SEVENTH FRAMEWORK PROGRAMME

ON Wing Ice DetectioN and MonitorinG System

FOHEC'11

Fibre Optics in Harsh Environments Conference

May18 2011 Swindon

towards the future of ice protection

ON-WINGS

Project Partners

GKN AEROSPACE	GKN Aerospace	United Kingdom
	University of Ioannina	Greece
National and Kapodistrian UNIVERSITY OF ATHENS	University of Athens	Greece
AOS	AOS Technology	United Kingdom
TWT	TWT GmbH	Germany
PZL-ŚWIDNIK S.A.	PZL Świdnik SA	Poland
Schlumberger	Sensor Highway (division of Schlumberger)	United Kingdom
JENOPTIK	ESW GmbH	Germany
AIRBUS	AIRBUS France SAS	France

Project Overview

- The key objective is to provide a primary 'On-Wing' ice detector to enable safe flight in icing conditions in accordance with new regulations.
- The sensor uses optical technology for ice detection and health monitoring.

Direct Ice Detection

- Most ice sensors use an indirect means of detection and are remote from the ice accreting surfaces.

- The On-Wings sensor is aero-conformal and can be flush mounted into any aerofoil – wing, rotorblade or engine nacelle.

- It offers a distributive array arrangement so it can activate individual 'zones' of an ice protection system and can be integrated directly into the ice protection system itself.

Schematic of Project

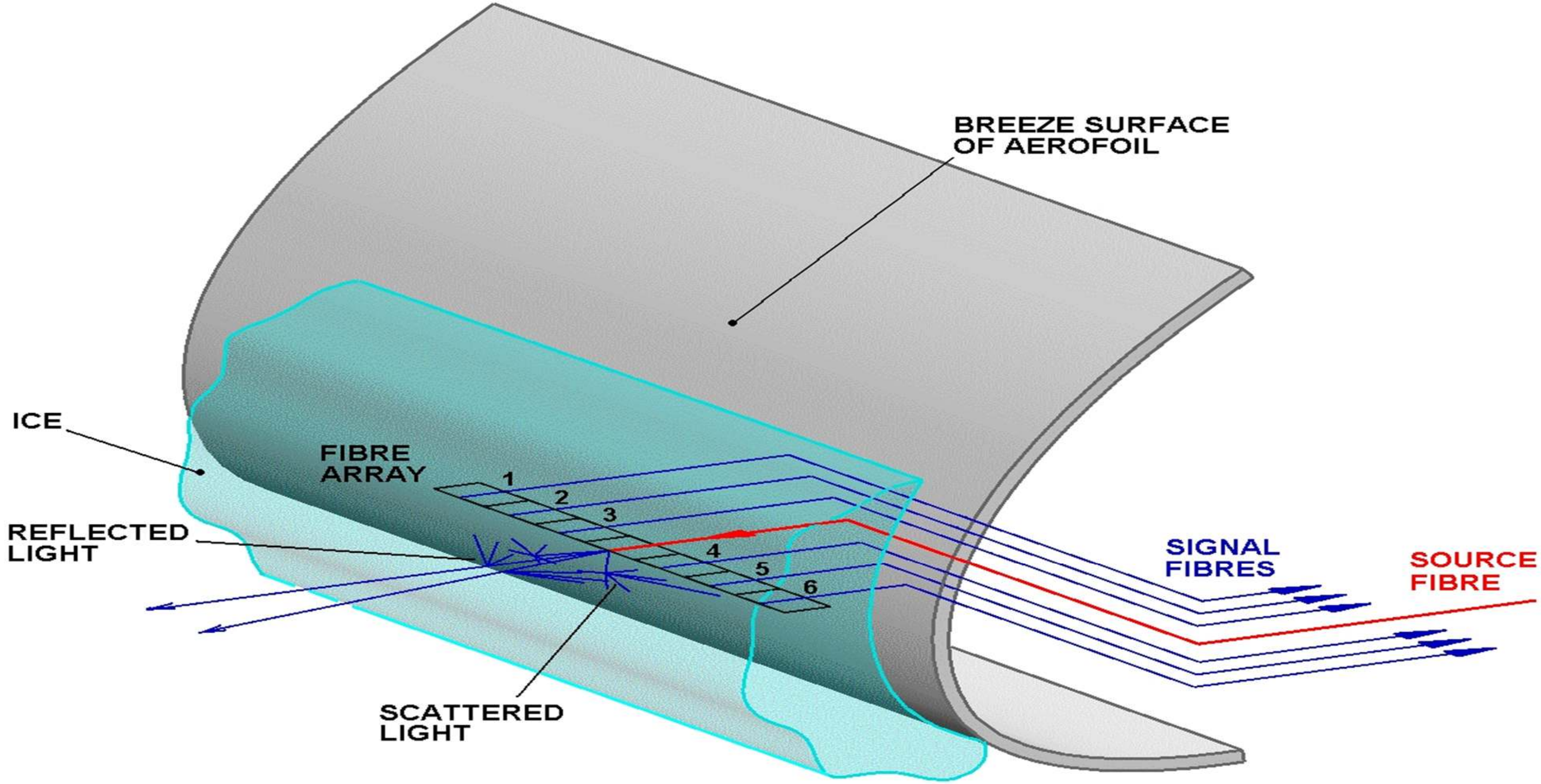
On-Wings Sub-Project	Technology Readiness Level				
	1	2	3	4	5
Sensor Head Development					
Fixed Point Ice Sensor					
Single Sensor Head					
Multi-sensor Head					
Fuselage Mounted Sensor Trial					
Aerofoil Mounted Sensor Trial					
Fixed Point Temperature Sensor					
Distributed Ice Sensor					
Distributed Temperature Sensor					
Health Monitoring Temp Sensor					

