

Radiation-Resistant Temperature Monitoring in High-Energy Physics Environments

Speaker: Timothy Brooks

Collaboration: A. S. Cassim, S. Connell, L. Truong, D. Unwuchola, X. Mapekula, M. P. Connell, B. Maqabuka, S. Temauee, D. Madyira



UNIVERSITY
OF
JOHANNESBURG

FACULTY OF
ENGINEERING AND THE
BUILT ENVIRONMENT



YEARS OF IMPACT

70th SAIP Conference

Our Future
Reimagined

Introduction

- High Energy Particle Physics is a window into the fundamental structure of the universe
- CERN (European Organization for Nuclear Research) hosts High-Energy Physics (HEP) experiments on the Energy Frontier
- Houses the Large Hadron Collider (LHC) - proton-proton (p-p) and heavy-ions collisions
- ATLAS is a detector at the LHC. Famous for discovery of the Higgs Boson particle in 2012
- High Luminosity LHC (HL-LHC) upgrades on the accelerators – more collisions/pile-up
- For ATLAS: replacing Inner Detector with the advanced Inner Tracker (ITk) for HL-LHC

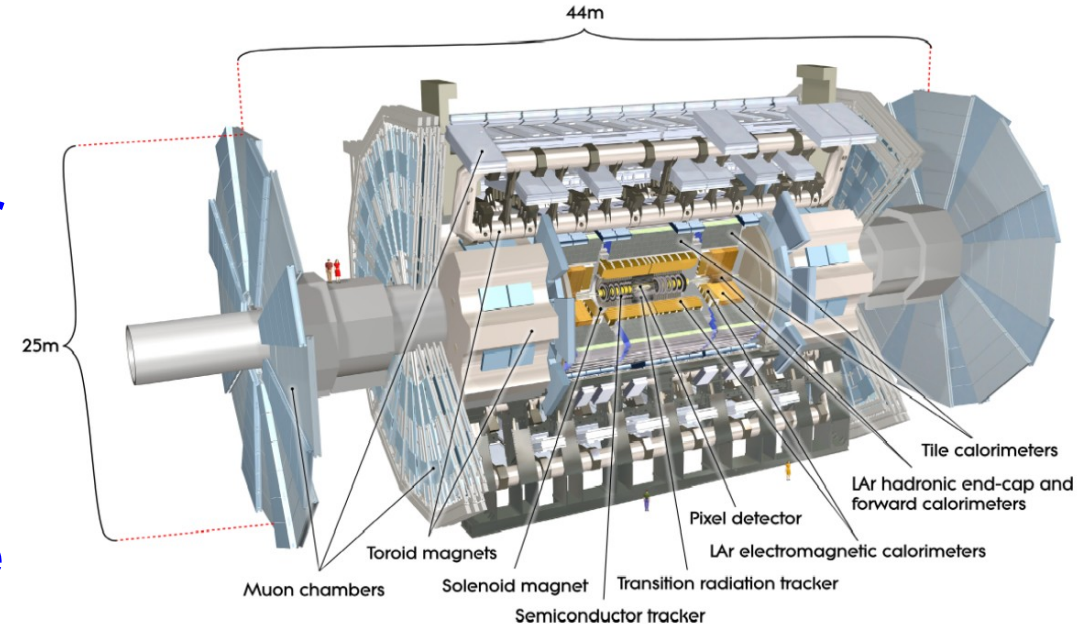


Figure 1: The LHC and ATLAS detector at CERN



Problem Statement: Radhard FBG sensors

- Need accurate temperature sensor
- Capable of decoupling temperature effects on humidity sensor
- Resistant to radiation

Aim

- To qualify radiation-hard FBG sensors for temperature monitoring

Objectives

- Perform pre-irradiation tests
- Monitor and assess radiation damage
- Perform post-irradiation tests
- Conclude on suitability

