# Fiber sensitivities with pressure set-up

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DUNE Group Meeting

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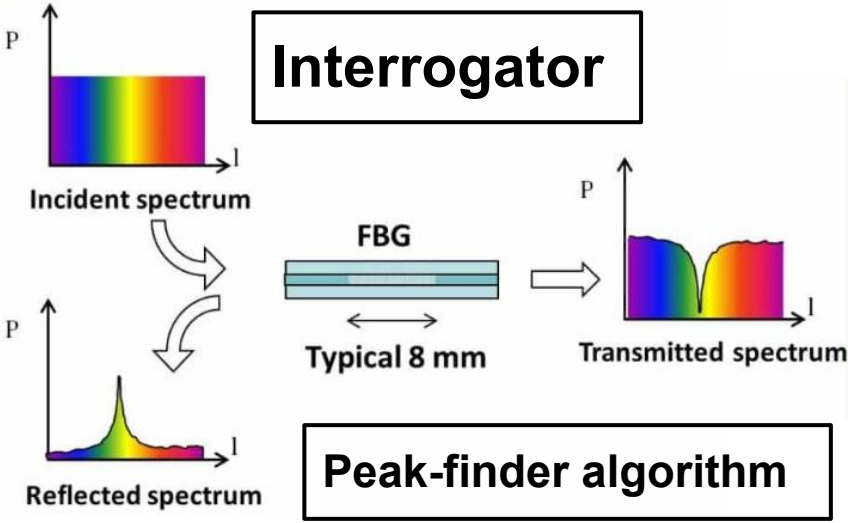
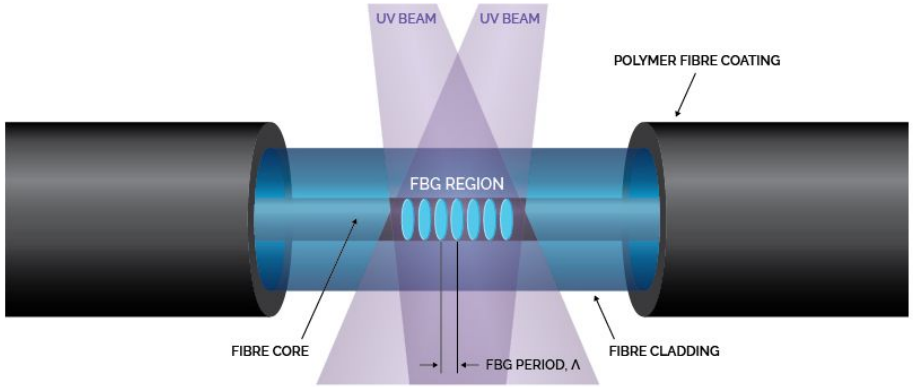
# FBG technology

Fiber Bragg Grating (FBG) technology is planned to be the base of the Temperature Monitoring System (TMS) for the FD-2 module in DUNE.

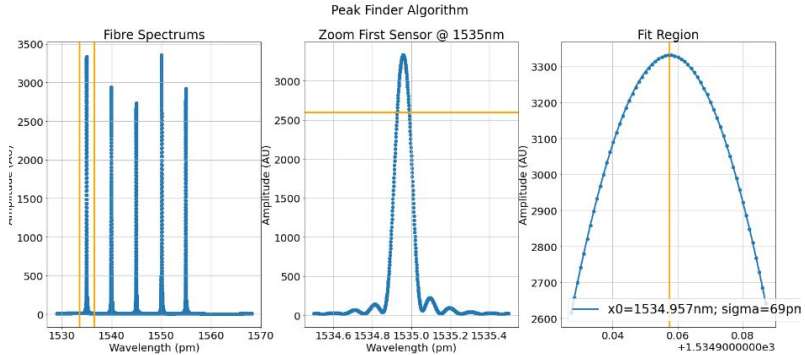
## Interrogator




## FBG sensor




## Peak-finder algorithm



# Pressure-Based Measurement Setup

**77–92 K**
**Temperature Range**

Adjustable via 1–4.5 bar pressure control.

**1–4.5 bar**
**Pressure Control**

**~1 mK**
**Resolution**

Absolute temperature measured with Lakeshore PT-102 RTDs.

- Precise temperature control achieved through pressure regulation.
- High-precision absolute temperature measurement with calibrated RTDs.

# Pressure-Based Measurement Setup

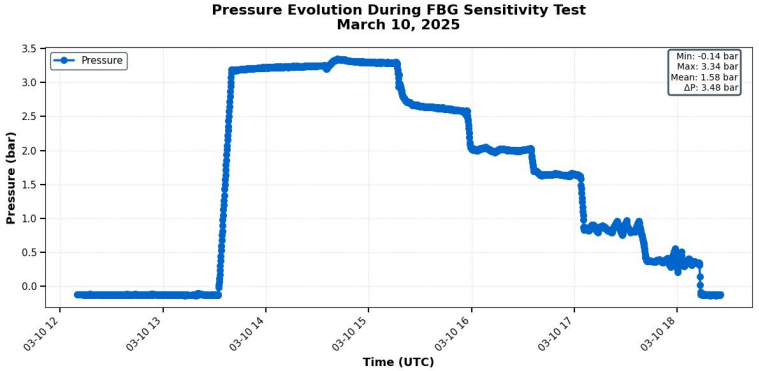
Liquid Nitrogen Filling & Sensor Prep.

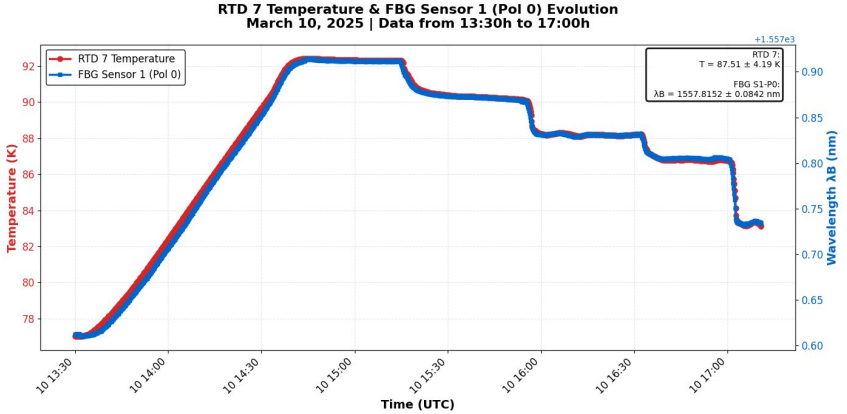
Sensor Insertion into Pressure Vessel.

Sealed System with Wires & Instrumentation.

Final Setup with Ice Formation & Connections.

# Pressure-Based Measurement

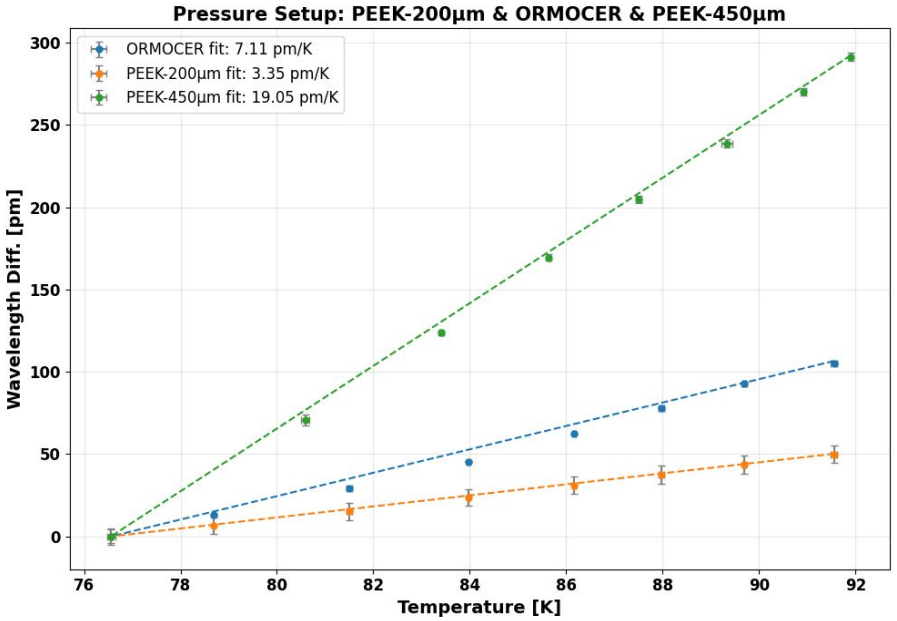


# Pressure-Based Measurement

## Thermal Sensitivity Analysis

The PEEK-450µm coated fiber demonstrates the highest thermal sensitivity among the tested samples, with a fit value of 19.05 pm/K. Its response to temperature changes is significantly greater than that of the ORMOCER (7.11 pm/K) and PEEK-200µm (3.35 pm/K) coatings.