Principle of Ice Detection

- Ice has a very complex crystalline structure. It varies in its appearance and hence optical properties depending upon the air trapped during its formation.

- The operation of this sensor is based on detecting the optical dispersion of light in the ice, by measuring the light scattered or reflected from the micro-cracks and micro-bubbles trapped in its volume.

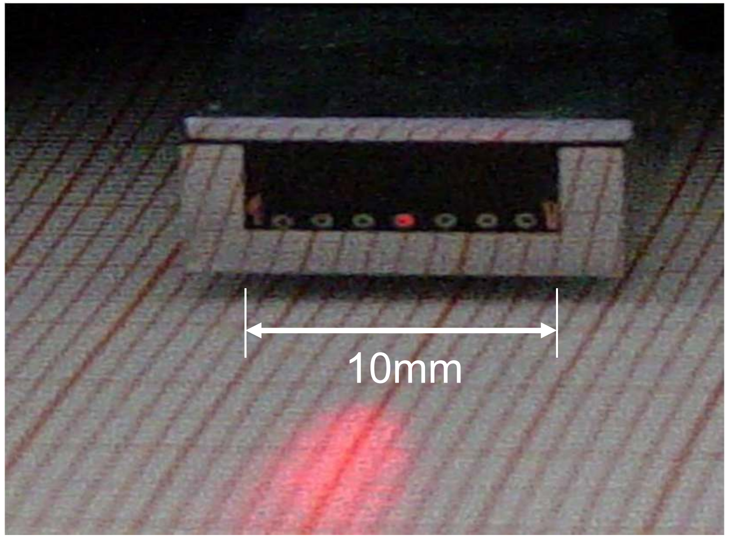
Optical Ice Detector Technology



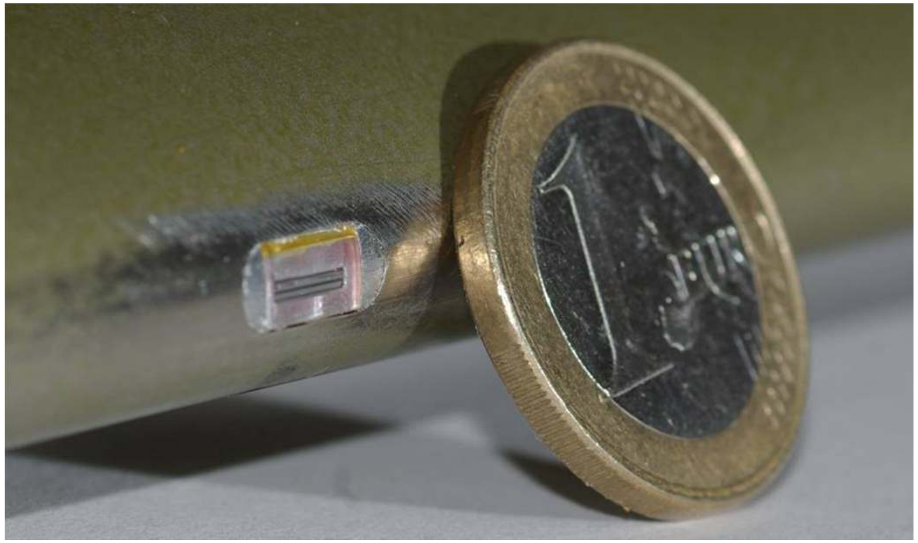
ICE SENSOR - EXPERIMENTAL ARRANGEMENT

Ice Sensor Head

- Prototype sensor heads



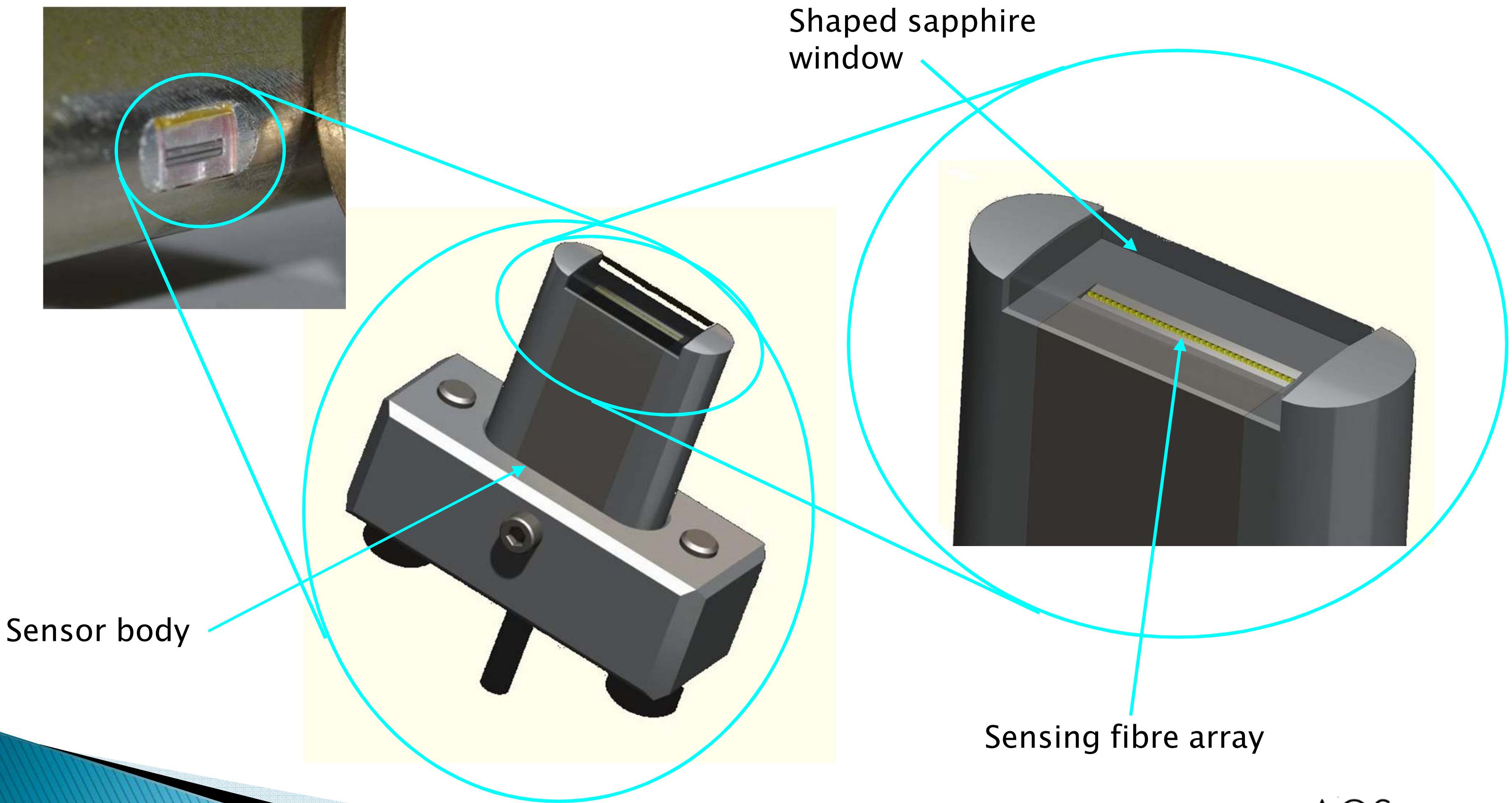
Proof of principle prototype
produced by
University of Ioannina