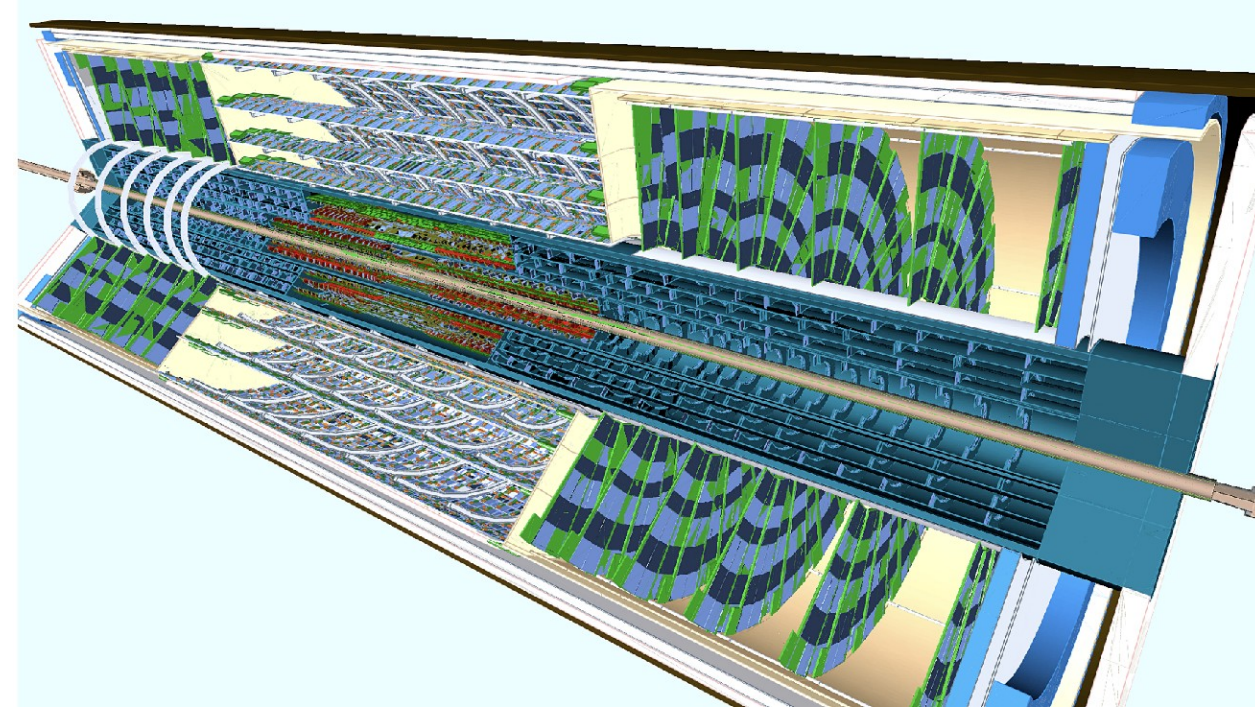


Figure 3: Internal cross-section of the ATLAS ITk [1]



What are Fiber Optic Sensors?

- Reflect specific wavelength of light (Bragg wavelength).
- Governed by the Bragg equation:

$$\lambda_B = 2n_{eff}\Lambda$$

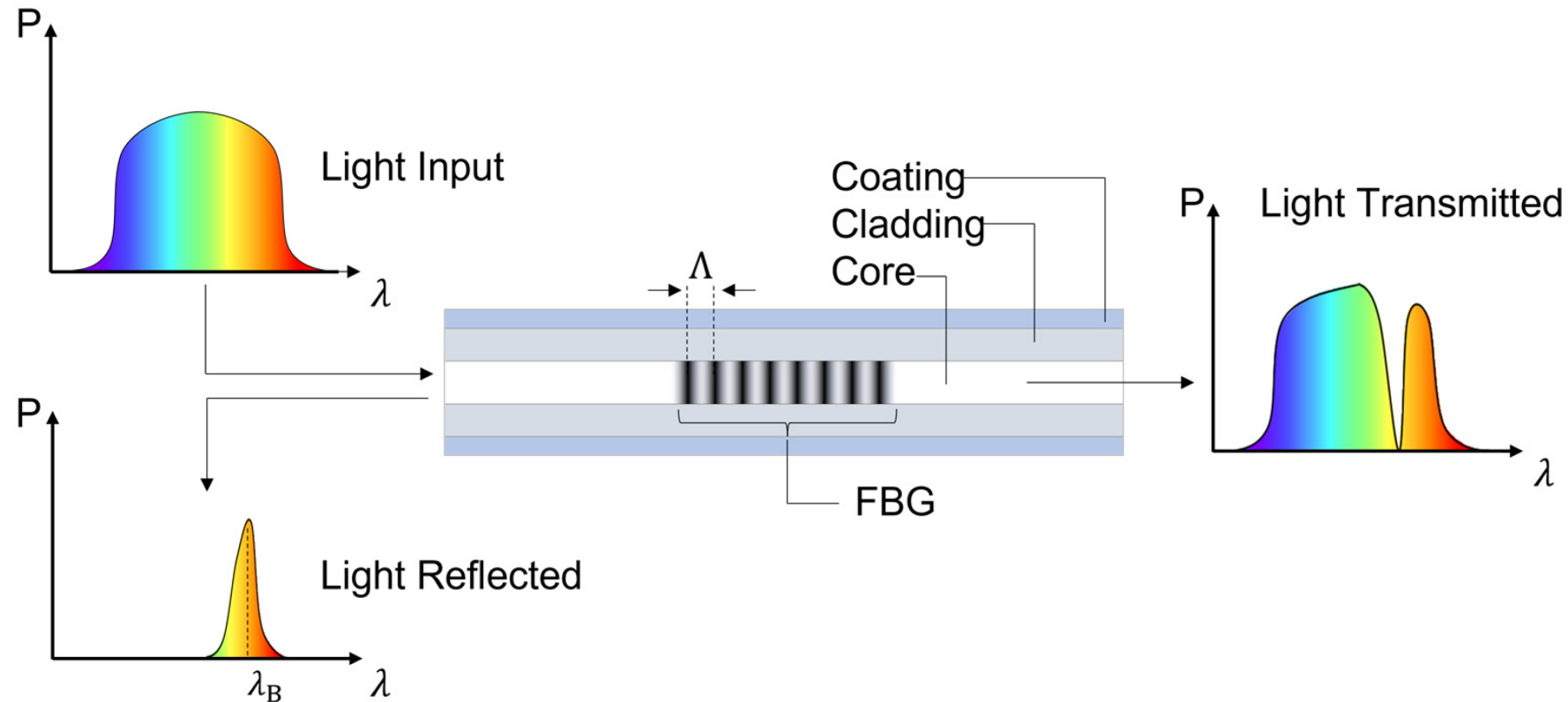


Figure 4: Principle of operation for an Fibre Bragg Grating sensor [2]



The Answer: Fiber Optic Sensors for Environmental Monitoring

- Novel Fiber Optic Sensors (FOS)
- Package comprises:
 - I. Humidity sensitive Long Period Grating (LPG)
 - II. Radiation-soft Fiber Bragg Grating (FBG)
 - III. Radiation-hard FBG

