Karlsruhe Institute of Technology

A study on intermediate buffer layer of coated Fiber Bragg Grating cryogenic temperature sensors

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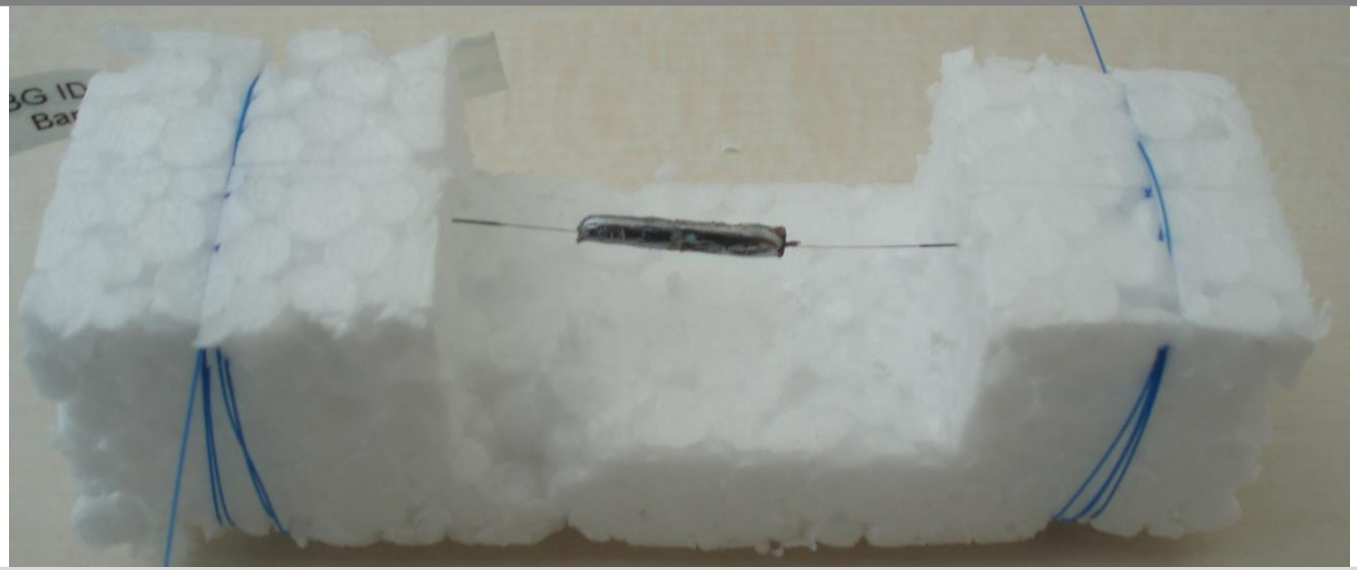
INSTITUTE OF TECHNICAL PHYSICS, CRYOGENICS

