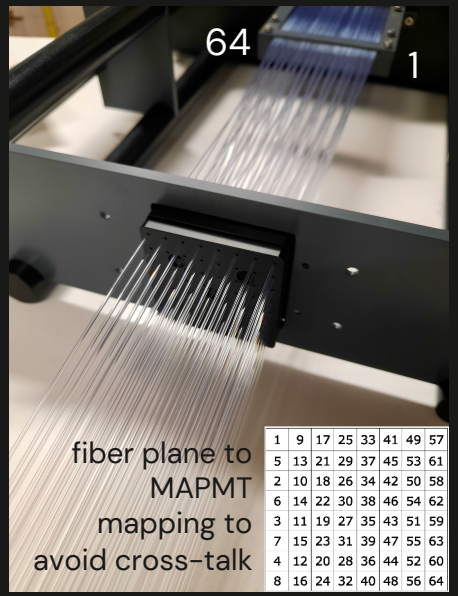
$$I^{al} = I_x;\ I^{nal} = I_0 \times e^{-\frac{x}{L_{at}}}$$

Fiber module assembly

Aligning the fibers and gluing the frame with cyanoacrylate



Putting the fibers in their connector hole

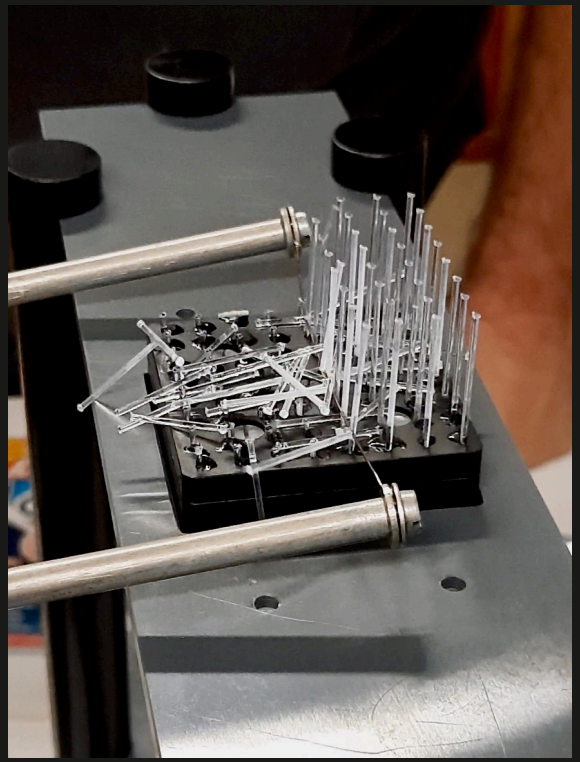


fiber plane to MAPMT mapping to avoid cross-talk

1	9	17	25	33	41	49	57
5	13	21	29	37	45	53	61
2	10	18	26	34	42	50	58
6	14	22	30	38	46	54	62
3	11	19	27	35	43	51	59
7	15	23	31	39	47	55	63
4	12	20	28	36	44	52	60
8	16	24	32	40	48	56	64

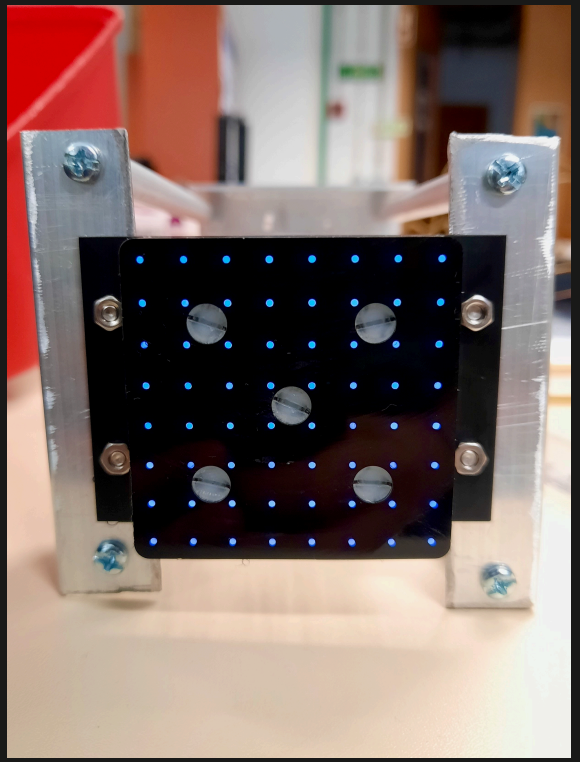
Trimming the excess and gluing the fibers

