Optical Fibre Dosimetry

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Agenda

1. Optical Fibre Dosimetry Work Package
2. Distributed Optical Fibre Radiation Sensors (DOFRS)
3. DOFRS installations
4. O&M and R&D activities
5. Conclusions and Outlook

Optical Fibre Dosimetry Work Package

Optical Fibre Dosimetry Work Package

WP holder

EN-EL-FC

Mandate and main objectives

The mandate of the Optical Fibre Dosimetry Work Package (OFD WP) **is to develop, deploy, operate and maintain the optical fibre radiation sensors** that are employed in the monitoring of the radiation dose levels in CERN's accelerators and transfer lines.

As of today, **the main deployed system is the Distributed Optical Fibre Radiation and temperature Sensor** (DOFRS).

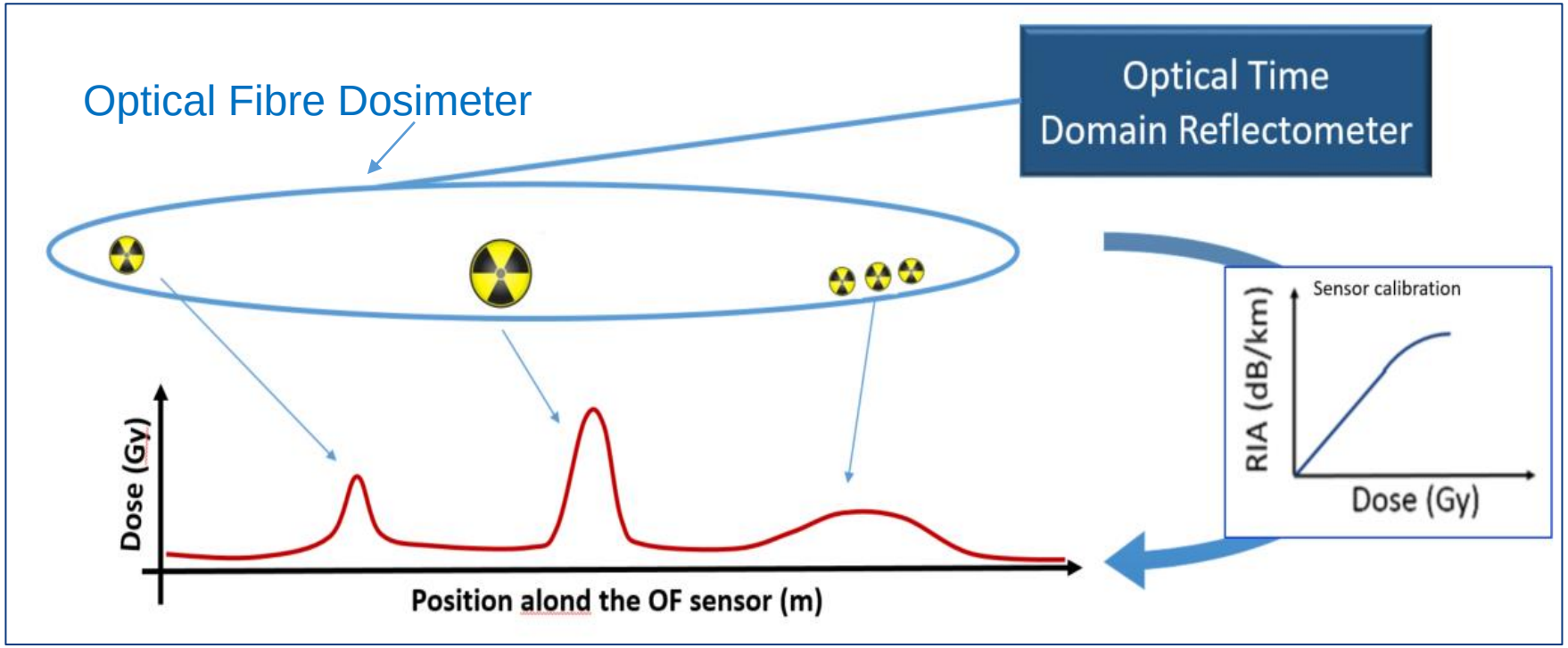
The OFD WP is instrumental to the *Monitoring & Calculation Working Group* (*MCWG)* as it contributes to its main tasks: addressing specific requests from equipment groups; the general reporting activities; the comparison and cross-validation of radiation field simulations; the comparison and cross-validation of radiation measurements from other monitors and detectors.