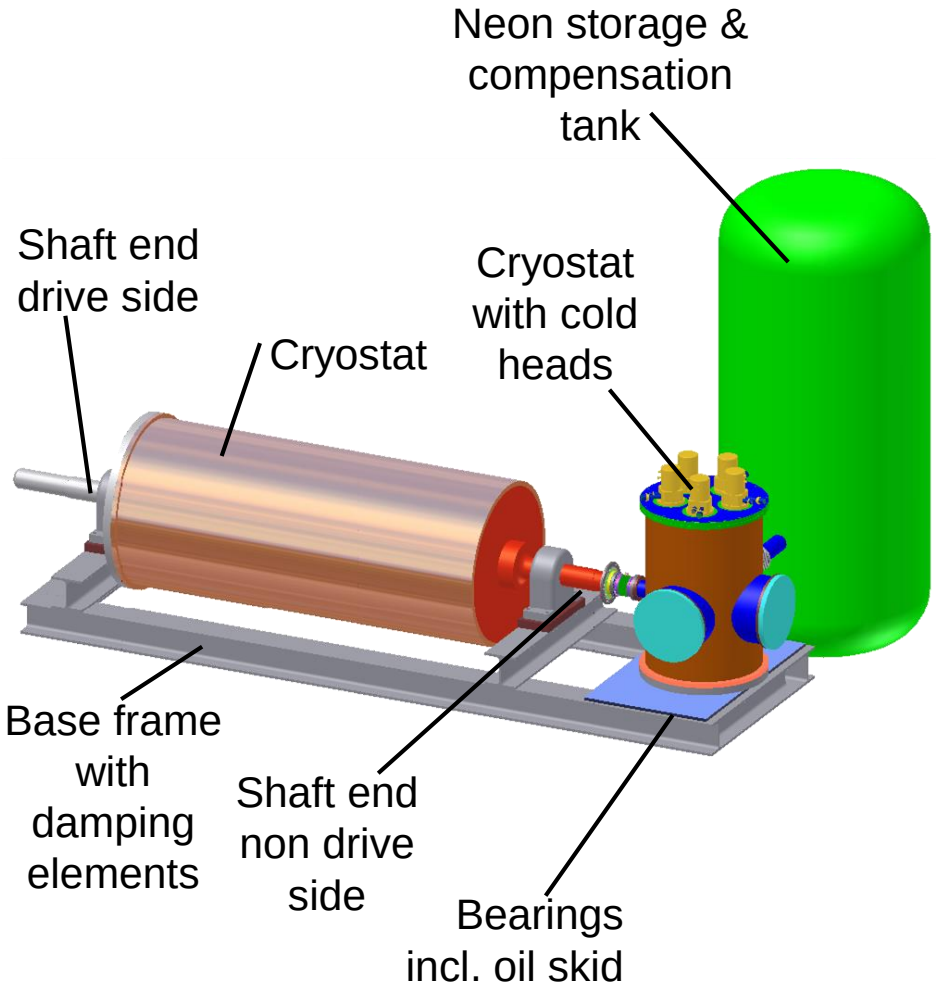


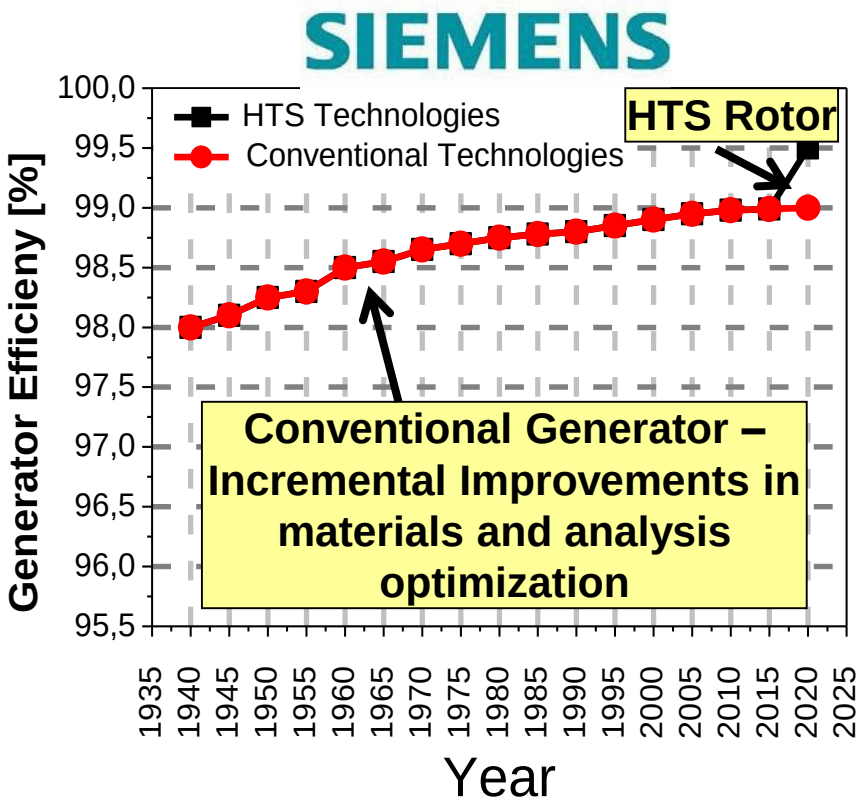
For Today‘s discussion

- **Motivation**
- **FBG sensor and detection principle**
- **Selection of coating materials and methods**
- **Sensor training & calibration**
- **Results and Conclusion**

TEMPERATURE:- ITER, KATRIN , HTS Generator

BMWi Project in collobration with siemens

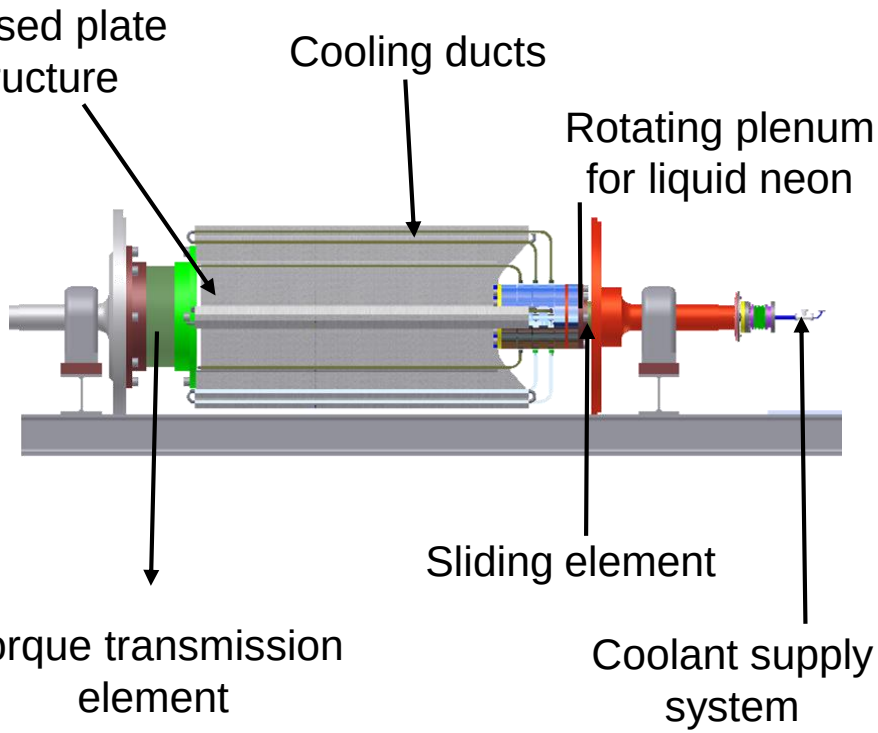




0.5% efficiency improvement can equal $3.8 M for 900 MVA Generator

Dr.-Ing.R.Ramalingam : *A study on intermediate buffer layer of coated Fiber Bragg Grating cryogenic temperature sensors*