Aero-conformal optical sensor head
mounted in rotorblade erosion shield
produced by AOS

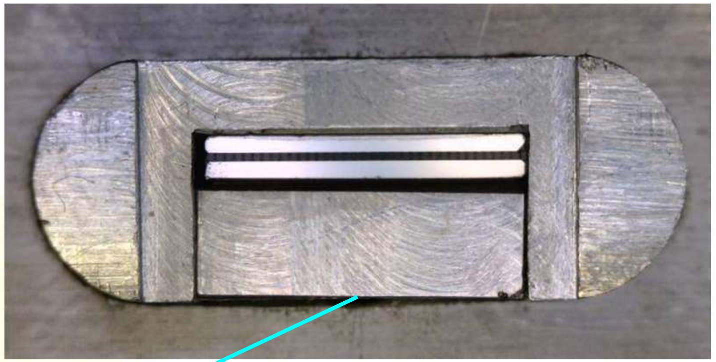
AOS Sensor Head

- Exploded view showing the internal mounting of the AOS sensor.

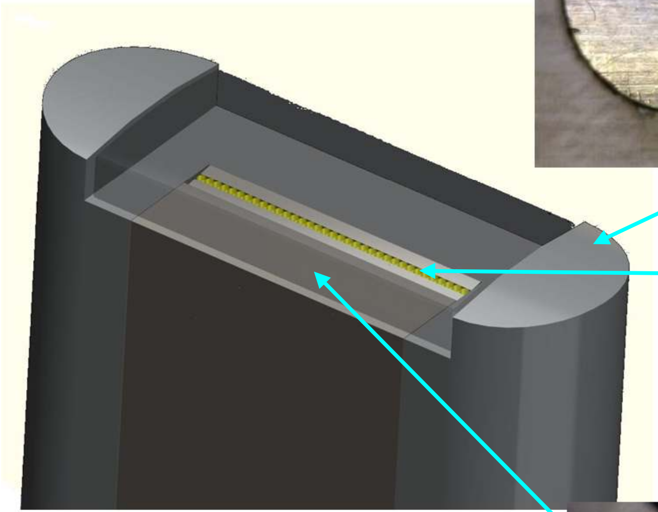


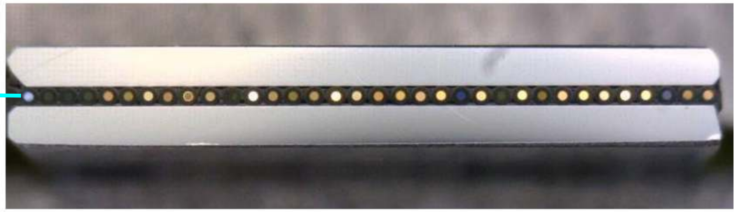
AOS Sensor Head

- Close up view of the individual components that are used in the AOS sensor head.

