Beam imaging system with radiation tolerant fibre bundle

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Introduction

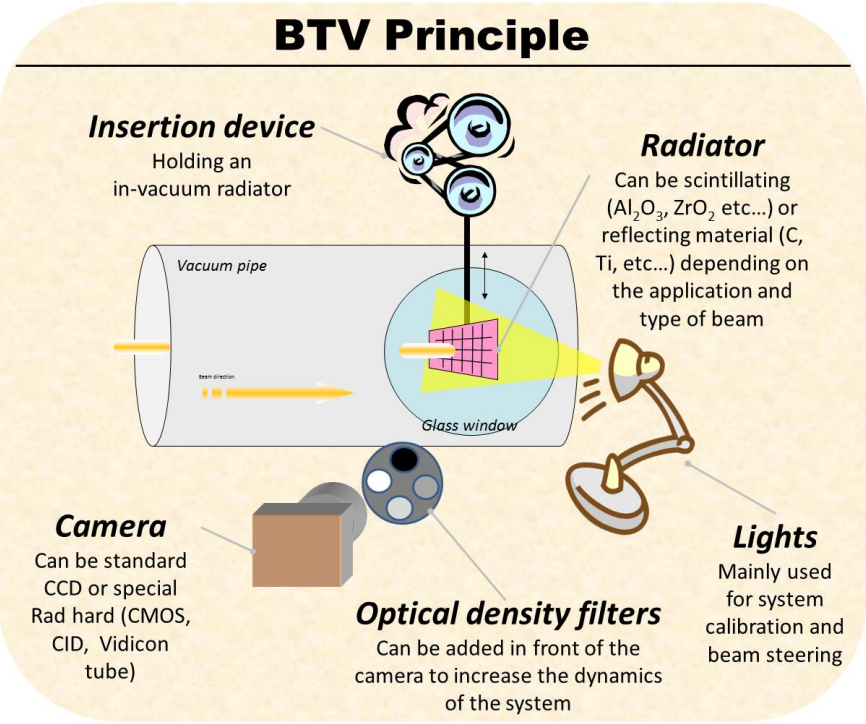
Beam profile imaging nowadays: BTV – VIDICON tube cameras

Advantages:

1. Most Rad Hard so far…
2. No active components inside.

Drawbacks:

1. Limited life.
2. Limited sensitivity (observation instruments).
3. Issues of procurement (no production since > 5years, still ≈100 pieces in stock).

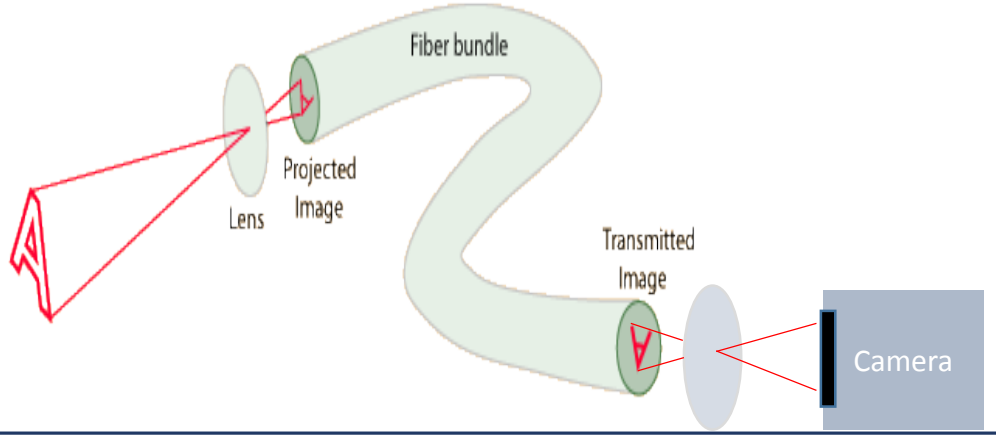


Beam profile imaging upgrade: imaging fiber system

Principle: Transport an image away from a high radiation level area up to the camera located in a 'safer' place.

Advantages: Increased life time.

Procurement of 2x2m and 2x10m long/bunch of 10k fibers.



Summary

- Introduction
- Optical characterization setup
- Radiation hardness tests on fibre @ IRMA
- Beam imaging test @ TT2
- Conclusions

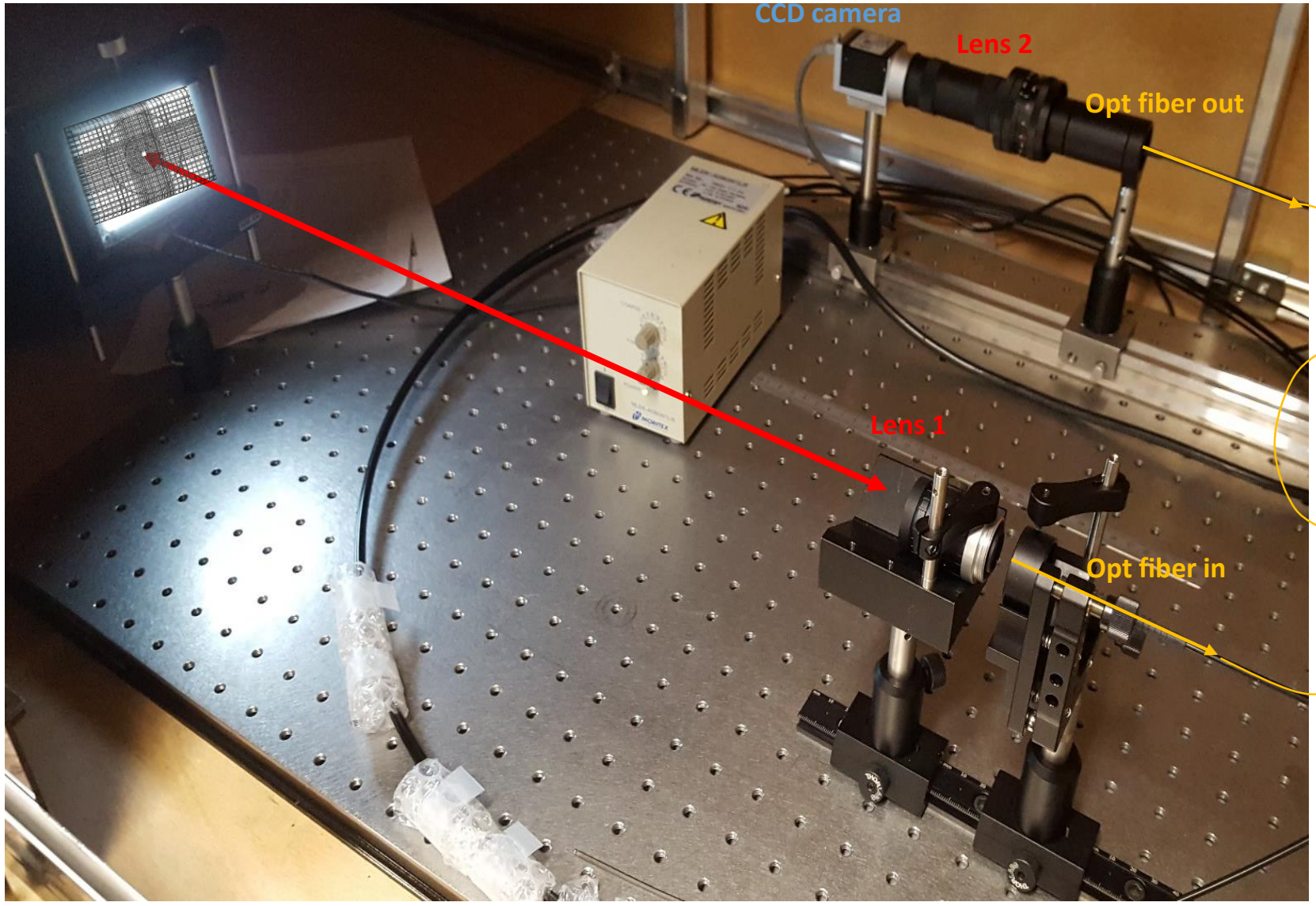
Beam profile imaging with optical fiber bundle

Fiber bundle choice:

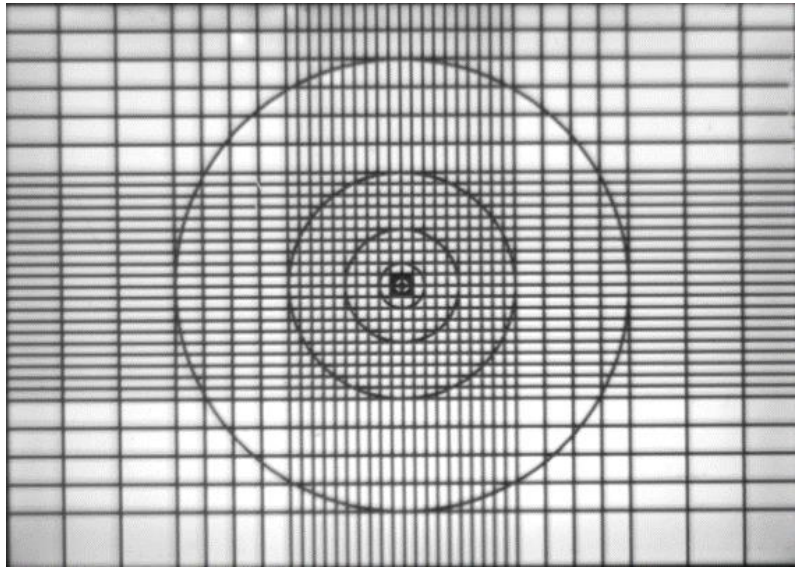
- 10m Fujikura RadHard FIGR10 – 10k fibers in 1.5mm diameter.

Lens choice:

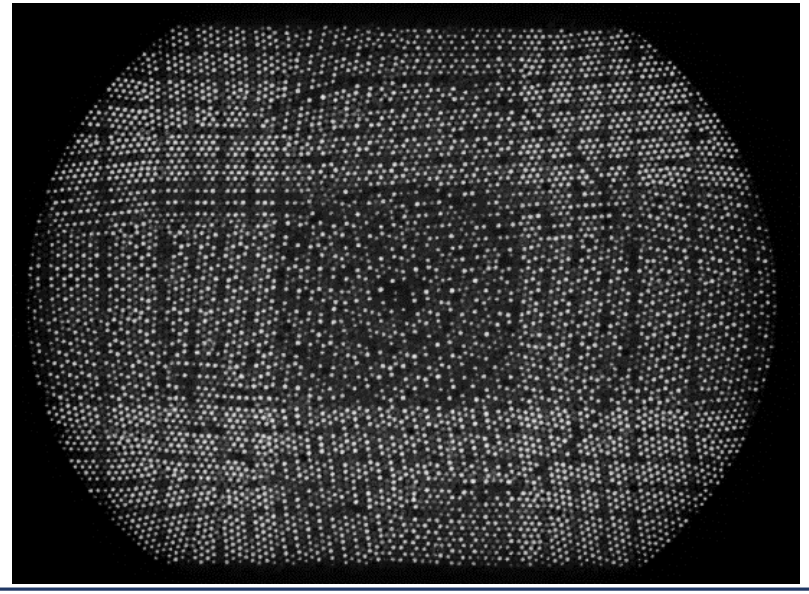
- 9mm lens to focus a 65mm diameter circular area @ 500mm into the fiber bundle.
- 25 or 50mm lens to magnify the image on the camera sensor



Optical characterization results



Reference image:
Target @ 500mm
Texp = 20ms
Cam + Lens 25mm



Acquired image:
Target @500mm
texp=20ms
1st lens 9mm
10k fiber bundle
2nd lens 25mm

Analysis	Results
Light loss due to 2nd lens	From 100% to 26.2%
Light loss due to Fujikura fiber interfaces	From 26% to 2.9%
Light attenuation in fibers	0.65 dB/km
Contrast loss due to fibers with 9mm lens	From 34% to 16%

Advantage:

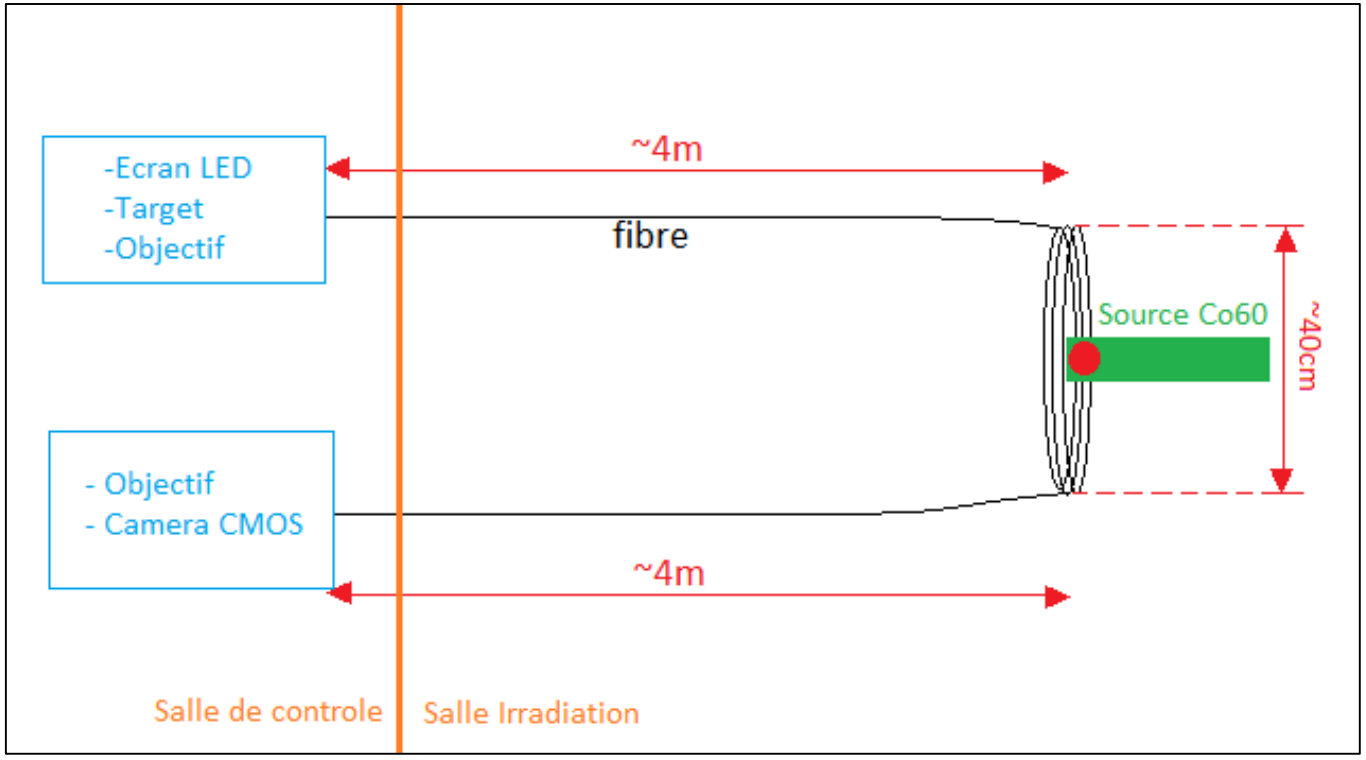
- Digital cameras allow many options (exposure time, etc..) that can significantly compensate optical losses.

Fibre radiation hardness: intro

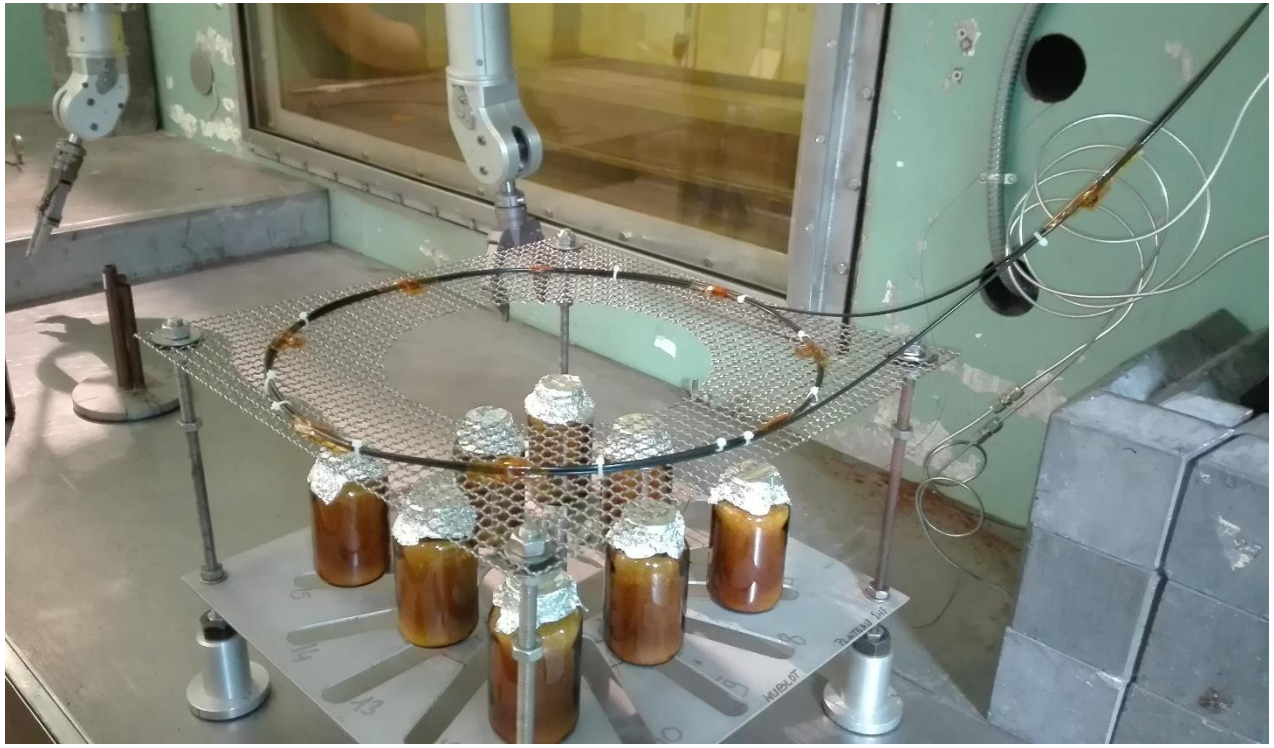
Simulating 10 years of operation of fiber bundle
Choice of gamma radiation and 10m bundle
On-line results to monitor behaviour

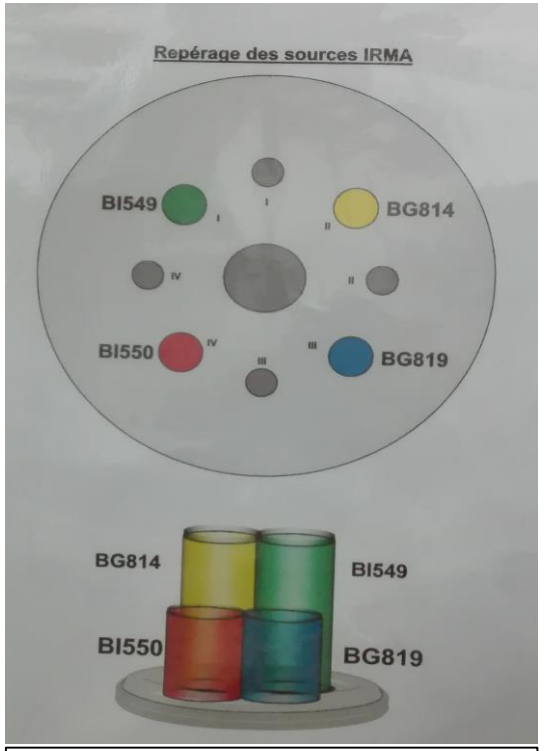
Isotropic ^{60}Co source facility
Dose rate to reach at least 500 kGy total dose
Reasonable measurement time (days/month)
Reasonable cost

IRMA facility at CEA Saclay



Fibre radiation hardness: IRMA setup

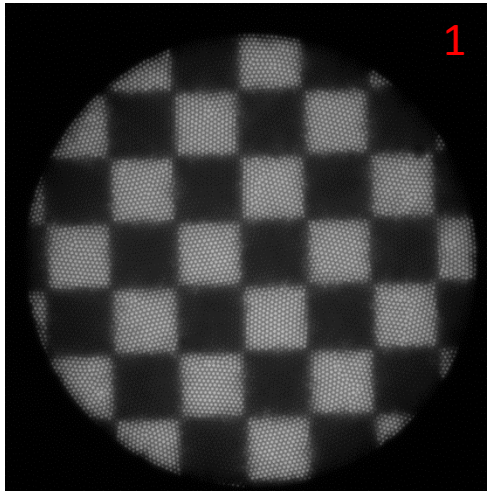


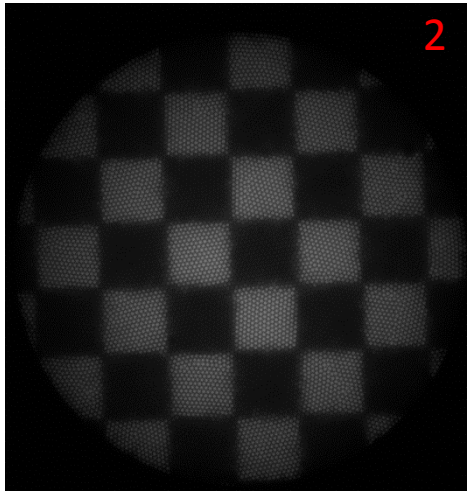


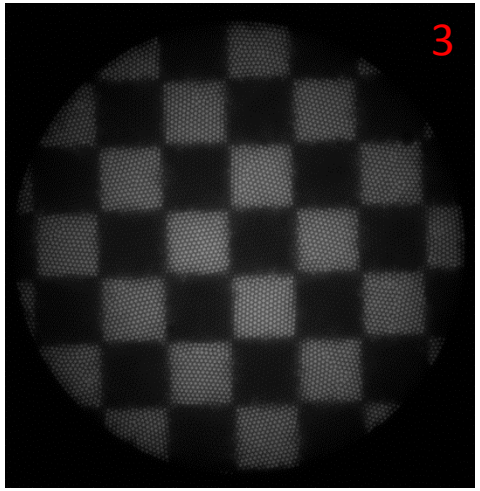
Date/Time	Integrated Dose [Gy]
Start acquisition: 10/09/2018 14:41:03	0
Start irradiation: 10/09/2018 15:14:05	0
Stop irradiation: 18/09/2018 15:14:31	694.076 E+03
Stop Acquisition: 19/09/2018 14:36:25	694.076 E+03