TEMPERATURE :- HTS Generator



Method 1 - operation with constant heating power

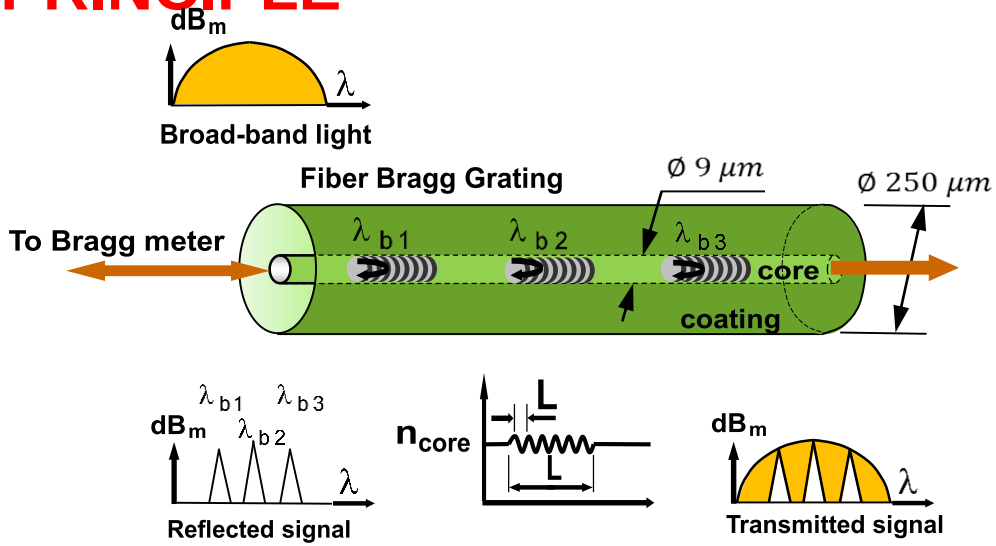
:- very good absolute measurement accuracy

Method 2 - application of heat pulses

:- very high measurement resolutions

Fiber Bragg Gratings

FBG BASIC PRINCIPLE



$$\Delta\lambda_b = 2nL(\{1-(n^2/2)[P_{12}-\nu(P_{11}+P_{12})]\}\varepsilon+[\alpha+(dn/dT)/n]\Delta T$$

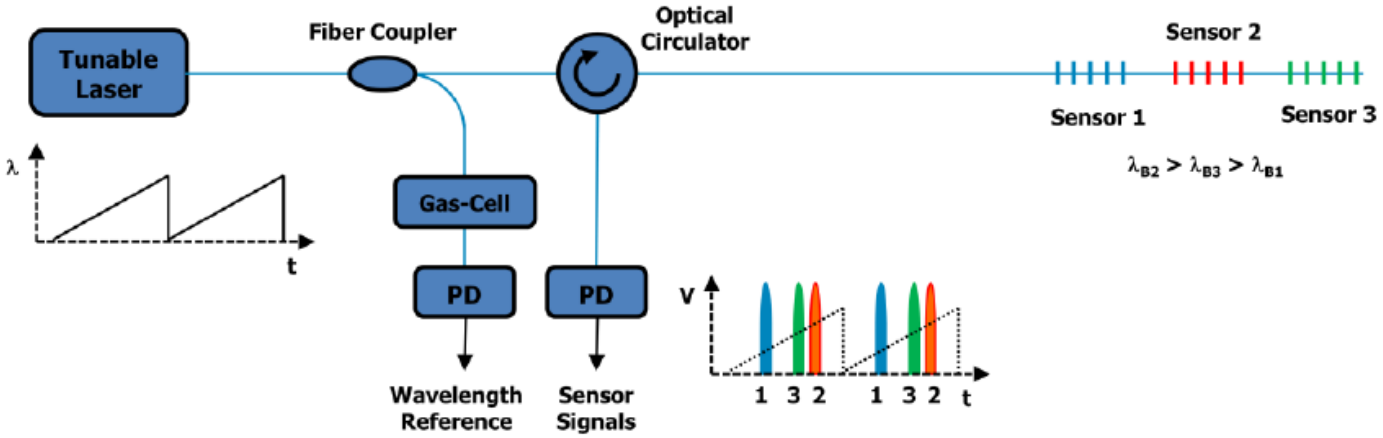
Strain

Temperature

FBG Sensors could be a possible choice

- ✓ **Immunity to electromagnetic interference and losses along the optical path**
- ✓ **High precision**
- ✓ **Reduced dimensions**
- ✓ **Durability**
- ✓ **Easy to multiplex a large number of sensors along a single fiber**
- ✓ **Corrosion resistance**
- ✓ **Reducing the size of the cables**