# 1. SET-UP

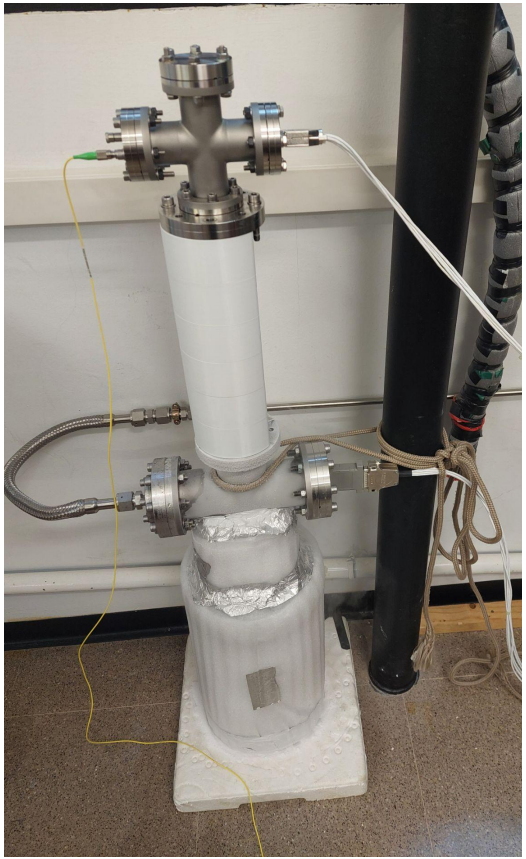
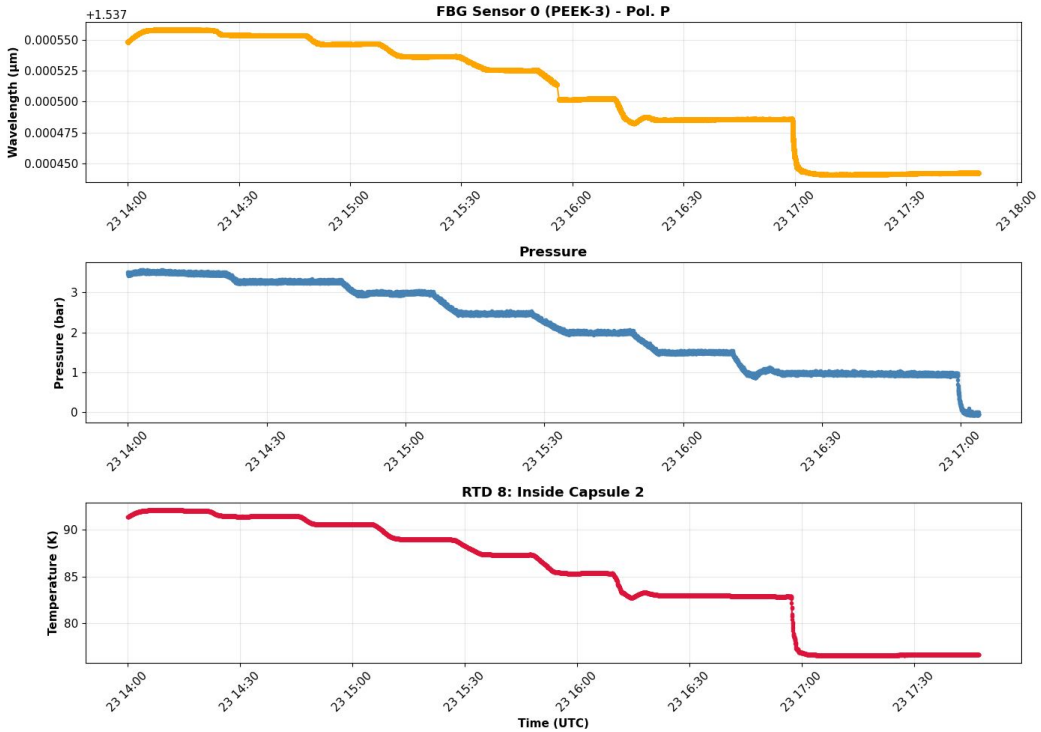
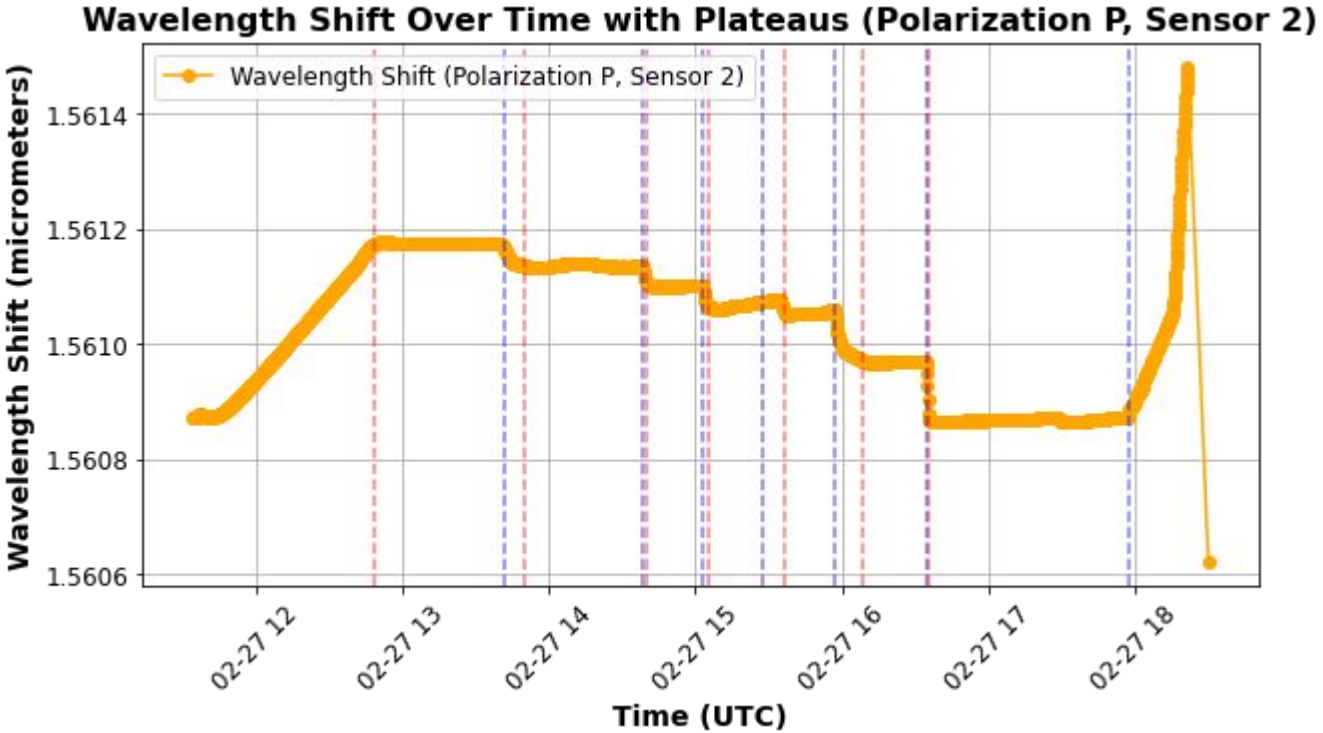


**Fig 1.** Pressure Set-Up

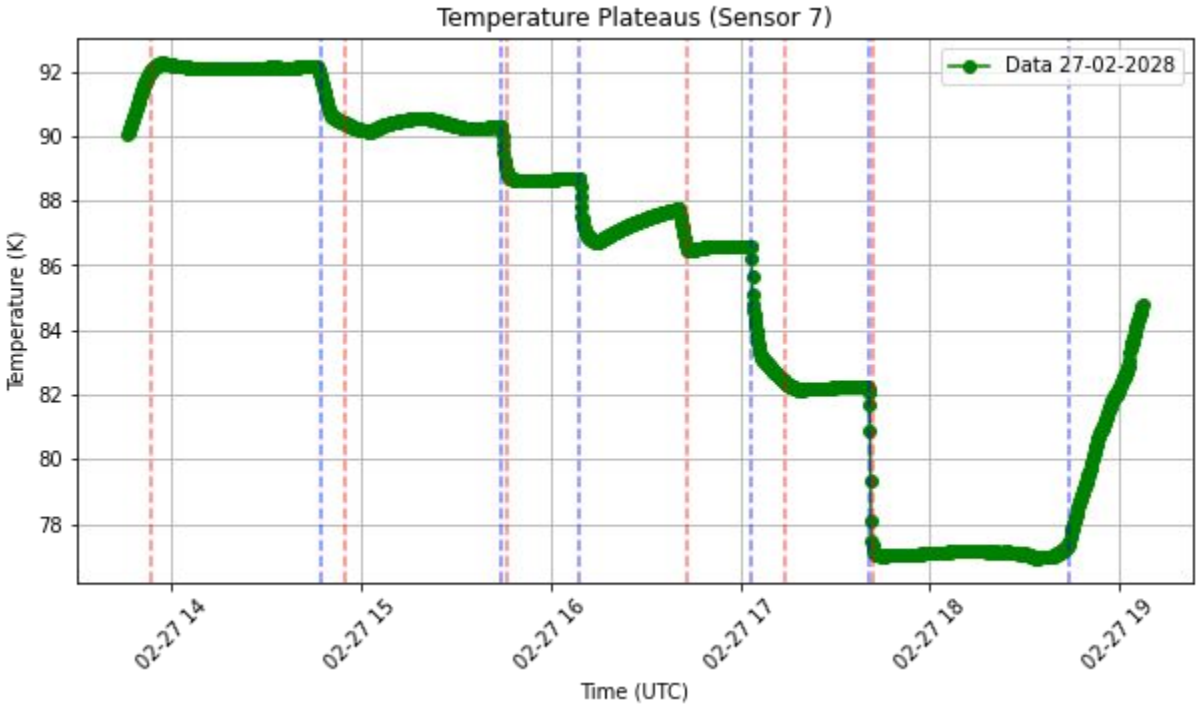
# 2. ANALYSIS: Data (Wavelength, Pressure and Temperature)