- Dose Rate = 3.6kGy/h
- Irradiation Time = 8 d
- Relaxation time = 1 d
- Acq. Image delay = 15’
- Temperature = 24-27 °C

Fibre radiation hardness: results (1)

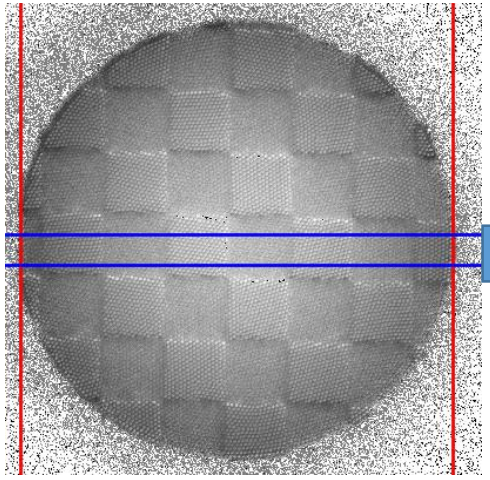


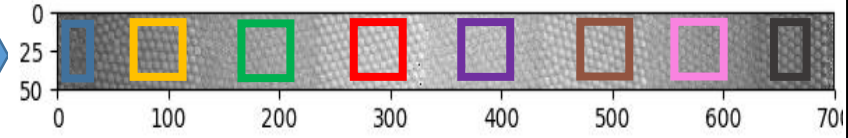


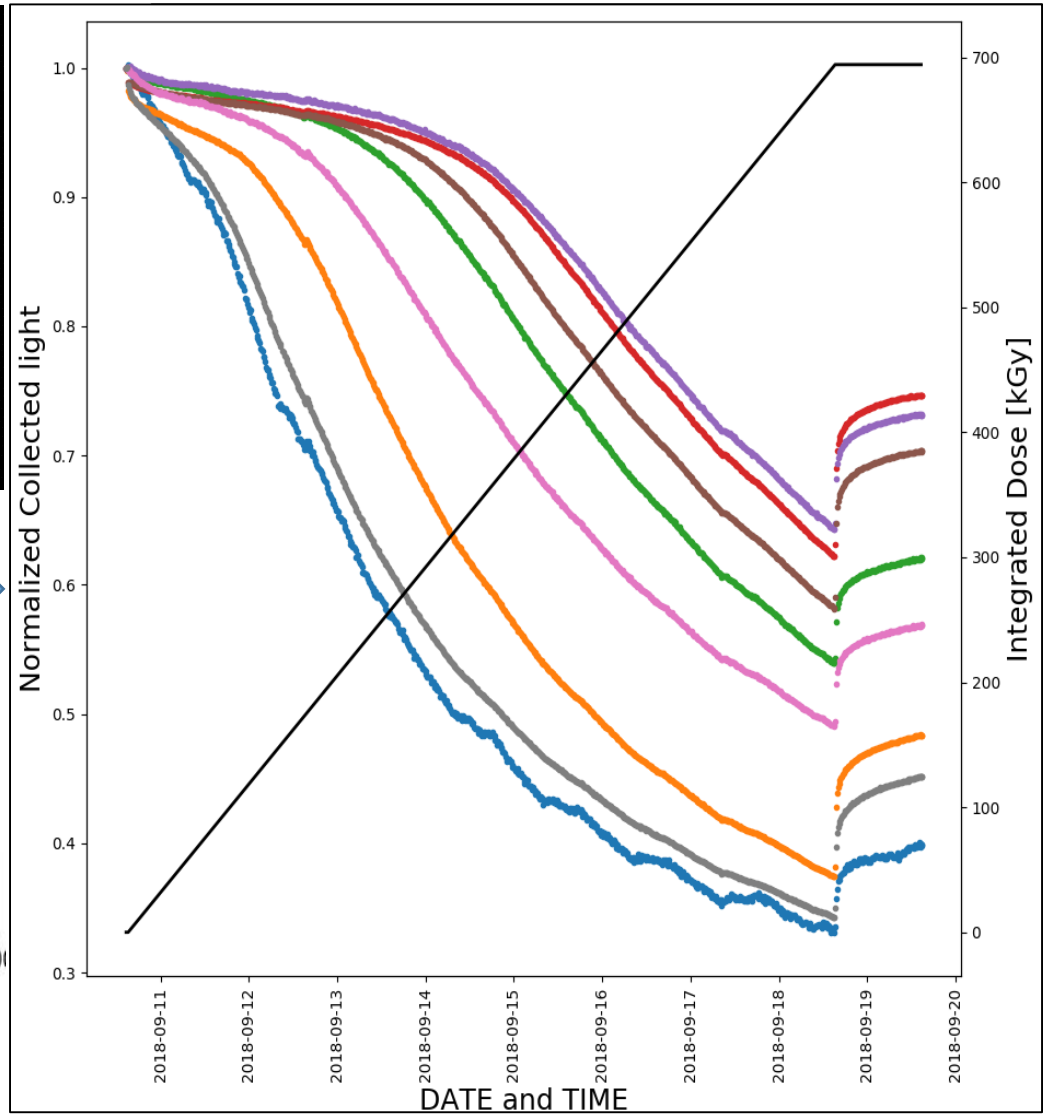


Before Irradiation (0 Gy) After Irradiation (700 kGy) After relaxation (700 kGy)

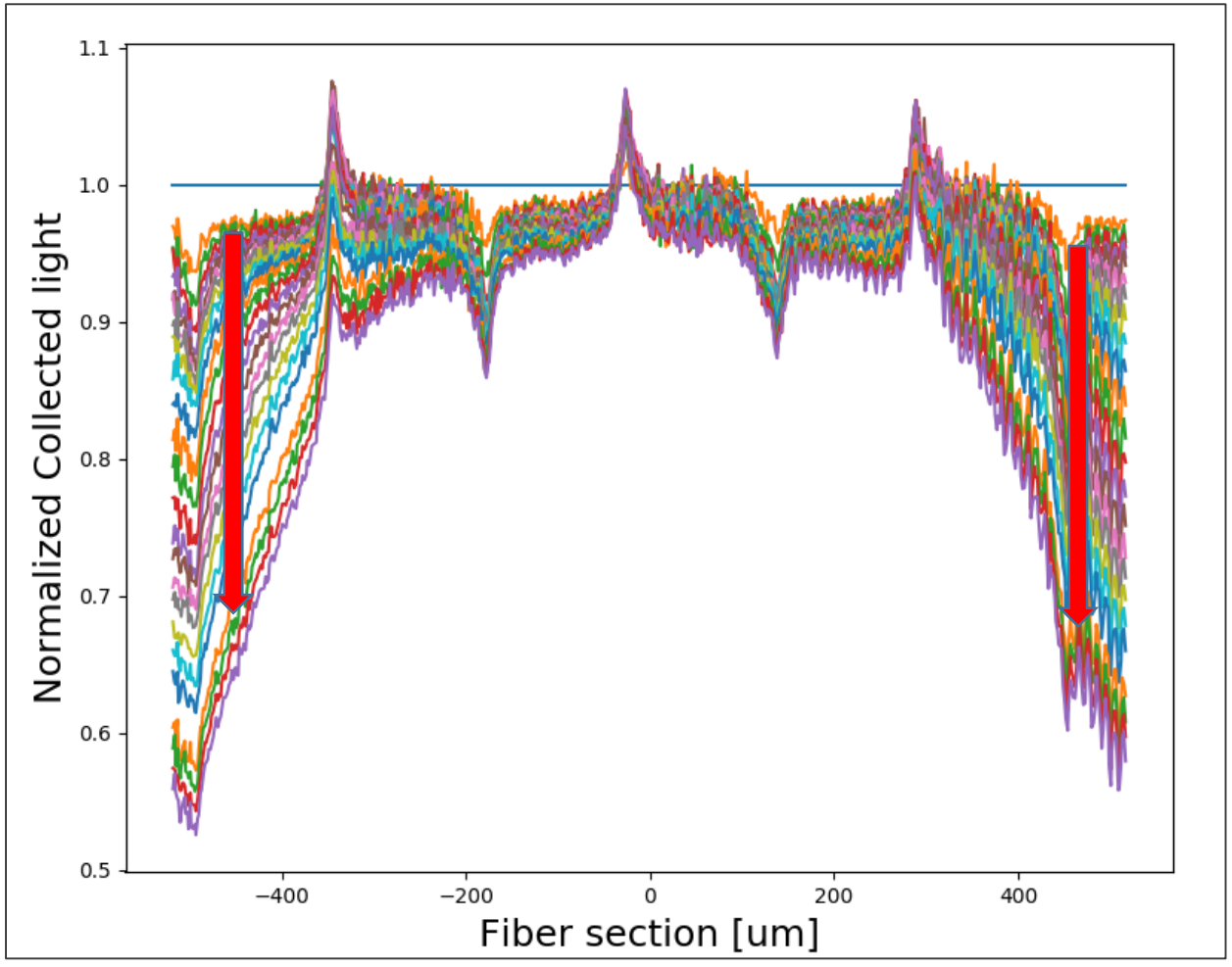
NORMALIZATION

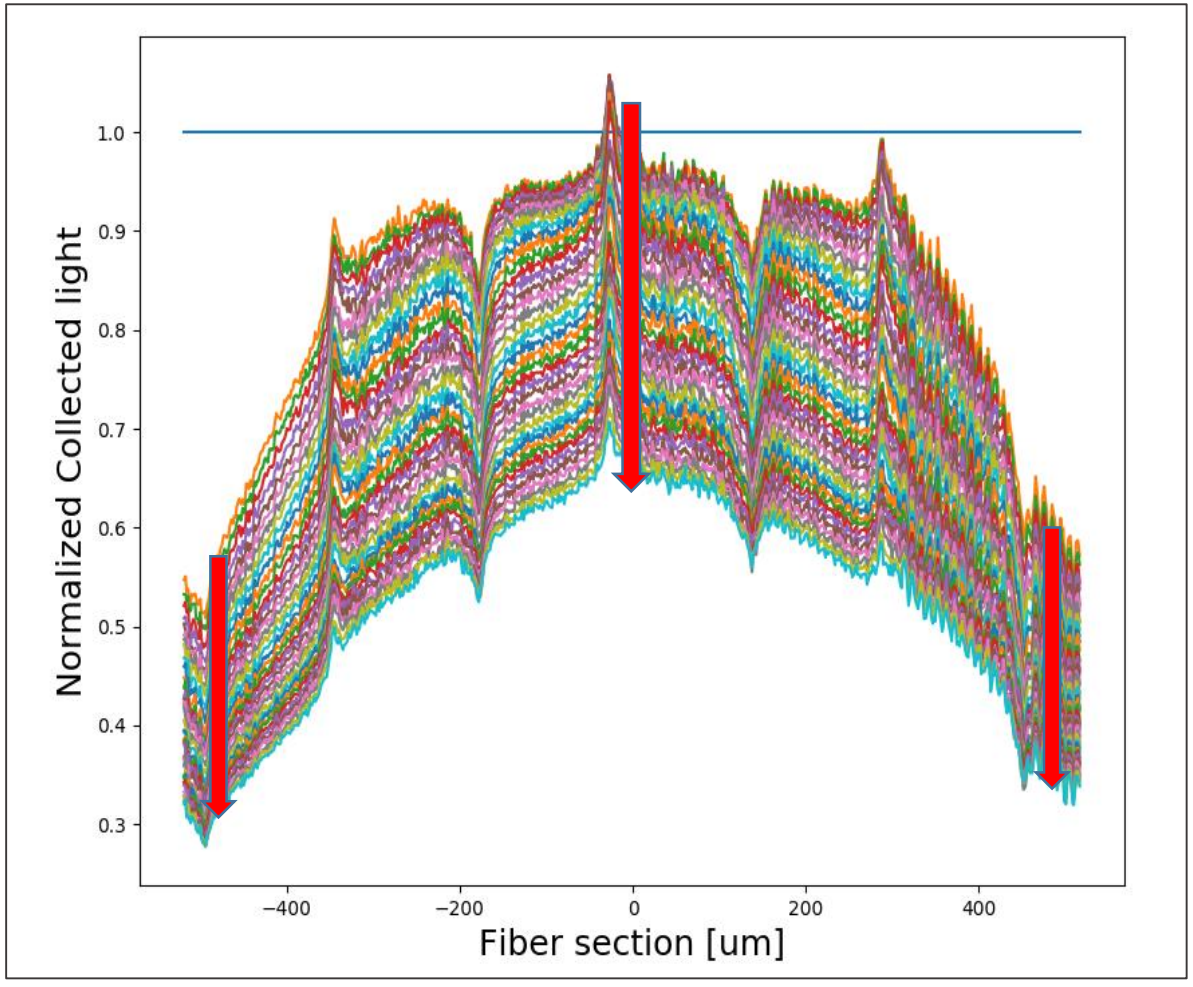






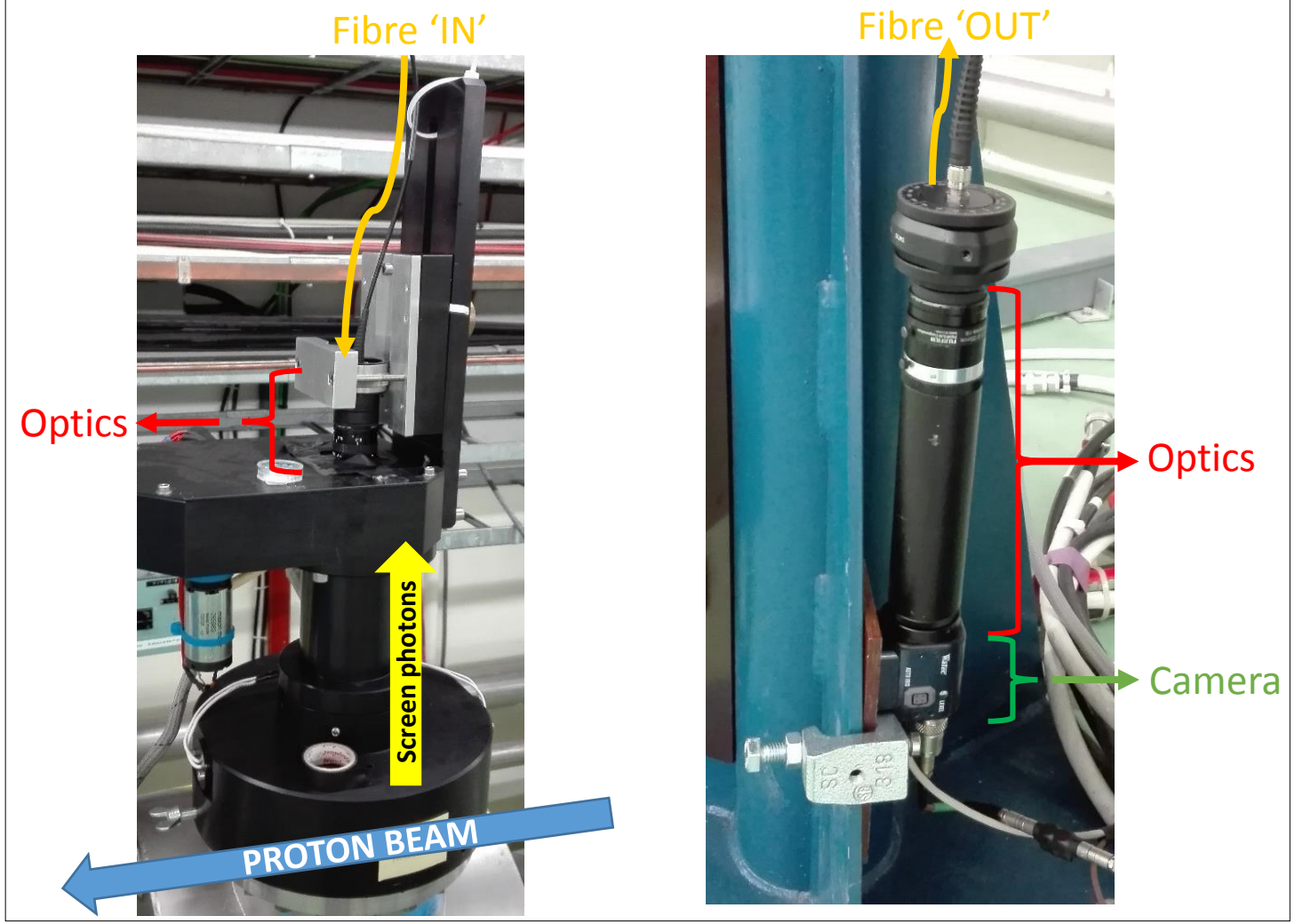
Fibre radiation hardness: results (2)





Beam imaging test: intro & setup

Installation of a imaging fibre on FT16.BTV218 instrument in TT2



Equipment:

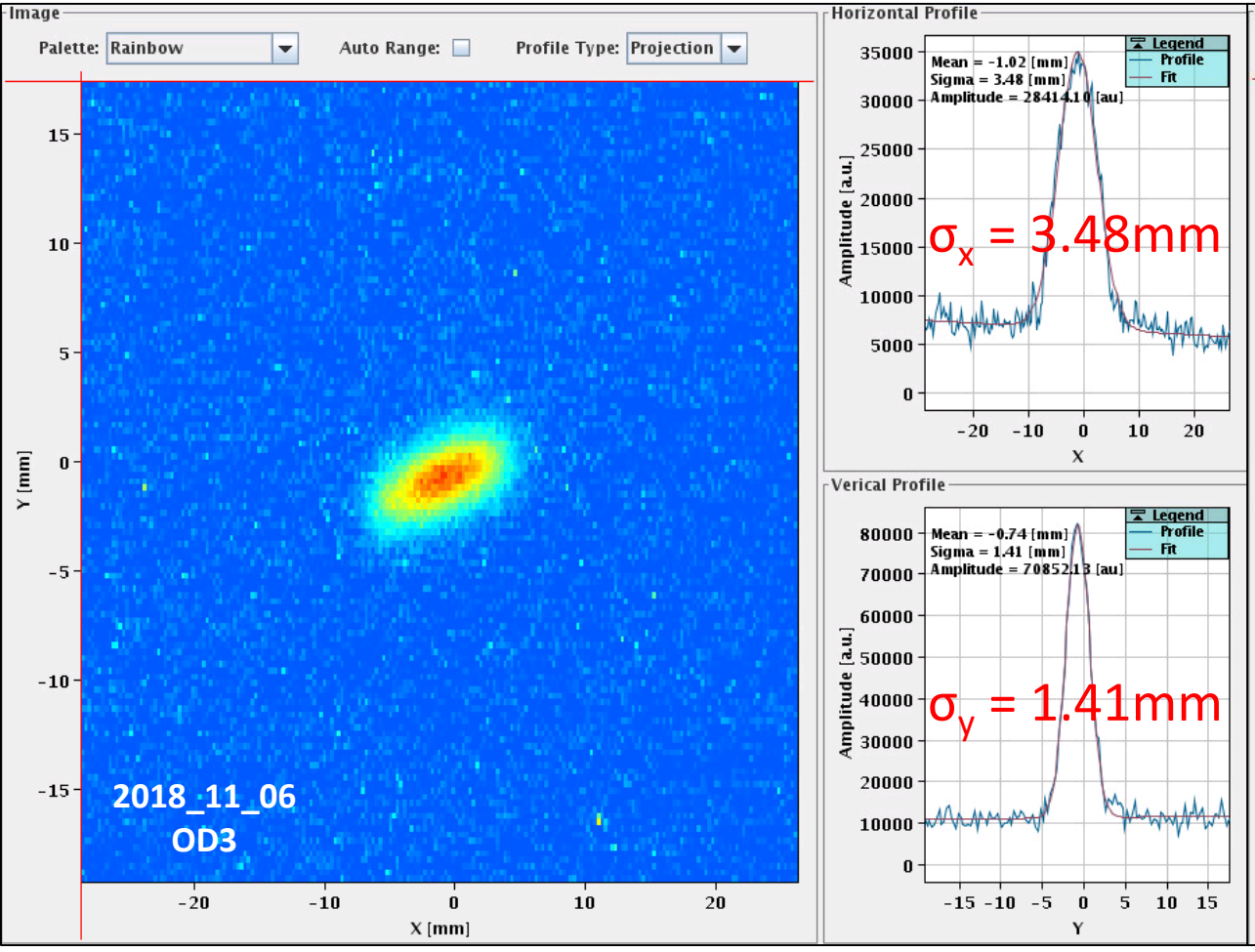
- Analog camera connected to control software
- Screen CHROMOX
- 8mm focal length input
- 25mm focal length output
- 10m, 10k optical fibers bundle

Measurements:

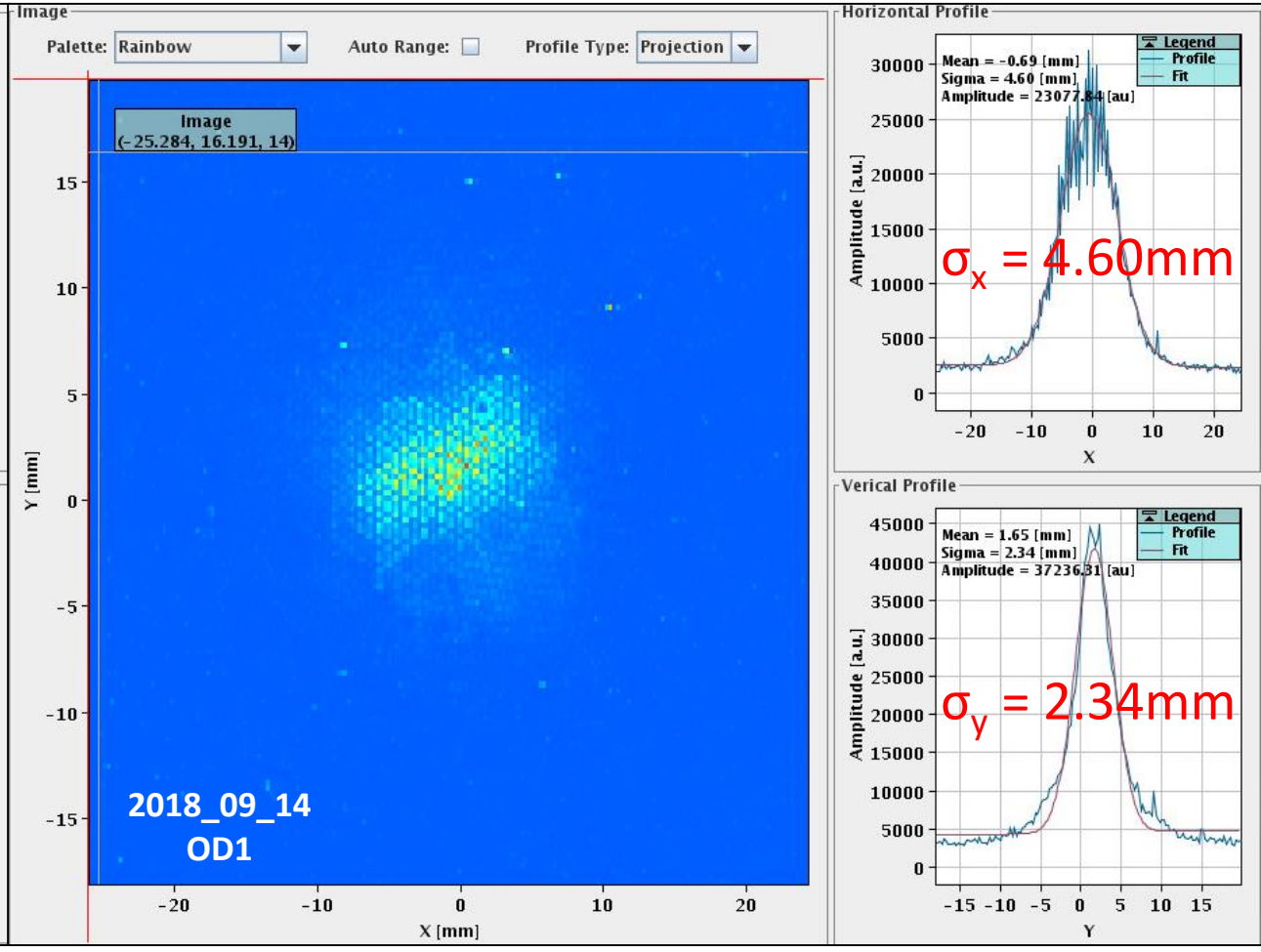
- Beam LHC_INDIV, intensity ≈ 1 E+11
- No control on exp. time nor gain
- Modifying trigger delay and filters to avoid saturation

Beam imaging test: results

- Acquisition with analog camera system



- Acquisition with analog camera and optical fiber



- 100x less light transmitted with fibres
- Accuracy of beam size measurement to be checked

Conclusions and next steps

Conclusions:

- Light loss up to 98 % due to optical coupling
- Able to compensate with digital parameters

- Fiber radiation hardness confirmed
- Non-uniform light loss up to 50% due to radiations
- Able to reconstruct qualitative images

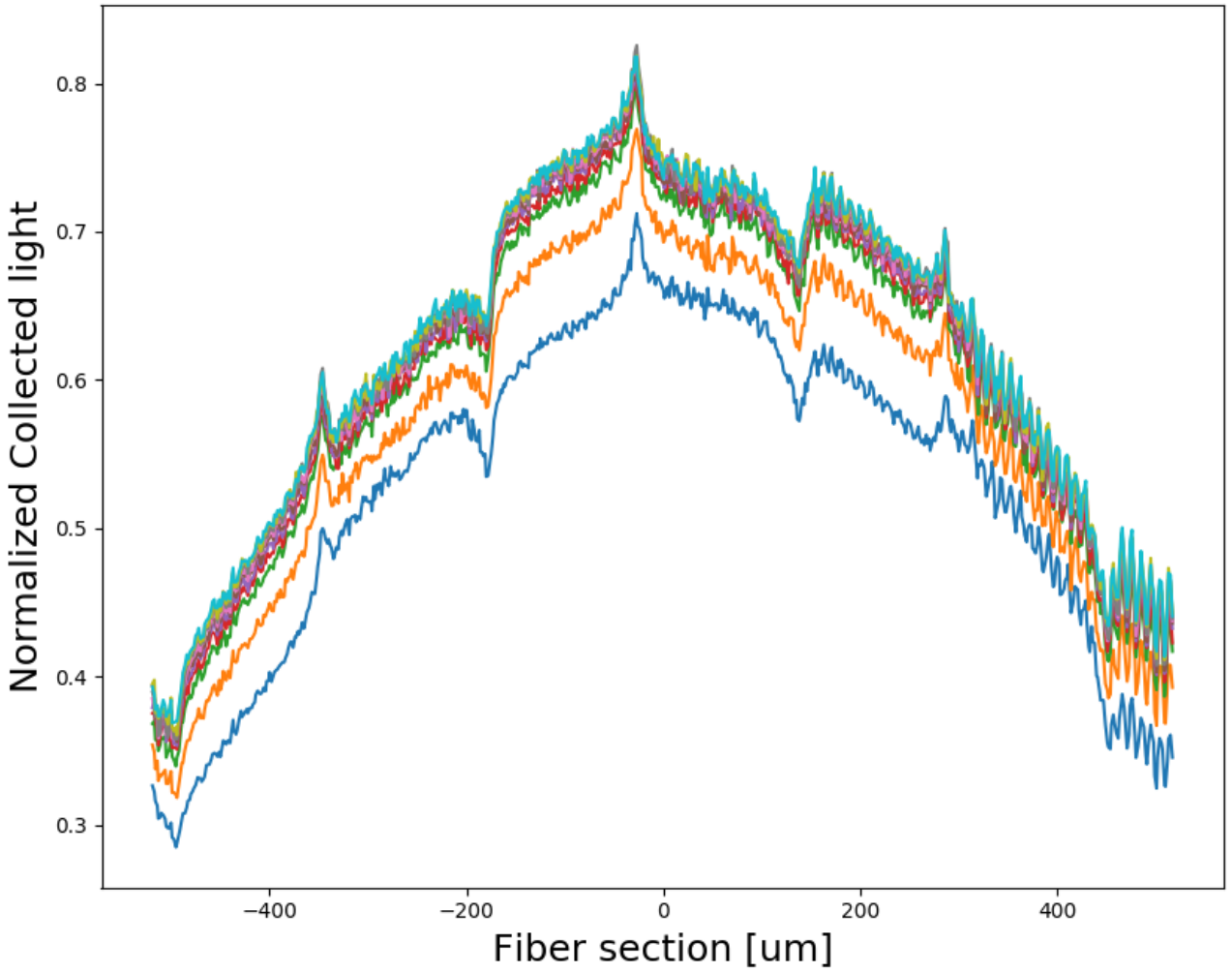
- Tests in TT2 confirmed 100 times less transmitted light
- System able to acquire beam images

To be clarified:

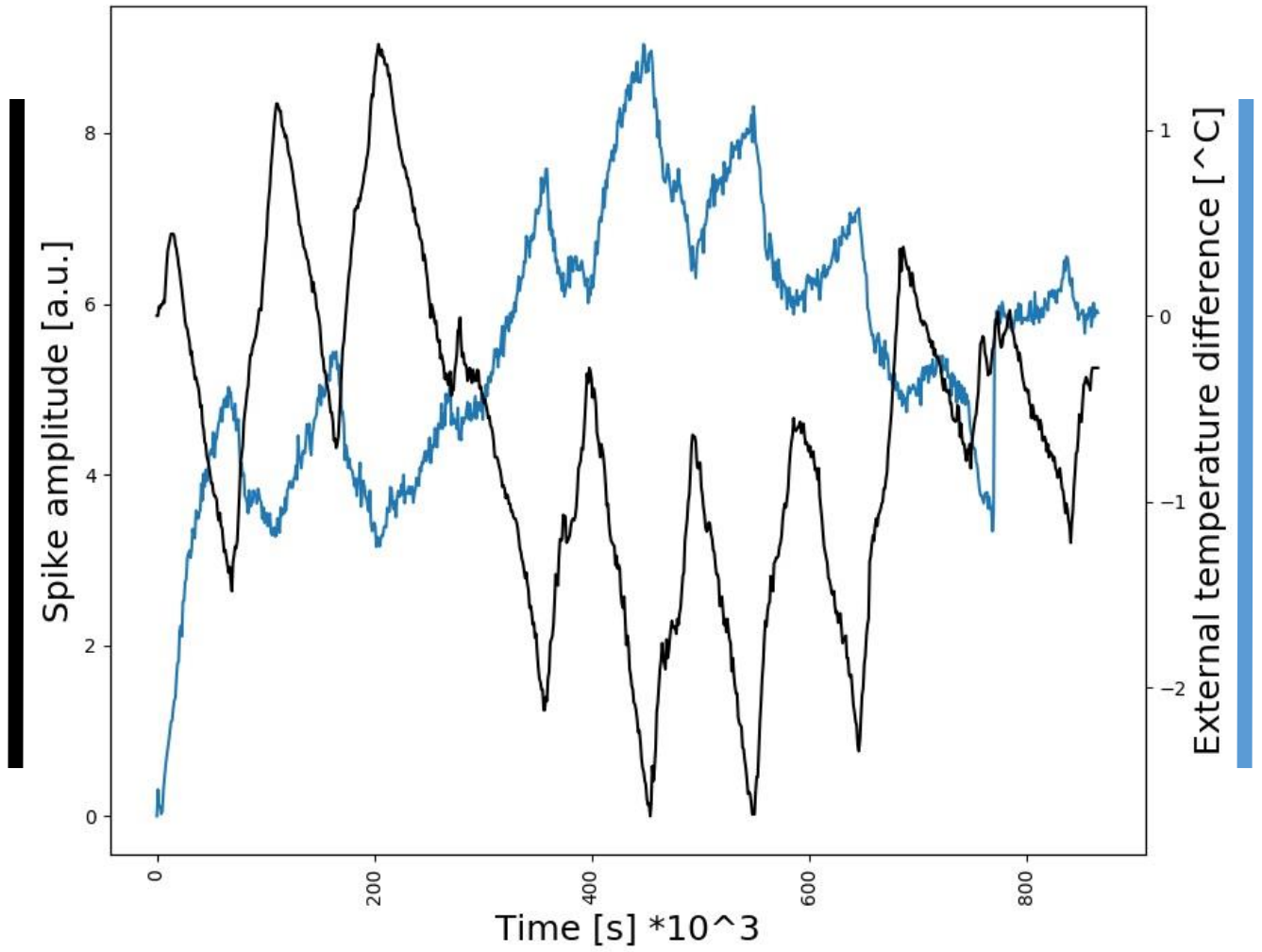
- Non uniform light loss in RadHard fibres:
  - Due to high rate/TID?
  - Due to other factors: temperature, cladding,…?

- Different beam sigmas:
  - Laser measurements to simulate beam?
  - Issue with resolution fiber?