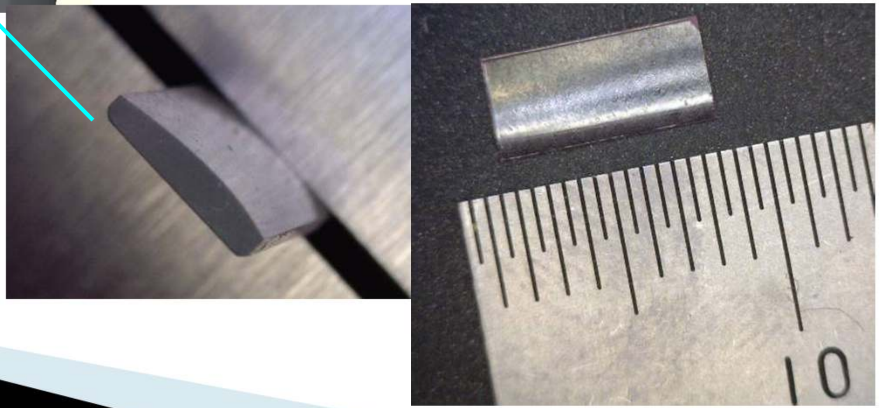


Sensing fibre array viewed from the front.





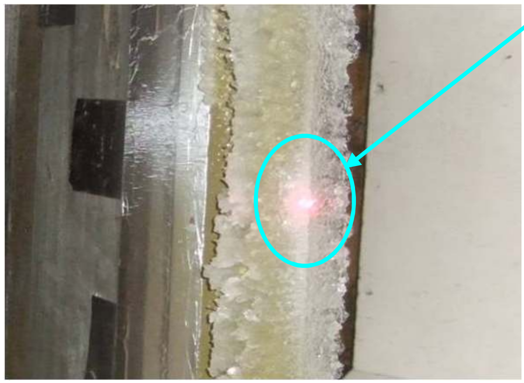
Sensor head w/o window viewed from the front.



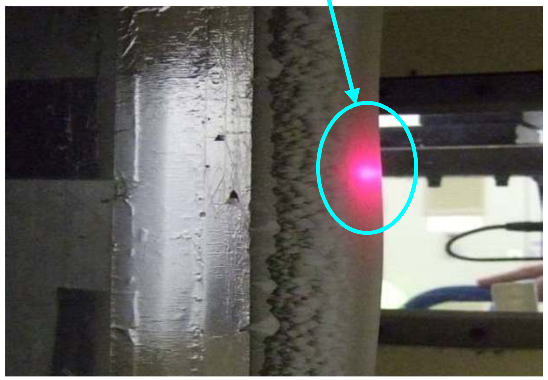
Shaped sapphire window

Icing Tunnel Evaluation

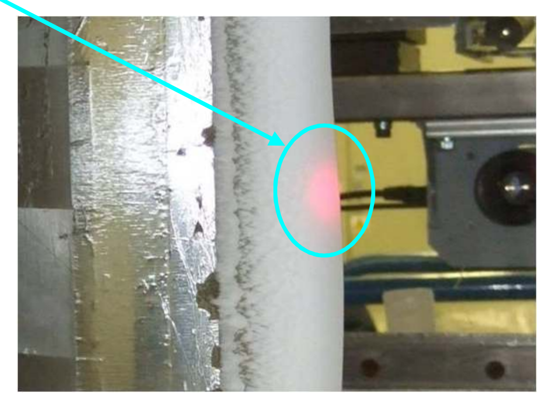
- These images show ice accretion on a rotorblade aerofoil at various temperatures from the December 2010 test campaign in the GKN Aerospace Icing Wind Tunnel.
- By mapping the FAR 25 C icing envelope in an icing tunnel, an algorithm is being developed that enables the thickness of ice and ice type to be recognised without requirement for any secondary data.
- The highlighted areas show the differences in light scattering and transmission caused by ice type.