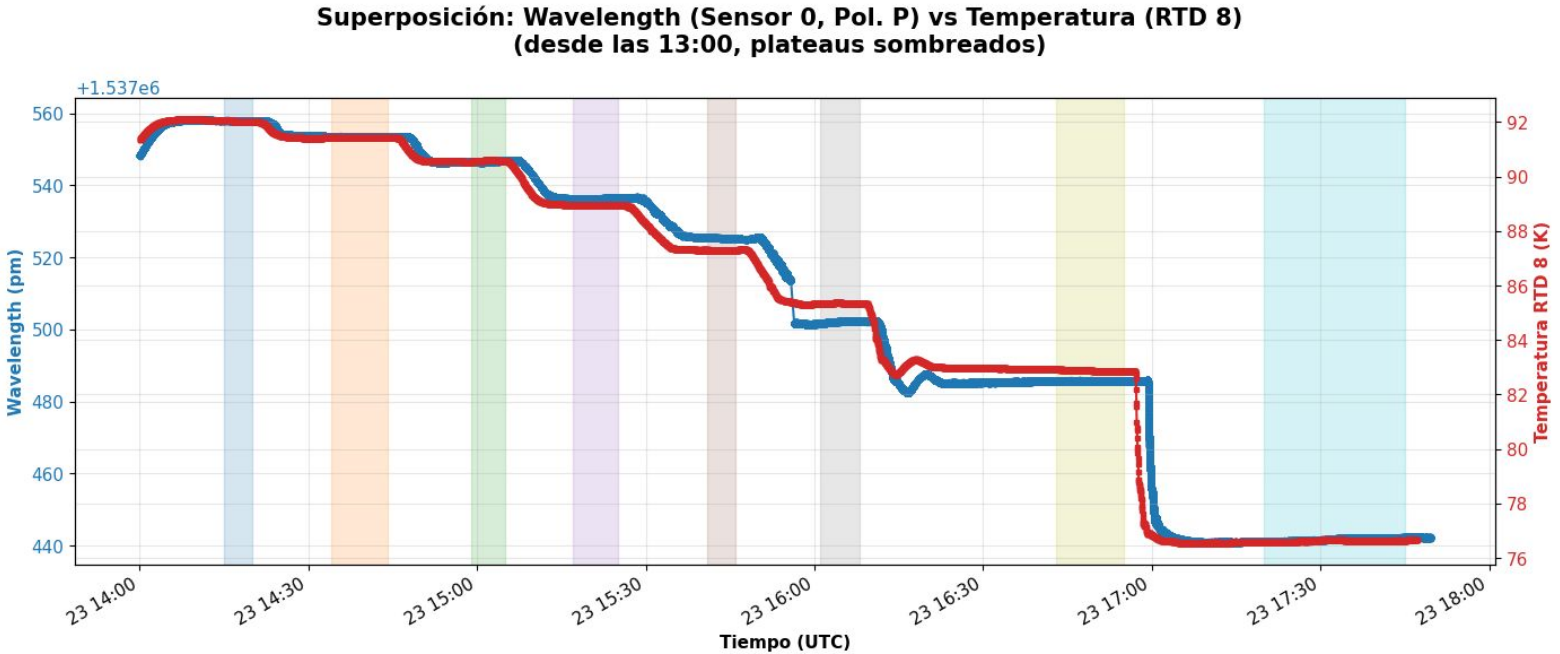
# 2. ANALYSIS: Wavelength Plateaus



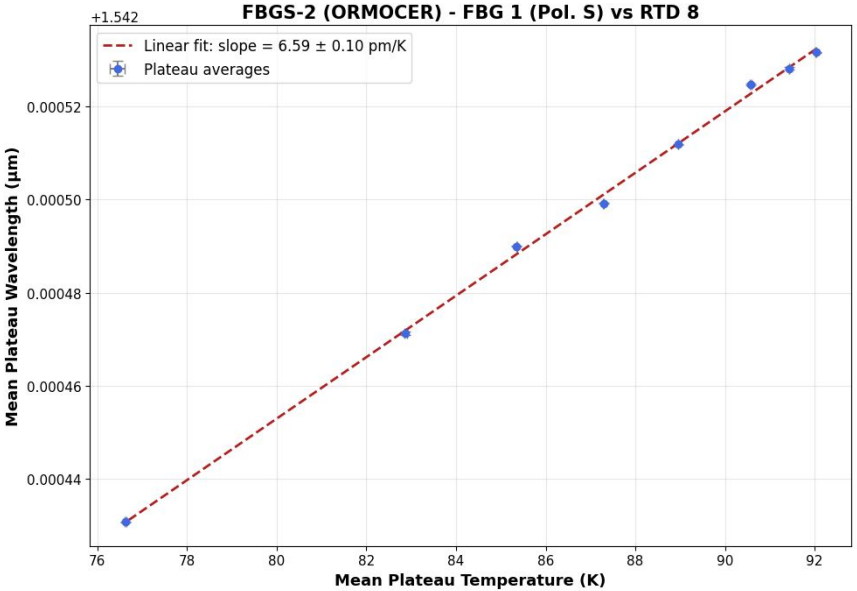
# 2. ANALYSIS: Temperature Plateaus

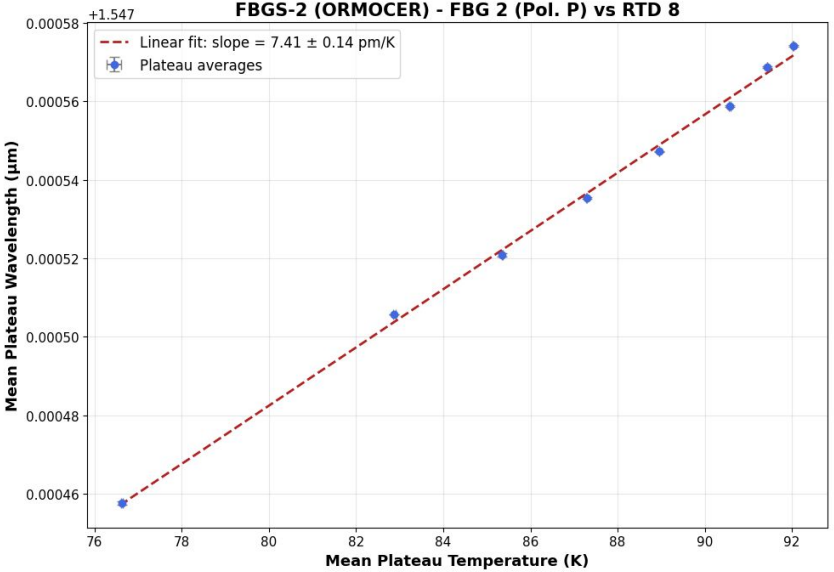


# 2. ANALYSIS: Plateaus detection



# 3. RESULTS: Thermal sensitivity (fit slope)



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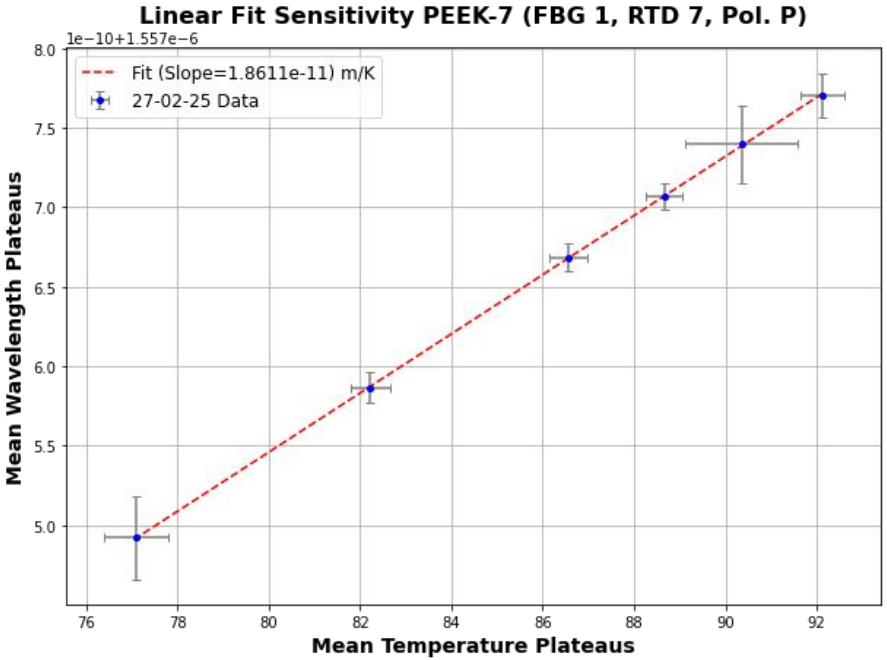
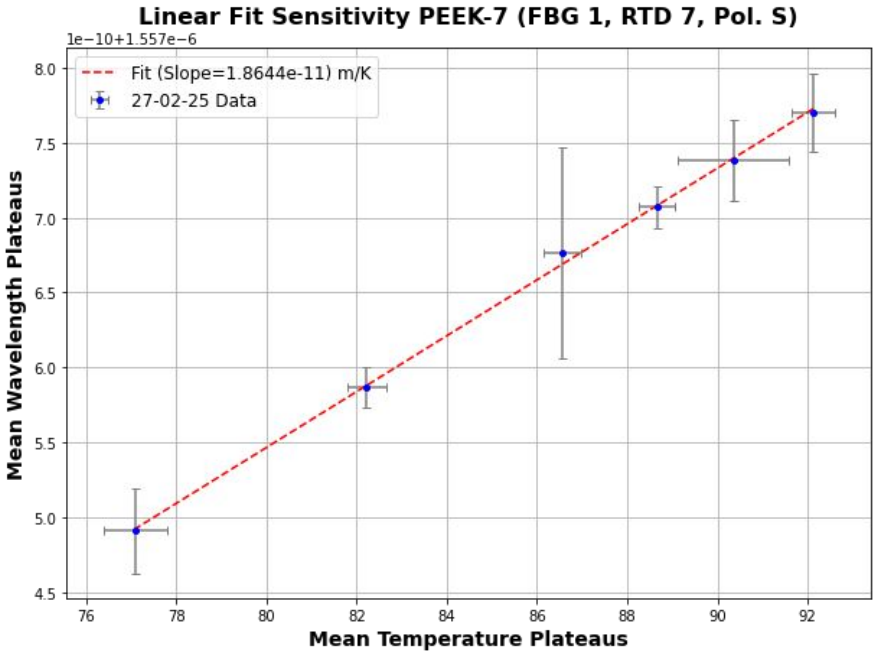
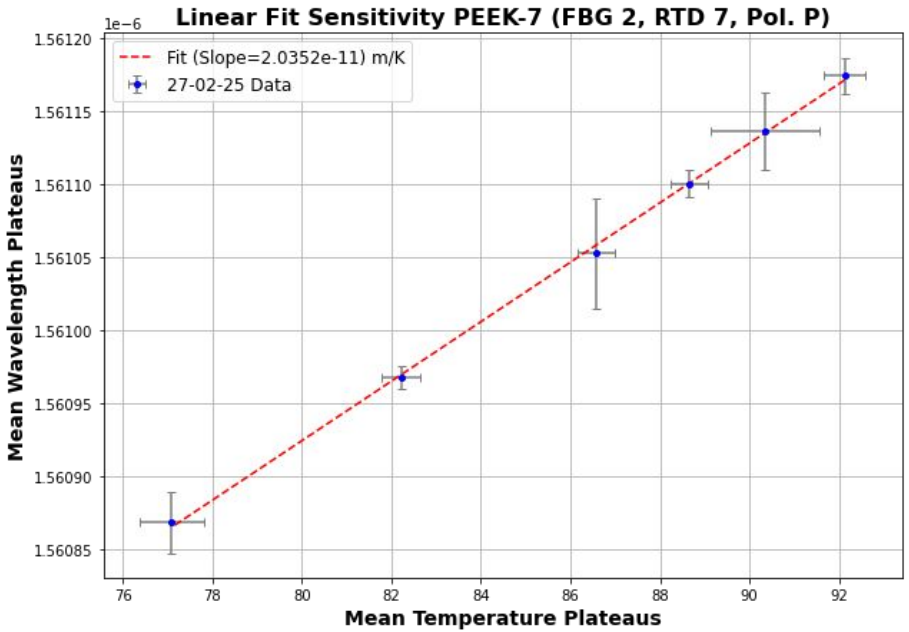
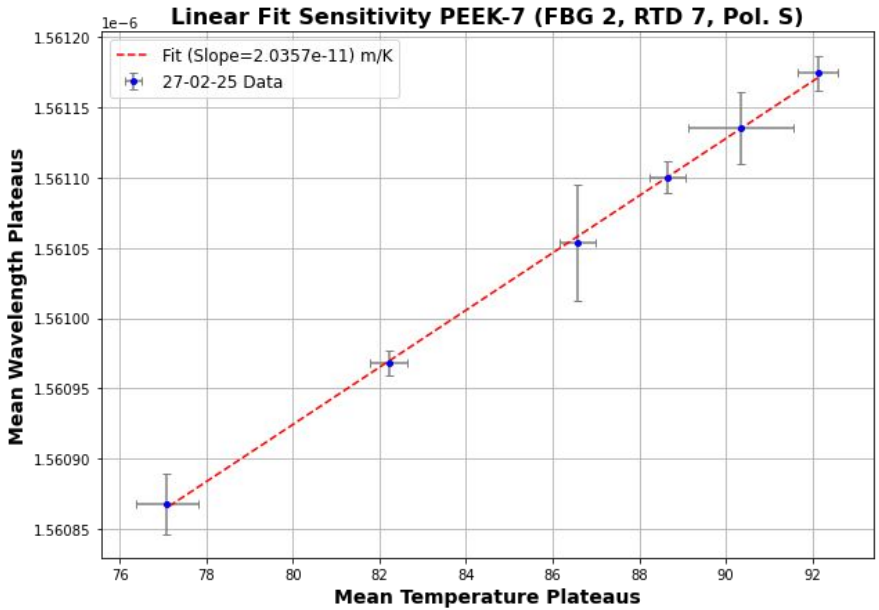



Linear Fit Sensitivity PEEK-7 (FBG 2, RTD 7, Pol. P)
1e−6
Fit (Slope=2.0352e-11) m/K
27-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
1.56120
1.56115
1.56110
1.56105
1.56100
1.56095
1.56090
1.56085
76
78
80
82
84
86
88
90
92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1e−6
Fit (Slope=2.0357e-11) m/K
27-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
1.56120
1.56115
1.56110
1.56105
1.56100
1.56095
1.56090
1.56085
76
78
80
82
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86
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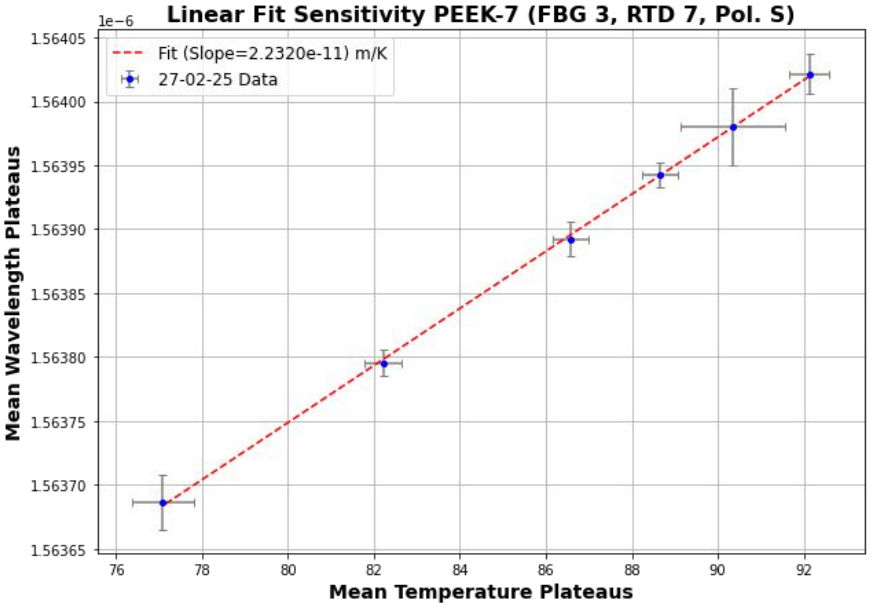
90
92