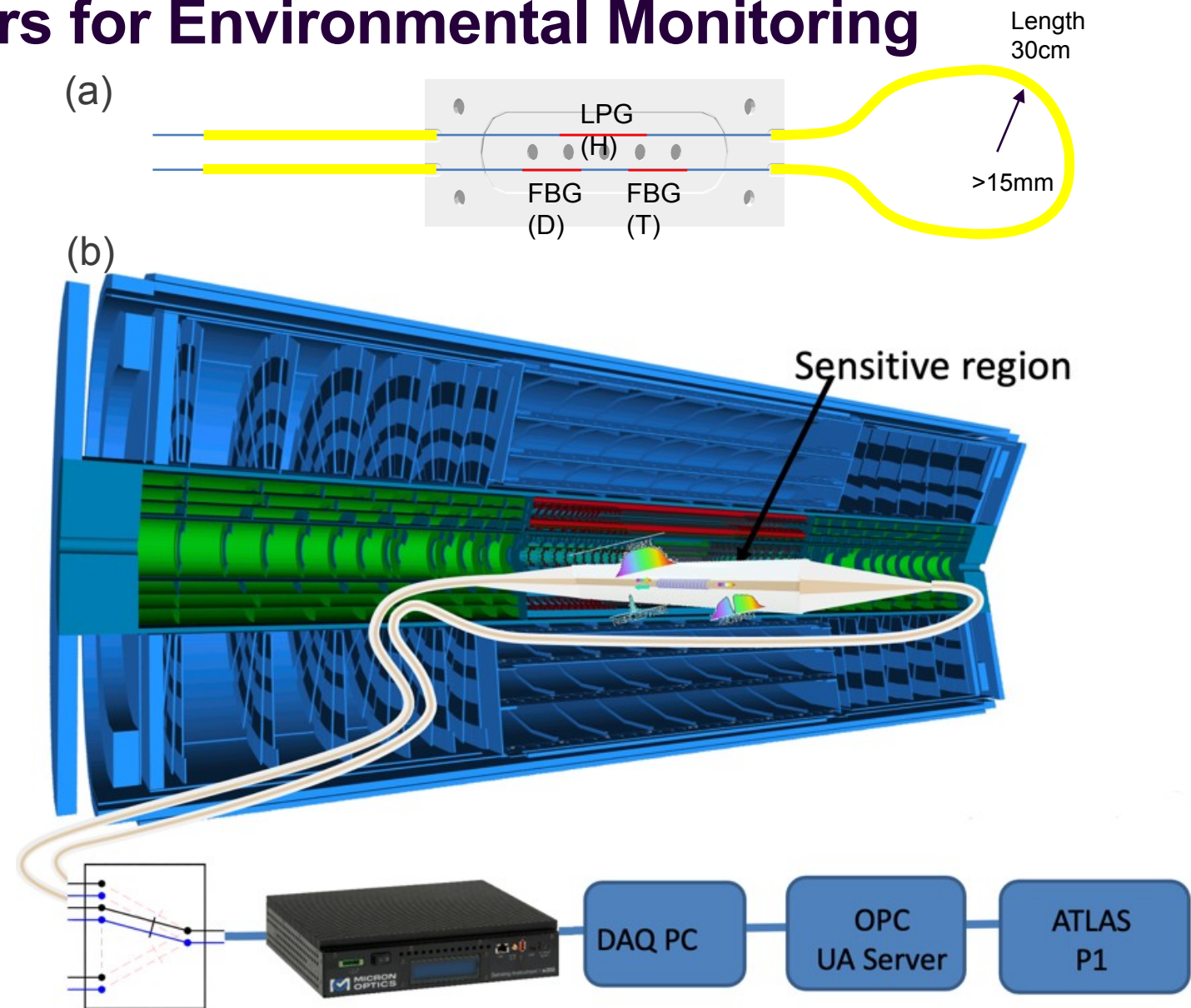
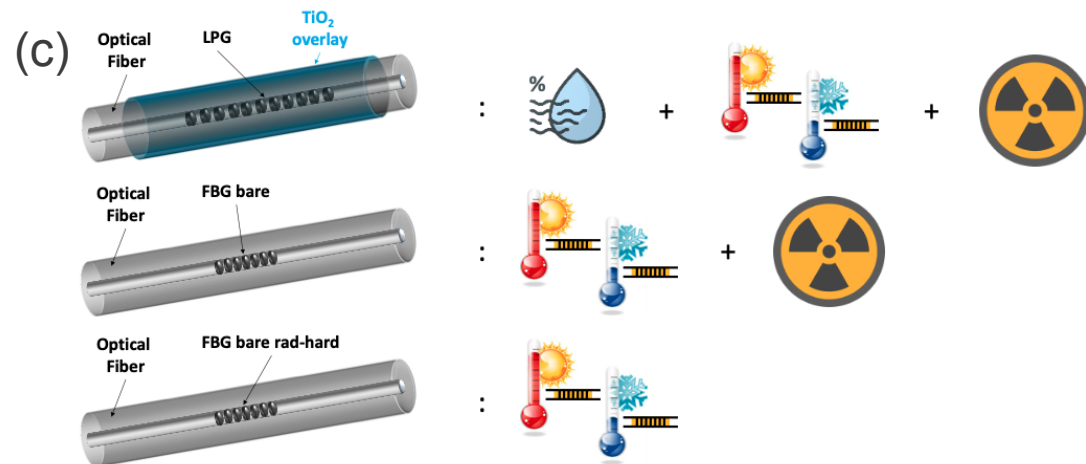


Figure 2: (a) Illustration of FOS package; (b) ATLAS ITk readout system; (c) Parameters each sensor is sensitive to



Parameter extraction

- Power spectrum fit with quadratic function
- Fit uncertainty of ~ 0.3 nm corresponds to 0.035°C