At -5 ºC Glazed Ice

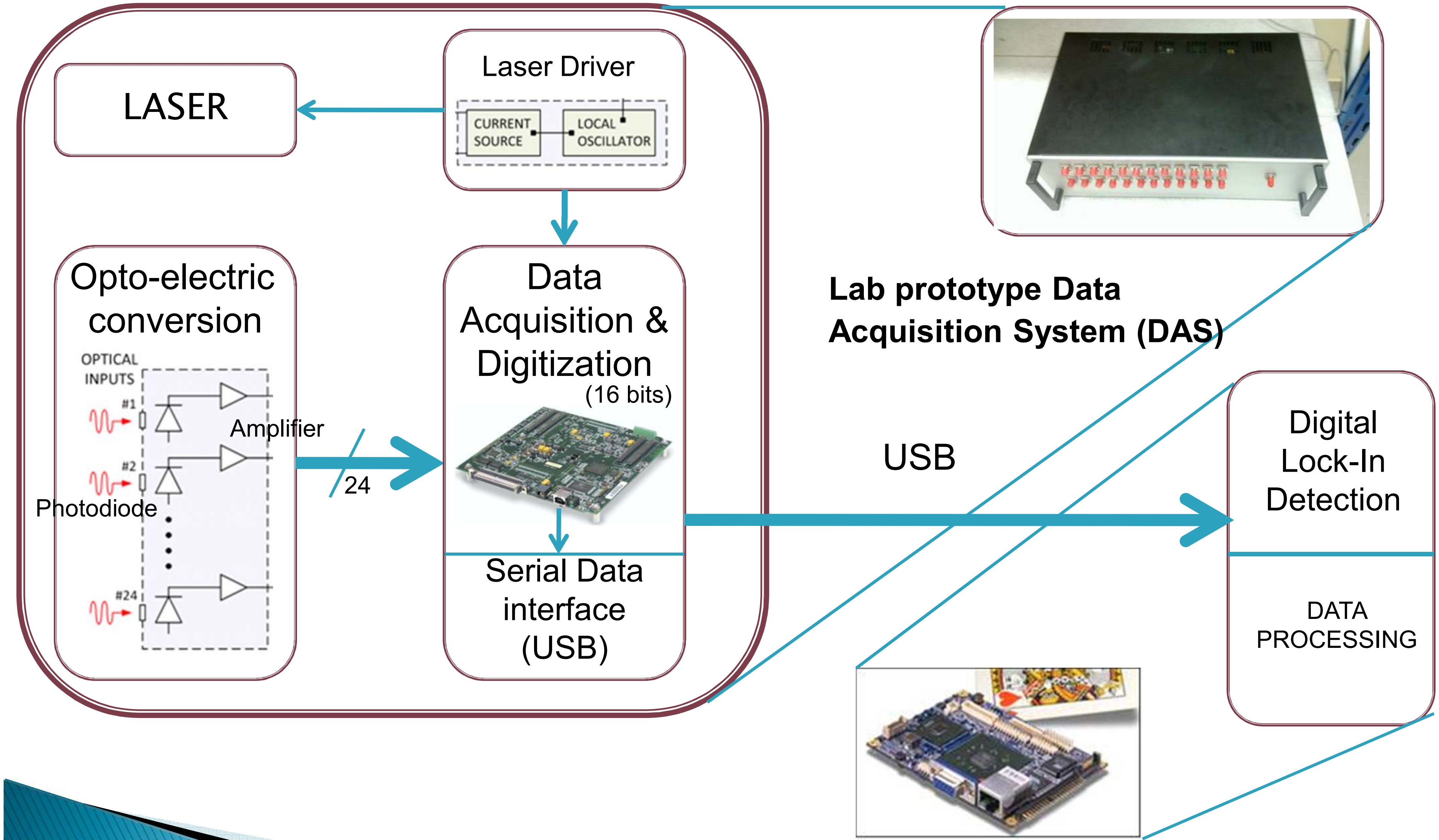


At -15 ºC Mixed Phase



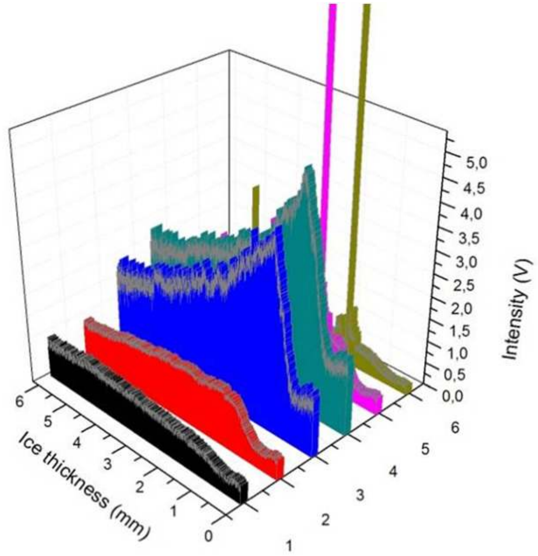
At -25 ºC Rime Ice

Opto-electronic Conversion & Data Acquisition