Linear Fit Sensitivity PEEK-7 (FBG 3, RTD 7, Pol. S)
1e−6
Fit (Slope=2.2320e-11) m/K
27-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
1.56405
1.56400
1.56395
1.56390
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76
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86
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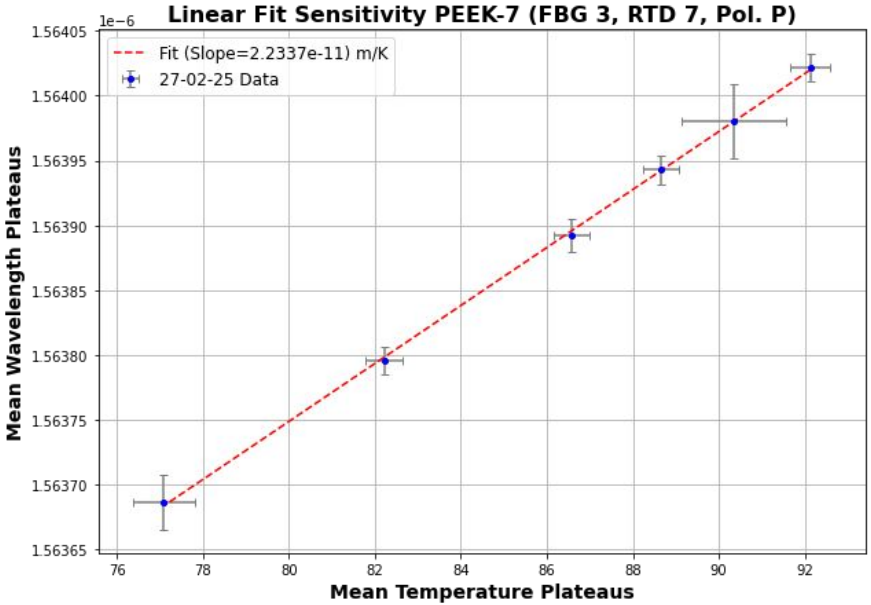
90
92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1e−6
Fit (Slope=2.2337e-11) m/K
27-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
1.56405
1.56400
1.56395
1.56390
1.56385
1.56380
1.56375
1.56370
1.56365
76
78
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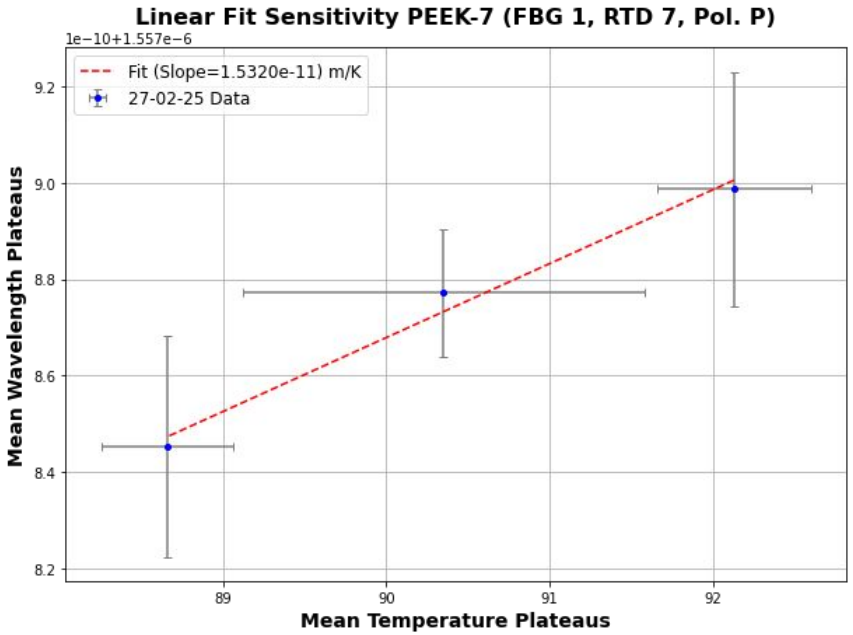
86
88
90
92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1e−10+1.557e−6
Fit (Slope=1.5320e-11) m/K
27-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
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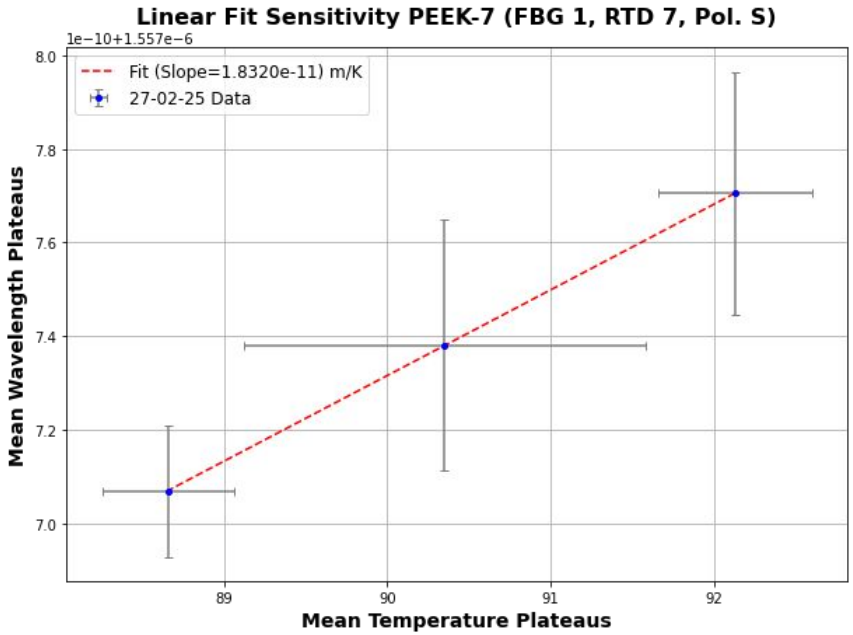
9.0
8.8
8.6
8.4
8.2
89
90
91
92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Mean Wavelength Plateaus
Mean Temperature Plateaus
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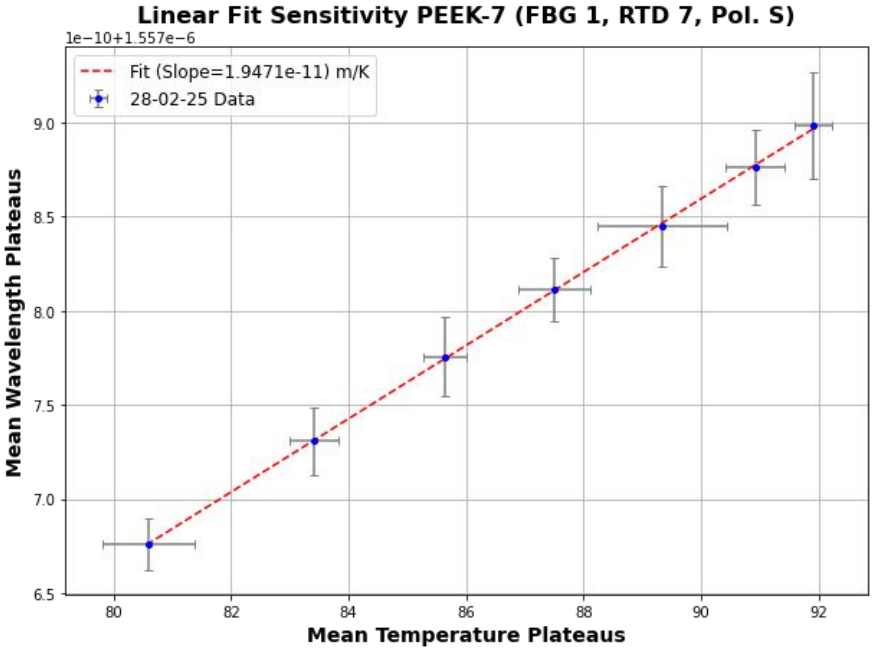
7.8
7.6
7.4
7.2
7.0
89
90
91
92


Linear Fit Sensitivity PEEK-7 (FBG 1, RTD 7, Pol. S)
1e−10+1.557e−6
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28-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
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7.0
7.5
8.0
8.5
9.0
80
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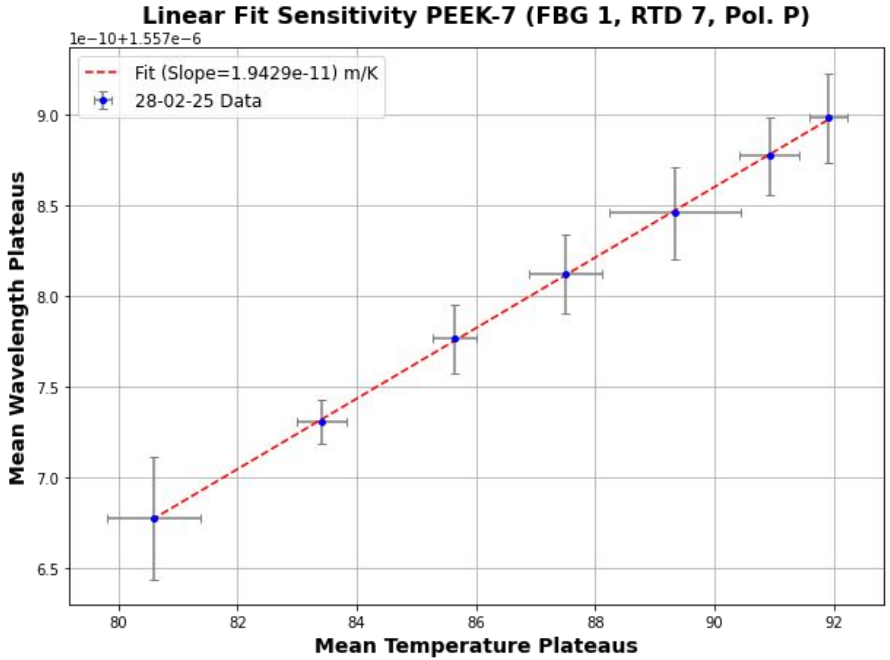
84
86
88
90
92


Linear Fit Sensitivity PEEK-7 (FBG 1, RTD 7, Pol. P)
1e−10+1.557e−6
Fit (Slope=1.9429e-11) m/K
28-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
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7.0
7.5
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8.5
9.0
80
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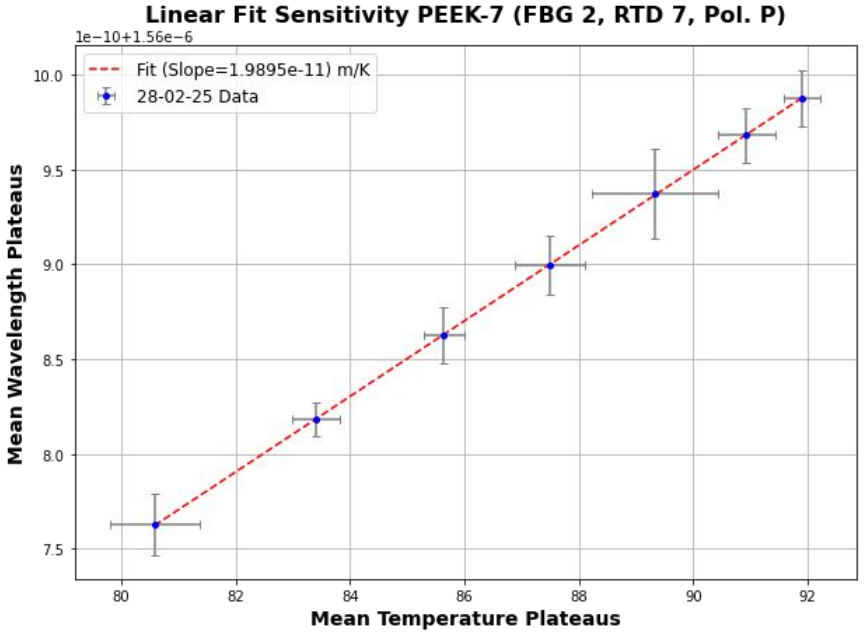
90
92