Trimming the excess with a hot copper wire

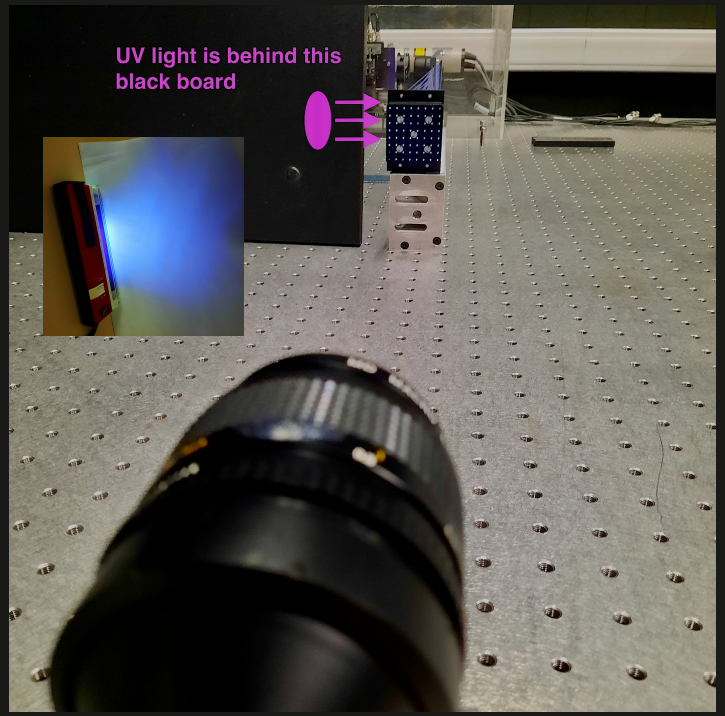


Polishing the surface at LIP

View of the surface



Quality control of the assembled module



UV lamp placed at 3 different distances:
d = 10, 25 and 45 cm.

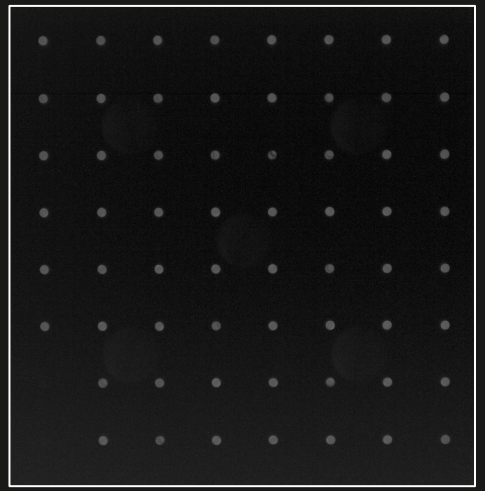
At each distance:

1. 10 photographs taken with the UV light on.
2. 5 photographs taken with the UV light off.
3. Image processing in ImageJ

Acknowledgments to the colleagues at IA/FCUL

Image processing in ImageJ

Average of 10, UV light on



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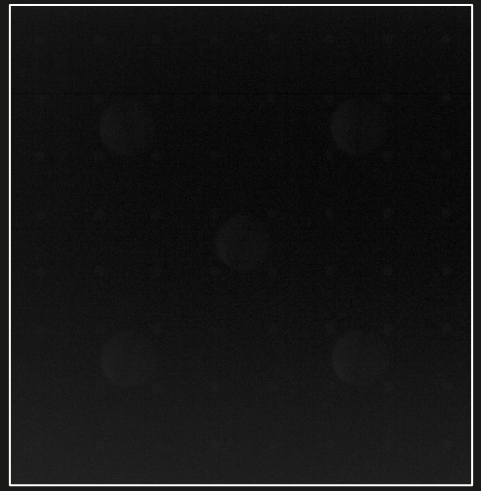
Average of 5, UV light off