DETECTION METHOD



- Light from the laser was split into two by a 50/50 fibre coupler and optical circulator.
- Half of the light was guided to a FBG-sensor array while the other half to a National Institute of Standards and Technology traceable wavelength gas cell.
- By comparing time synchronized spectra from both gas-cell and FBGs it is possible to monitor absolute Bragg wavelength changes as small as 1 pm.
- A centroid method is then used to determine the central wavelength of the FBGs

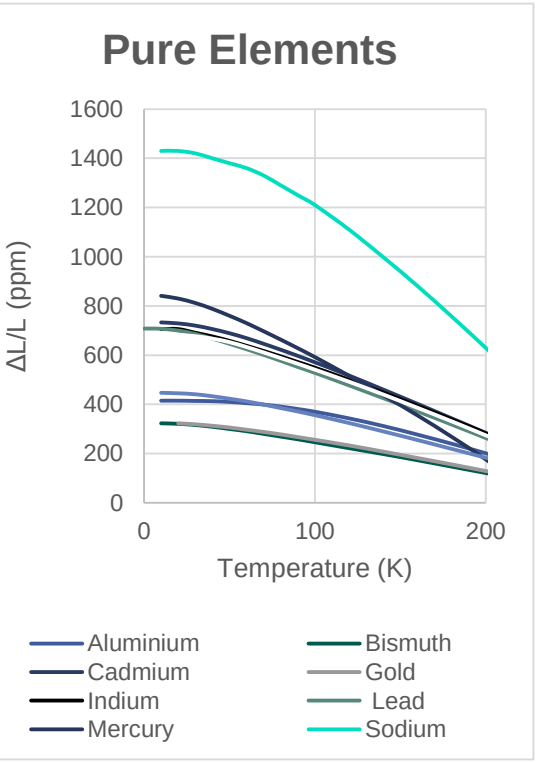
MATERIAL SELECTION

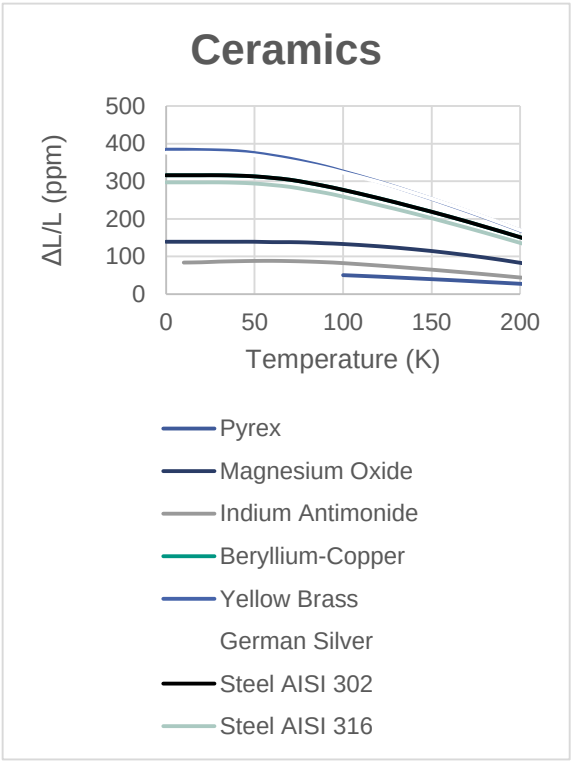
~ 120 K

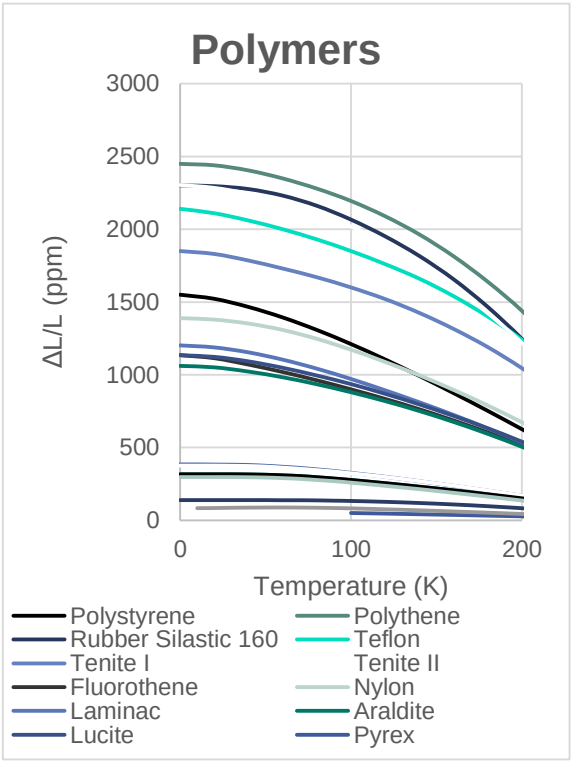
Coefficient of thermal expansion (CTE)

Young's modulus (E)