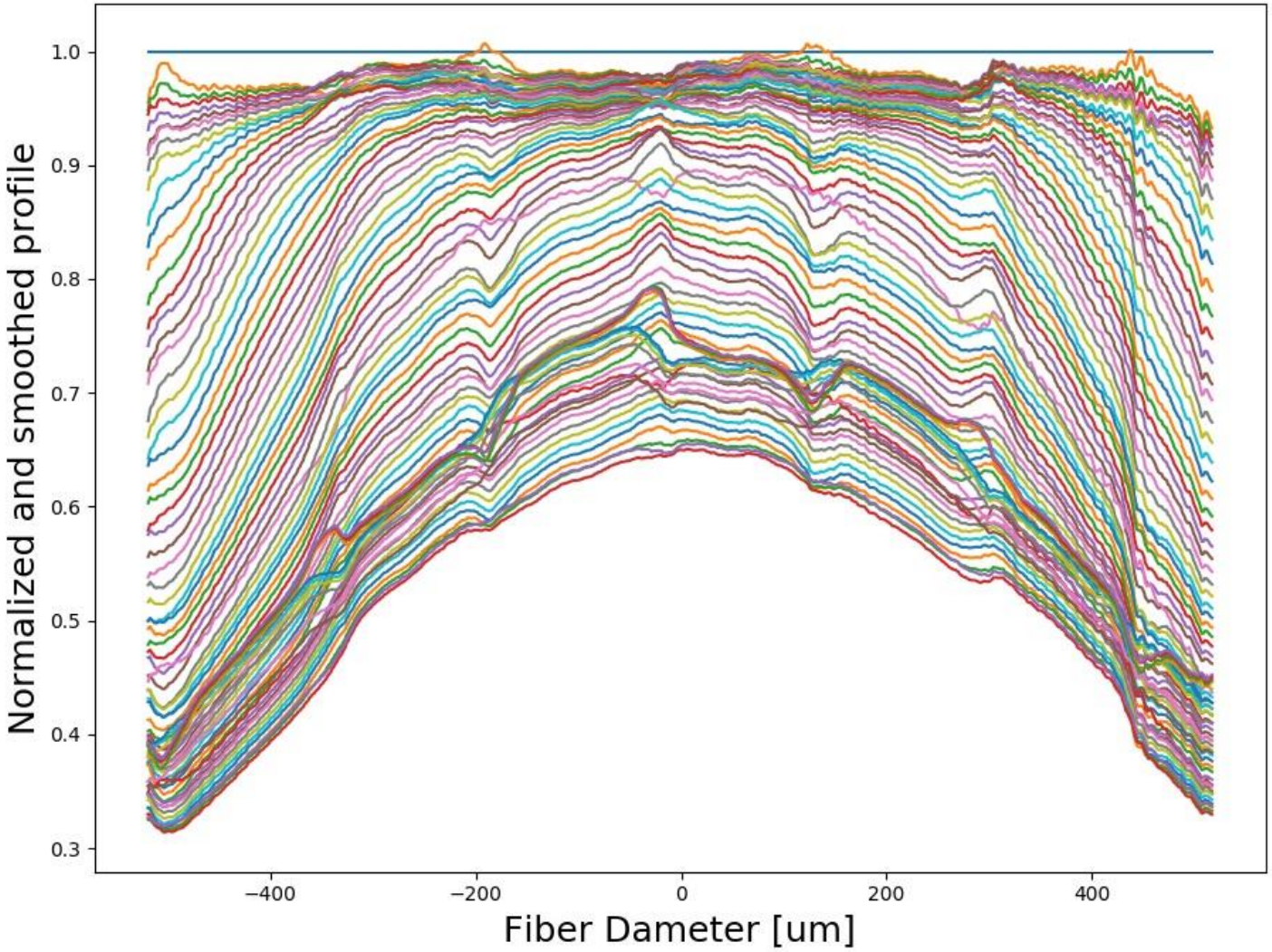
Relaxation time profiles



Spikes vs Temperature

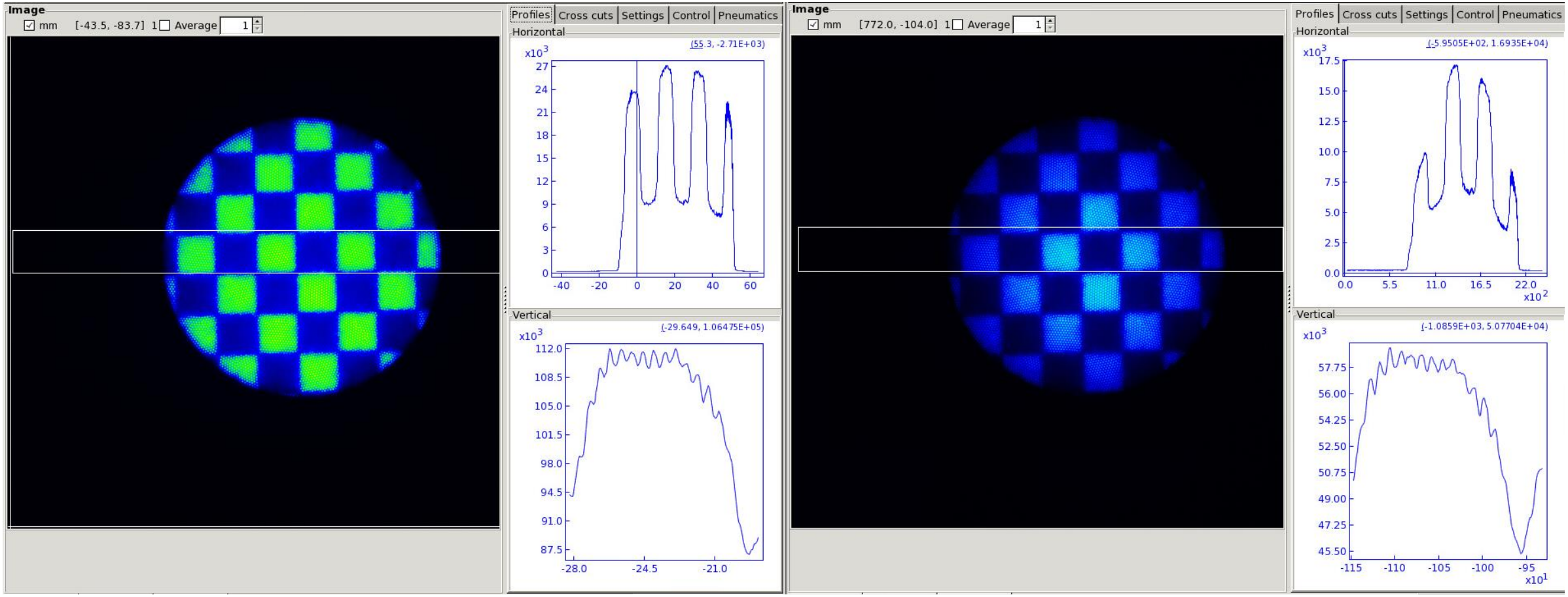


Temperature corrected profiles

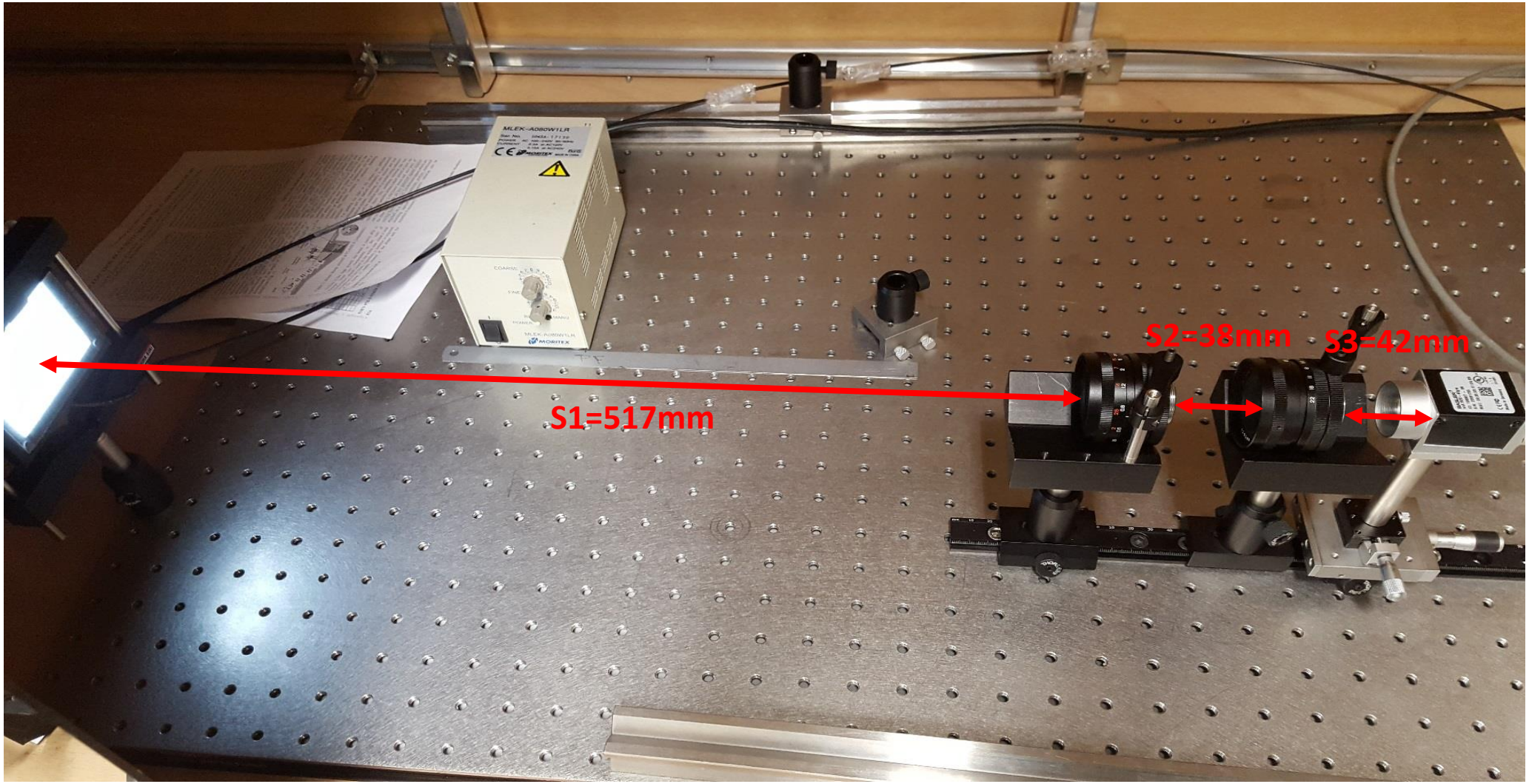


First and last image form irradiation test in IRMA September 2018

Slice fibre profile

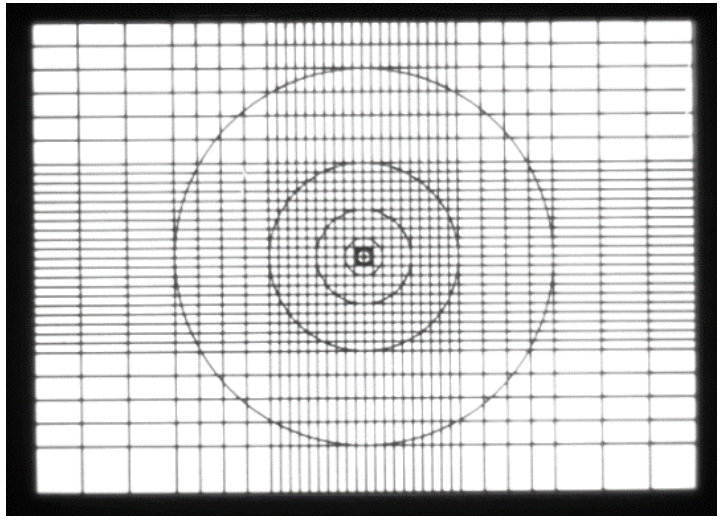


Picture of the setup: example with two 25mm lens

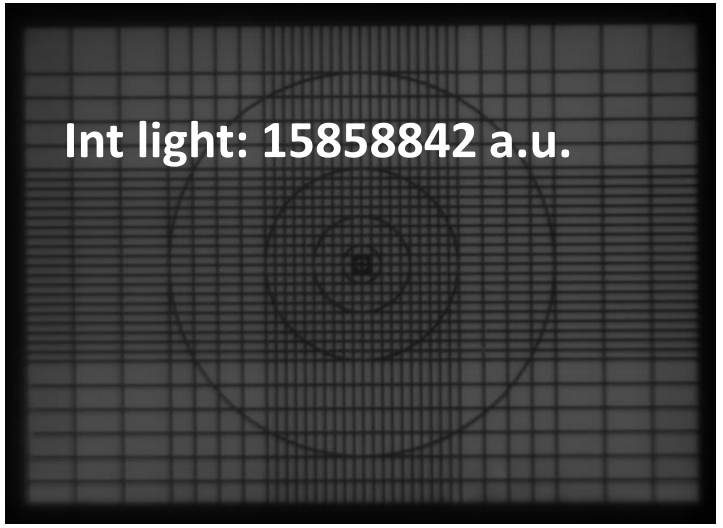


Study of the effect of 180° rotation

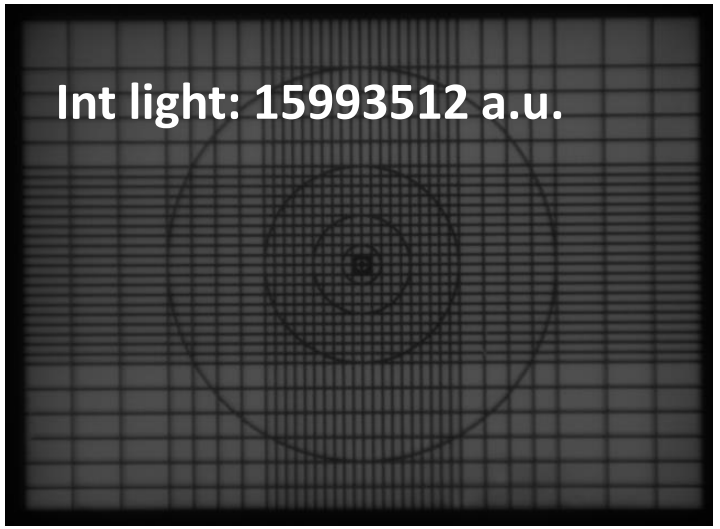
Reference image:
Target @500mm
CCD camera
One 25mm lens



1st configuration



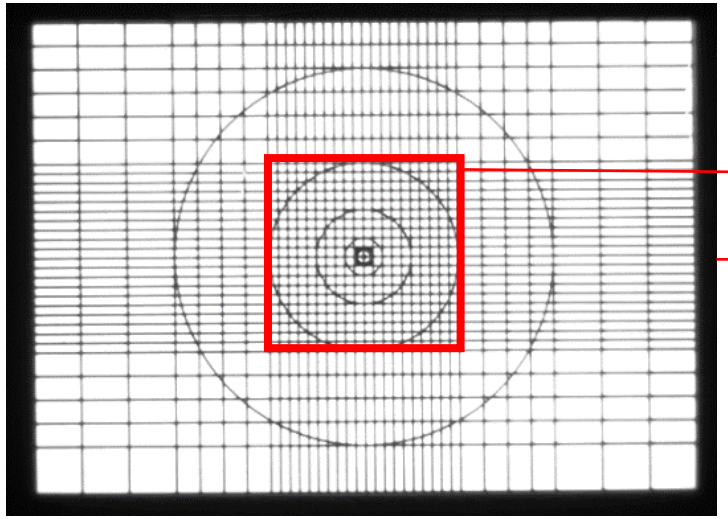
2nd configuration



<1%

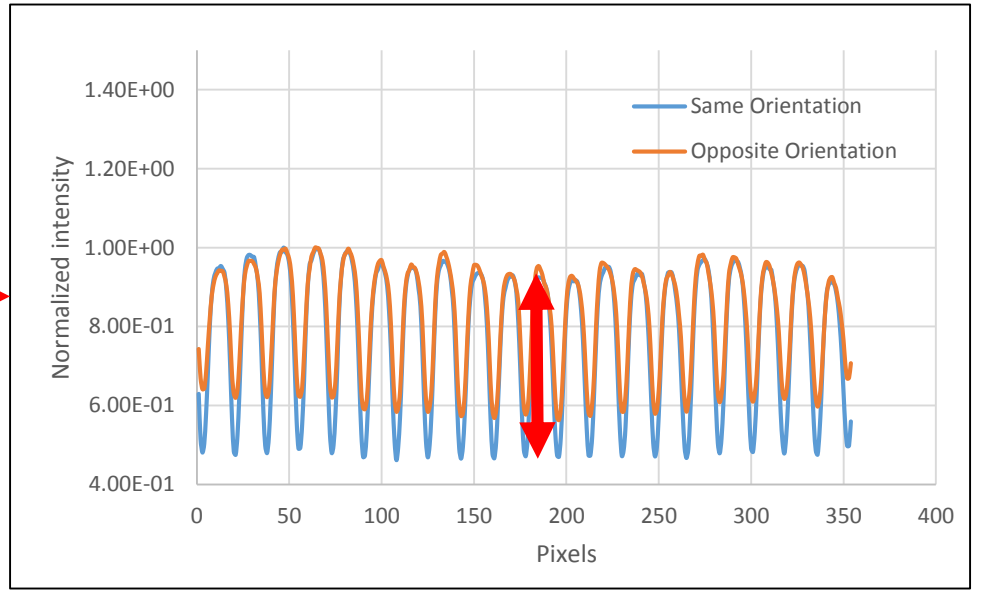
Study of the effect of 180° rotation

Reference image:
Target @500mm
CCD camera
One 25mm lens



Central square

Light profile and spatial resolution



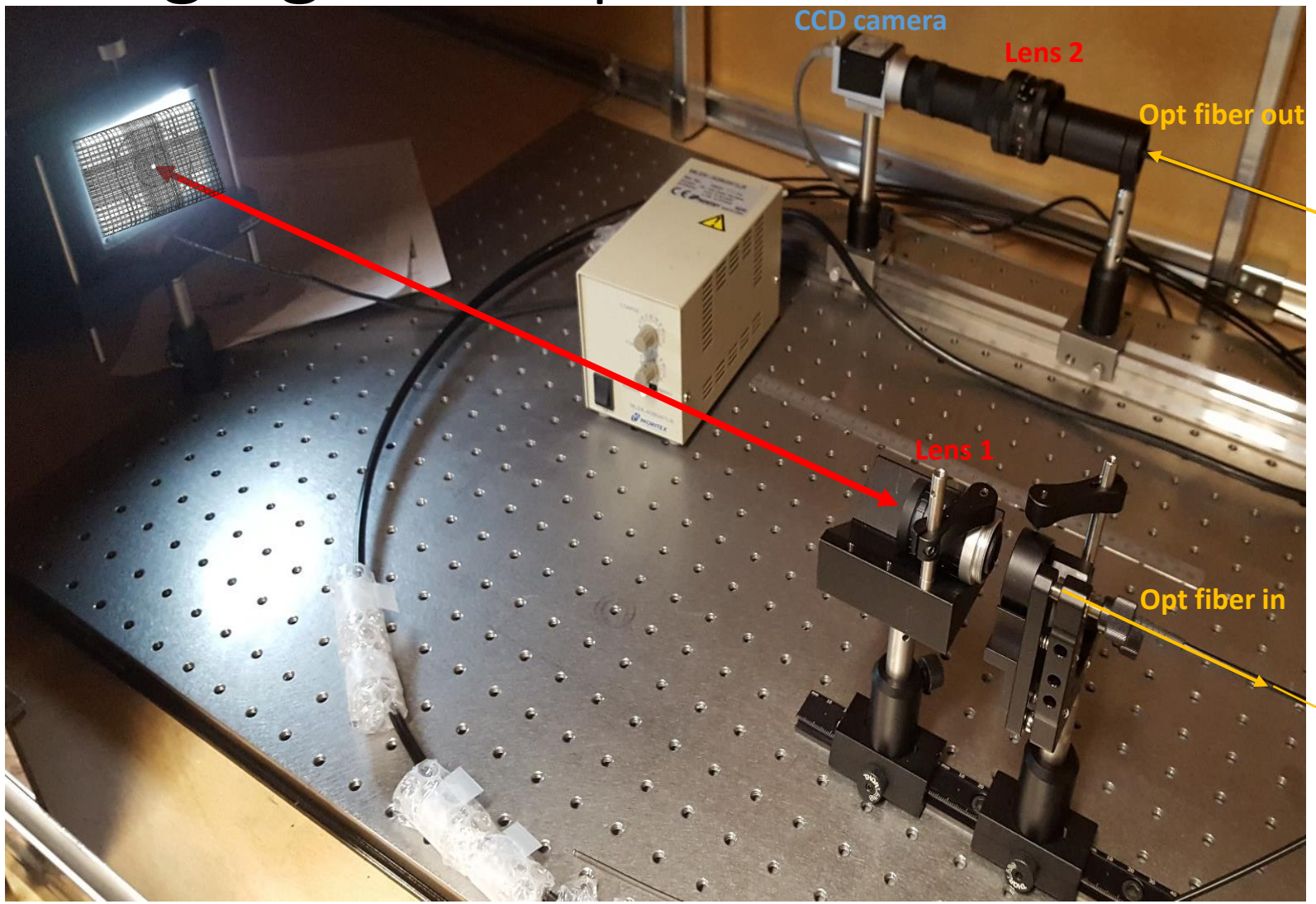
From 38%

To 52%

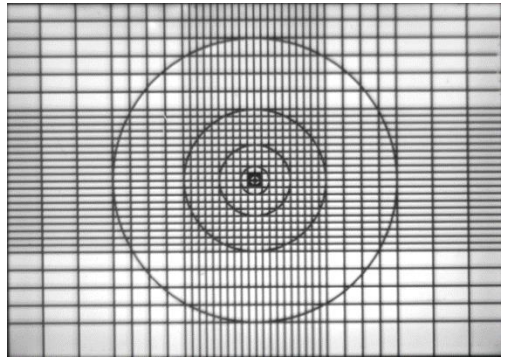
Beam profile imaging with optical fibers

Set up description:

- LED screen at 500mm from the 1st lens (25mm or 9mm)
- The optical fiber interface is placed at a distance d=f to catch the focalized image of the screen, created by the 1st lens.
- A 2nd lens is placed at the fiber output to obtain a certain magnification factor of the image on the CCD camera.