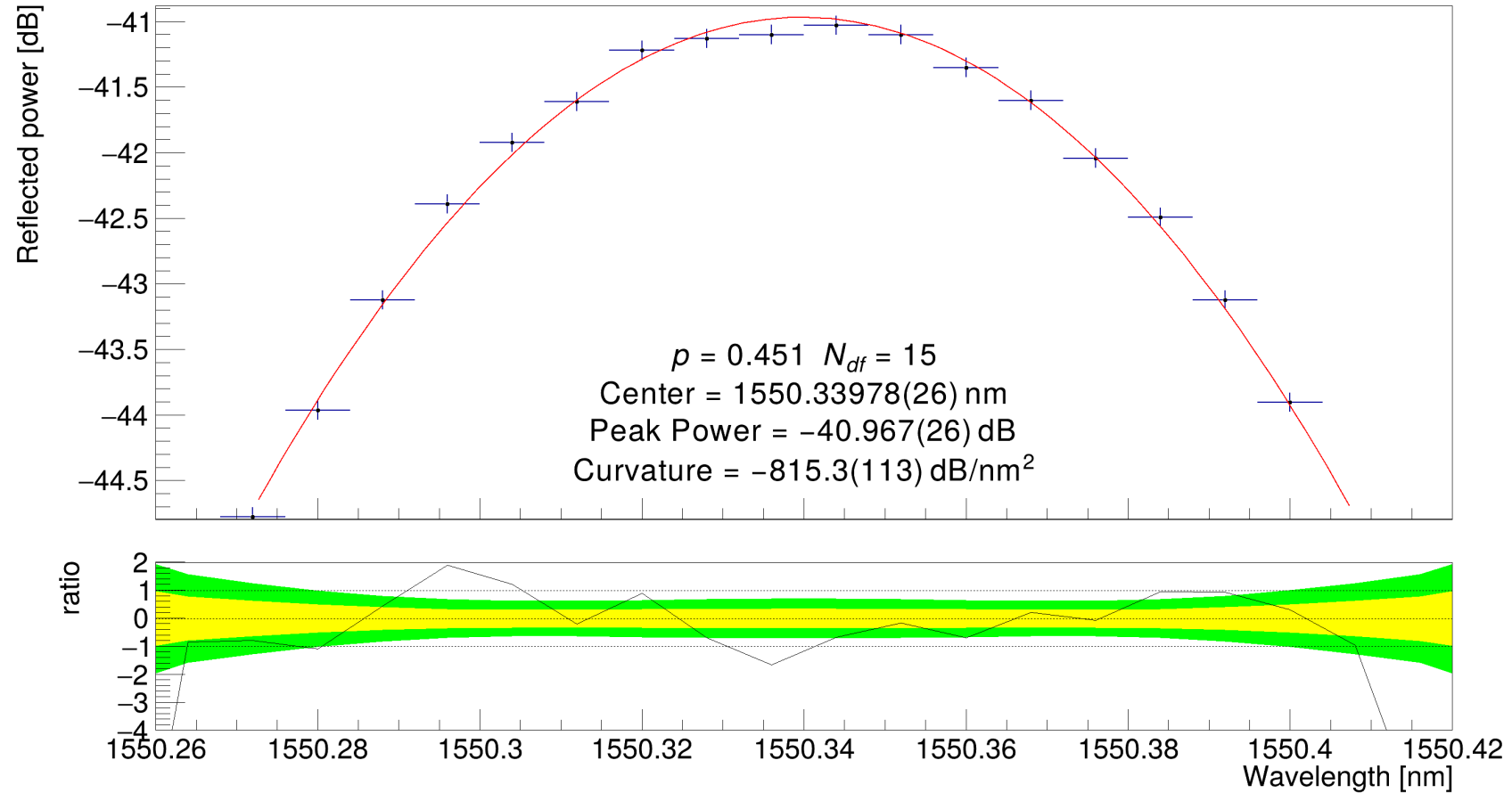


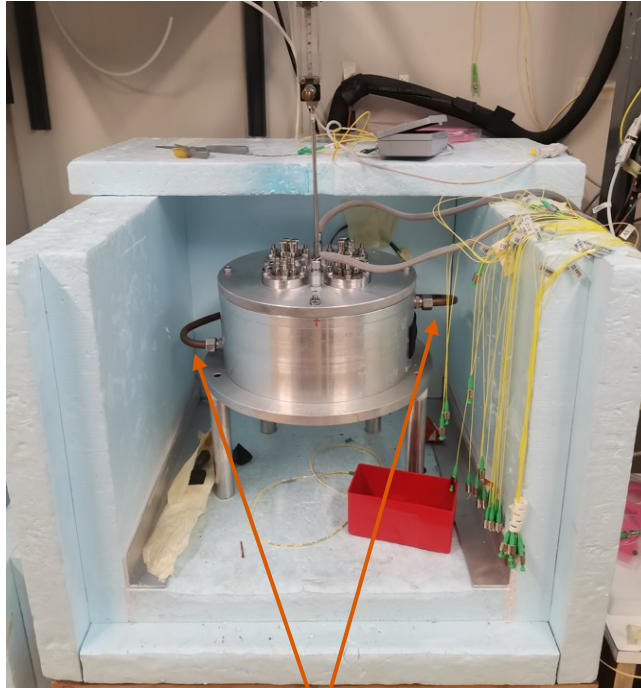
Figure 5: Fitting peak region of FBG sensor



Experimental Methodology

Calibration Set-Up

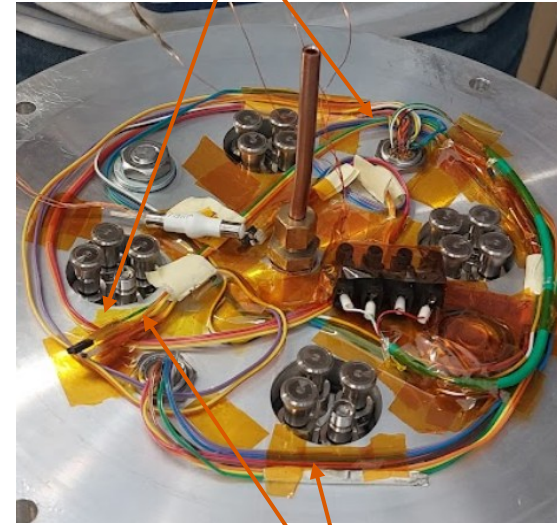
(a)