Distributed Optical Fibre Radiation Sensors

Distributed Optical Fibre Radiation Sensors

DOFRS is based on:

- **Radiation Induced Attenuation** (RIA) in suitable specialty OFs (*not any optical fibre*)
- **Optical Time Domain Reflectometry**



First implementation reported by *H. Henschel et al., Nucl. Instr. & Meth. in Phys. Res. A, vol. 526, no. 3, pp. 537–550, 2004*

Distributed Optical Fibre Radiation Sensors

Key Features of DOFRS

- **Well adapted for large facilities - several hundreds of meters up to 1 km**
- **Distributed 1D maps of the radiation dose - spatial resolution down to 1 m**
- **Online monitoring - temporal resolution of a few minutes**
- All electronics installed in remote and radiation-free locations – measurement can be deported over km distances
- One cable -> multiple OFs -> multiple radiation sensitivities
- Information of the cumulated dose stored in the OF itself
- Cost Efficient
- Need to replace the OF sensors: cable blowing
- NEW Possibility to reset and reuse some OF dosimeters by photobleaching (R&D phase)

DOFRS installations

Evolution of DOFRS at CERN

I. Toccafondo's PhD thesis

2013-2016

2017: 1st prototype installed in the PSB

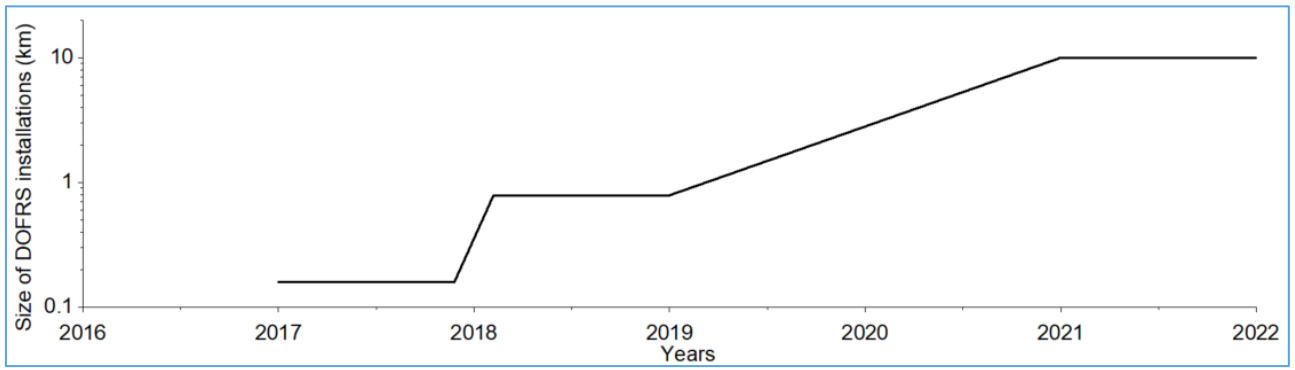
2018: A new version of DOFRS implemented in the PS