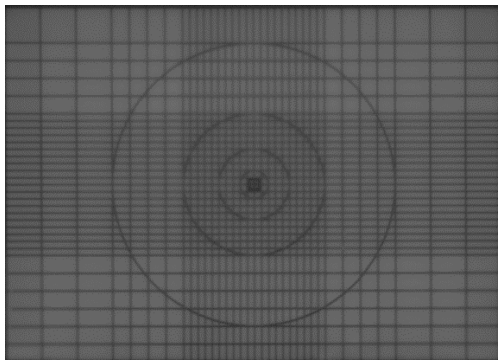


Acquired images: same MAG on camera

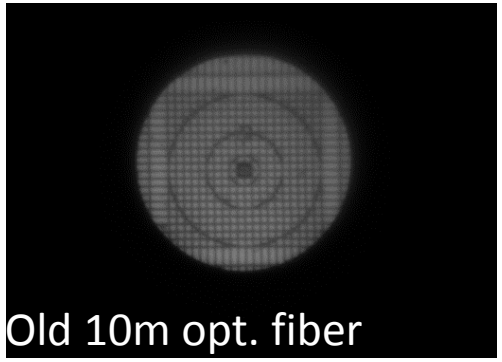


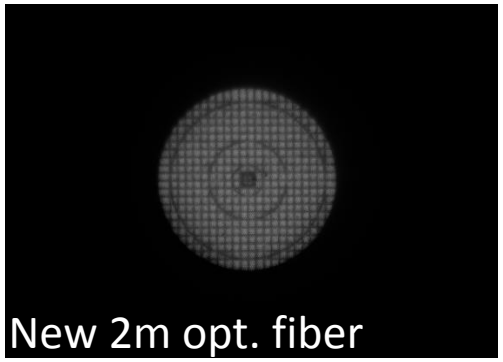
Reference image:
Cam + Lens 25mm

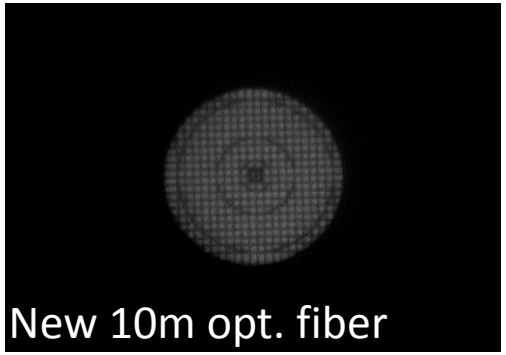
Cam + 2 Lens 25mm



Cam + 2 Lens 25mm

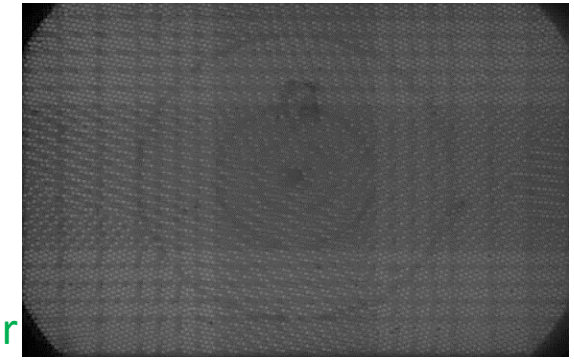




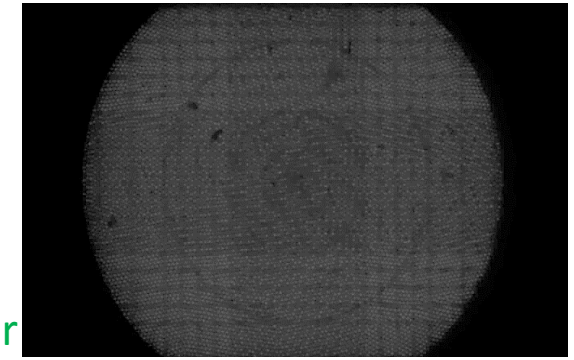


Cam + 1 Lens 9mm + 1 Lens 25mm

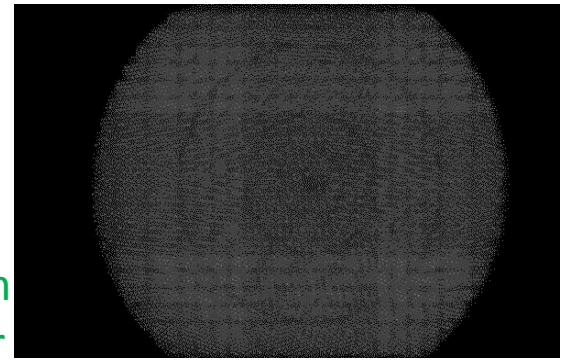
Old 10m
opt. fiber



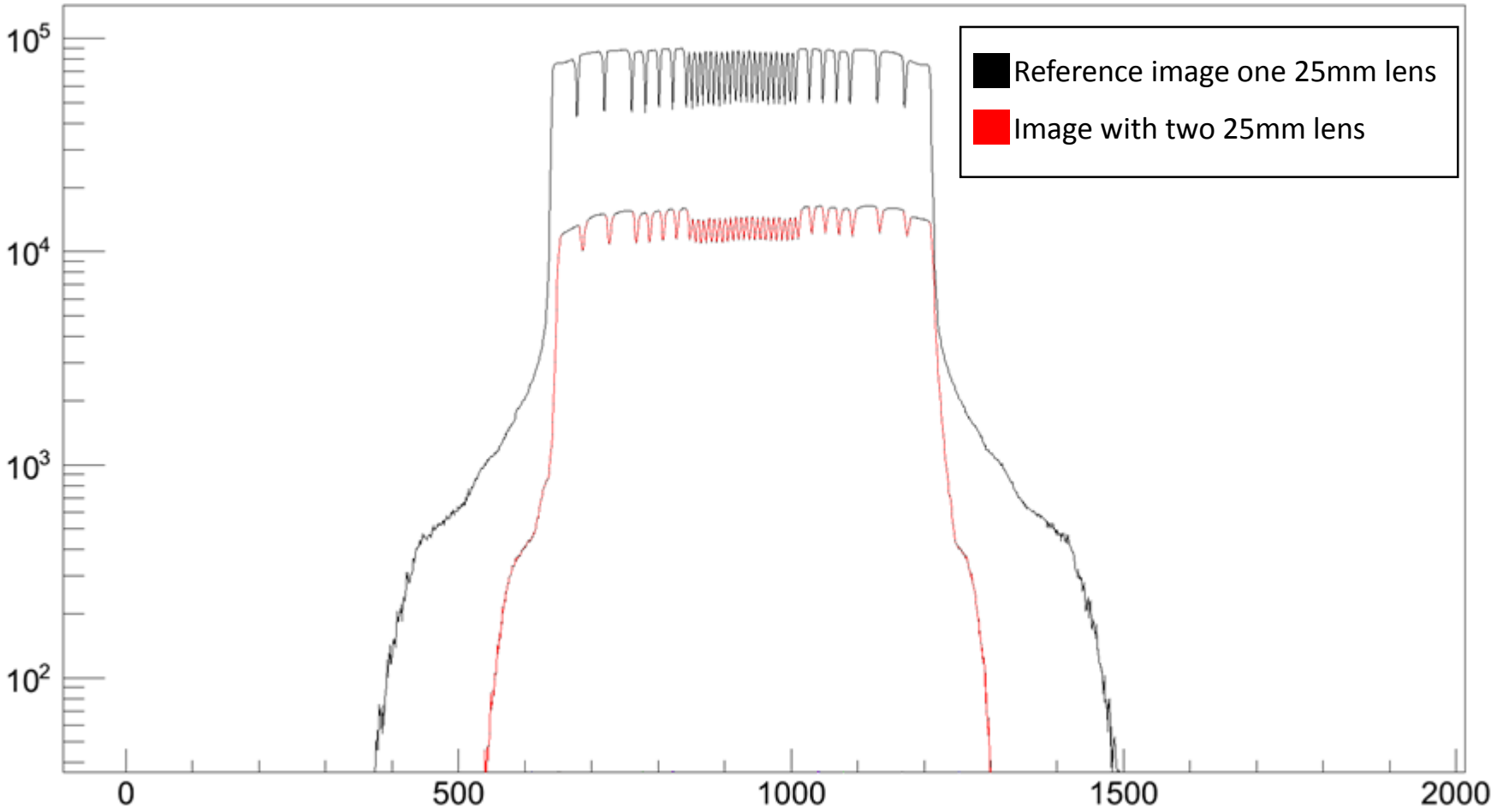
New 2m
opt. fiber

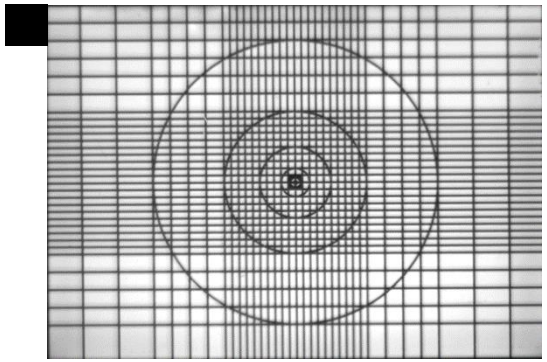


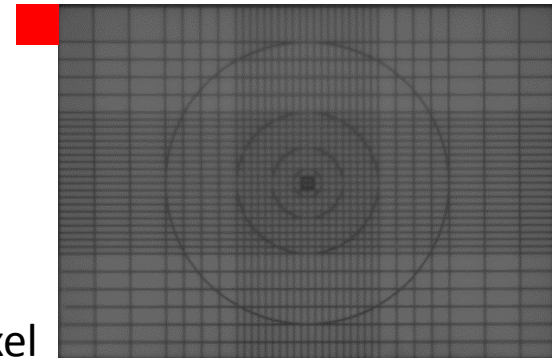
New 10m
opt. fiber



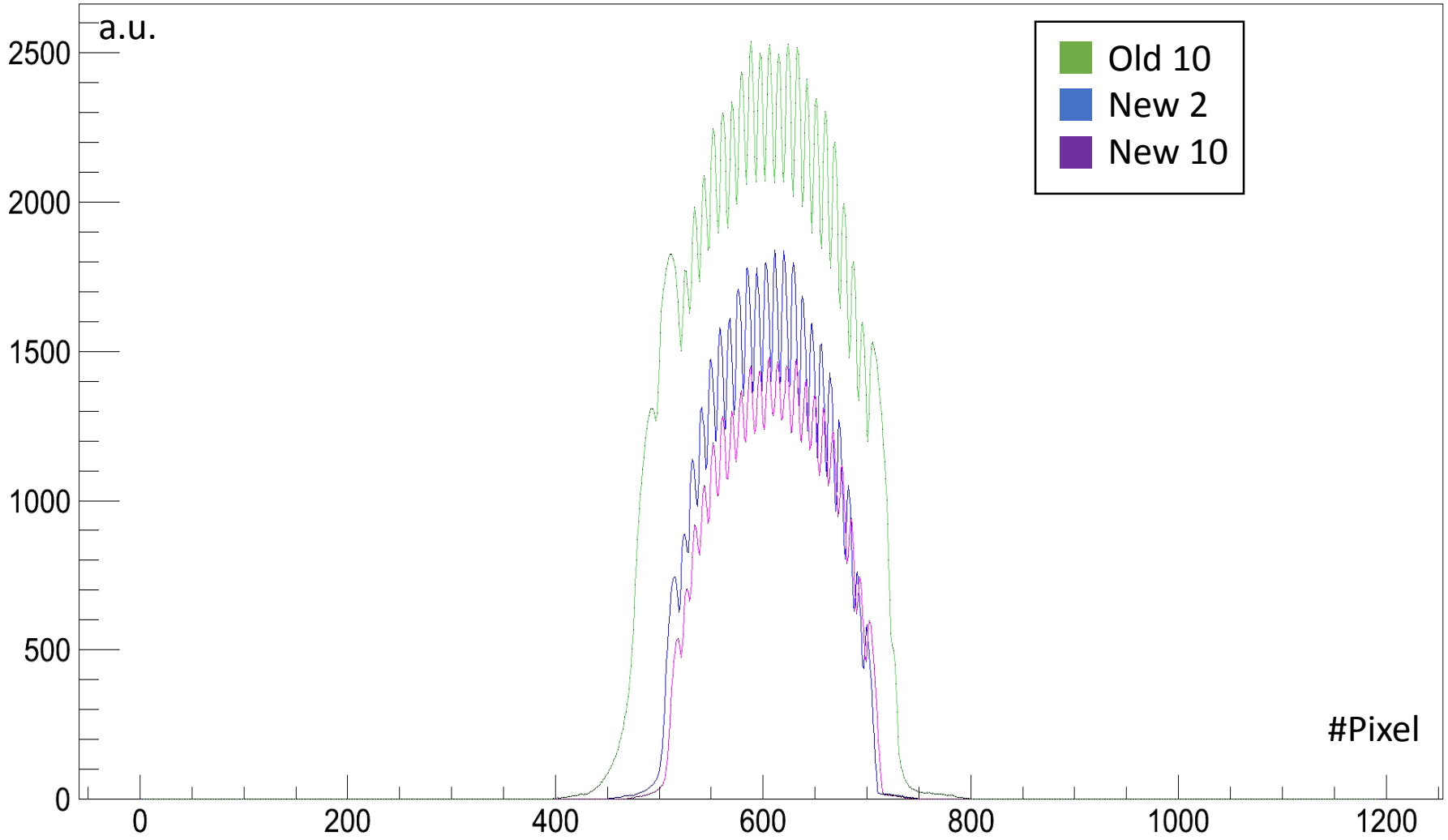
X-integrated light profile (a.u.)

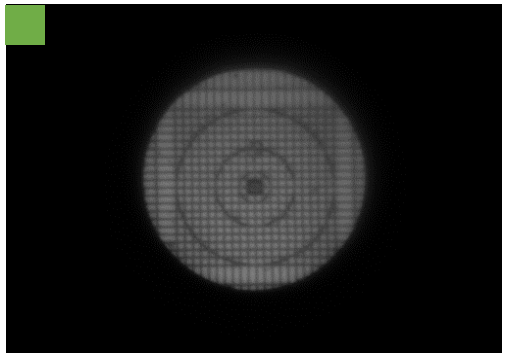


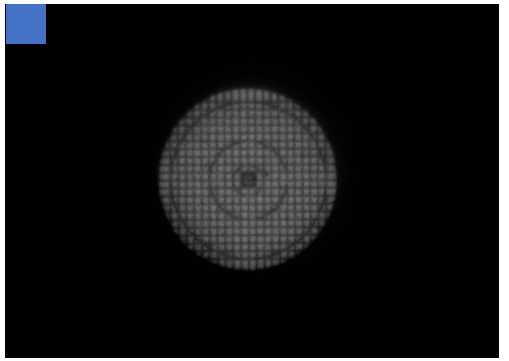


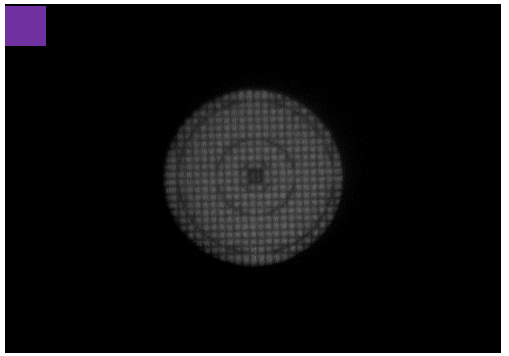


X-integrated light profile (a.u.)

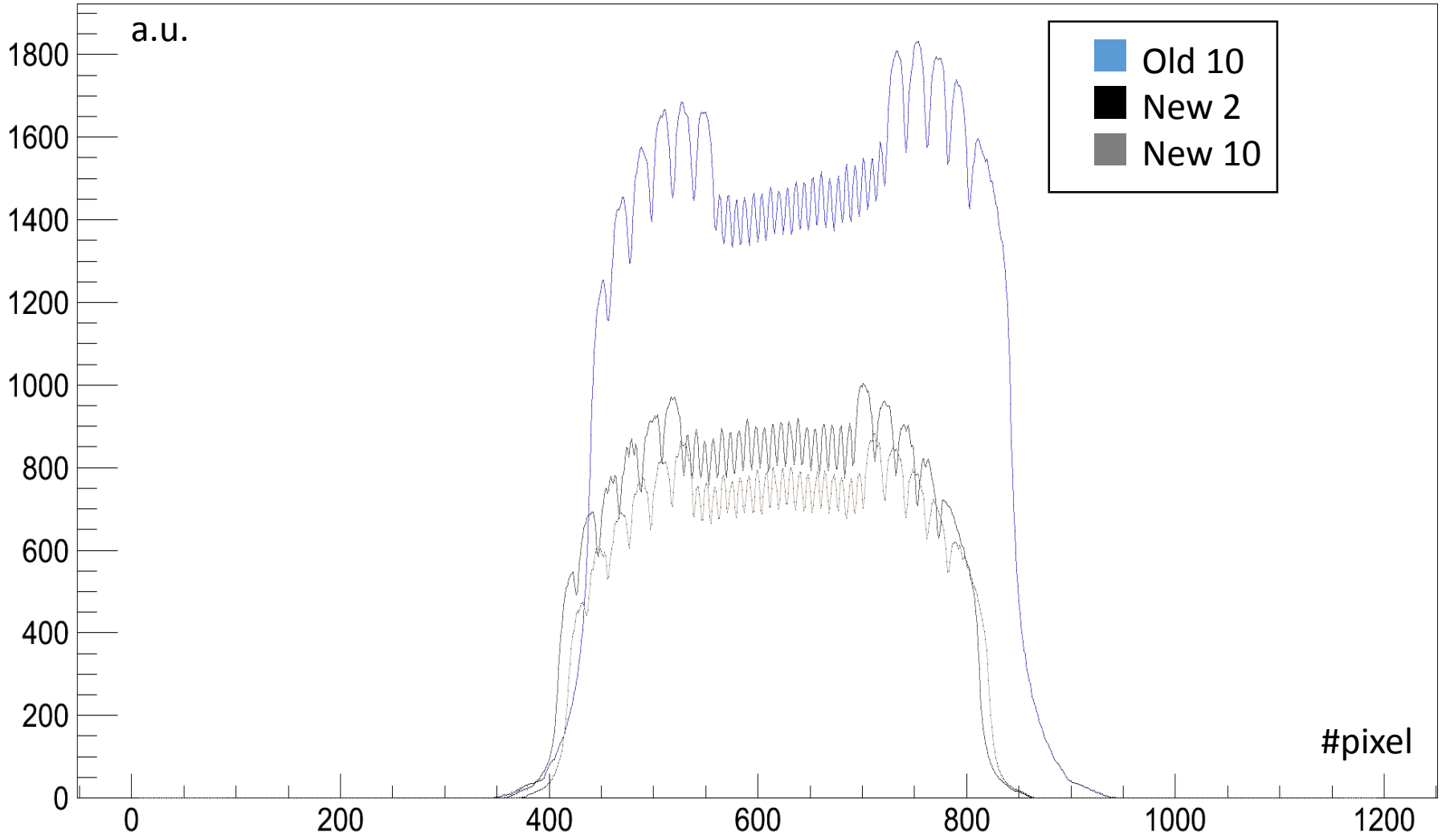


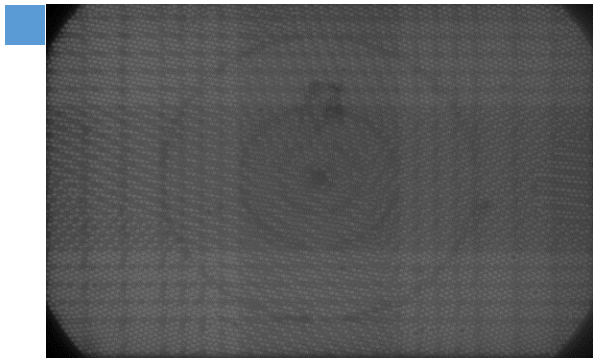


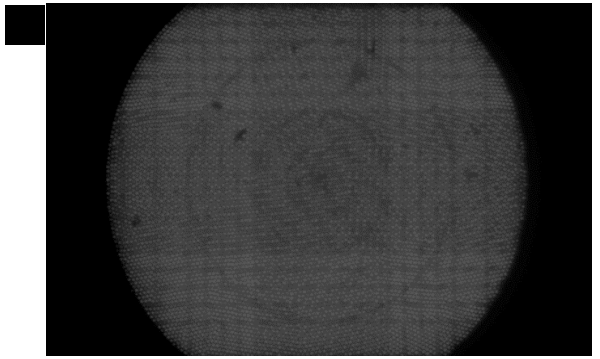


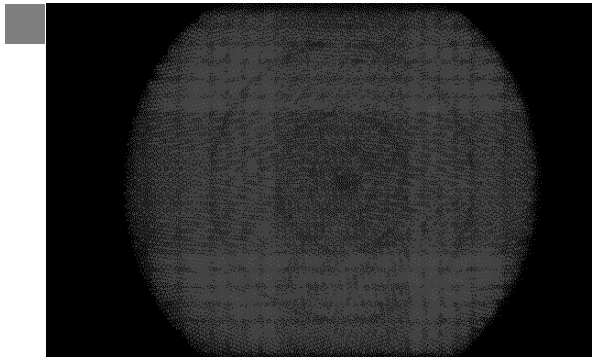


X-integrated light profile (a.u.)

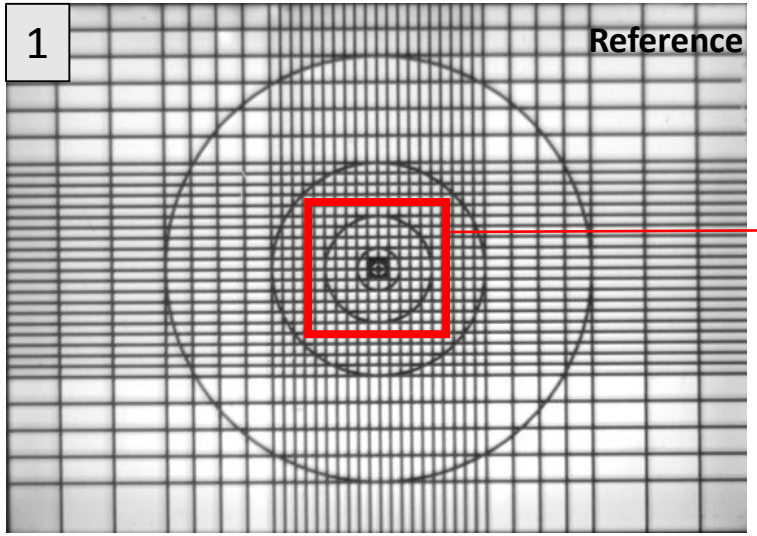


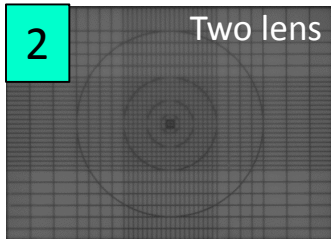


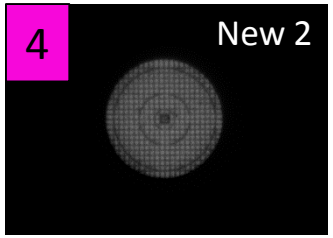


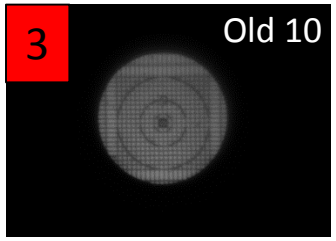


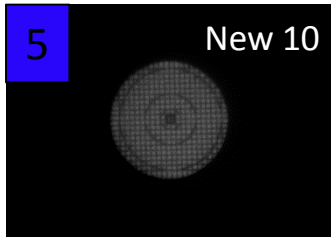
Effect of the presence of the optical fiber

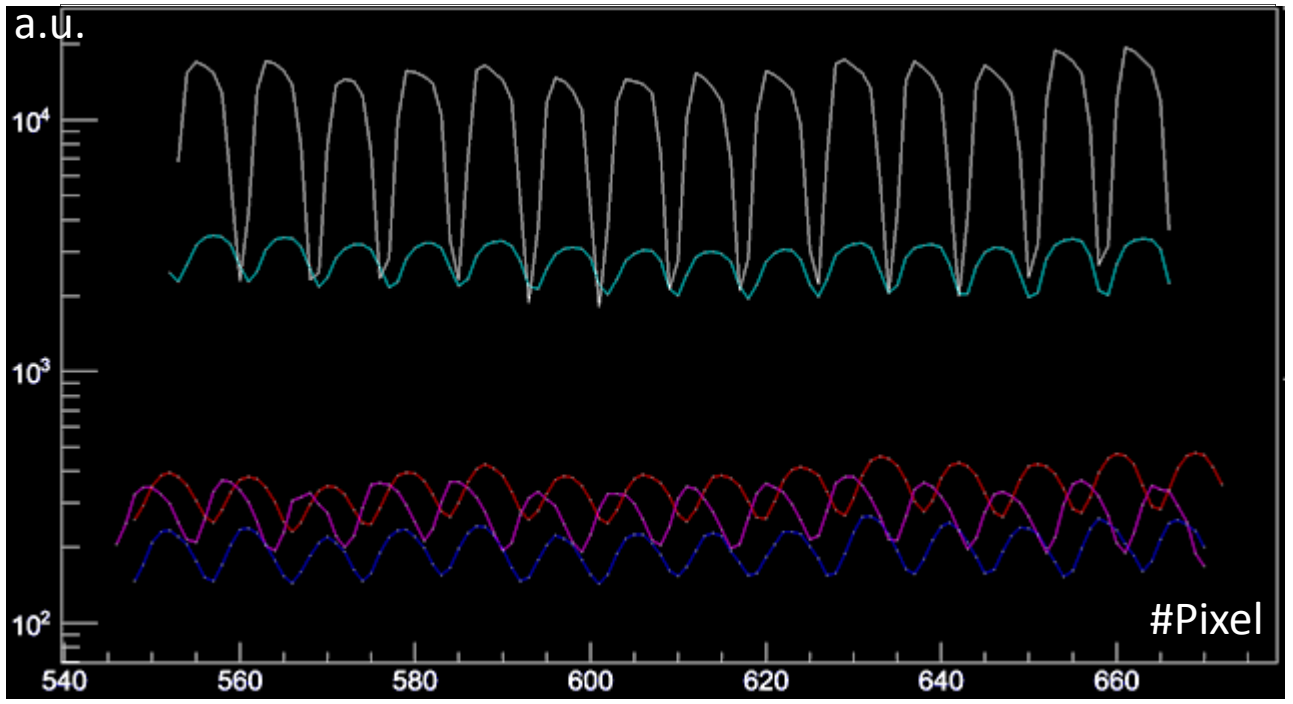












Integral value:

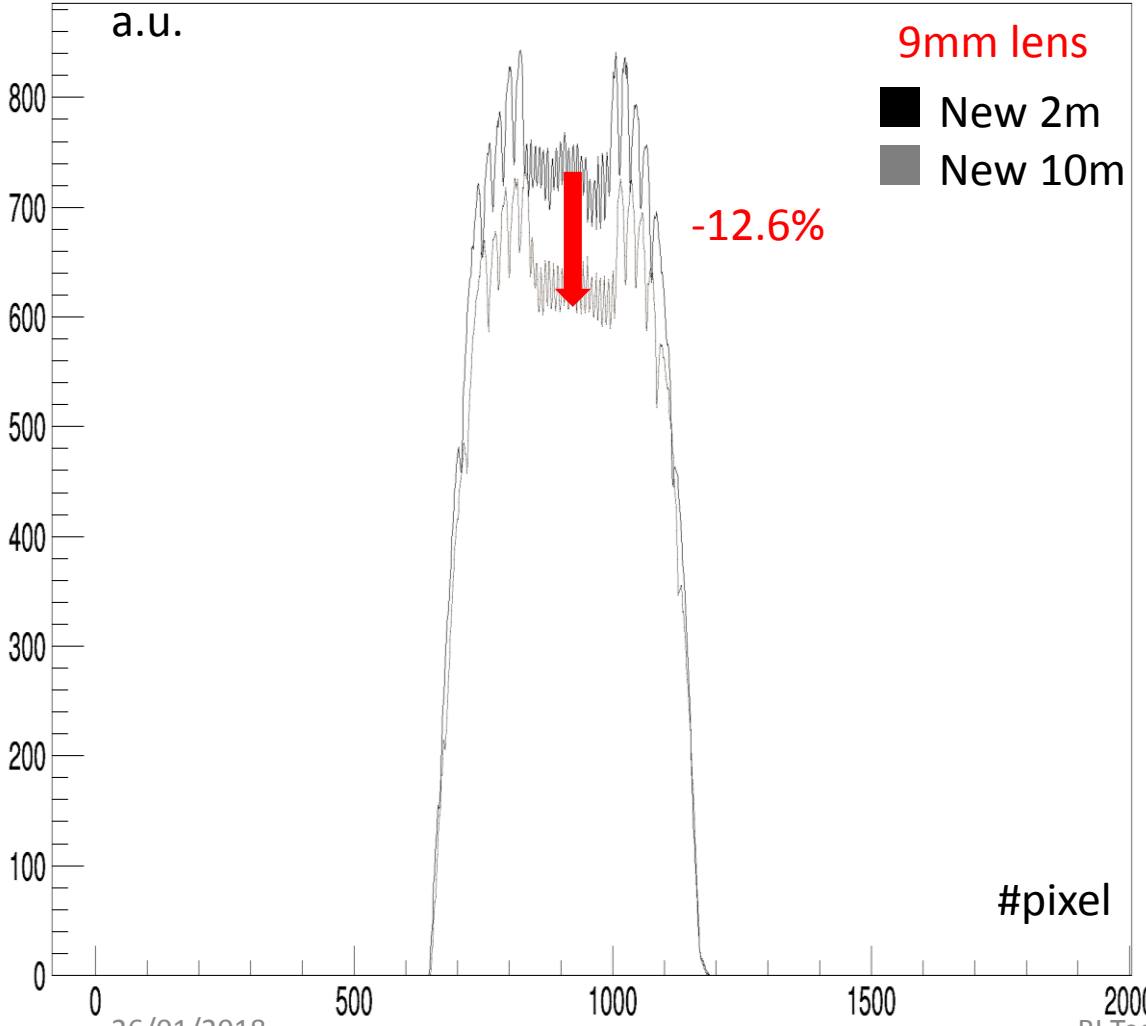
1. 1217222
2. 319084
3. 43197
4. 35316
5. 24443