Pipes to chiller and
humidity valves

(b)

HIH and PT10k
sensors



Sensor
Connection Pins

Figure 6: (a) Climatic chamber; (b) Reference sensors' connections

Experimental Methodology

Irradiation Area – CERN IRRAD Facility

- 24 GeV/c proton secondary beam

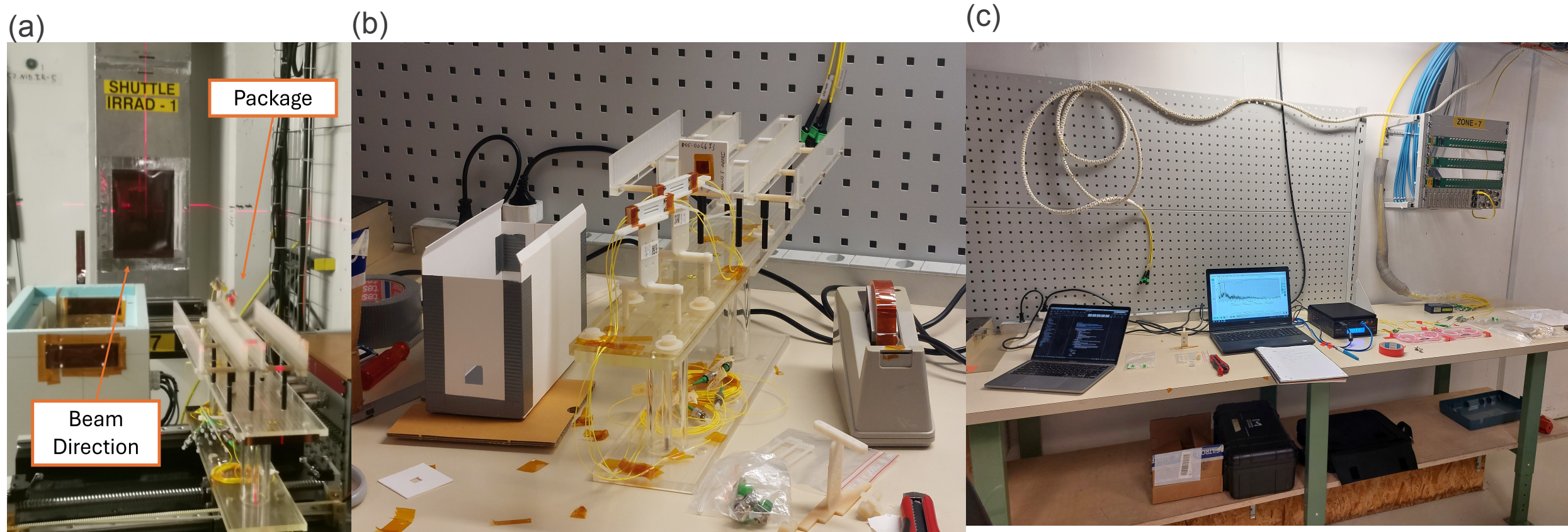


Figure 7: (a) Beam set-up of packages; (b) Package mount for irradiation; (c) Data Acquisition room