Adhesion

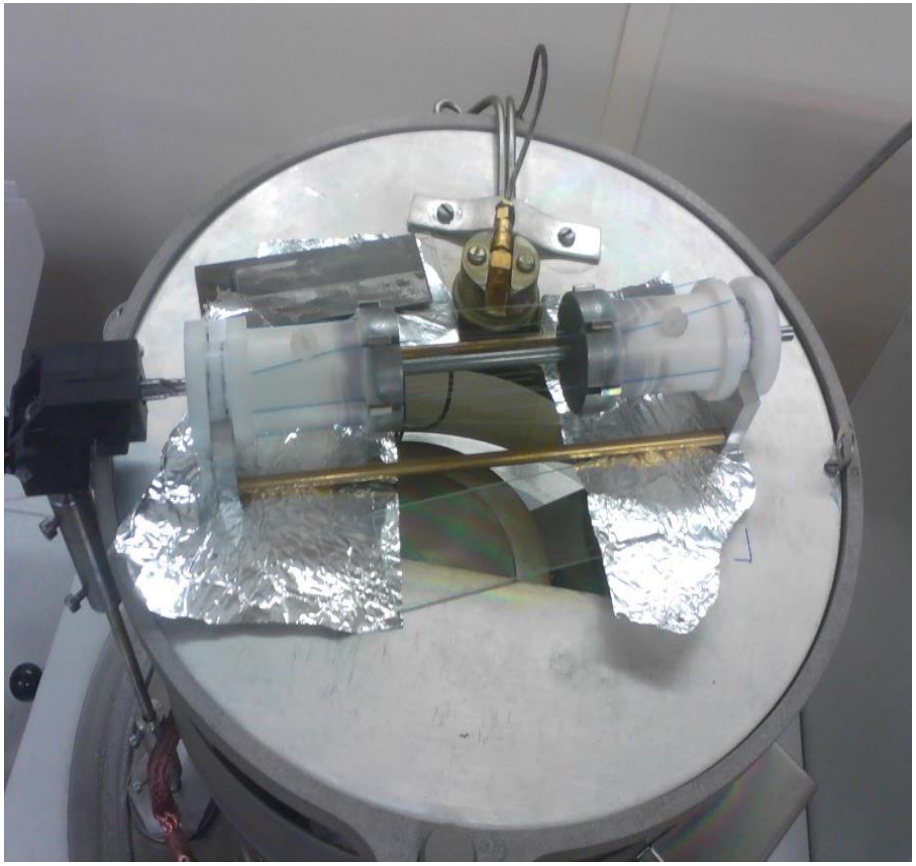






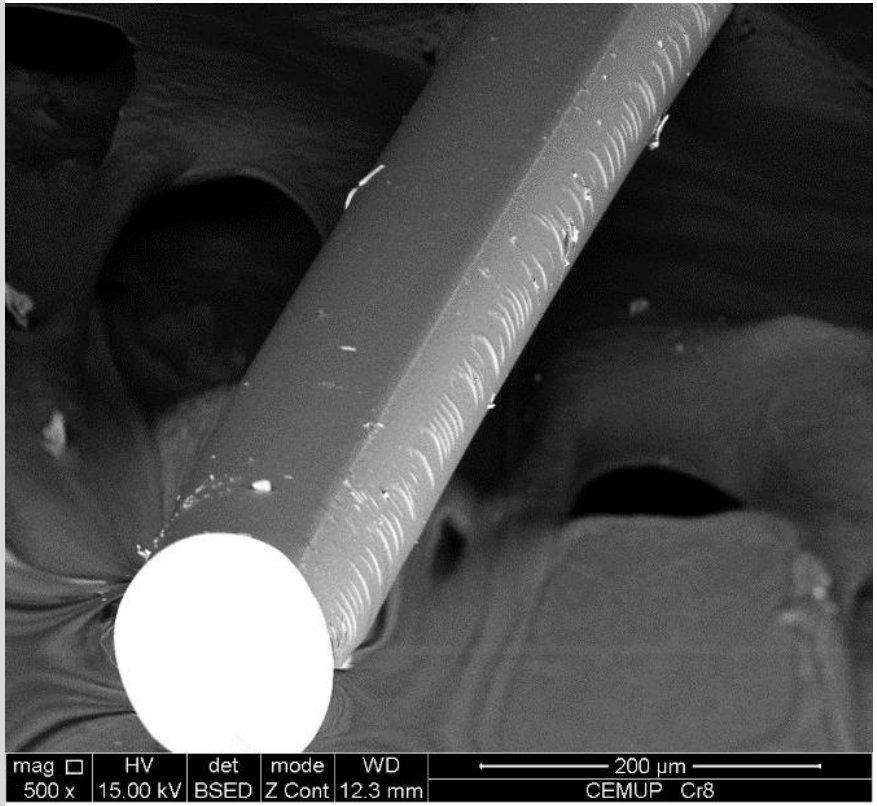
Electron beam deposition (EBD) – Primary coating

