Solutions for humidity and temperature monitoring in the Silicon Tracking System of Compressed Baryonic Matter Experiment: Sensors, Testing and DCS integration

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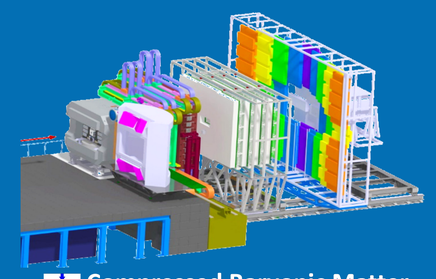
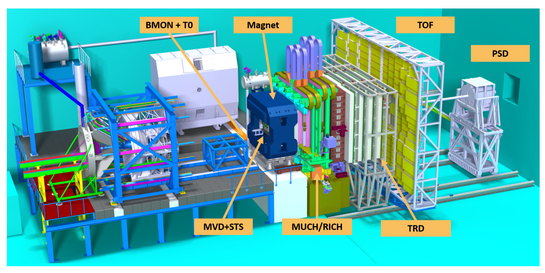


Compressed Baryonic Matter experiment at FAIR

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

Introduction

The Compressed Baryonic Matter experiment is one of the scientific pillars of the Facility for Antiproton and Ion Research (FAIR), Darmstadt, Germany. It aims to explore the QCD diagram in the region of the high baryon densities using high-energy nucleus-nucleus collisions.



Compressed Baryonic Matter Experiment

CBM subsystems' requirements:

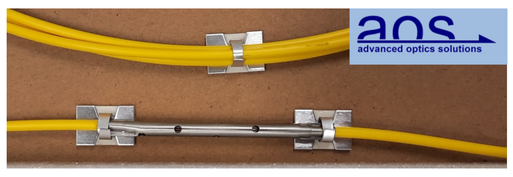
- ☐ Fast and radiation hard detectors
- ☐ Free-streaming DAQ
- ☐ 4D tracking
- ☐ Online event reconstruction and selection
- ☐ Tracking acceptance: $2.5^o < \theta_{lab} < 25^o$

Ambient conditions and potential sensing systems

During the detector operation sensors need to measure water content down to a few ppmV. Therefore, STS will be equipped with 3 different kinds of sensors:

- ☐ Fiber Optic Sensors (FBG/LPG based)
- ☐ capacitive sensors (SHT series, IST)
- ☐ sniffing system (several sniffing points with high precision for trace humidity detection and hardware interlock)

ES20 Sampling System

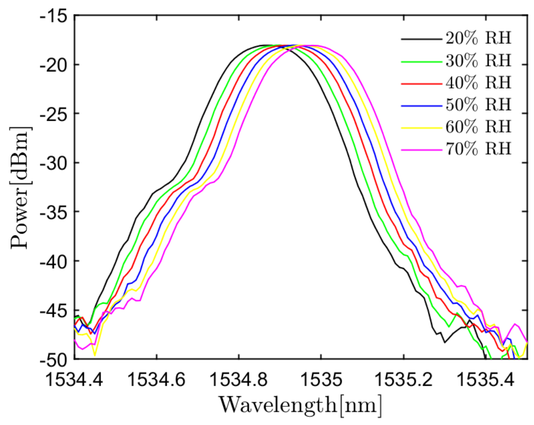


RH sensors array with 15 cm pitch

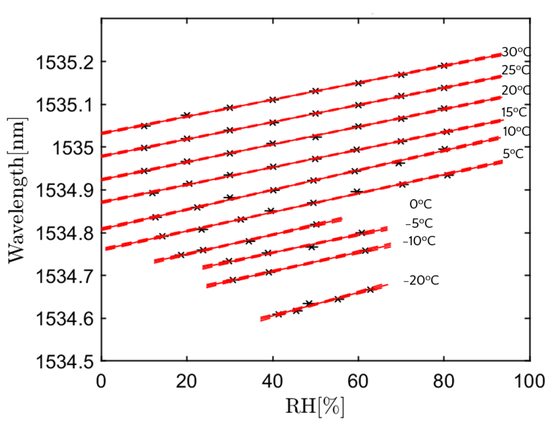
FBG-based hygrometers

FBG RH sensors

Two different designs of FOS were tested – 5 sensors in an array (multiplexed) and a single RH sensor combined with a temperature sensor for compensation. The polyimide coating was 15 μm for hygrometer and 4x5 μm for the array.