Results and Discussion

Pre-irradiation calibration

FBG transmission dip for demonstration

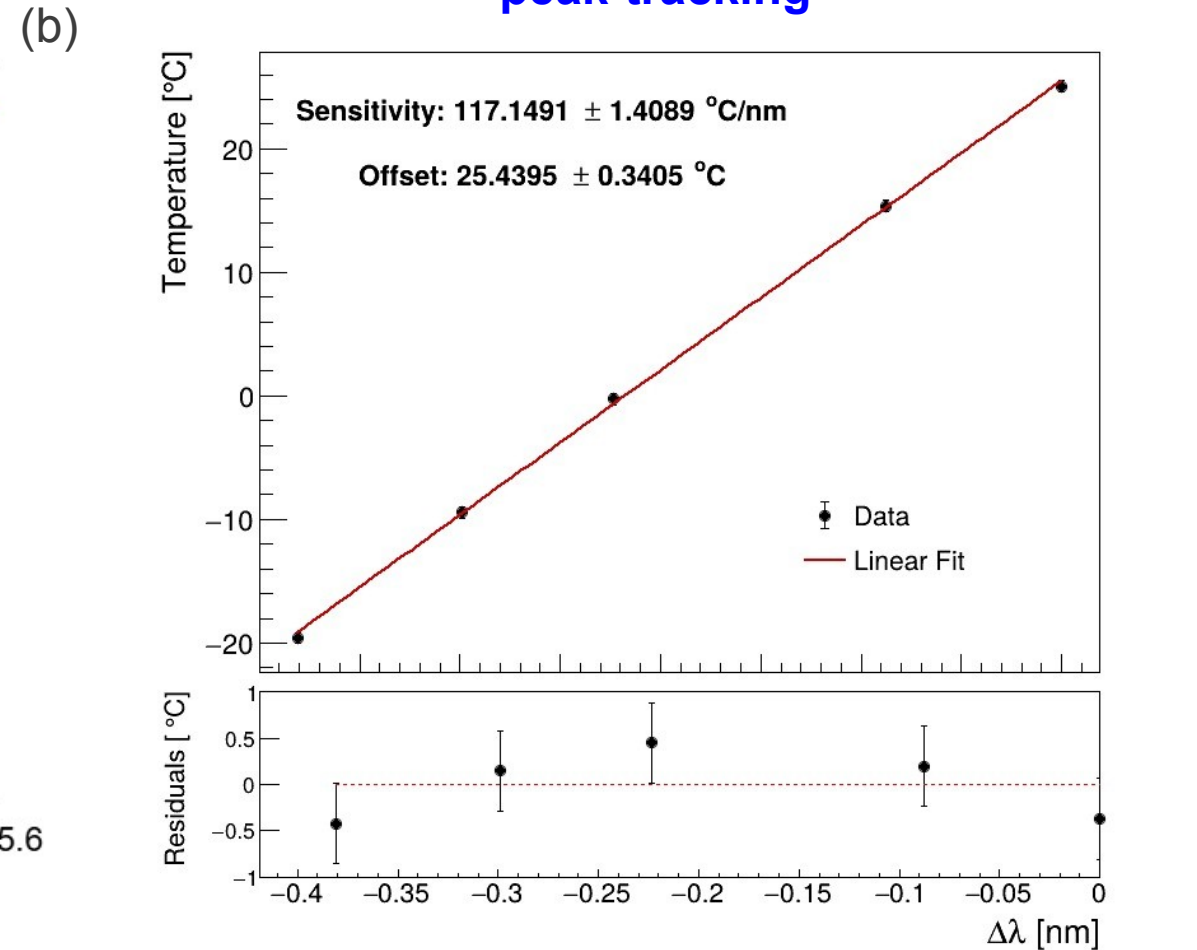
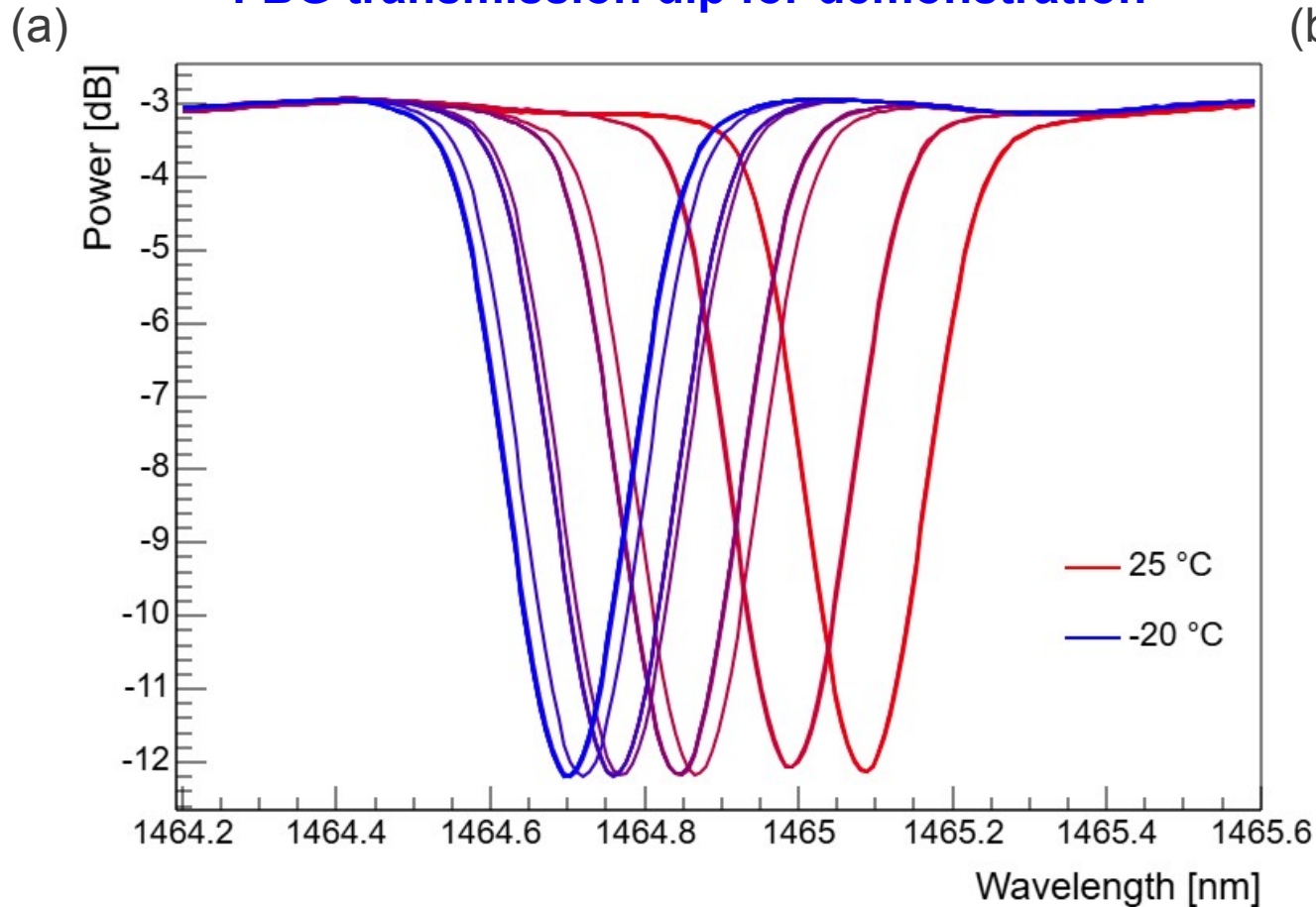


Figure 8: (a) Shift in FBG-RH spectra with temperature; (b) FBG-RH temperature calibration plot