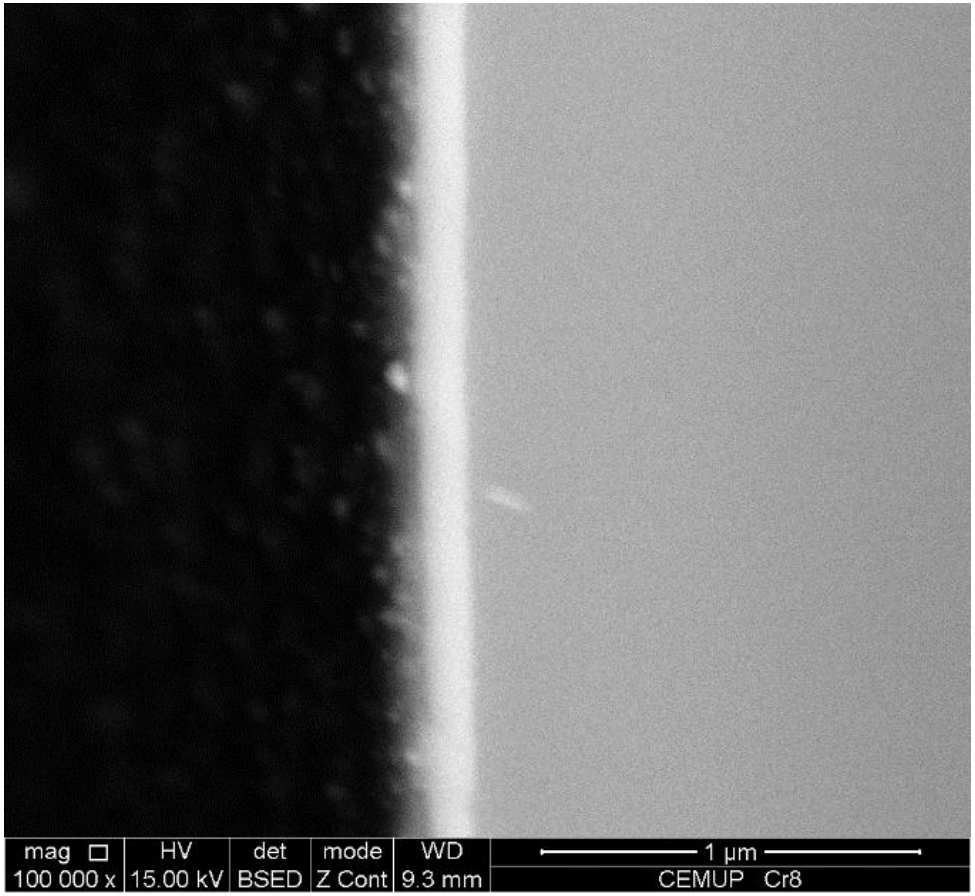
Buffer layer (Cr, Ti, Ni)



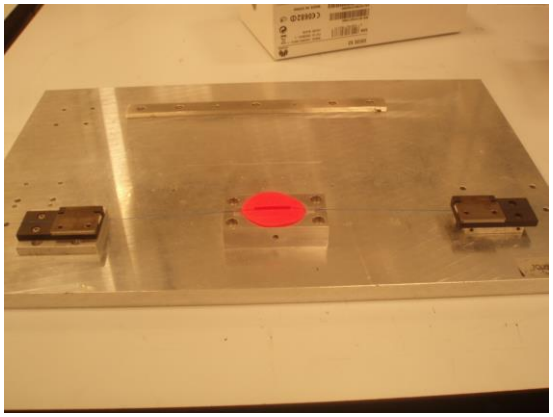
Rotating device at 6.6 rpm the chamber was put in 10^{-7} vacuum which took around 3 hours, then the deposition started at approximately 0.03 nm/s.