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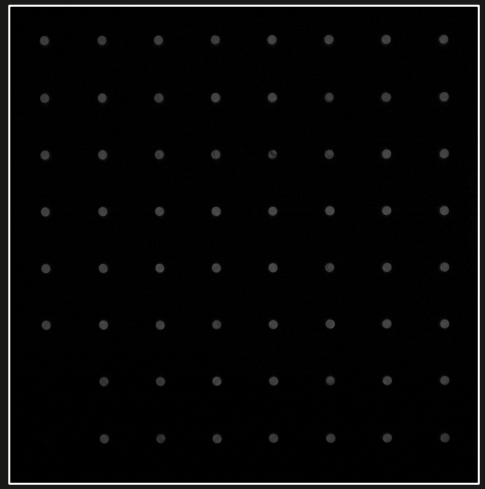
Result



Relative intensity (%) tables

d = 10 cm

72	72	75	74	81	80	75	78
76	84	81	95	89	78	78	84
88	94	86	94	64	94	99	98
98	107	103	114	108	120	108	110
107	108	113	116	117	107	109	118
108	120	113	110	120	130	124	129
5	113	113	130	127	117	127	129
9	119	103	124	121	128	124	106

d = 25 cm

97	93	101	98	112	109	111	110
93	100	98	110	115	95	106	103
100	107	99	102	74	102	115	111
100	106	107	115	116	123	121	119
100	100	112	107	114	99	109	110
96	106	99	95	110	112	113	115
5	89	90	104	101	88	105	103
3	91	81	96	95	98	99	89

Average value = 100%

d = 45 cm

100	94	104	94	113	109	110	108
94	102	102	112	113	96	103	105
98	103	97	107	76	99	115	119
96	106	106	118	118	124	119	116
103	94	108	106	114	97	107	110
97	102	100	94	109	112	111	118
5	90	91	109	100	88	108	107
5	89	77	95	92	100	99	90

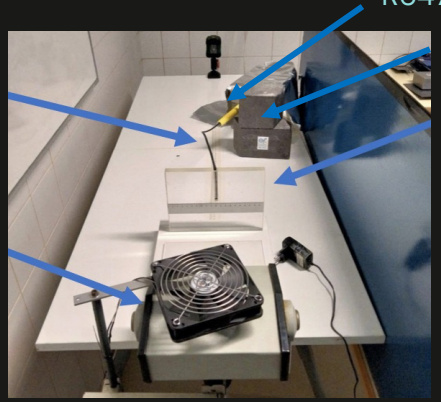
2 broken fibers

For d=25 and d=45 the tables are similar, showing result consistency. This is probably due to the light field being more uniform than at 10 cm.

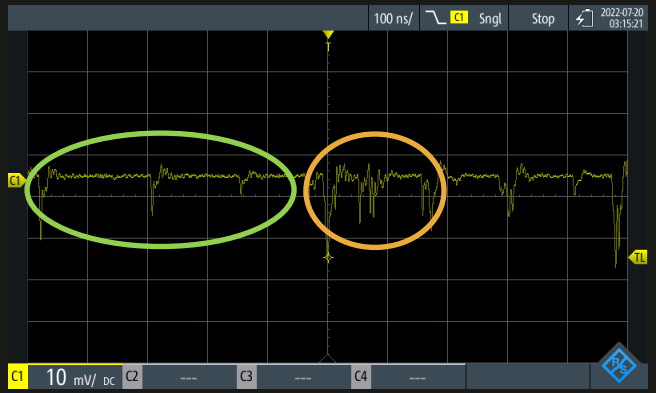
Preliminary measurements

It was not possible to have the full readout chain ready for the internship.

Preliminary measurements were made to evaluate the characteristic rate of an x-ray source available at FCUL.