Linear Fit Sensitivity PEEK-7 (FBG 2, RTD 7, Pol. P)
1e−10+1.56e−6
Fit (Slope=1.9895e-11) m/K
28-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
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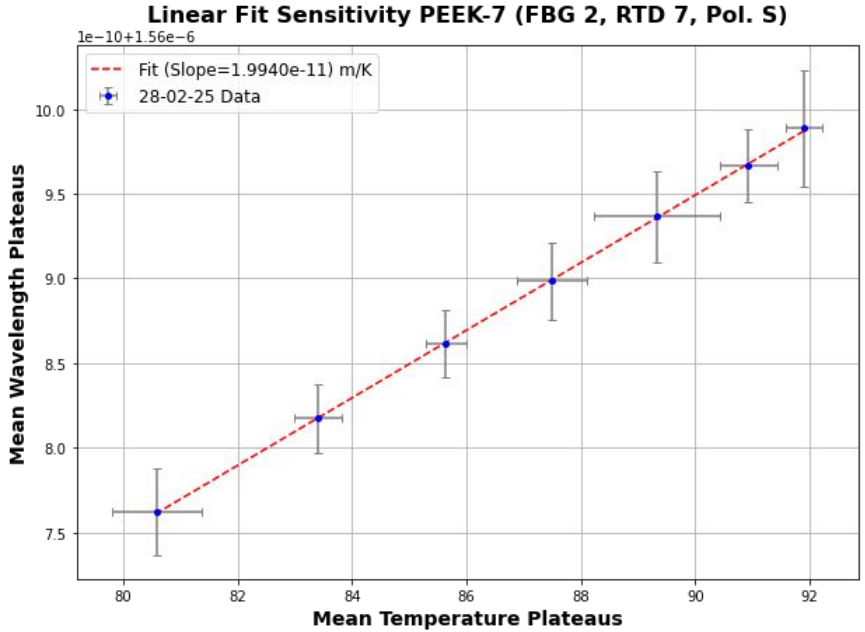
9.5
9.0
8.5
8.0
7.5
80
82
84
86
88
90
92


Linear Fit Sensitivity PEEK-7 (FBG 2, RTD 7, Pol. S)
1e−10+1.56e−6
Fit (Slope=1.9940e-11) m/K
28-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
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9.5
9.0
8.5
8.0
7.5
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82
84
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88
90
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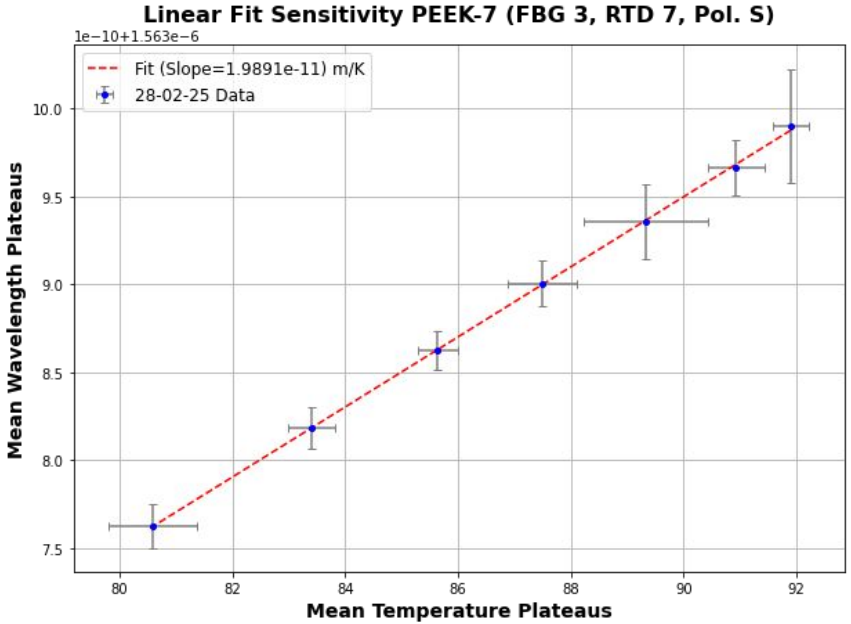
Linear Fit Sensitivity PEEK-7 (FBG 3, RTD 7, Pol. S)
1e−10+1.563e−6
Fit (Slope=1.9891e-11) m/K
28-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
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9.5
9.0
8.5
8.0
7.5
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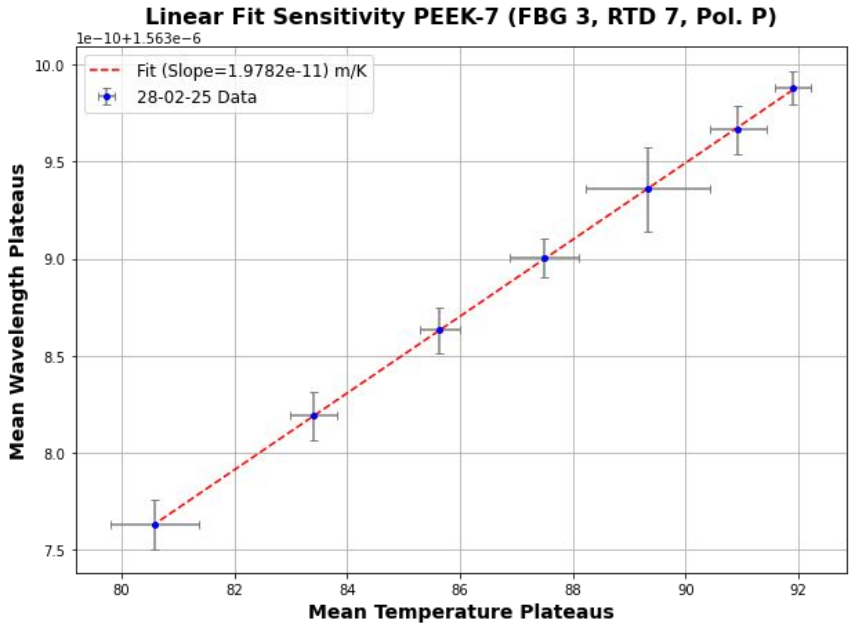

Linear Fit Sensitivity PEEK-7 (FBG 3, RTD 7, Pol. P)
1e−10+1.563e−6
Fit (Slope=1.9782e-11) m/K
28-02-25 Data
Mean Wavelength Plateaus
Mean Temperature Plateaus
10.0
9.5
9.0
8.5
8.0
7.5
80
82
84
86
88
90
92

# RUN 1: 27-02-2025

| Sensitivity PEEK-7 (pm/K) | Pol. P | Pol. S |
|---|---|---|
| **FBG 1** | 18.611±0.077 | 18.644±0.336 |
| **FBG 2** | 20.352±0.299 | 20.357±0.252 |
| **FBG 3** | 22.337±0.220 | 22.320±0.224 |

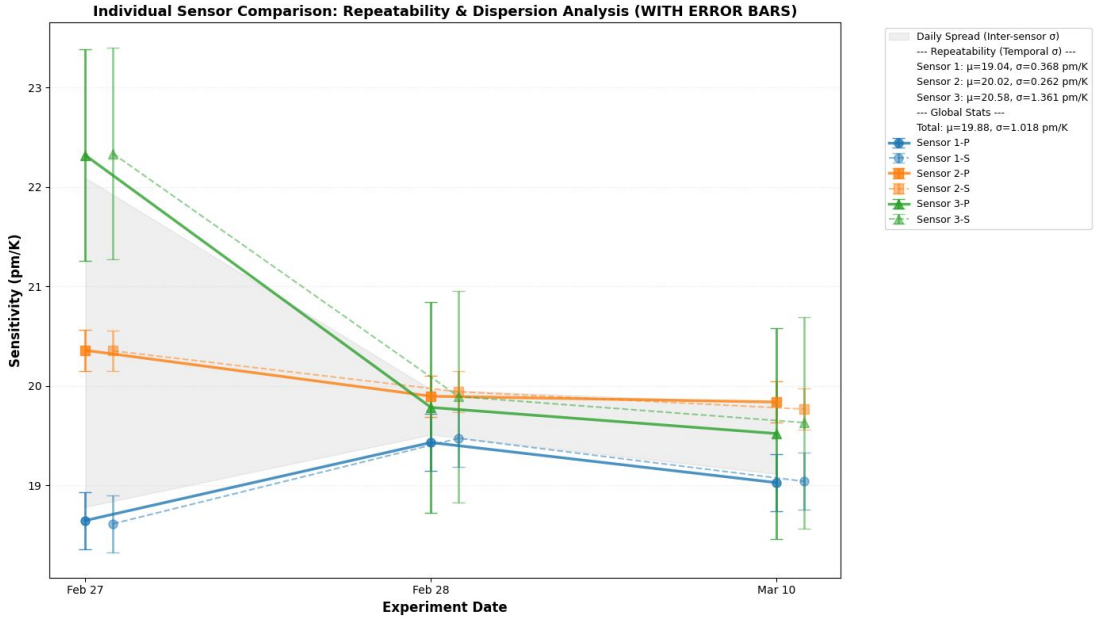
# RUN 2: 28-02-2025

| Sensitivity PEEK-7 (pm/K) | Pol. P | Pol. S |
|---|---|---|
| **FBG 1 (FBG 2)** | 19.429±0.125 | 19.471±0.138 |
| **FBG 2 (FBG 3)** | 19.895±0.050 | 19.940±0.113 |
| **FBG 3 (FBG 1)** | 19.782±0.082 | 19.891±0.142 |