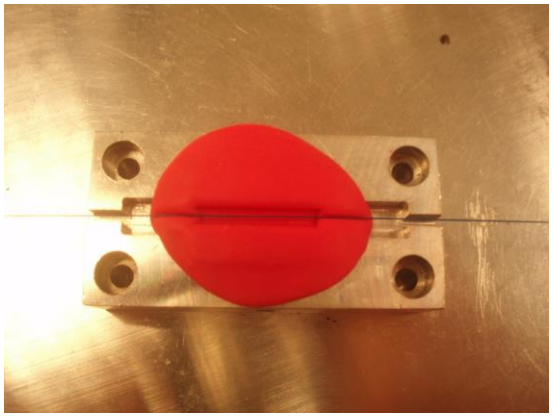
SEM analysis of an optical fiber





SECONDARY COATING - CASTING





CERNIT

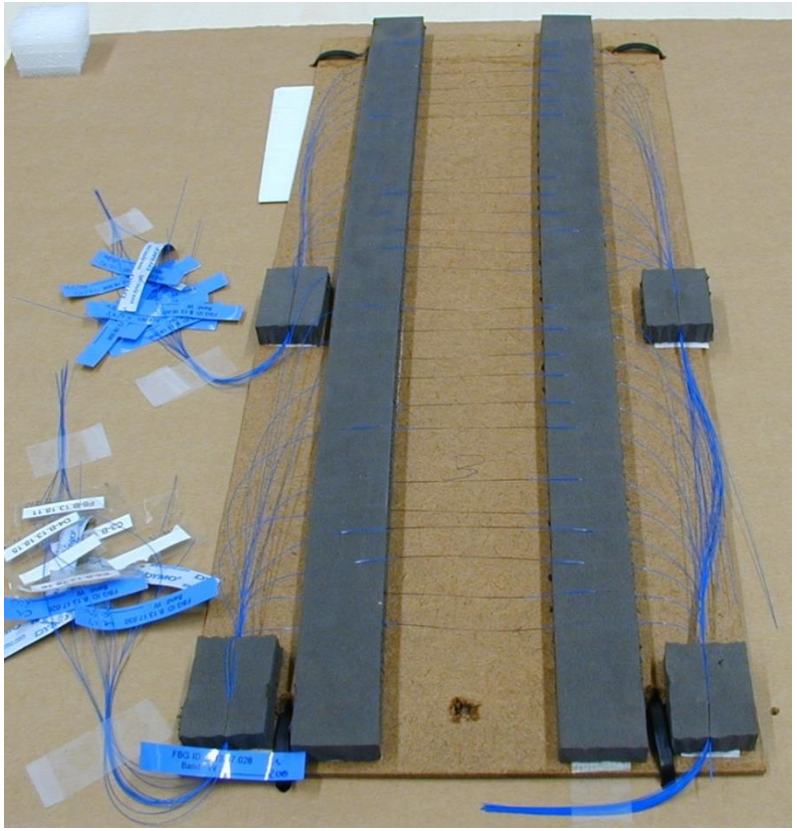
15mm long and 2.5mm in diameter

FABRICATION AND CALIBRATION

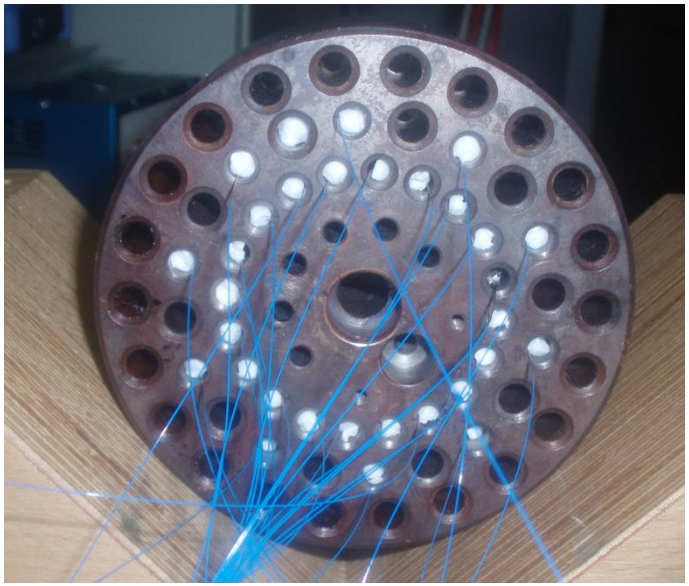
- Buffer layer : To ensure better Adhension :- Better performance

Series	Thin Film Coating	External Coating
S1	100 nm Ti	In
S2	100 nm Ti	Pb
S3	200 nm Ti	In
S4	200 nm Ti	Pb
S5	100 nm Cr	In
S6	100 nm Cr	Pb
S7	200 nm Cr	In
S8	200 nm Cr	Pb
S9	50 nm Cr + 50 nm Ni	In
S10	50 nm Cr + 50 nm Ni	Pb
S11	150 nm Cr + 18.5 nm Ni	In
S12	150 nm Cr + 18.5 nm Ni	Pb

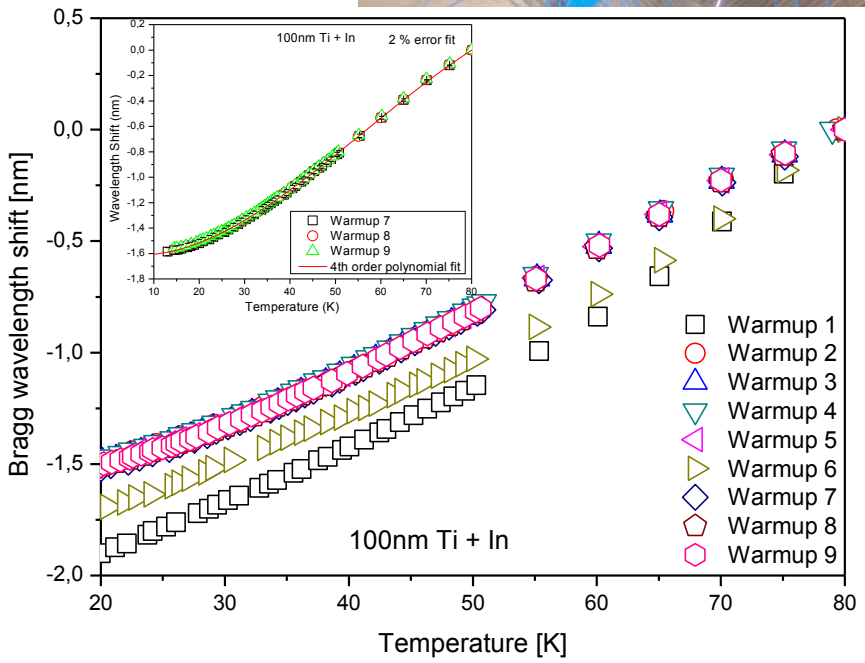
FiberSensing
bringing light to measurement