Many pulses appearing well separated in time > 100 ns



Higher rates sometimes appear → difficult to measure different pulses → DAQ board requires ~100 ns separation between pulses

Summary and future improvements

- This dosimeter is being developed to get a dose distribution map at a submillimeter scale
- 3 main fiber characteristics for a scintillator microdosimeter: light yield, attenuation length and reflectivity of the aluminum mirror
- Quality control of assembled module (optics):
    - Channel intensities have an upper variation of 23% and lower of 25%
    - Gain adjustments at DAQ for each channel

Future improvements

- Smaller fibers (less than 1 mm diameter) → better resolution
- Overlapped fibers → less dead space due to cladding thickness
- A second set of fibers, perpendicular to the first → 2D distribution map
- A more rigorous quality control procedure

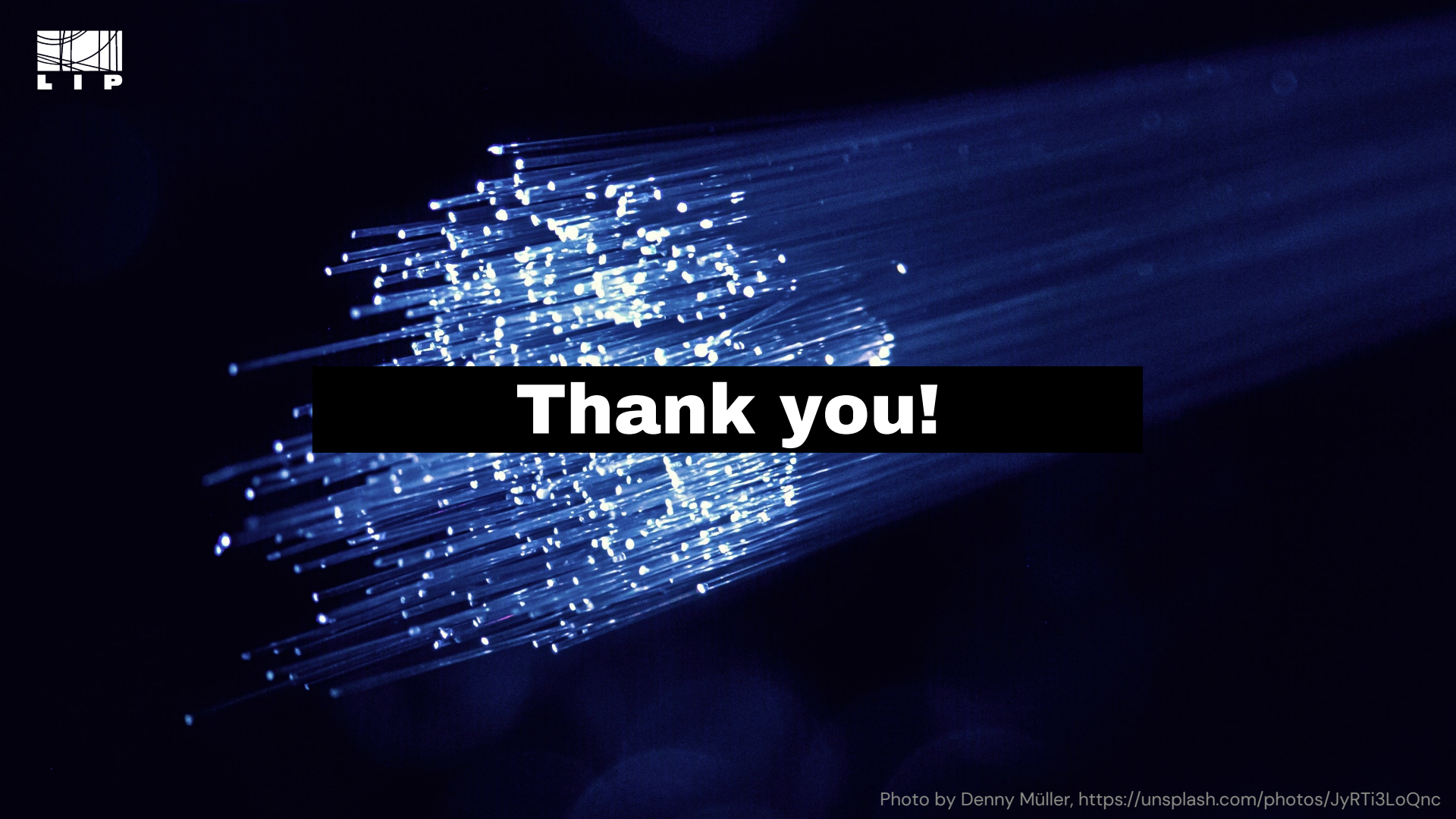


Photo by Denny Müller, https://unsplash.com/photos/JyRTi3LoQnc