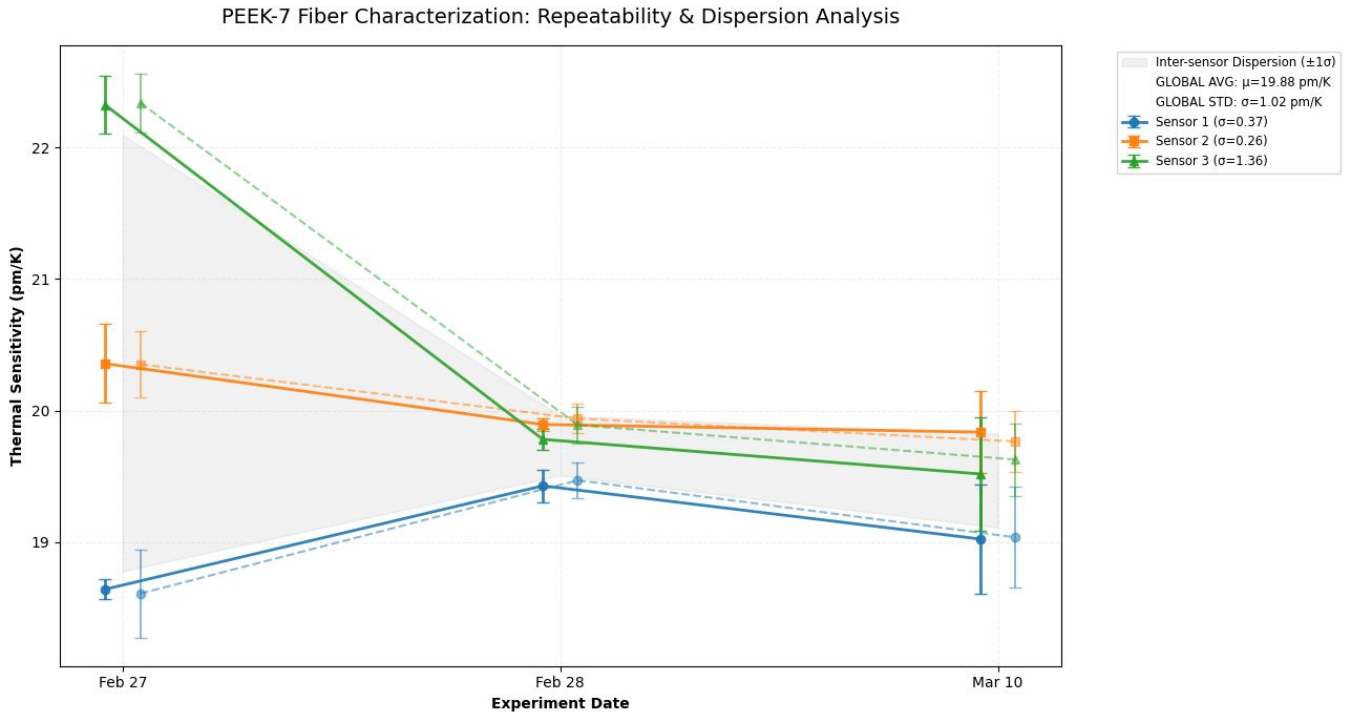
# RUN 3: 10-03-2025

| Sensitivity PEEK-7 (pm/K) | Pol. P | Pol. S |
|---|---|---|
| **FBG 1 (FBG 2)** | 19.038±0.412 | 19.025±0.383 |
| **FBG 2 (FBG 3)** | 19.765±0.309 | 19.837±0.229 |
| **FBG 3 (FBG 1)** | 19.519±0.275 | 19.629±0.432 |

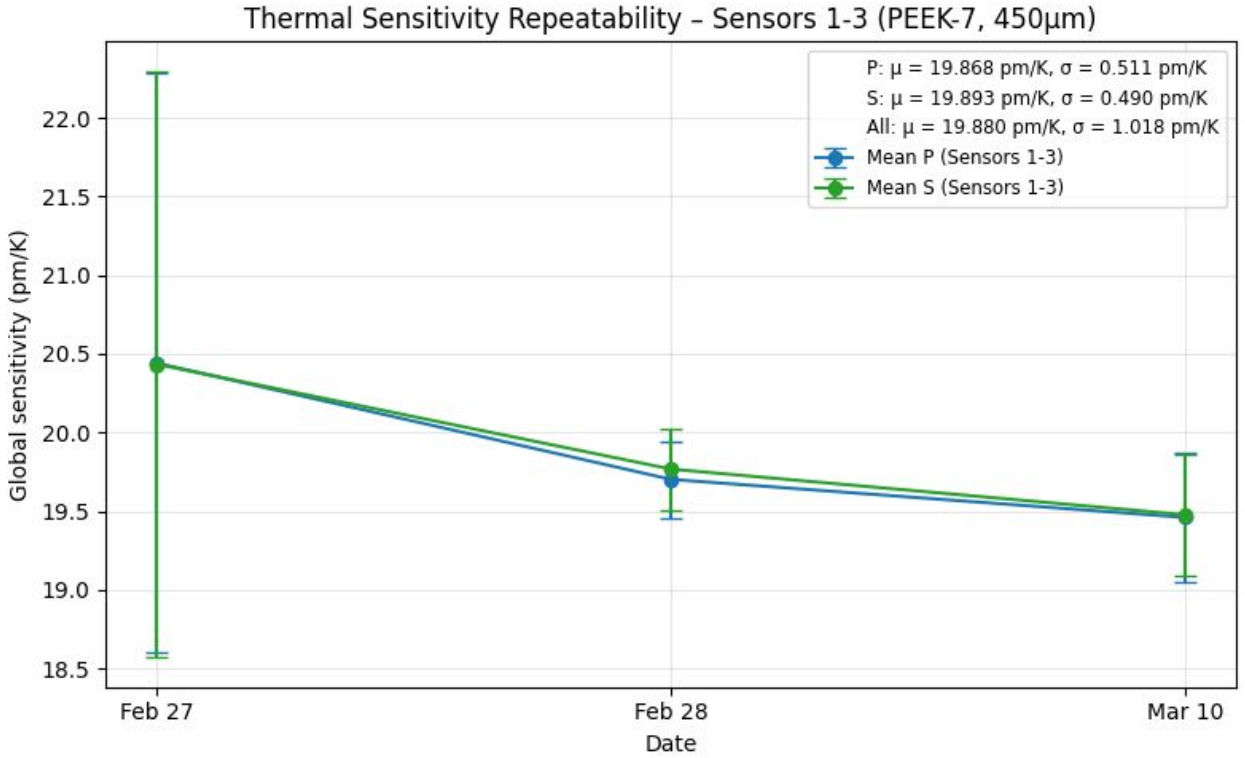
# PEEK-7(450um): Repeatability study



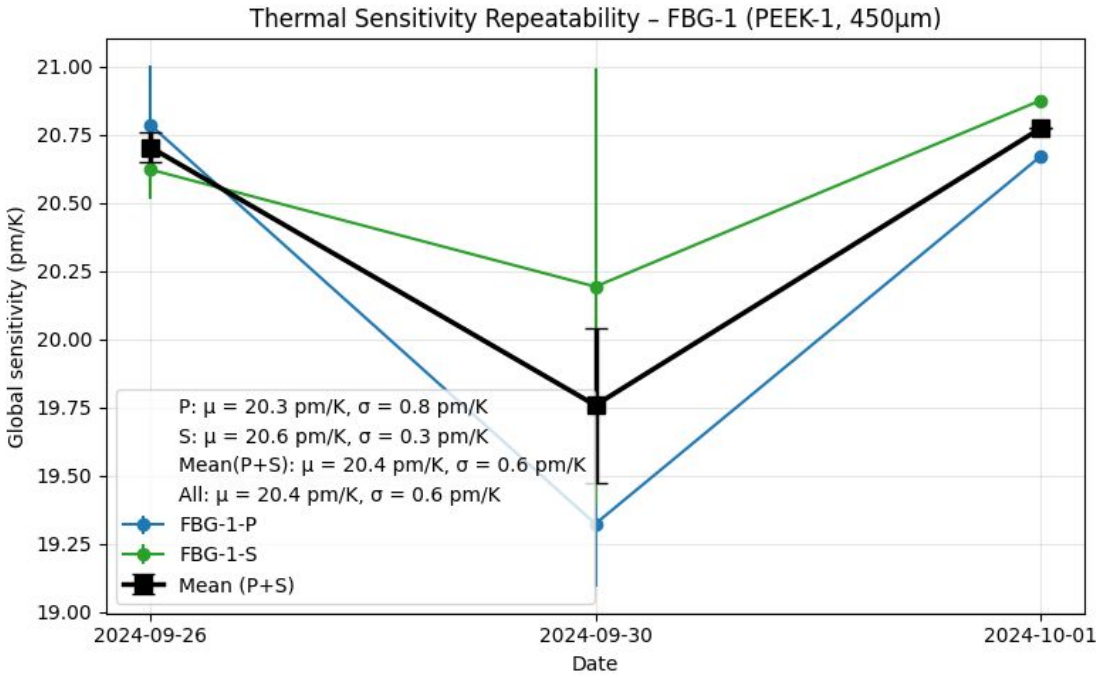
# PEEK-7(450um): Repeatability study



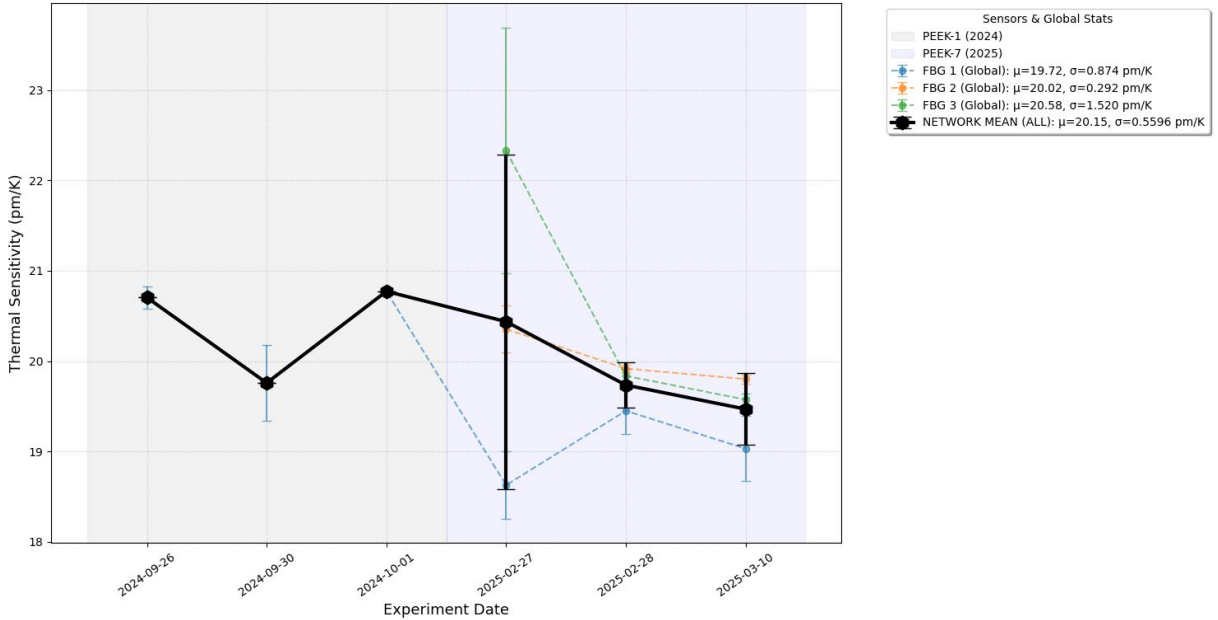
# PEEK-7 (450um): Repeatability Analysis (Mean)