2019-2020: DOFRS installed in SPS, TT20 and LHC

Run 3 operation

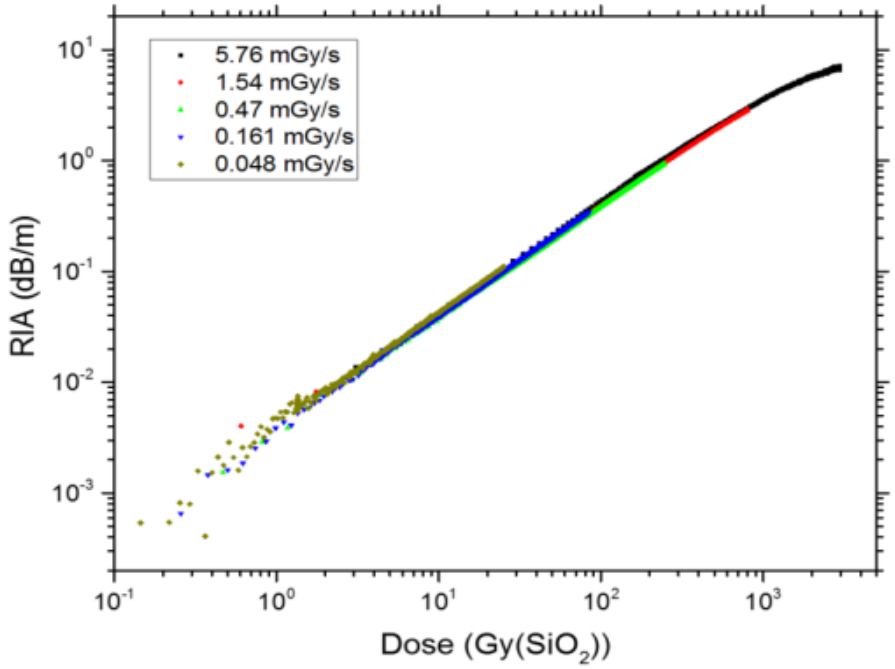
DOFRS project *KT-Funded*

ORION project *KT-Funded*



Most important LS2 activities

- Large procurement of OFs (sensors and auxiliary OFs)
- Qualification and testing of the OF sensors
- Procurement of optical interrogators and control units
- Installations of rack and mini-racks
- Installations of the OF infrastructure
- Software upgrade
- Commissioning of the systems