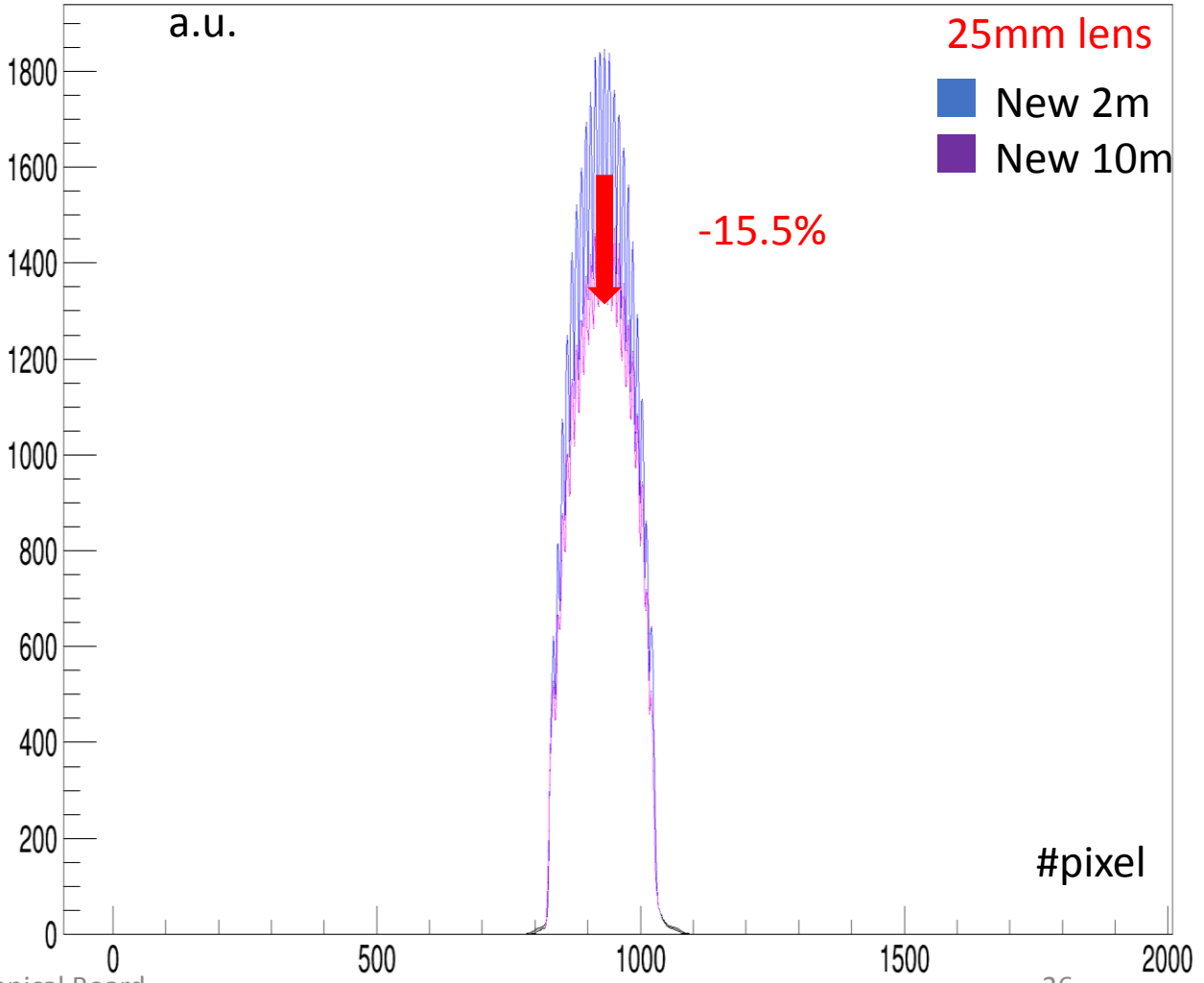
Normalized integral value:

1. 1
2. 0.2621
3. 0.0355
4. 0.0290
5. 0.0201

Light attenuation in fibers

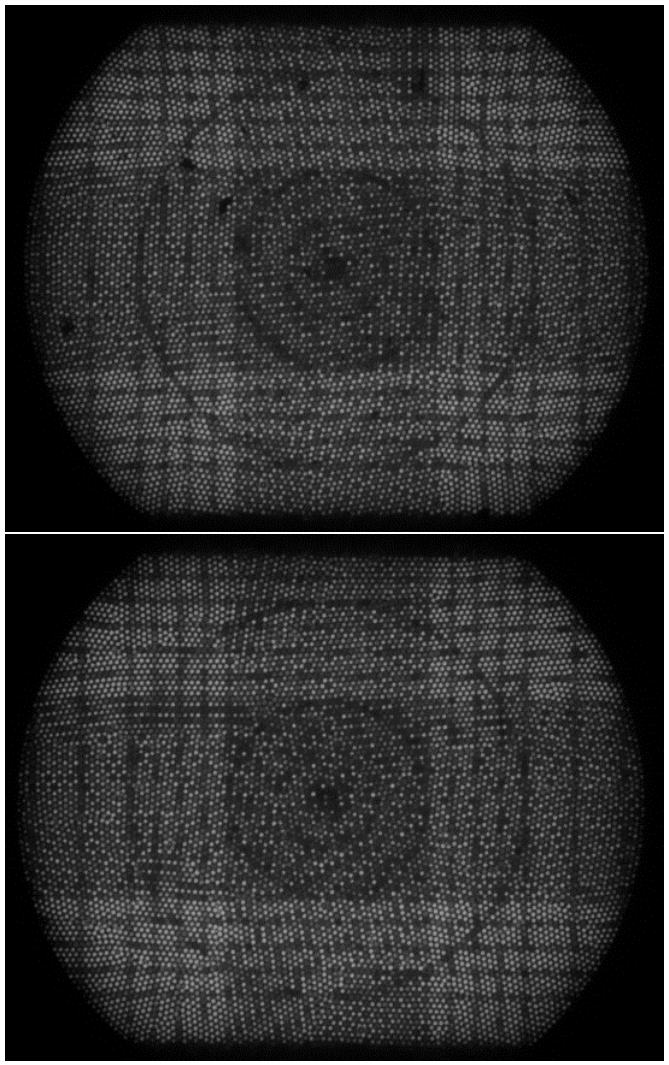
Light loss ~ 14% in 8m (1.75%/m if linear -> 0.68 dB/km)





Reproducible measurements (camera t_{exp} = 20 ms)

Comparison between two new 2m opt. fibers by Fujikura

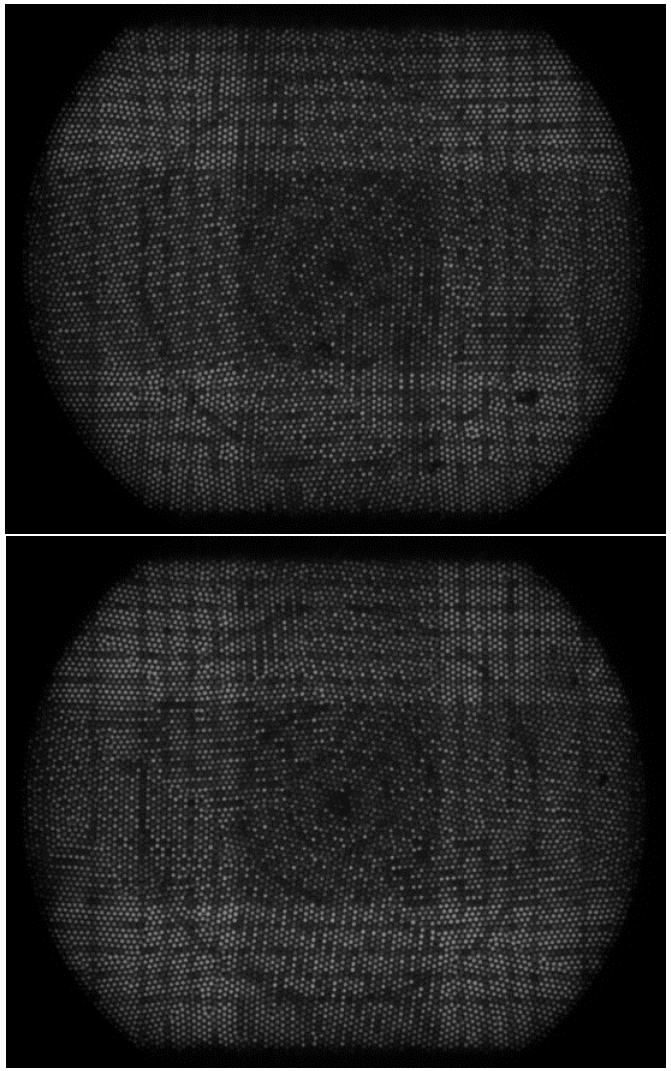


1) 6820955 a.u.

2) 7005164 a.u.

Differences < 3%

Comparison between two new 10m opt. fibers by Fujikura

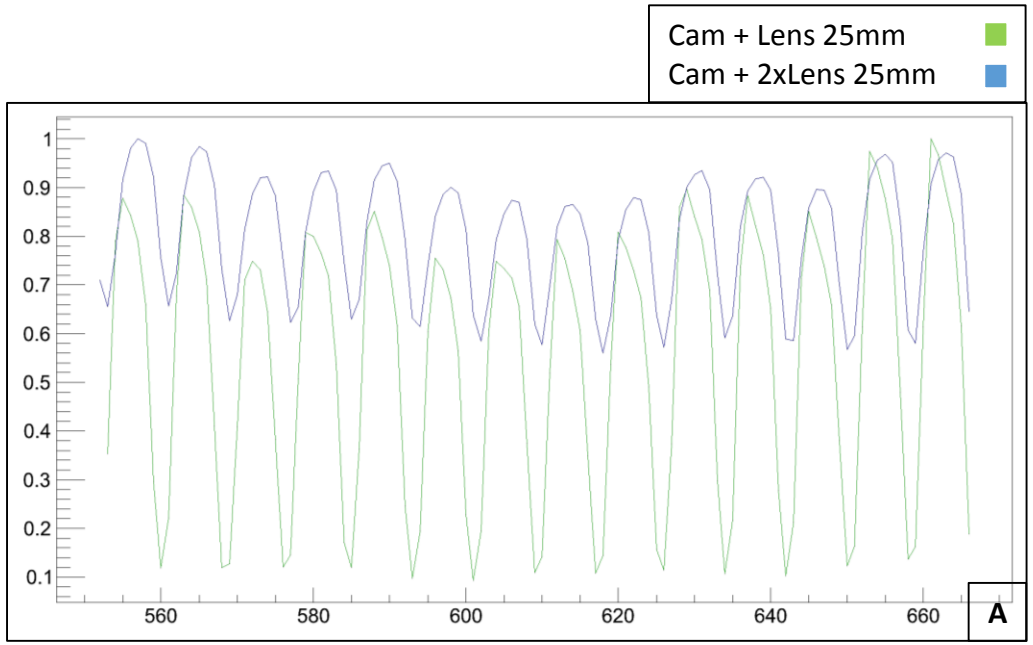


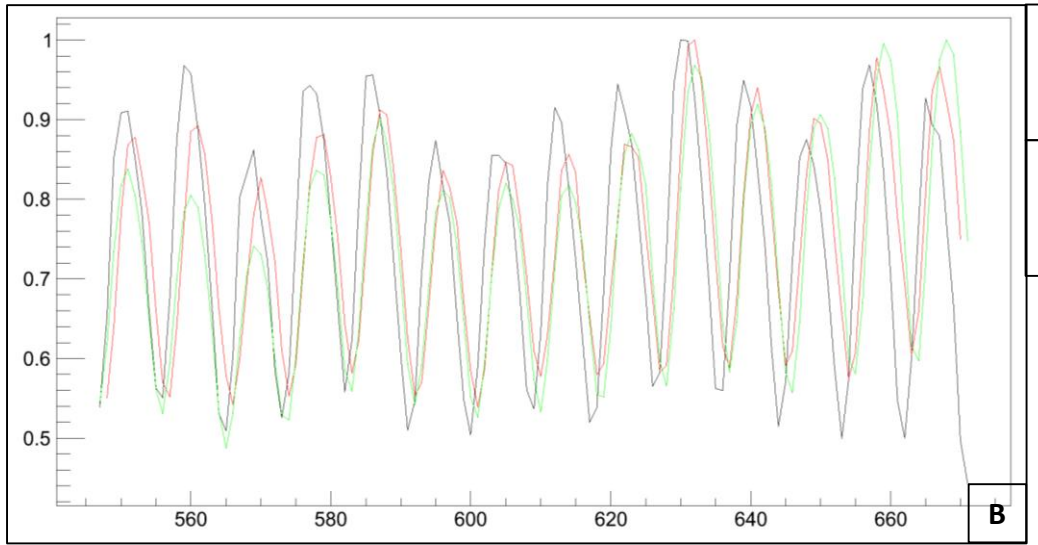
1) 5743142 a.u.

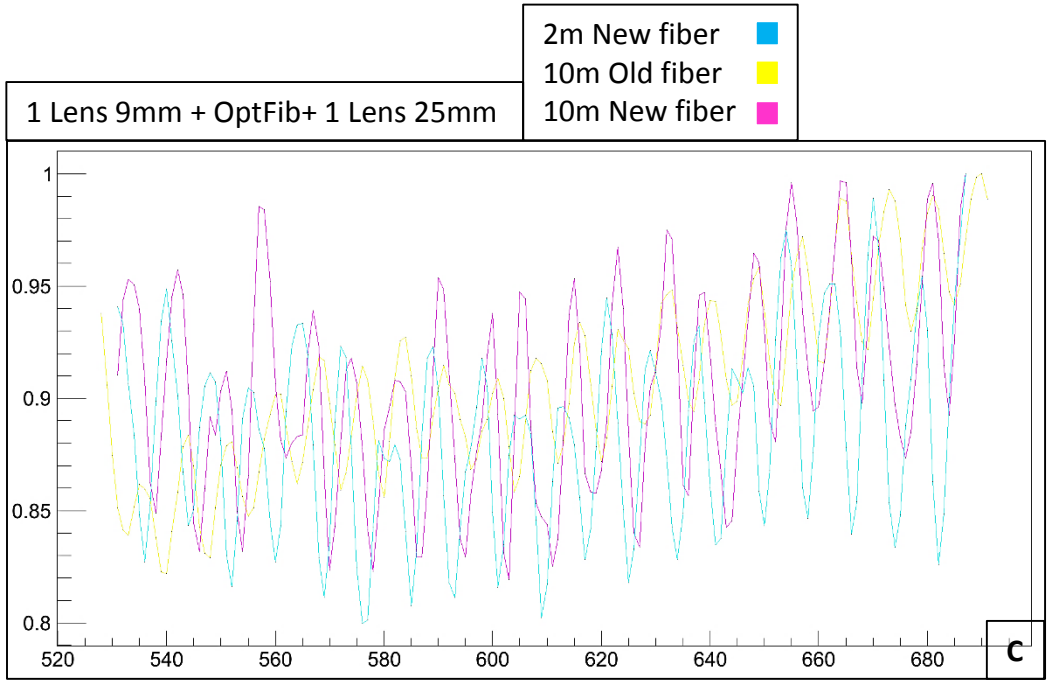
2) 5921904 a.u.

Differences < 3%

Resolution loss: analysis of the central square







Conclusions:

1. The first main factor worsening the resolution is the presence of the 2nd lens: with respect to the mean value, we go from 90% to 34% approximately (graph A).
2. The presence of the optical fibers does not drive further resolution losses in the case with two 25mm lens (graph B).
3. In the case of the 9mm lens before the optical fiber, a further decrease of the spatial resolution is noticed: 16%

Comparison with Eyepiece

- Main goals:
  - Increase light collection
  - Improve spatial resolution
- Choice of the eye piece: f=24mm
- Comparison with the 25mm lens

Comparison with eye-piece

Set-up and measurements:

1. The 9mm lens is used as 1st optical input in the fiber.
2. The 2nd camera lens (f=25mm) is substituted with an eye-piece (f=24mm) and the distance with the camera is adjusted to obtain approximately the same MAG.
3. Two comparative measurements were performed with both the 2m and 10m new optical fibers, with t_{exp}=20ms.

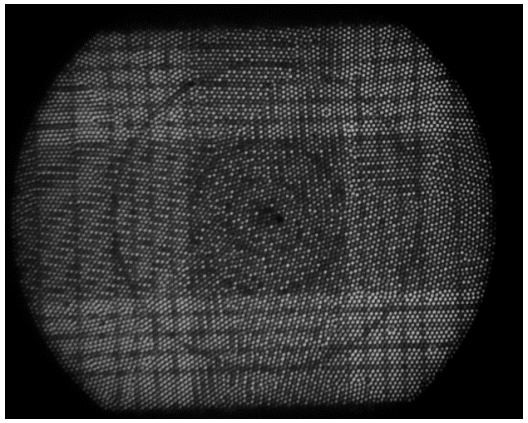
Eye-piece 24mm

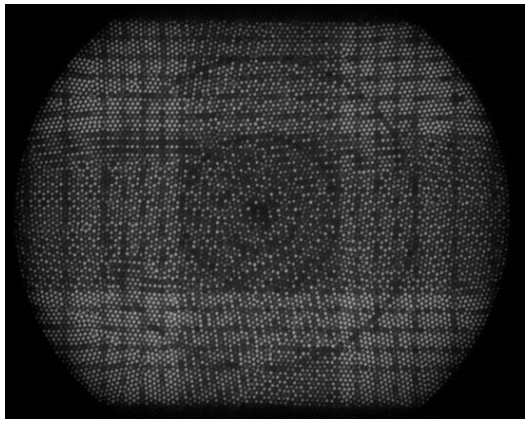
Camera lens 25mm

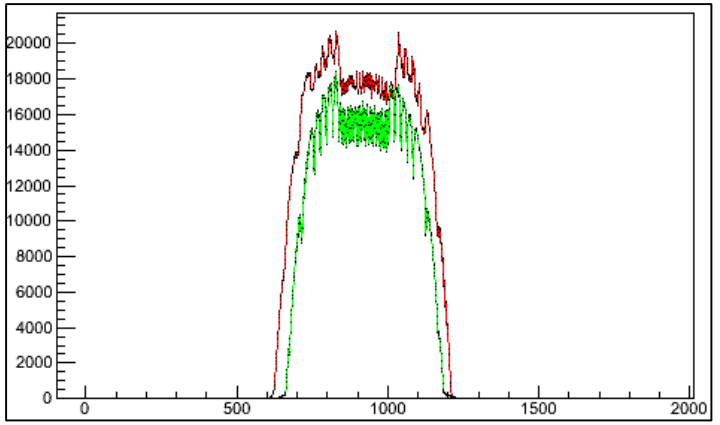
X-Profiles

Integral values [a.u.]

2m Opt fib





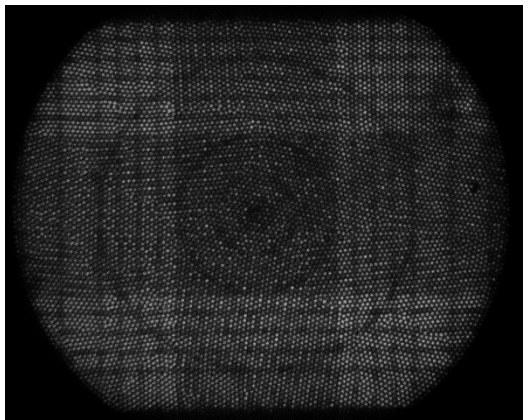


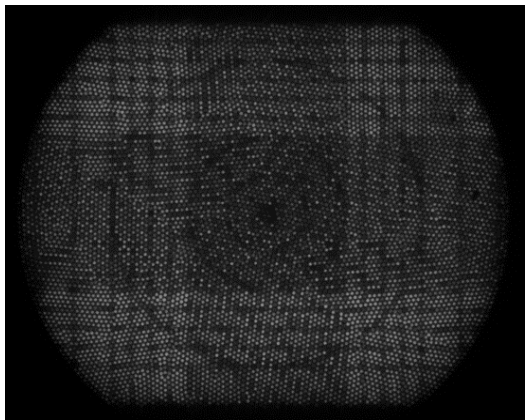
EyeP_2m: 9066809

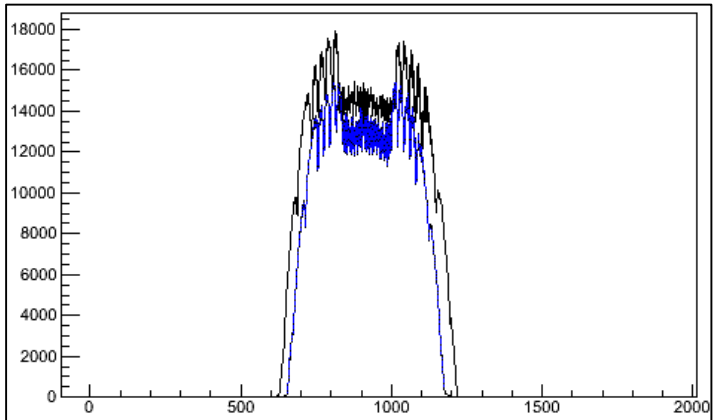
+ 29.4%

Lens_2m: 7005164

10m Opt fib







EyeP_10m: 7515769

+ 26.9 %

Lens_10m: 5921904

Comparison with eye-piece

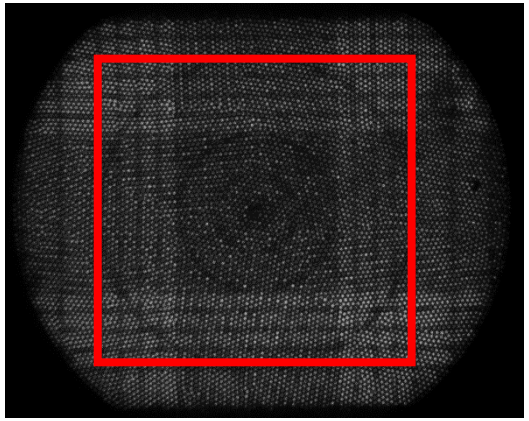
Eye-piece 24mm

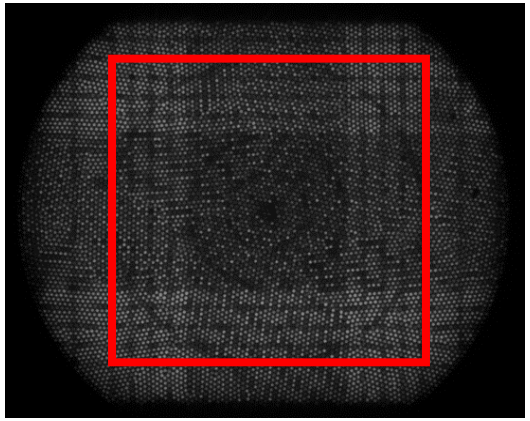
Camera lens 25mm

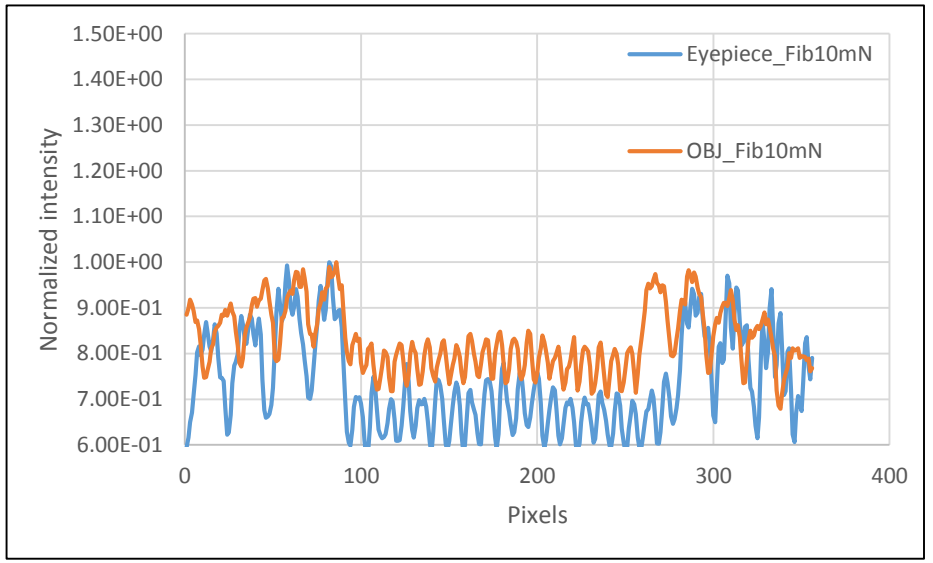
X-Profiles

Spatial resolution value:

10m Opt fib





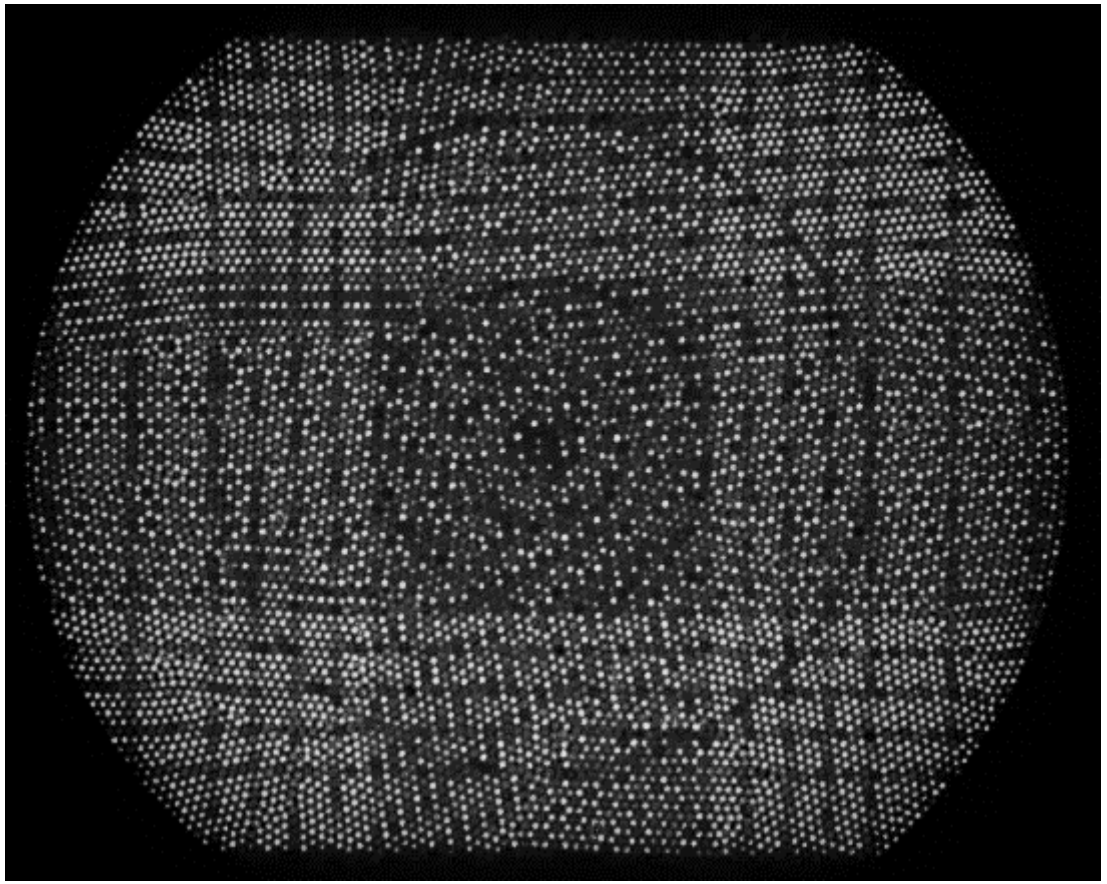


From 20% to 30%
(in 2.5mm gaps)

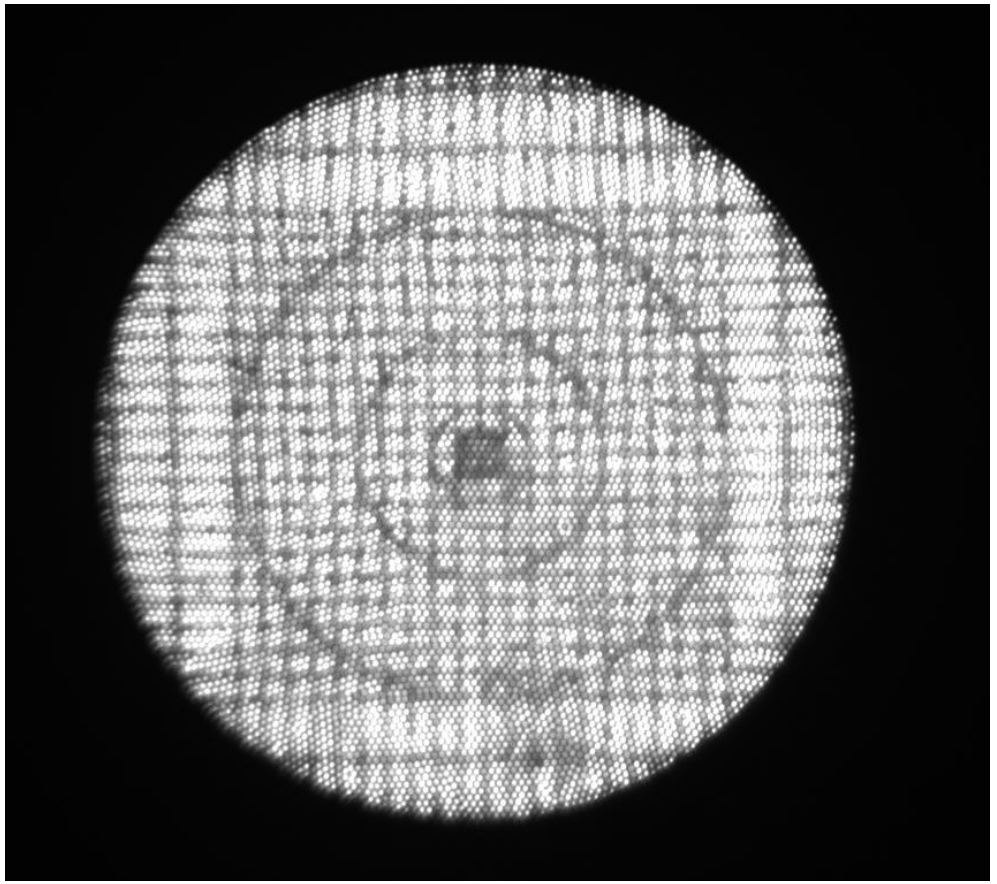
From 10% to 15%
(in 1mm gaps)

Best images

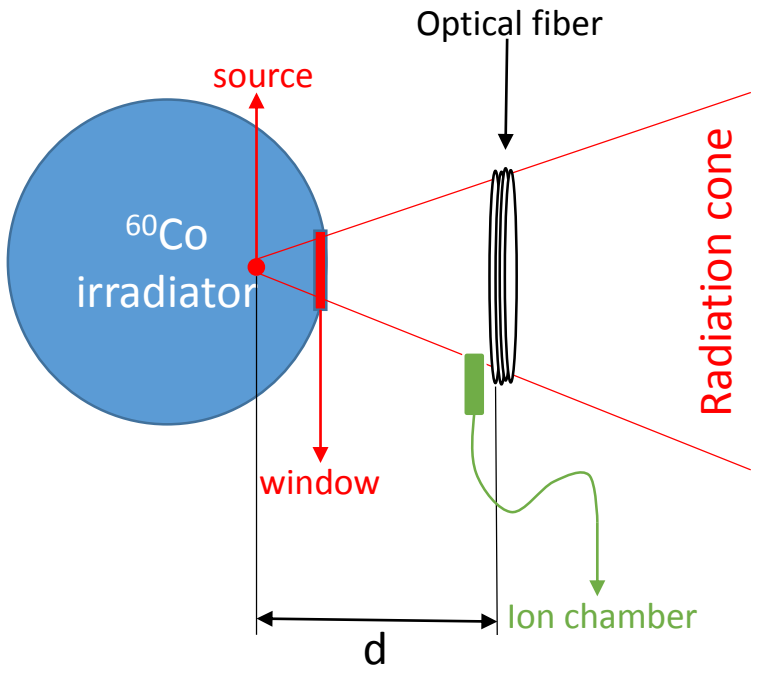
Target @500mm, texp=20ms, 1st lens 9mm, 2nd lens 25mm

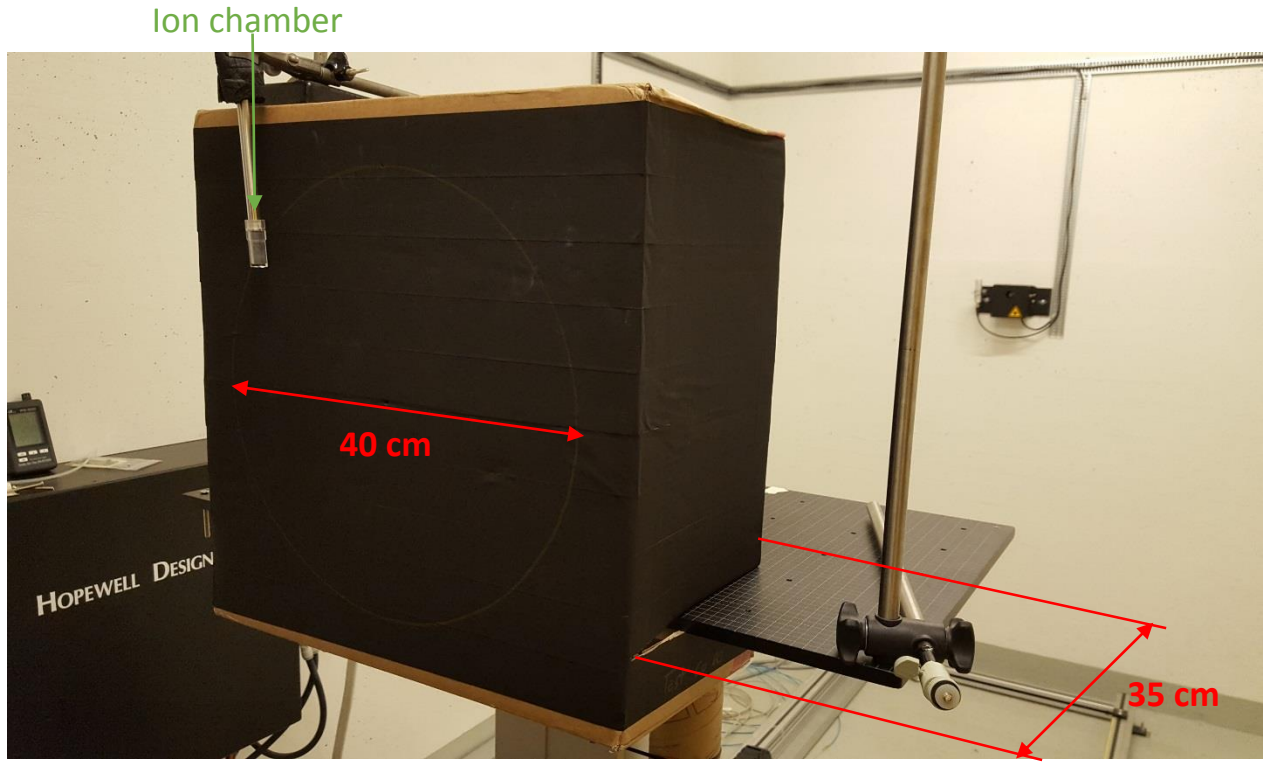


Target @200mm, texp=40ms, 1st lens 9mm, 2nd lens 25mm



Fiber radiation hardness: mapping test set up

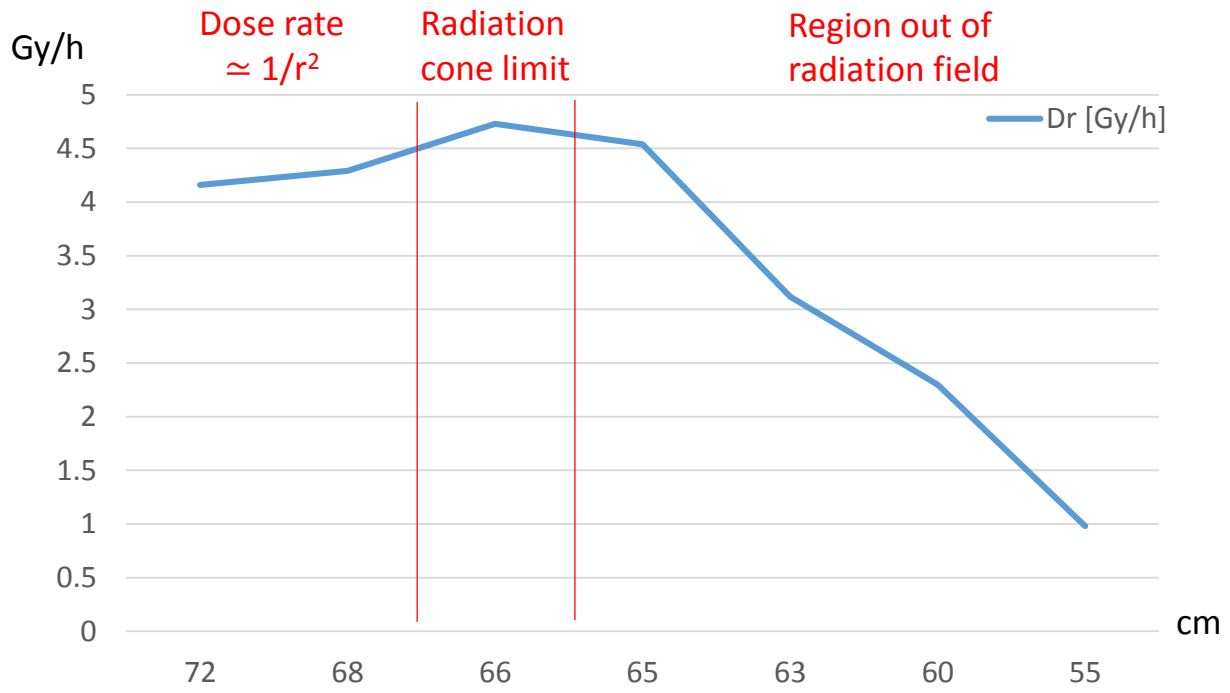




Where d is the distance chosen to maximize the dose rate

Choice of the distance

Distance [cm]	Dose rate [Gy/h]
72	4.16
68	4.29
66	4.73
65	4.54
63	3.12
60	2.30
55	0.98



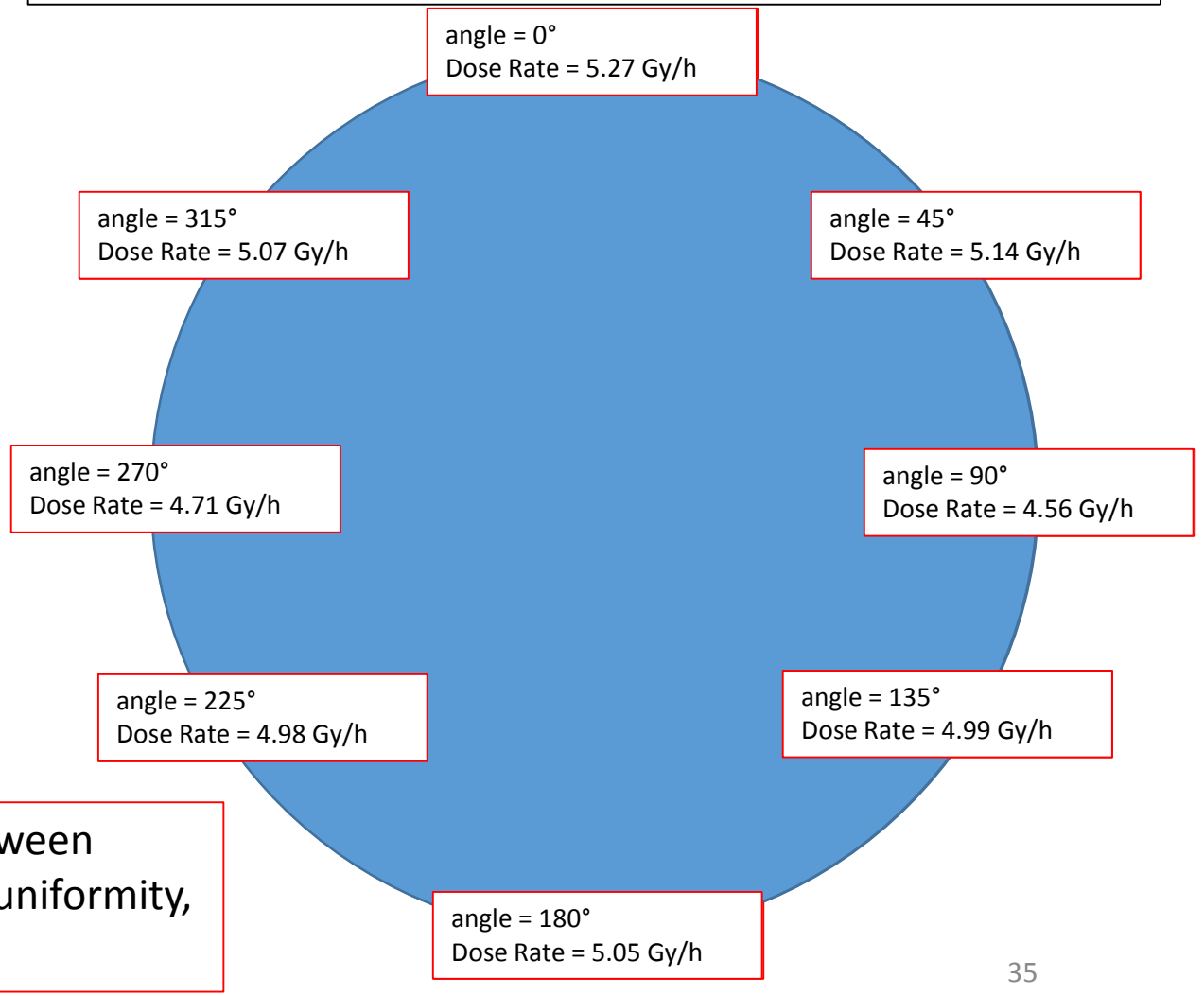
The distance of 66 cm between the fiber support and the source is chosen

Uniformity check

The obtained map is presented below, where the average dose rate is approximately 5 Gy/h over the all fiber. In this situation at the limit of the radiation cone and very close to the source, even 1-2 cm of displacement can drive a big difference in the dose rate.