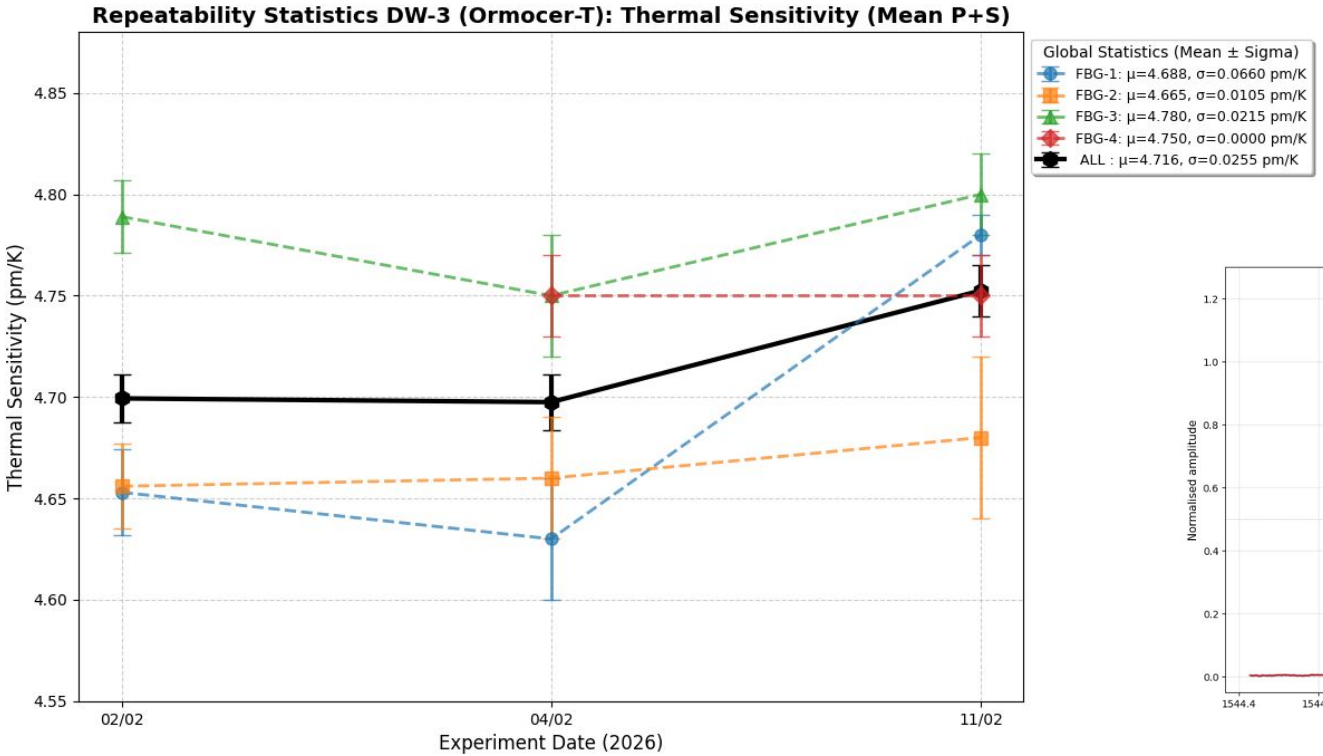
# PEEK-1 (450 um): Repeatability Analysis