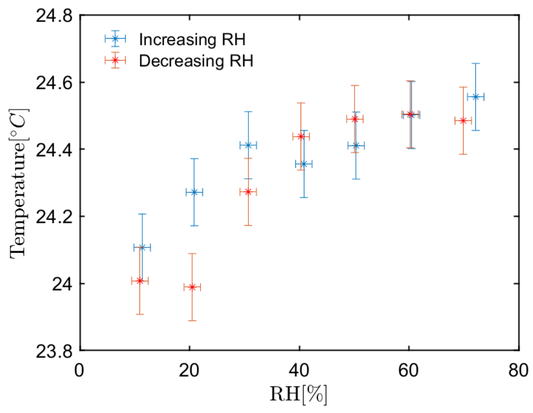
Response to humidity changes in constant temperature for the hygrometer



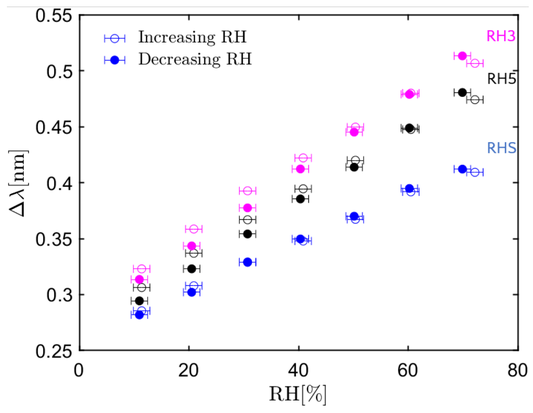
Hygrometer calibration curves (30 °C to −20 °C)

Hysteresis at 25°C

Hygrometer's hysteresis - 1 %, array sensors - 2 %

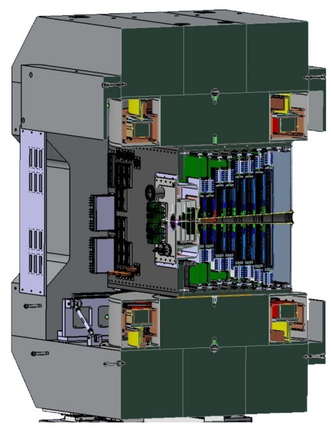


The temperature stability plot



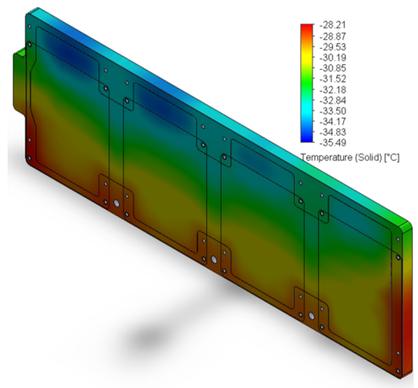
Hysteresis at 25 °C

The Silicon Tracking System



Silicon Tracking System inside the magnet

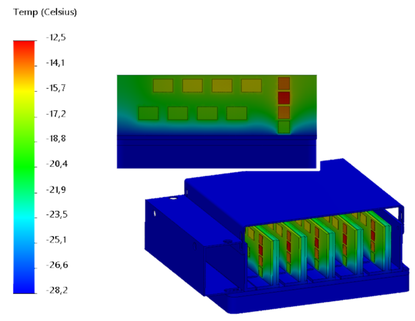
The STS consists of 8 tracking stations comprising 876 double-sided microstrip silicon sensors attached to Front End Electronics via ultra-thin micro cables.



Temperature map of the cooling block during nominal operation of the Front End Boards

The subsystem's design defines the requirements for ambient sensors:

- ☐ The subsystem is placed inside a 1 Tm magnet
- ☐ Radiation tolerance of the system - up to $10^{14}\,\mathrm{MeVn_{eq}/cm^2}$
- ☐ Efficient NOVEC-based cooling system to ensure $-10\,^{\circ}\mathrm{C}$ target operation temperature
- ☐ water content of around 20 ppm and lower



Temperature map of the FEB box

Fiber Bragg Grating Sensors

What is Fiber Bragg Grating?