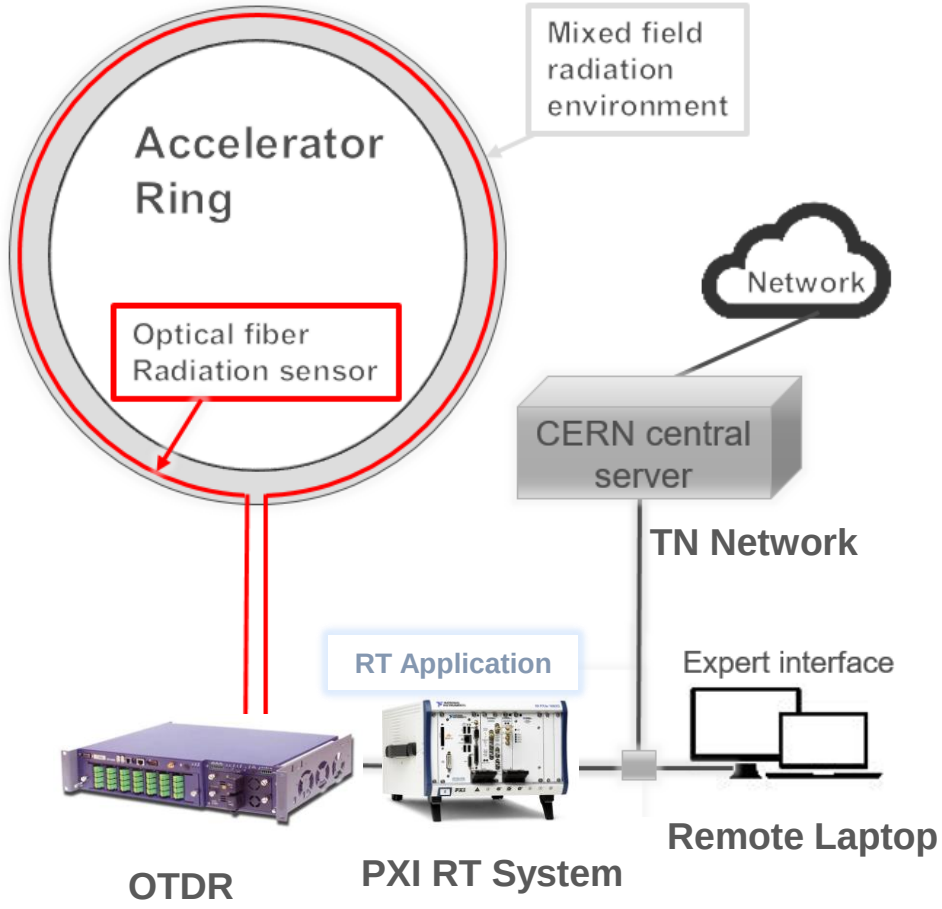


Data acquisition started in the PSB

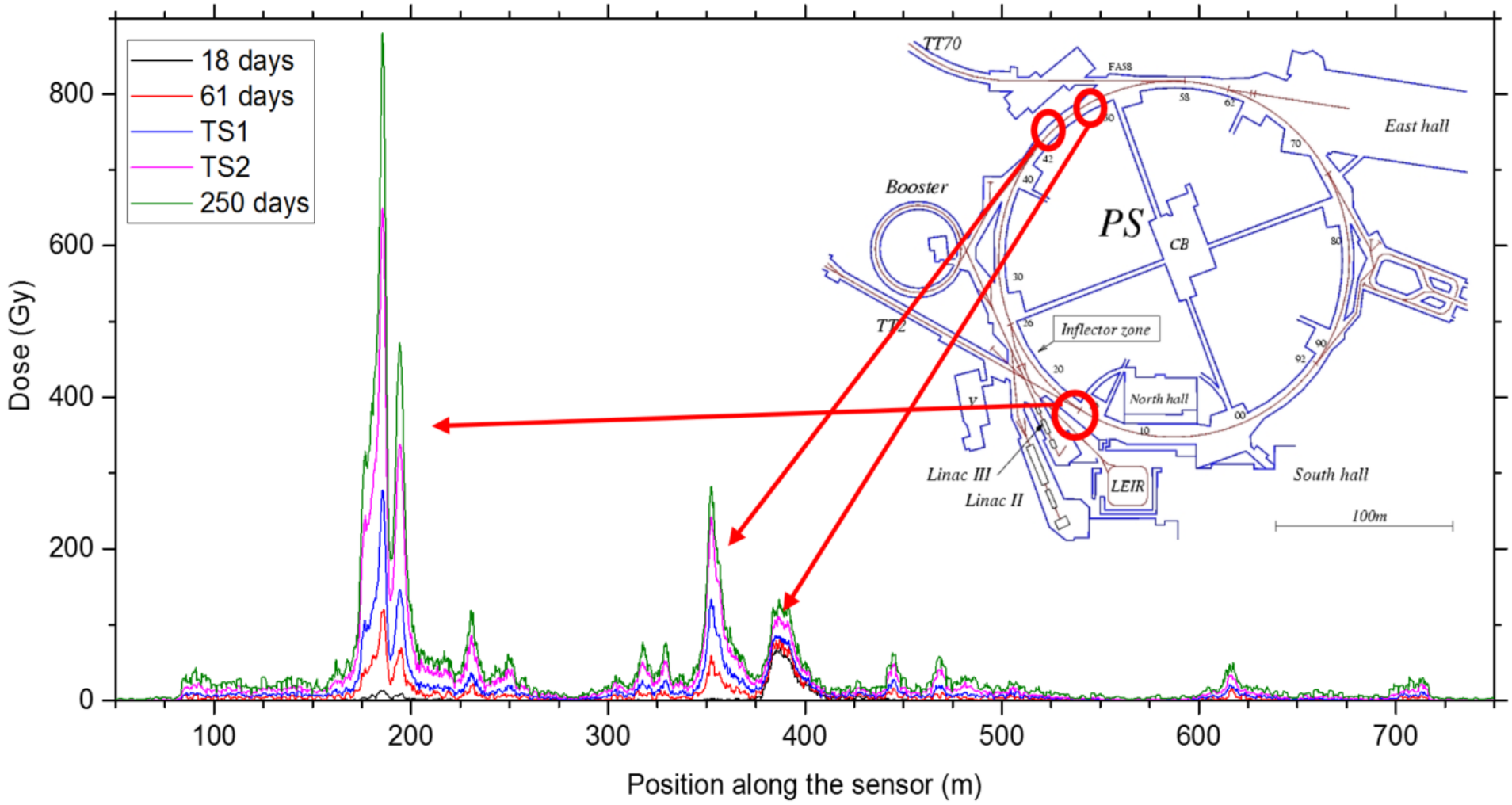
Example of DOFRS systems

- **Hardware Architecture:**
  - Radiation Sensitive **Optical fibers (OFs)** in the accelerator
  - OTDR instrument connected to the OFs
  - PXI RT System connected to the OTDR and to the Technical Network (TN) through Ethernet interfaces.
- **Software Architecture:**
  - **A Real Time (RT) LabView Application** running on the **RT PXI** system acquiring
    - Object Oriented Programming (**OOP**).
    - Use of CERN librabries for data logging and server communication.