Results and Discussion

Irradiation Effects

Spectra recorded during irradiation

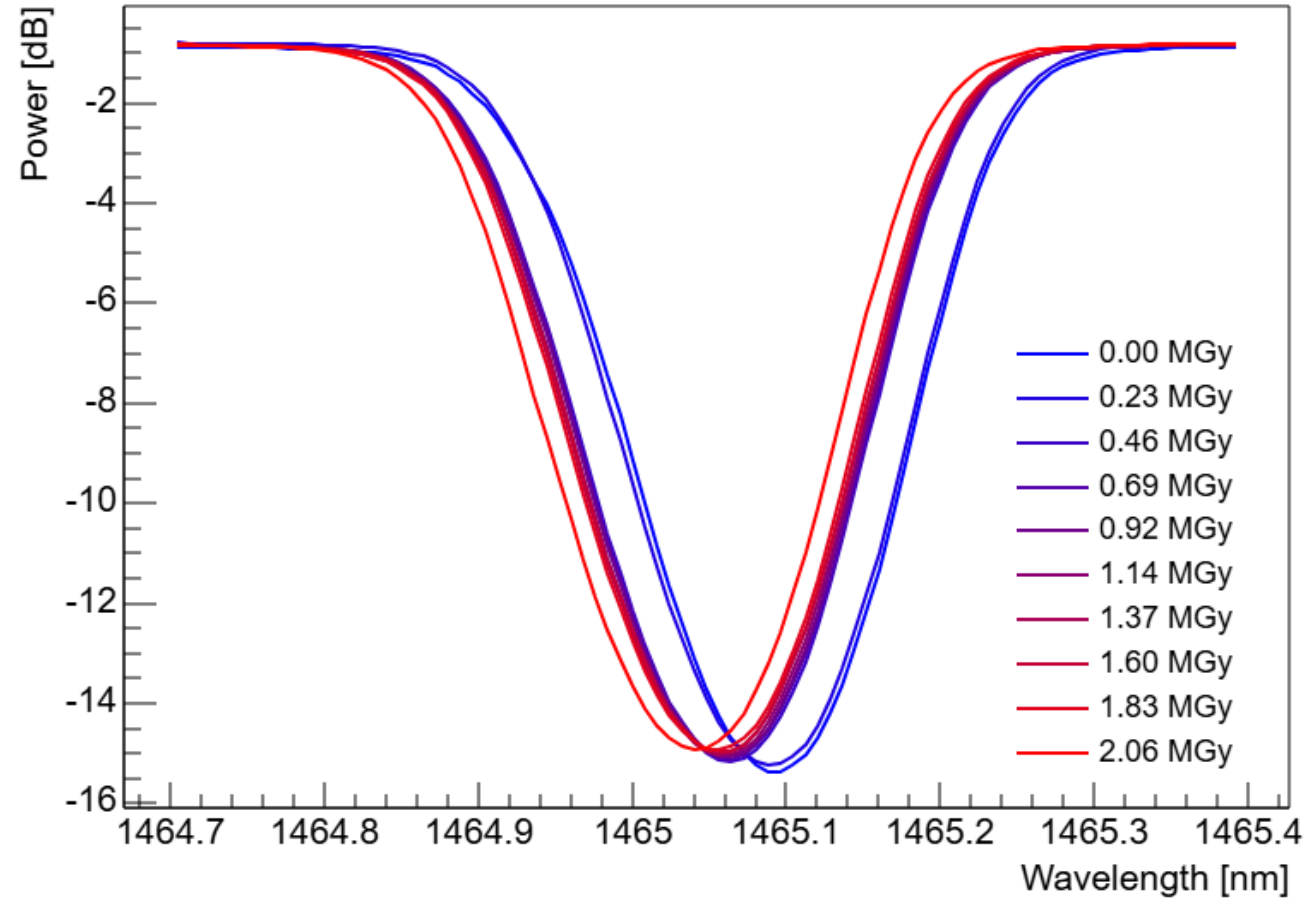


Figure 9: (a) Shift in FBG-RH spectra with dose



Results and Discussion

Post-irradiation Calibration

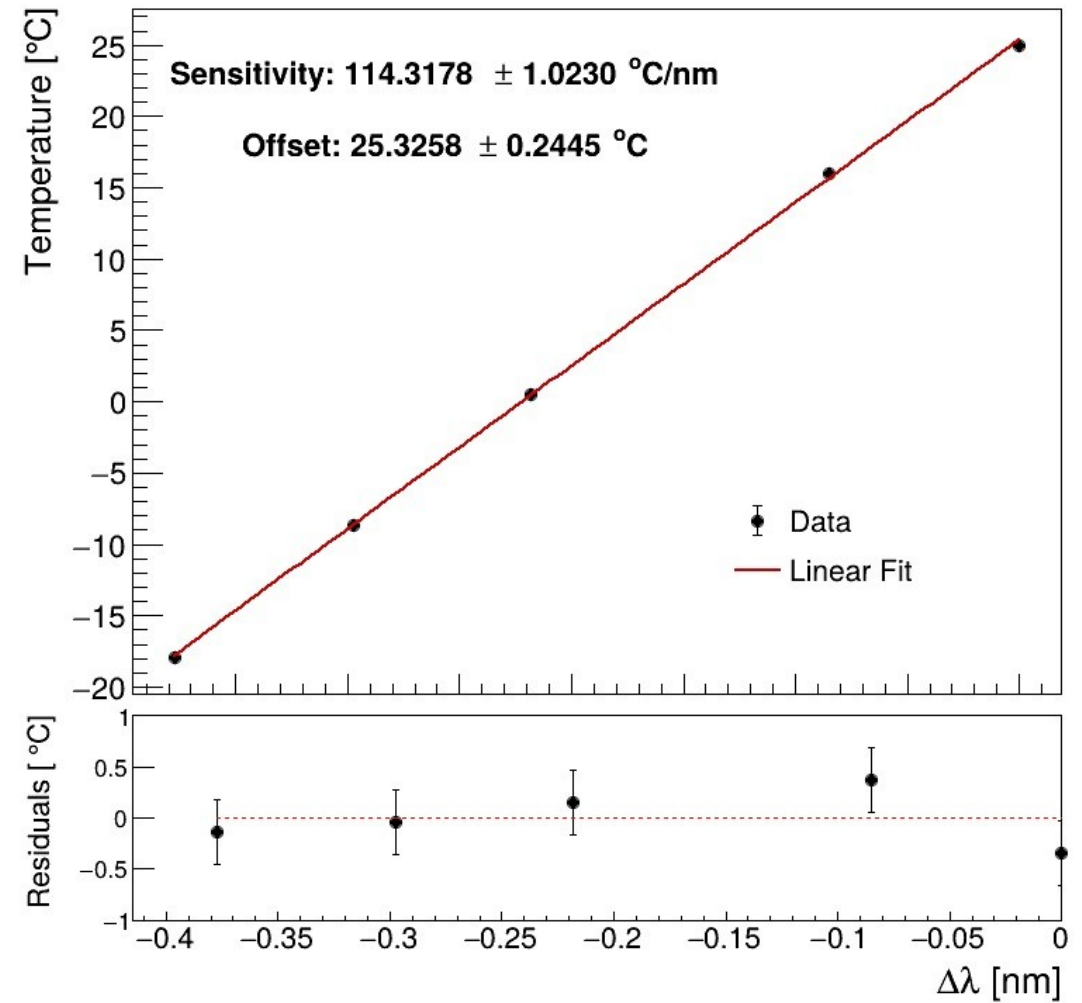
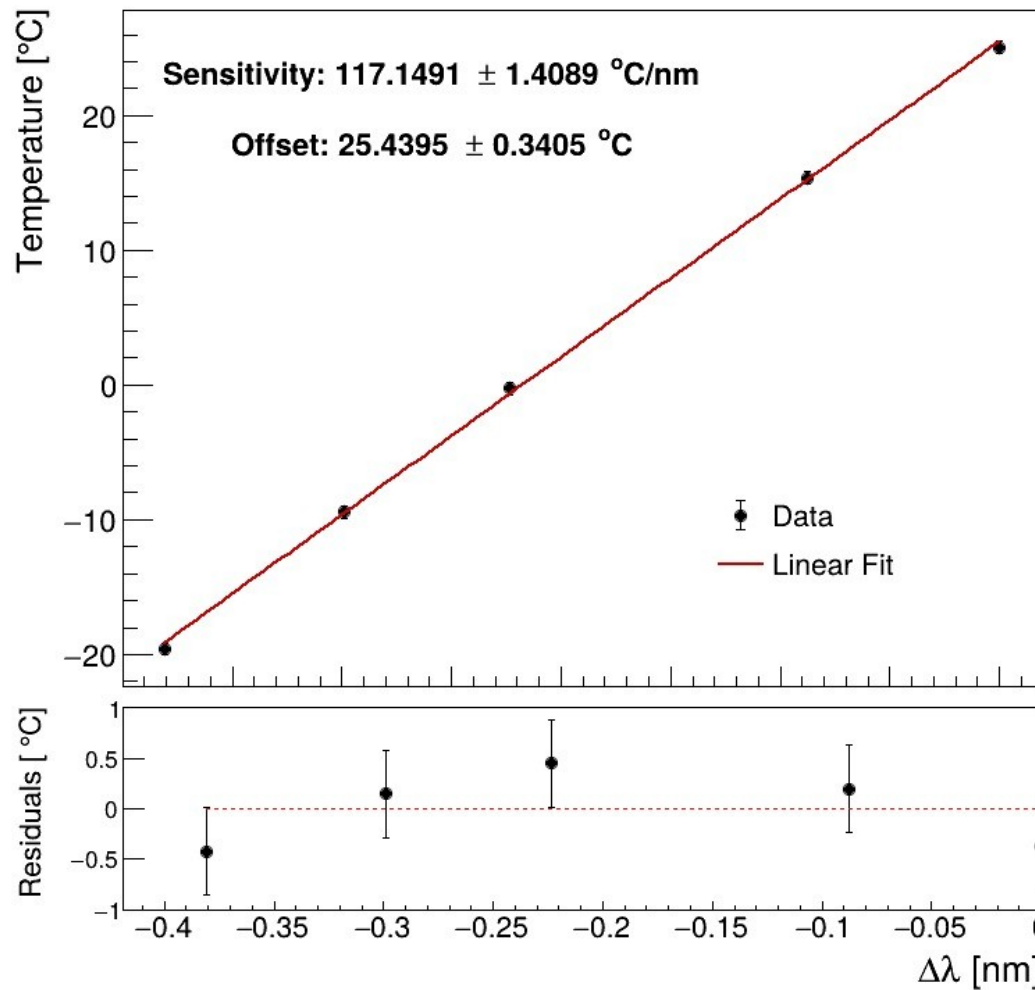


Figure 10: (a) Pre-irradiation temperature response; (b) Post-irradiation temperature response



Conclusion

- **Radiation-hard Fibre Optic Temperature Sensors are validated for dew point monitoring in the ATLAS inner detector environment**
- **Good temperature sensitivity is maintained over ITk lifetime-equivalent doses**
- **Sampling fiber temperature directly allows accurate compensation for FOS humidity sensors**
- **Absolute accuracy is on-par with conventional sensors**
- **Per-sensor calibration data has been archived for use in production measurements**



UJ Fiber Optic Sensors (FOS) for ATLAS Group



Thank You