For each point, 10 dose measurements integrated over 10s were taken and then the avg and the std dev is calculated, as follows:

Position [deg]		Gy/10s	Gy/s	mean	std%
0	1	14.39	5.1804	5.27652	0.766482
	2	14.84	5.3424		
	3	14.64	5.2704		
	4	14.64	5.2704		
	5	14.6	5.256		
	6	14.69	5.2884		
	7	14.76	5.3136		
	8	14.61	5.2596		
	9	14.7	5.292		
	10	14.7	5.292		

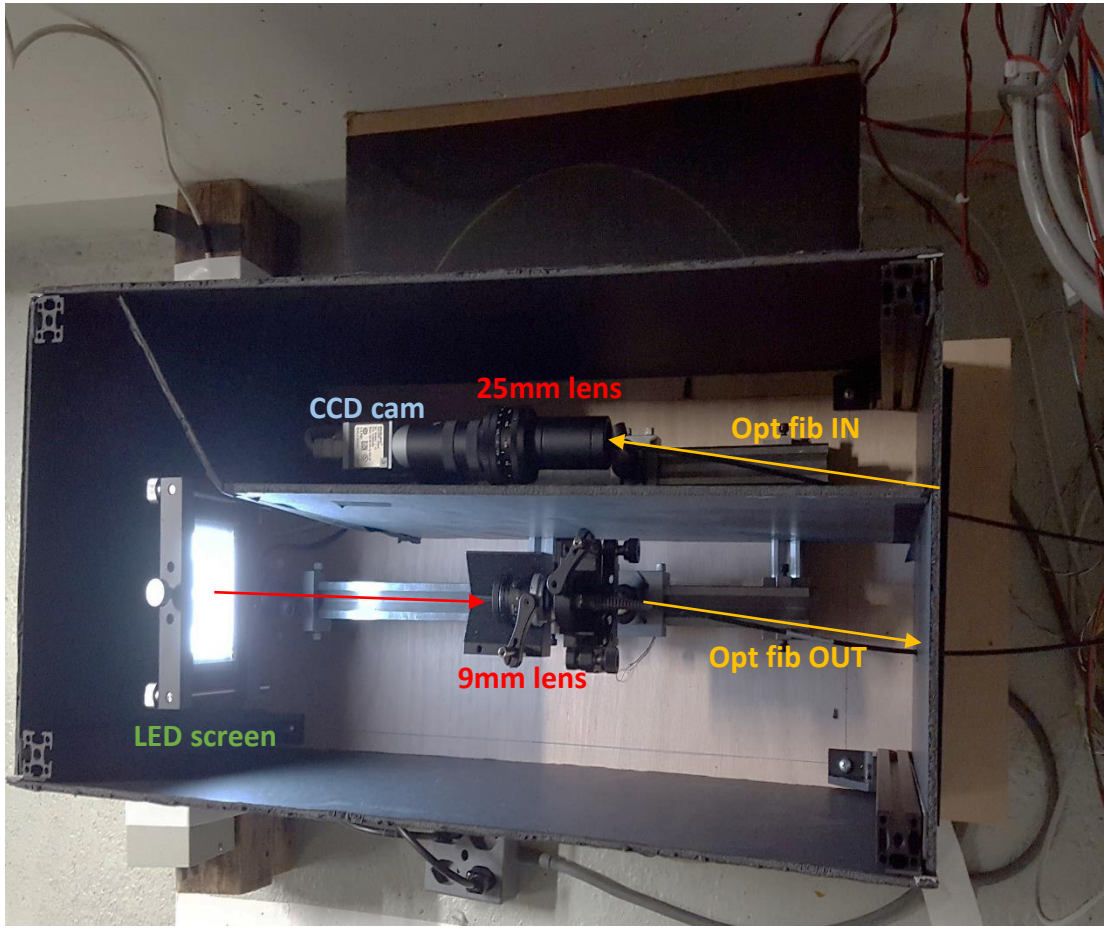


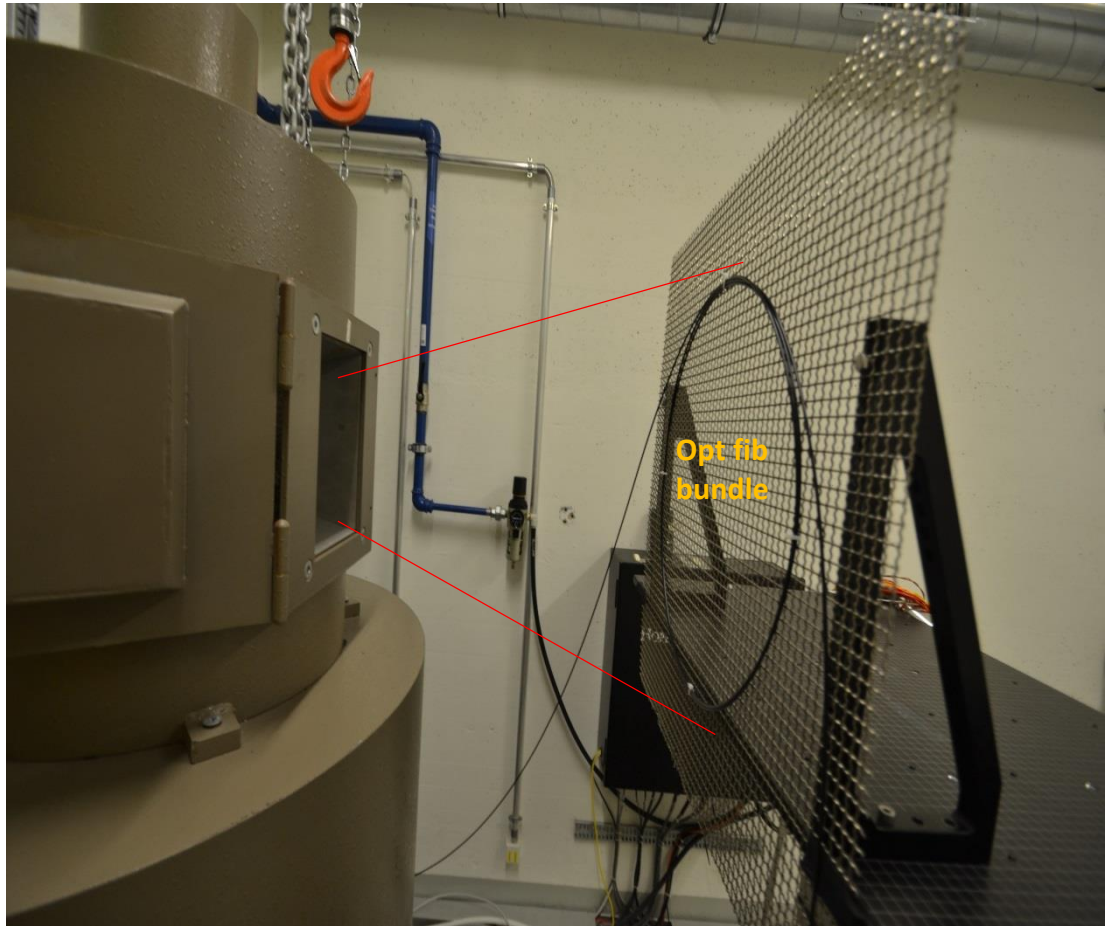
The best obtained result, looking for a compromise between the maximum achievable dose rate and the irradiation uniformity, is $\simeq$ 5Gy/h

Starting irradiation test

- Reference image taken at the beginning
- Acquired image every hour
- Light-tight box with all optical components and supports

- Testing the new 10m fiber by Fujikura
- 10 TBq active Co60 source
- Integrated dose over 3 weeks: 2 kGy



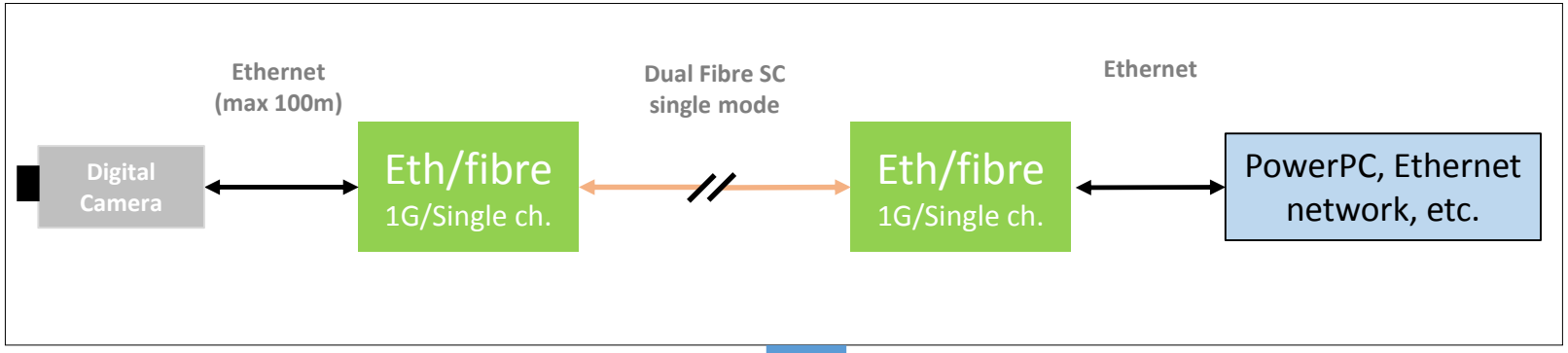


ETH/Fiber converters radiation hardness: intro

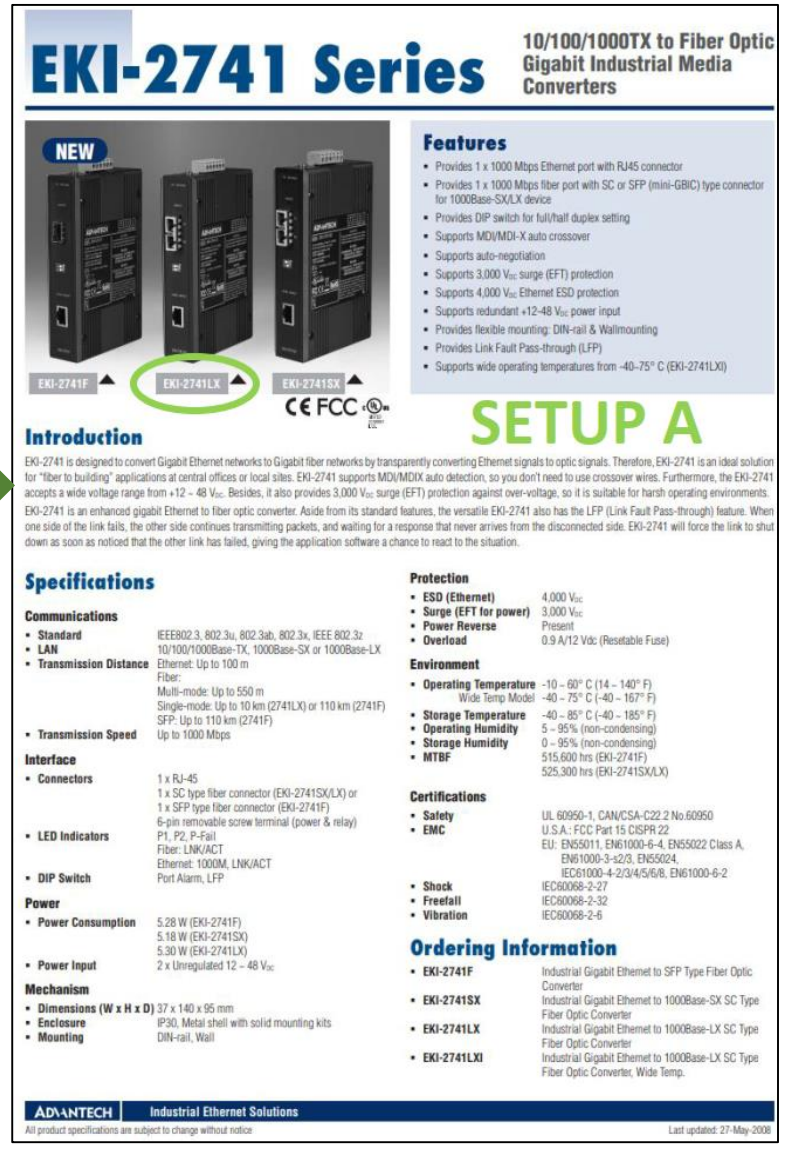
Increase of the use of high performance digital cameras in BI.
Radiation effect issue mitigated with optical line, shielding and RadHard innovation.

Distance to its control front end.
The Gigabit Ethernet allows up to 100m connections.
Not enough in the case of the SPS BTV dump future camera based (BTV) system.

Ethernet to Fibre Optic converter



As SPS machine…test in CHARM facility



EKI-2741 Series

10/100/1000TX to Fiber Optic Gigabit Industrial Media Converters

NEW

EKI-2741F EKI-2741LX EKI-2741SX

Features

- Provides 1 x 1000 Mbps Ethernet port with RJ45 connector
- Provides 1 x 1000 Mbps fiber port with SC or SFP (mini-GBIC) type connector for 1000Base-SX/LX device
- Provides DIP switch for full/half duplex setting
- Supports MDI/MDI-X auto crossover
- Supports auto-negotiation
- Supports 3,000 V_{DC} surge (EFT) protection
- Supports 4,000 V_{DC} Ethernet ESD protection
- Supports redundant +12-48 V_{DC} power input
- Provides flexible mounting: DIN-rail & Wallmounting
- Provides Link Fault Pass-through (LFP)
- Supports wide operating temperatures from -40-75° C (EKI-2741LXI)

SETUP A

Introduction

EKI-2741 is designed to convert Gigabit Ethernet networks to Gigabit fiber networks by transparently converting Ethernet signals to optic signals. Therefore, EKI-2741 is an ideal solution for "fiber to building" applications at central offices or local sites. EKI-2741 supports MDI/MDIX auto detection, so you don't need to use crossover wires. Furthermore, the EKI-2741 accepts a wide voltage range from +12 ~ 48 V_{DC}. Besides, it also provides 3,000 V_{DC} surge (EFT) protection against over-voltage, so it is suitable for harsh operating environments.

EKI-2741 is an enhanced gigabit Ethernet to fiber optic converter. Aside from its standard features, the versatile EKI-2741 also has the LFP (Link Fault Pass-through) feature. When one side of the link fails, the other side continues transmitting packets, and waiting for a response that never arrives from the disconnected side. EKI-2741 will force the link to shut down as soon as noticed that the other link has failed, giving the application software a chance to react to the situation.

Specifications

Communications

Standard	IEEE802.3, 802.3u, 802.3ab, 802.3x, IEEE 802.3z
LAN	10/100/1000Base-TX, 1000Base-SX or 1000Base-LX
Transmission Distance	Ethernet: Up to 100 m Fiber: Multi-mode: Up to 550 m Single-mode: Up to 10 km (2741LX) or 110 km (2741F) SFP: Up to 110 km (2741F)
Transmission Speed	Up to 1000 Mbps

Interface

Connectors	1 x RJ-45 1 x SC type fiber connector (EKI-2741SX/LX) or 1 x SFP type fiber connector (EKI-2741F) 6-pin removable screw terminal (power & relay)
LED Indicators	P1, P2, P-Fail Fiber: LNK/ACT Ethernet: 1000M, LNK/ACT
DIP Switch	Port Alarm, LFP

Power

Power Consumption	5.28 W (EKI-2741F) 5.18 W (EKI-2741SX) 5.30 W (EKI-2741LX)
Power Input	2 x Unregulated 12 ~ 48 V_{DC}

Mechanism

Dimensions (W x H x D)	37 x 140 x 95 mm
Enclosure	IP30, Metal shell with solid mounting kits
Mounting	DIN-rail, Wall

Protection

ESD (Ethernet)	4,000 V_{DC}
Surge (EFT for power)	3,000 V_{DC}
Power Reverse	Present
Overload	0.9 A/12 Vdc (Resetable Fuse)

Environment

Operating Temperature	-10 ~ 60° C (14 ~ 140° F)
Wide Temp Model	-40 ~ 75° C (-40 ~ 167° F)
Storage Temperature	-40 ~ 85° C (-40 ~ 185° F)
Operating Humidity	5 ~ 95% (non-condensing)
Storage Humidity	0 ~ 95% (non-condensing)
MTBF	515,600 hrs (EKI-2741F) 525,300 hrs (EKI-2741SX/LX)

Certifications

Safety	UL 60950-1, CAN/CSA-C22.2 No.60950
EMC	U.S.A.: FCC Part 15 CISPR 22 EU: EN55011, EN61000-6-4, EN55022 Class A, EN61000-3-2/3, EN55024, IEC61000-4-2/3/4/5/6/8, EN61000-6-2
Shock	IEC60068-2-27
Freefall	IEC60068-2-32
Vibration	IEC60068-2-6

Ordering Information

EKI-2741F	Industrial Gigabit Ethernet to SFP Type Fiber Optic Converter
EKI-2741SX	Industrial Gigabit Ethernet to 1000Base-SX SC Type Fiber Optic Converter
EKI-2741LX	Industrial Gigabit Ethernet to 1000Base-LX SC Type Fiber Optic Converter
EKI-2741LXI	Industrial Gigabit Ethernet to 1000Base-LX SC Type Fiber Optic Converter, Wide Temp.

ADVANTECH Industrial Ethernet Solutions

All product specifications are subject to change without notice

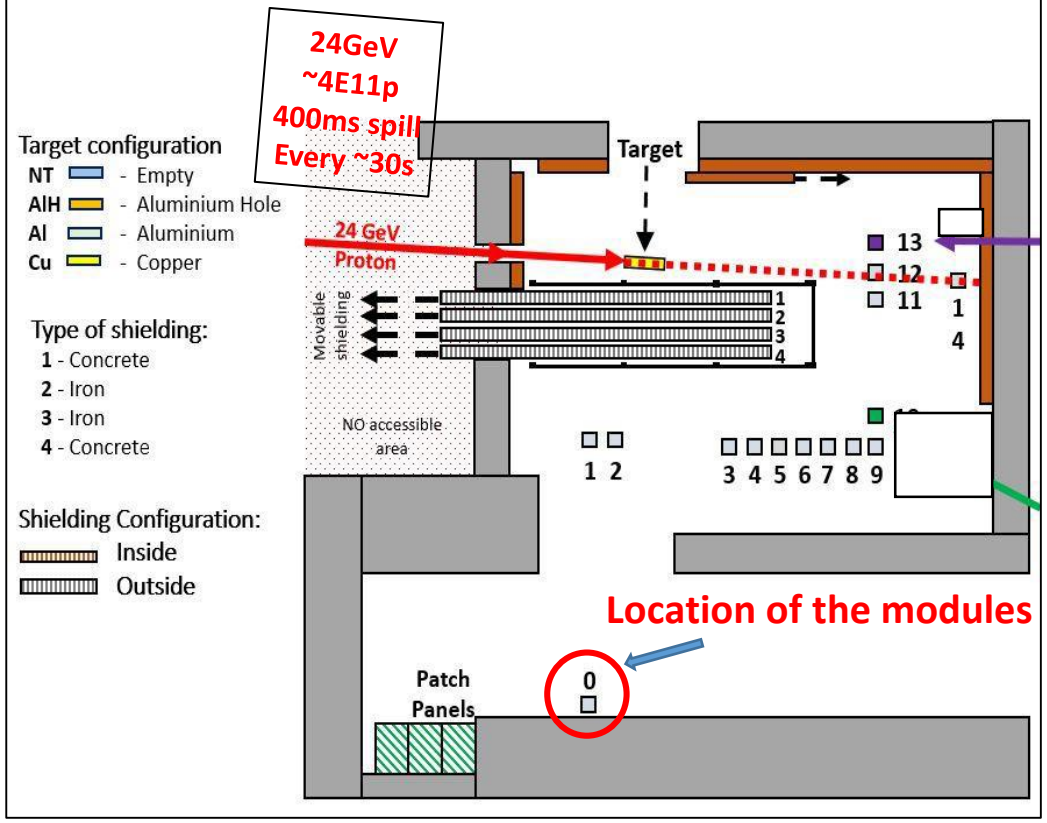
Last updated: 27-May-2008

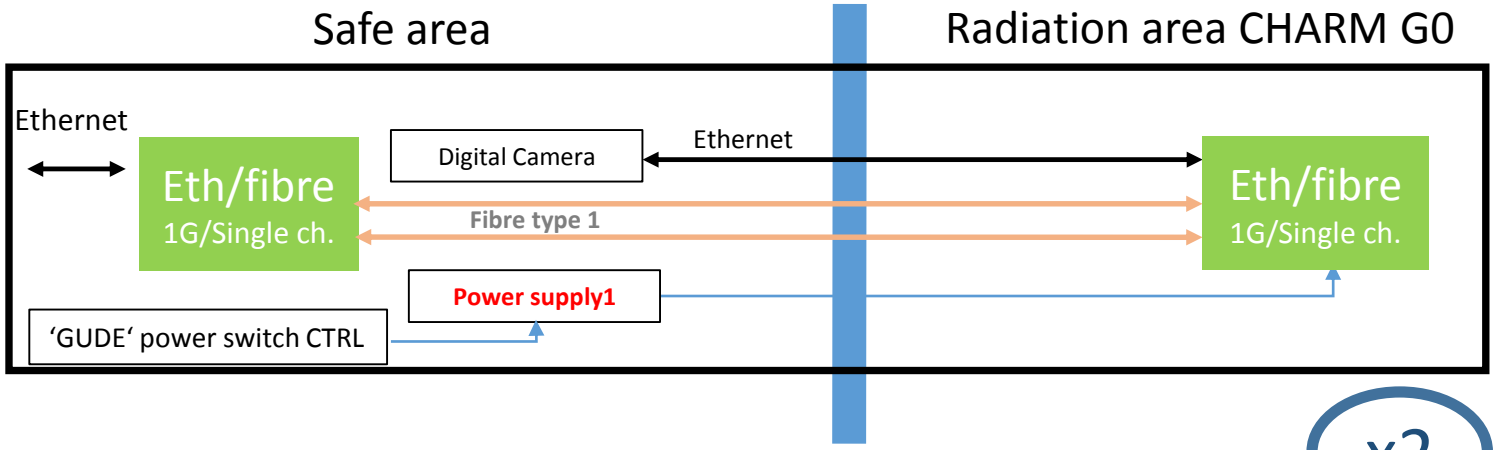
ETH/Fiber converters radiation hardness: setup

Request:

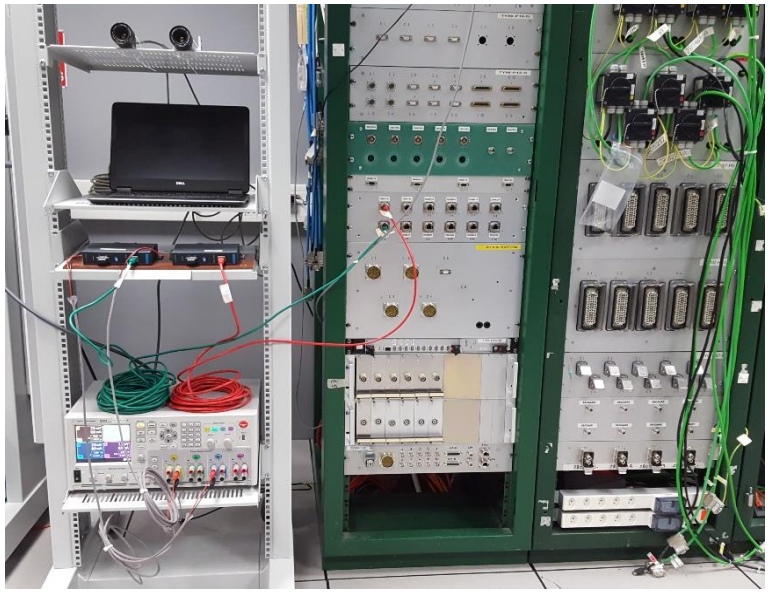
- To reach approximately 50 Gy TID
- RUN1: from 08/08/2018 to 14/08/2018
- RUN2: from 16/08/2018 to 21/08/2018

Configuration: CuOOOO





x2



ETH/Fiber converters radiation hardness: results

Test procedure:
- Image acquisitions every minute
- Power cycles at each connection loss

Analysis:
- Logging cameras
- Logging GUDE power switch
- Checking communication failures

	Module 1	Module 2
Reset number	*28*	*22*
HEHeq	*8.91E+10*	*8.91E+10*
σ_{SEE} *[cm2]*	*3.14E-10*	*2.47E-10*
Φ_{fail} *[cm-2]*	*3.18E+09*	*4.05E+09*
$\Phi_{failCam}$ *[cm-2]*	1.5 E+09