    - Acquire, process and publish autonomously the OF data
  - **Expert User Interface**
    - Can be accessed from any computer on the TN
    - Allows to visualize and change on the fly the acquisition and publication parameters.

Collaboration with BE-CEM-EPR



Example from PS in 2018



Some numbers about DOFRS

Four DOFRS systems installed:

- PSB, PS, SPS + TT20, 6 DS regions of Large Hadron collider
- More than 9 km of monitored area
- 4 control units (+1 spare)
- 8 optical interrogators (+1 spare)
- 48*2 optical links (probed in both direction)
- about 97 km of total OF length for the full DOFRS infrastructure
- OFs procured from three different OF manufacturers

O&M and R&D activities

Operation and maintenance during RUN 3

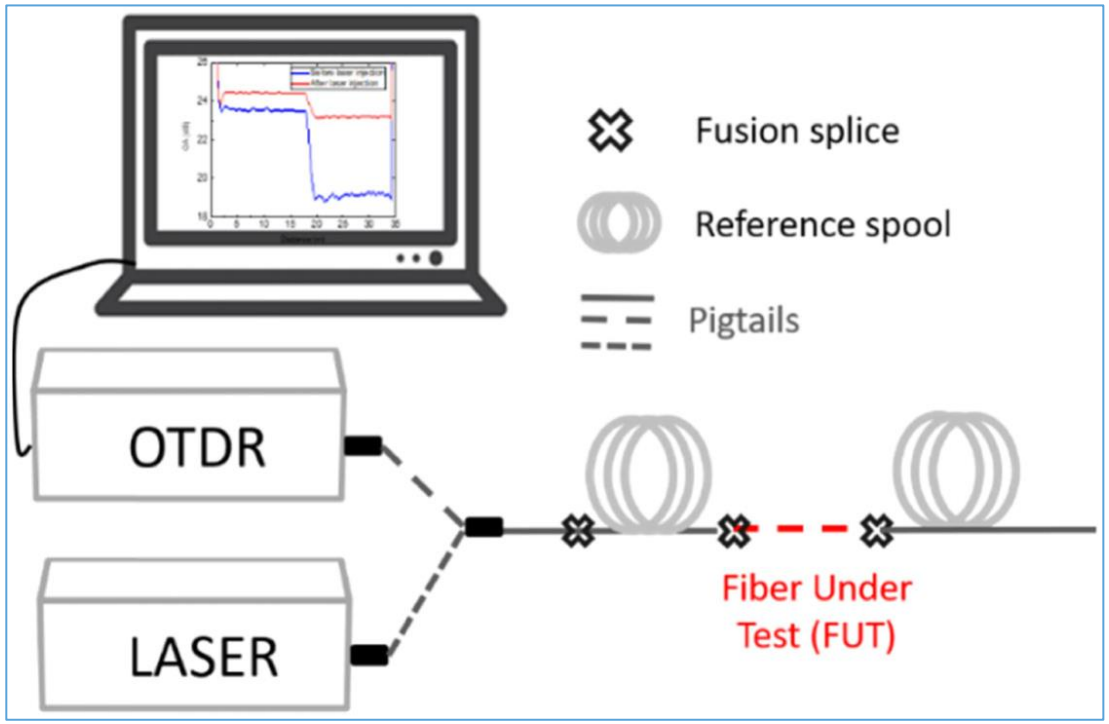
- Monitoring of regular data acquisition from all DOFRS systems
- Development of the tools for the automatic data analysis with SY-STI-BMI
- Full exploitation of results in MCWG context
- Preparation of all maintenance activities to be carried out at the end of the year in the coming years
- Preparation of further installations (if any request is received)
- Improvement of the systems