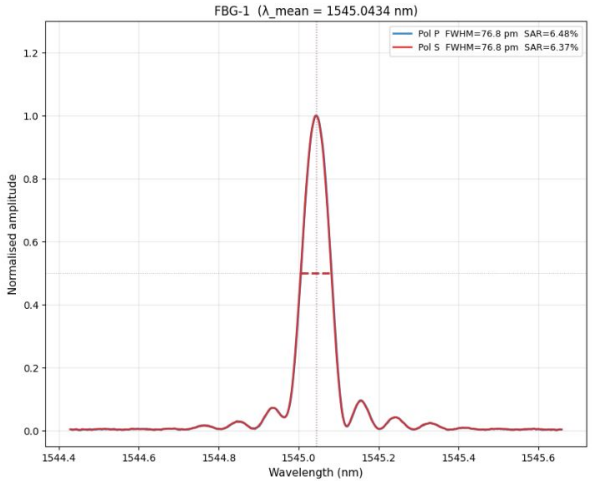


# PEEK-1 + PEEK-7 fibers (450 um both): Repeatability Analysis

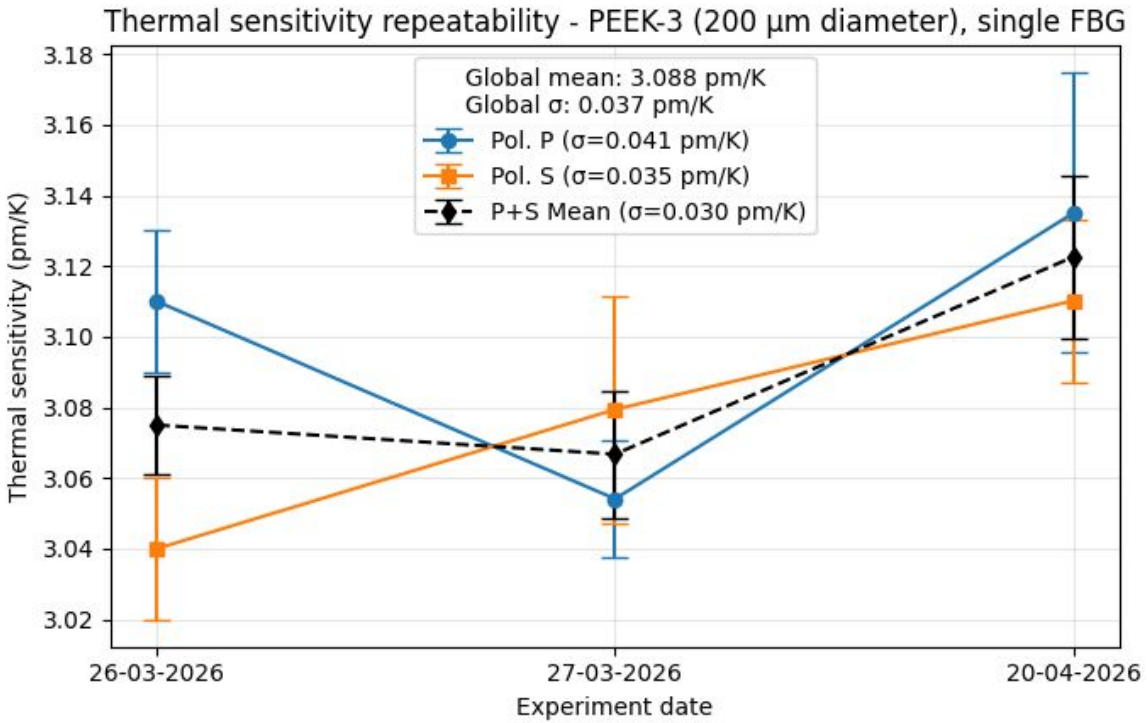


# DW-3: Ormocer-T Repeatability Analysis

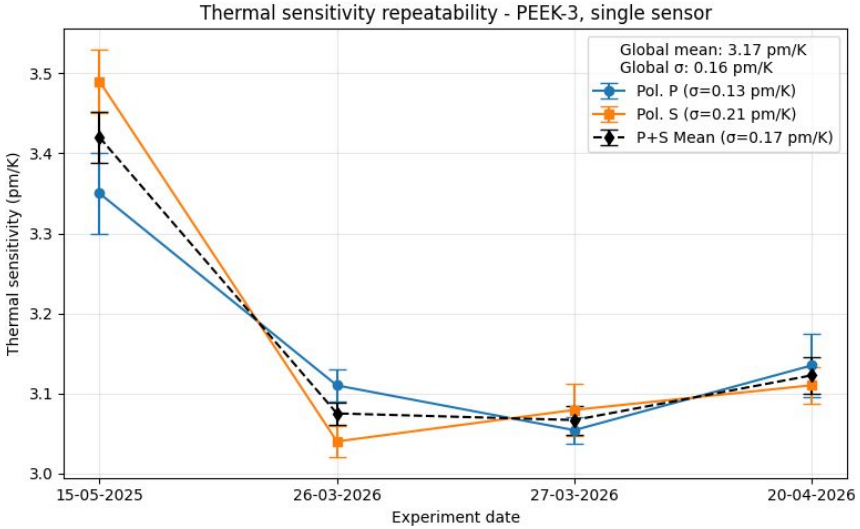


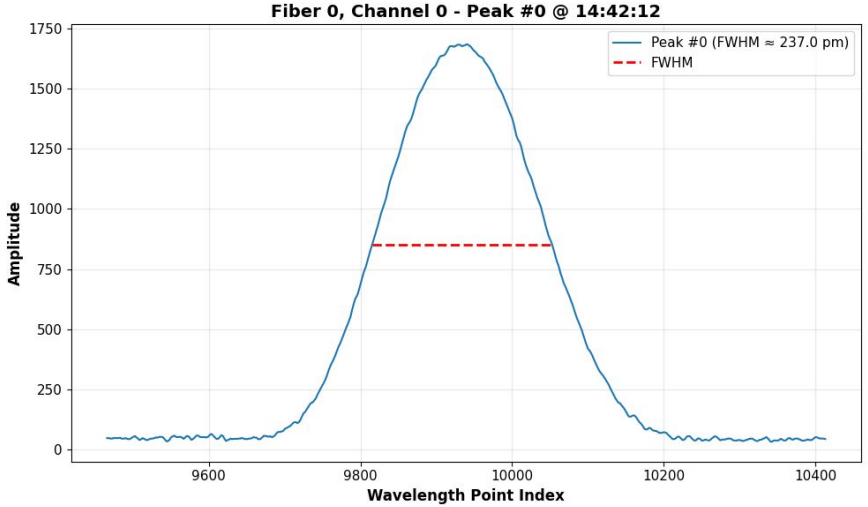



# PEEK-3 (200um): Repeatability Analysis

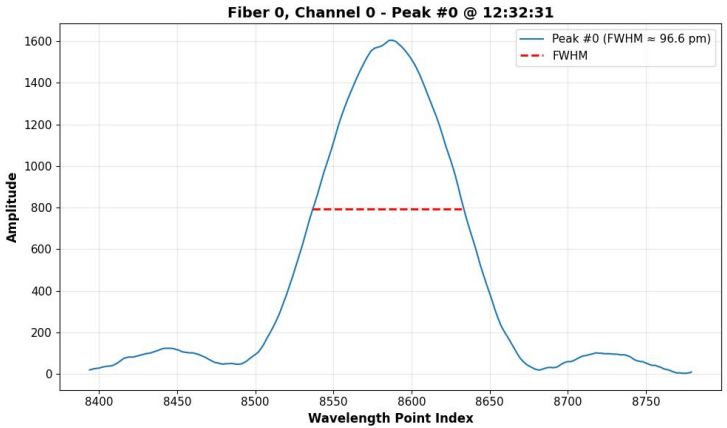


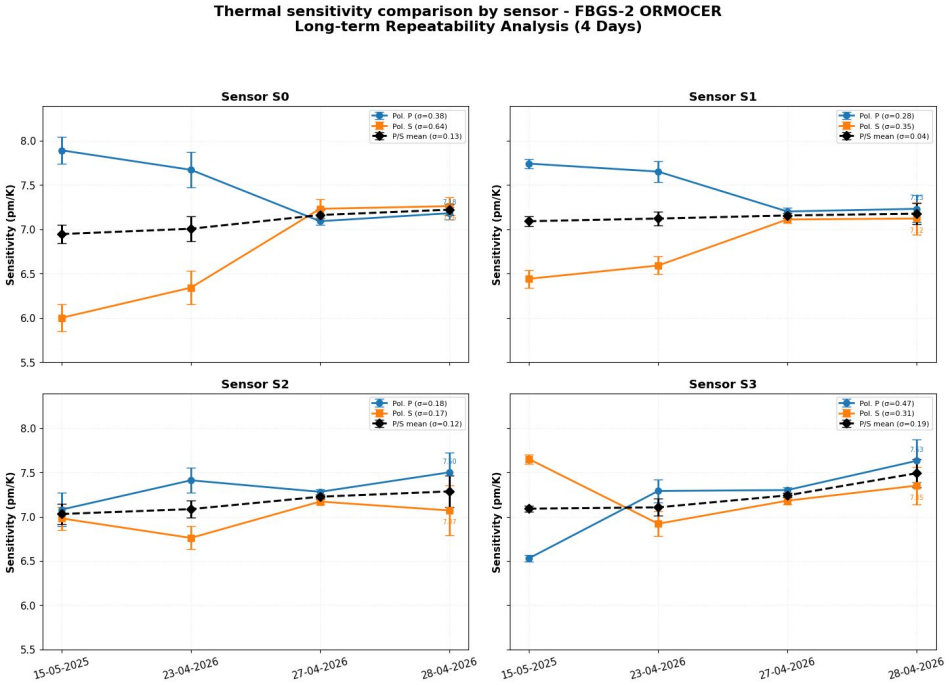
# PEEK-3 Fiber: Analysis



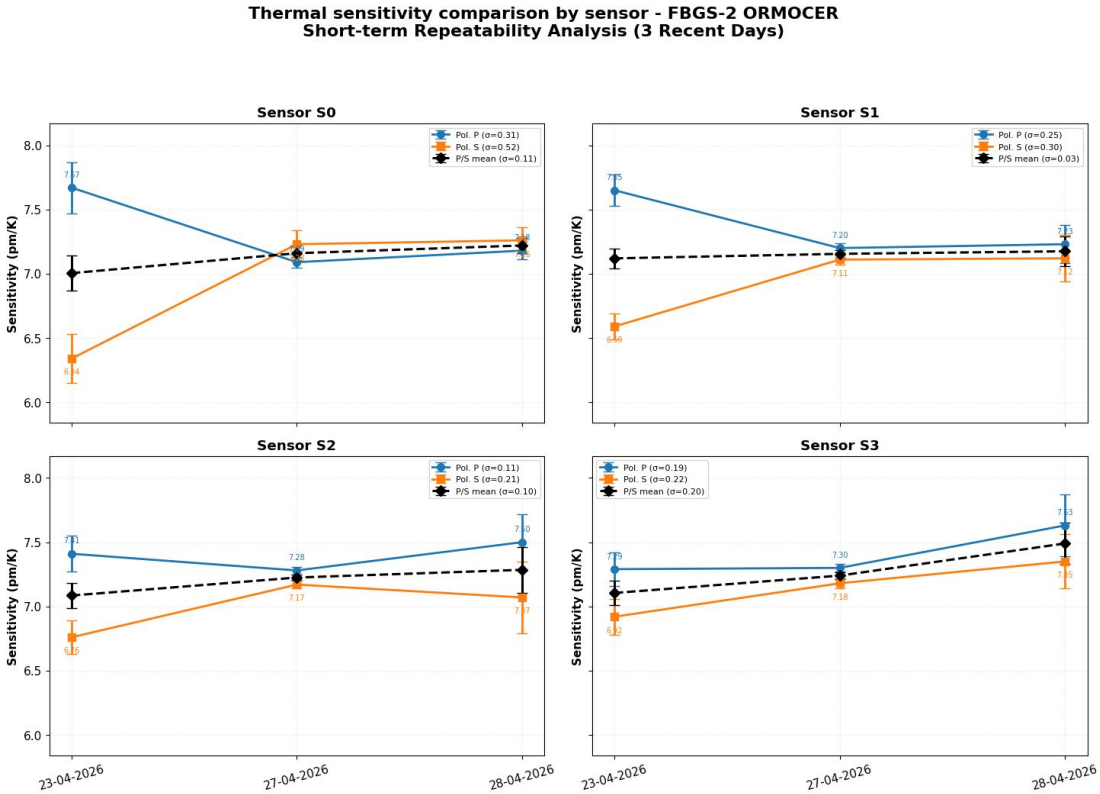



# FBGS-2 (Ormocer) Fiber Repeatability Study



# FBGS-2 (Ormocer) Fiber Repeatability Study



# NEXT STEPS

- Continue the repeatability study with different coatings:
  - Bare Fiber
  - Polyamide (?)

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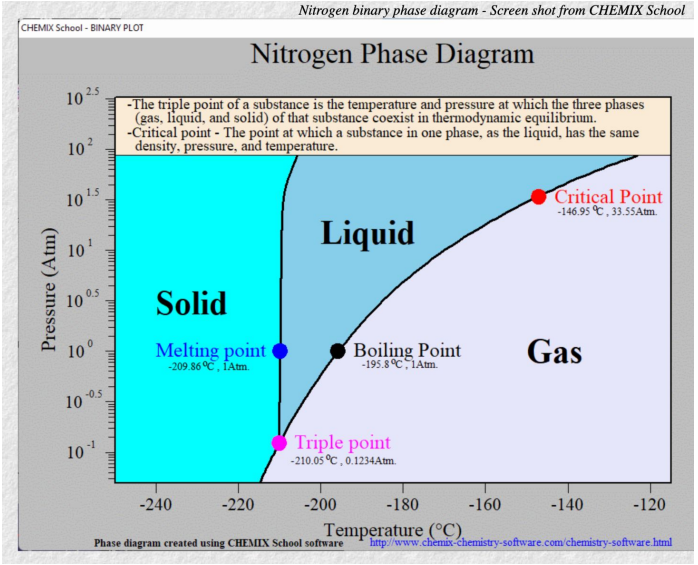
Continue the repeatability study with different coatings:

- Bare Fiber
- Polyamide (?)

# Nitrogen Phase Diagram

*Nitrogen binary phase diagram - Screen shot from CHEMIX School*




## Antoine Equation Parameters

$\log_{10}(P) = A - (B / (T + C))$

P = vapor pressure (bar)

T = temperature (K)

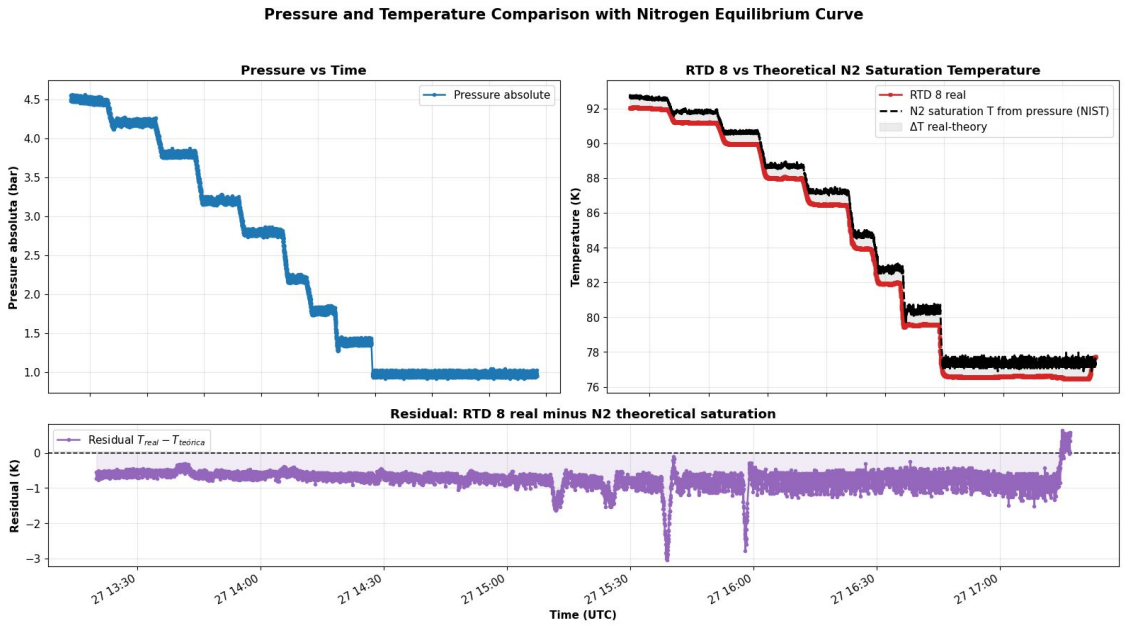
View plot Requires a JavaScript / HTML 5 canvas capable browser.

| Temperature (K) | A | B | C | Reference | Comment |
|---|---|---|---|---|---|
| 63.14 to 126. | 3.7362 | 264.651 | -6.788 | Edejer and Thodos, 1967 | Coefficents calculated by NIST from author's data. |
| 63.14 to 78.00 | 3.63792 | 257.877 | -6.344 | Moussa, Muijlwijk, et al., 1966 | Coefficents calculated by NIST from author's data. |

# Nitrogen Phase Diagram

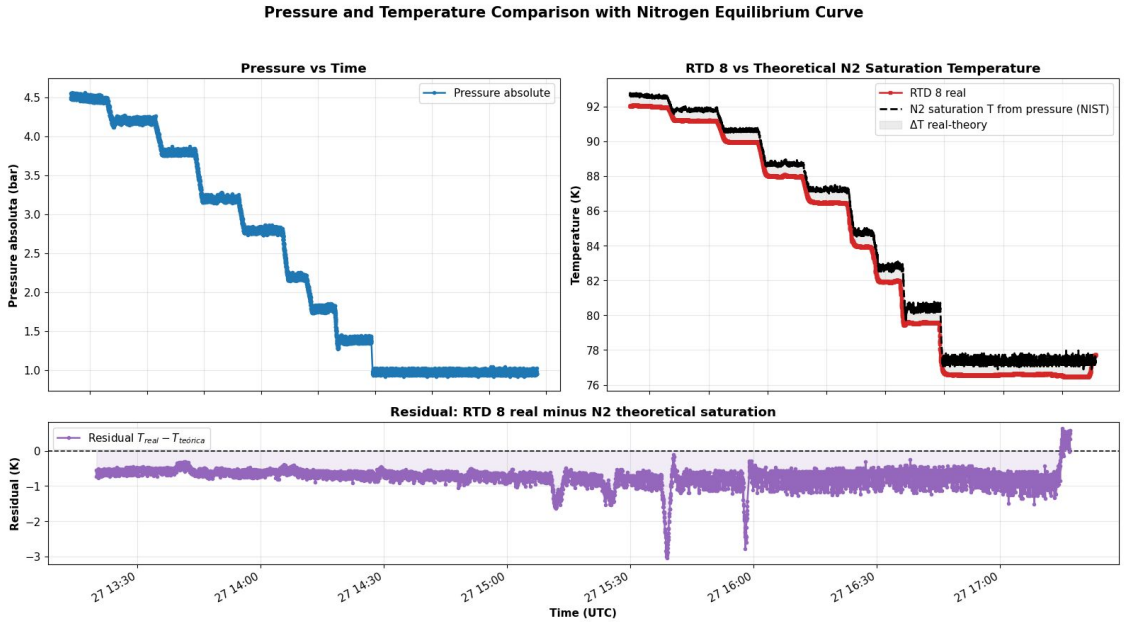
- Thermal Stratification
- Local Barometric Offset:
  - atm_pressure_bar = 1.01325
- Dynamic Lag

  (Non-Equilibrium)



# Thermodynamic Validation: RTD vs. Antoine Curve

- **Experimental Data (Means):**
  - **Measured Temp (RTD 8):** 83.67 K
  - **Theoretical Saturation Temp:** 84.39 K (at 2.4 bar).
  - **Average Deviation:** -0.71 K
- **Physical Interpretation:**
  - **Subcooled Liquid State.**
  - **Thermal Stratification.**
  - **System Stability:** A low standard deviation (0.26 K) confirms a stable plateau.



# REFERENCES


- https://www.chemix-chemistry-software.com/school/phase-diagram/nitrogen-phase-diagram.html#:~:text=Melting%20point%20for%20Nitrogen%20(%201%20atm,%2D346.09%20F%20Fahrenheit%20Critical%20point%20for%20Nitrogen
- https://webbook.nist.gov/cgi/cbook.cgi?ID=C7727379&Mask=4

# QUESTIONS

# ProtoDUNE VD