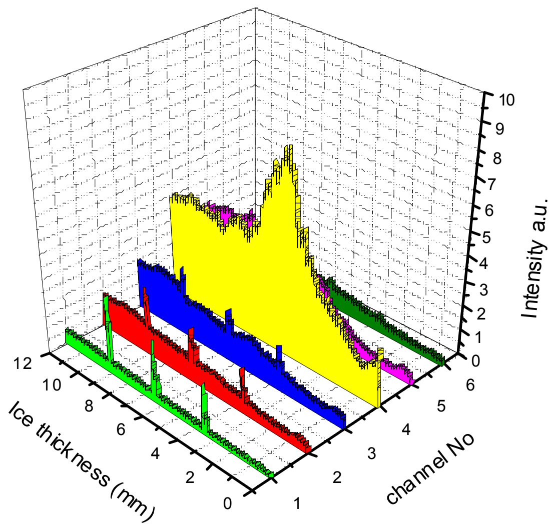


Analysis of Sensor Output

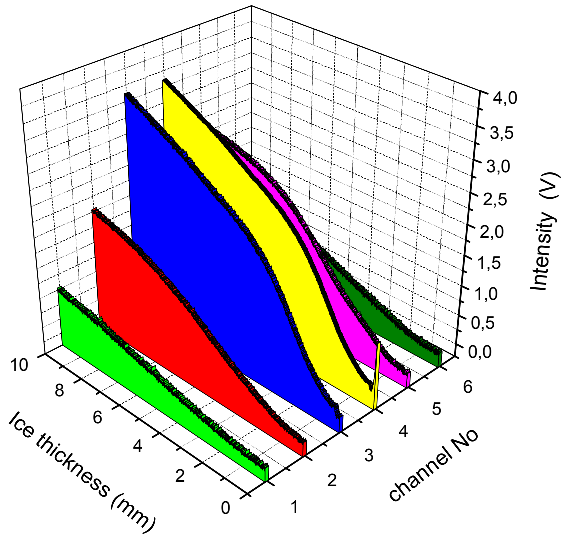
- 3D plots of optical output created by UoI from the AOS sensor head test shown in the previous slides.