R&D activities and collaborations

- Development and characterization of new OF sensors which are of interest for future use of DOFRS
- Investigation of techniques to reset and reuse of OF dosimeters[1]
- Characterization of radio-luminescent OFs to carry out dose measurements with higher temporal resolution[2]

[1] G. Li Vecchi *et al.*, "In-situ regeneration of P-doped optical fiber dosimeter," ***Opt. Lett.*,** 2020, doi: 10.1364/OL.402382.
[2] N. Kerboub *et al*., "Temperature Effect on the Radioluminescence of Cu, Ce and CuCe Doped Silica-based Fiber," ***IEEE Trans. Nucl. Scie***., under review.

R&D activities: regeneration of the OF Dosimeter



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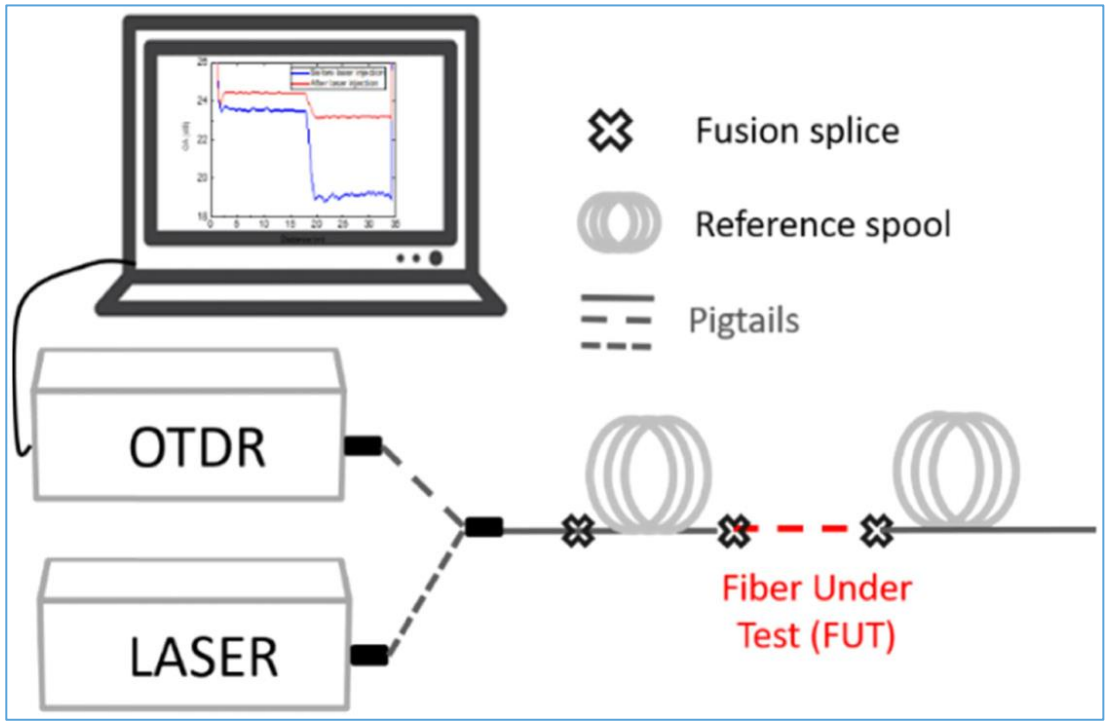