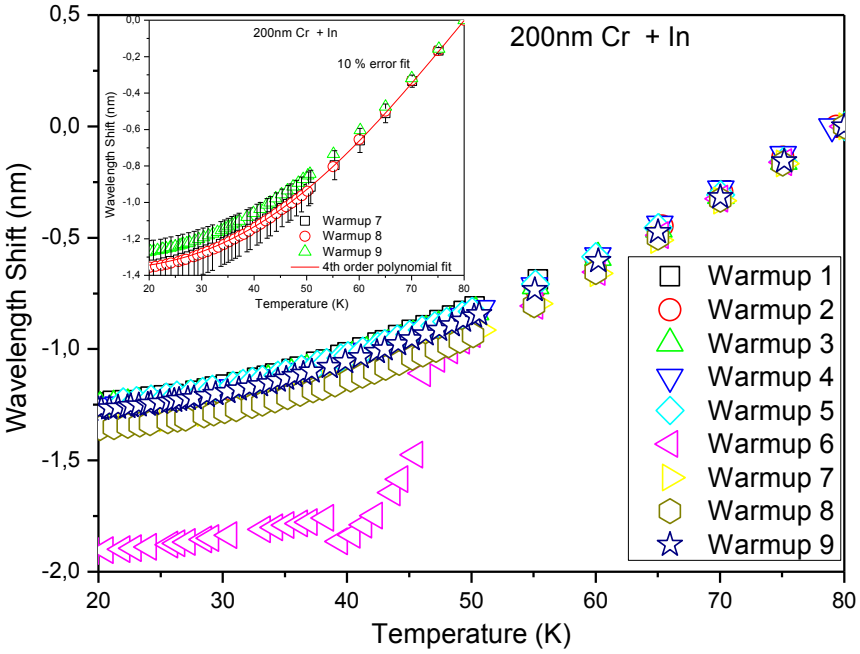
TRAINING

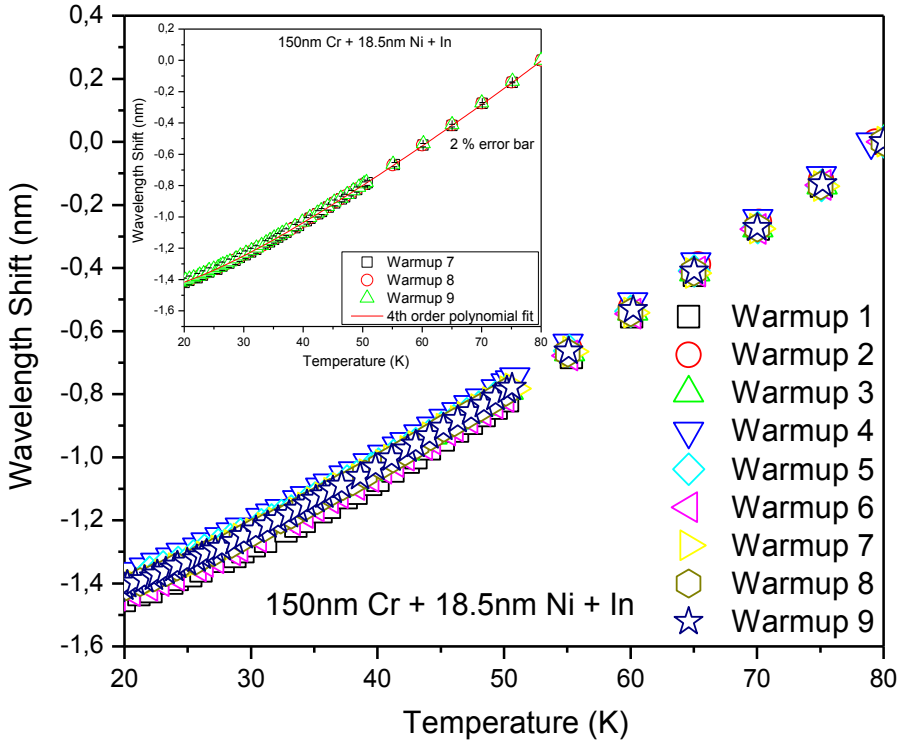


36 sensors



Chromium (Cr) and Nickel(Ni).





RESULTS

Temp.	Sensitivity nm/K											
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
20K	0.013	0.012	0.010	0.013	0.005	Broken	0.013	0.007	0.014	0.013	0.013	Broken
30K	0.018	0.019	0.015	0.019	0.010		0.018	0.008	0.019	0.017	0.017	
40K	0.034	0.034	0.029	0.035	0.025		0.034	0.014	0.030	0.035	0.029	
70K	0.025	0.023	0.022	0.023	0.036		0.028	0.003	0.021	0.032	0.031	
Buffer	100nmTi		200nmTi		100nmCr		200nmCr		50nmCr+50nm Ni		150nmCr+ 18.5nmNi	

Conclusion

- Characteristics of FBG sensors with tin, chromium and chromium plus nickel buffer layers were studied.
- The sensors fabricated with different buffer layers were then coated with indium and lead secondary layers.
- The sensors subjected to temperature variation of 80–10 K initially showed a drift from their previous cycles, but it slowly gets stabilized and repeatable after 6th cycle.
- Sensor with a chromium buffer layer exhibits non repeatability due to the poor adhesion to indium secondary layer.
- The temperature sensitivity of the sensors were found to be 34 pm/ K @ 40 K and 13pm/ K at 20 K.
- With the detection unit of 1 pm resolution an temperature resolution of 0.29 K and 0.76 K respectively can be obtained.

Thank you !!!