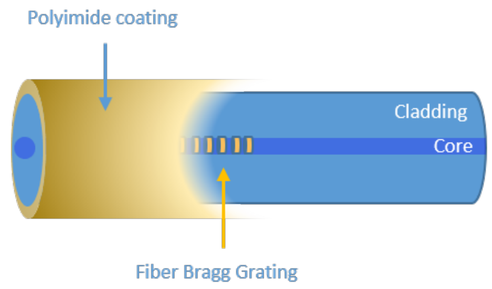
A selective filter which reflects the light signal at certain wavelength named as Bragg wavelength.

$$\lambda_B = 2n_{eff}\Lambda \qquad (1)$$

n_{eff} - effective refractive index, Λ - grating pitch
Furthermore, the Bragg wavelength shift is a superposition of temperature and humidity effects.

$$\frac{\Delta\lambda_B}{\lambda_B} = \Delta RHS_T + \Delta TS_{RH} \qquad (2)$$

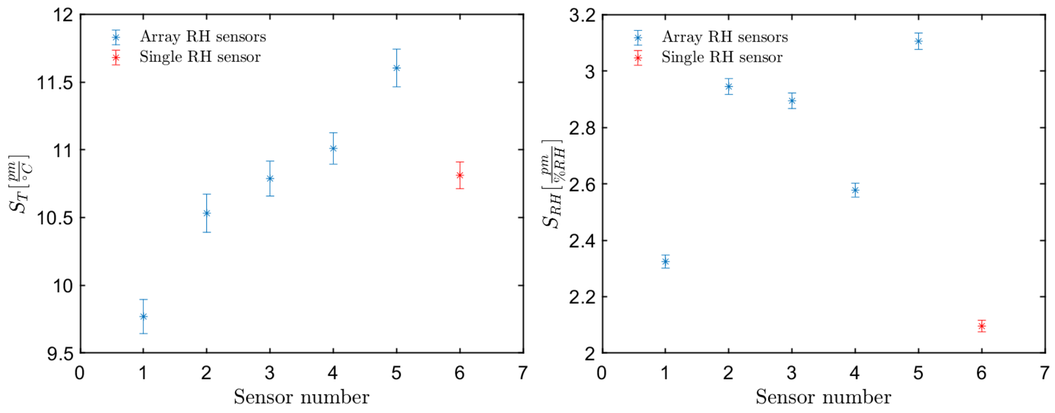
Λ_B - Bragg wavelength, $S_{T/RH}$ - sensitivity coefficients for relative humidity and temperature



Fiber Bragg Grating Relative Humidity Sensor

Calibration - S_T and S_{RH}

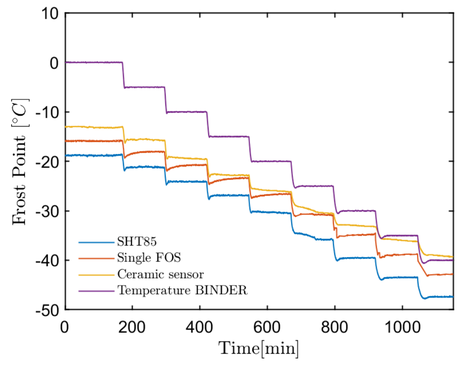
S_T remains similar for all sensors regardless of the polyimide thickness. The thicker layer of polyimide coating causes higher S_{RH} for sensors 1–5.



Temperature and humidity sensitivity for single RH sensor and sensors array

Performance and outlook

- ☐ Response time ($10-80\,\%$) for the single sensor 6 min, for the sensors array - 10 min
- ☐ High repeatability of the single sensor
- ☐ Sensors in the array have strongly attenuated signal below $-20\,^{\circ}\mathrm{C}$
- ☐ Hygrometer shows good performance for values down to 50 ppmV, to be further tested with Thermal Demonstrator (trace humidity levels, similar temperatures to the final system)



Performance of the hygrometer below 0 °C in comparison to capacitive sensors