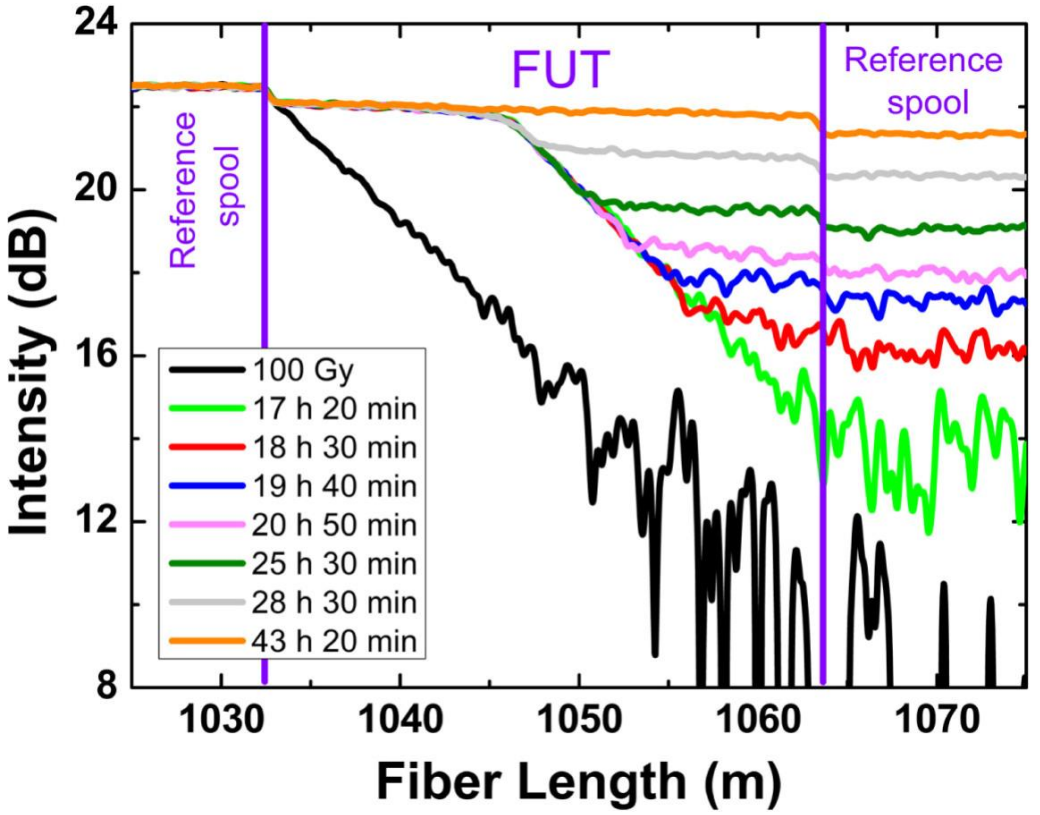

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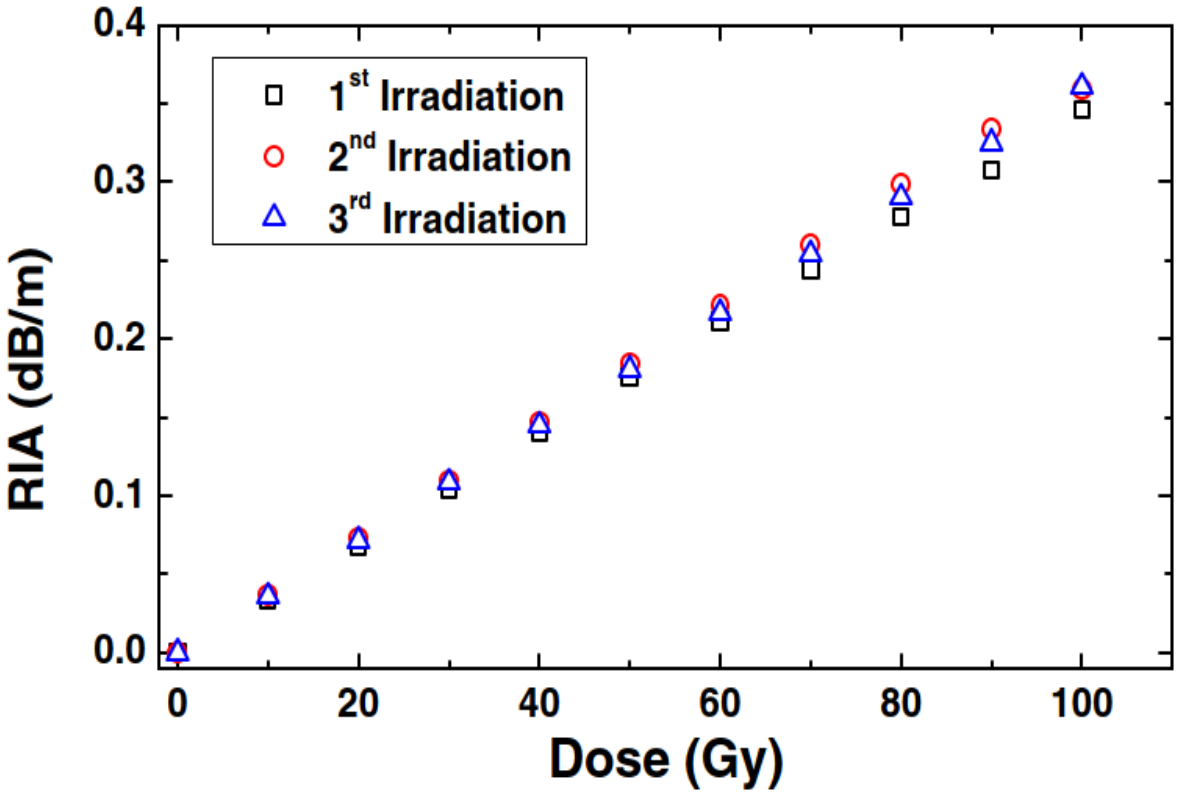

- Injection of light of suitable wavelength allows the recovery of the RIA.
- The initial calibration of the sensor is maintained
- In our tests, the regeneration has been applied three consecutive times on the same sample successfully.

The possibility to implement a prototype of such system in the PSB is under evaluation.

[1]G. Li Vecchi *et al.*, "In-situ regeneration of P-doped optical fiber dosimeter," *Opt. Lett.*, 2020, doi: 10.1364/OL.402382.

Conclusion and Outlook

- In the last two years SPS+TT20 and six DS regions of LHC were instrumented with DOFRS systems. DOFRS in PSB and PS were consolidated.
- Total size of DOFRS systems increased by a factor 15 during LS2.
- Monitoring started in the PSB in December 2020 ready to start acquisitions in other accelerators.
- Planning and execution of maintenance activities.
- Ongoing R&D to extend the capabilities and applicability and to reduce costs.

Thank you for your attention!