Optical Output at -10 ºC
LWC 0.5 mg/m^3
Glazed Ice



Optical Output at -13 ºC
LWC 0.5 mg/m^3
Mixed Phase



Optical Output at -20 ºC
LWC 0.5 mg/m^3
Rime Ice

ON-WINGS

Ice Detection Algorithms

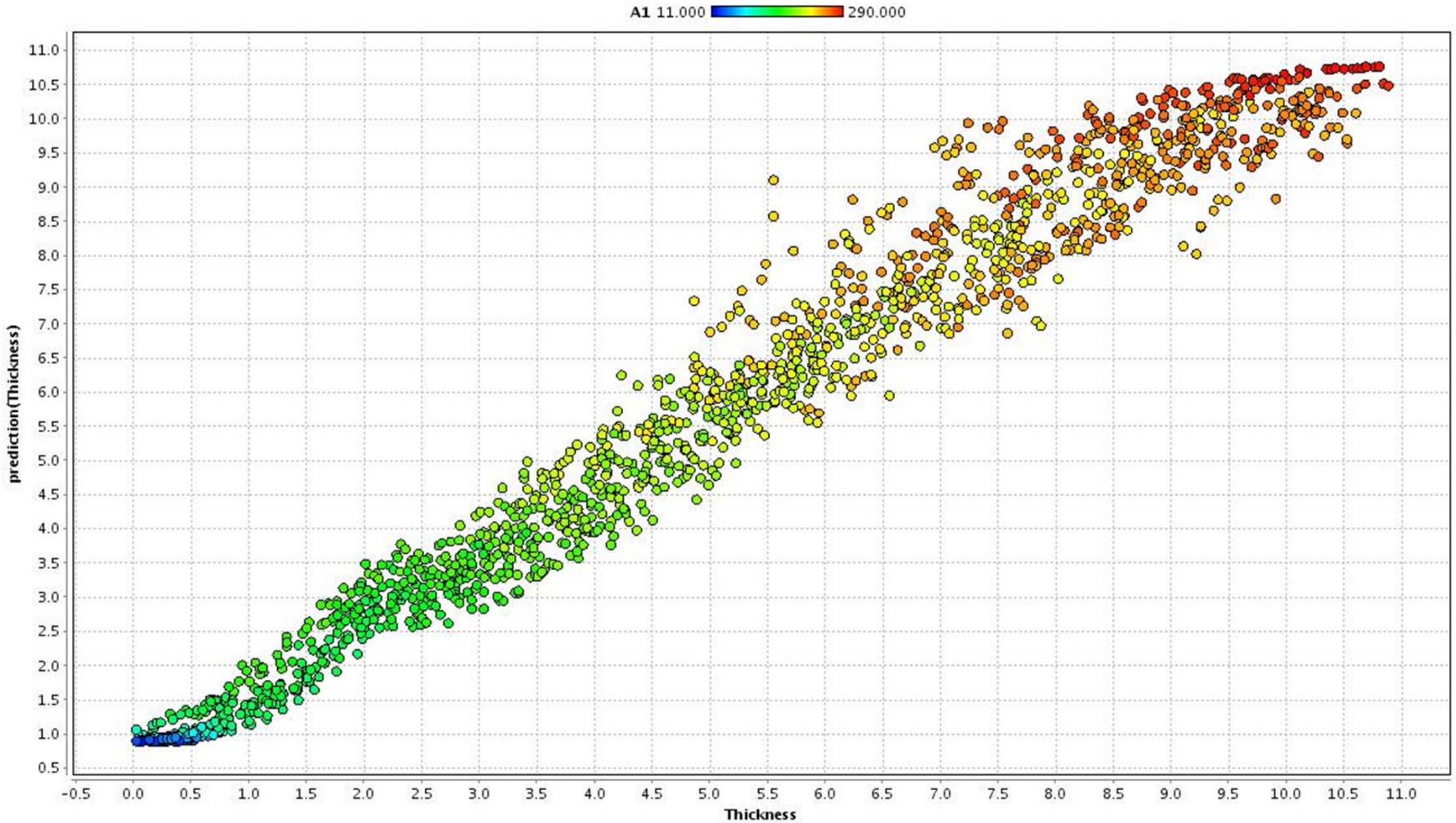
- Ice detection algorithms anticipate thickness and onset of ice from optical sensor data.

- Challenges
  - Reduce measurement noise
  - Investigate data correlations and patterns under specific conditions to determine ice thickness

- Solution
  - Deployment of digital signal processing algorithms
  - Support through artificial neural networks (ANN)
  - Development of a digital model for ice accretion

Algorithmic Ice Thickness Estimation

- Shown below are the processed output for the AOS sensor head trial produced by TWT. Further algorithm development will allow determination of on-set of ice.



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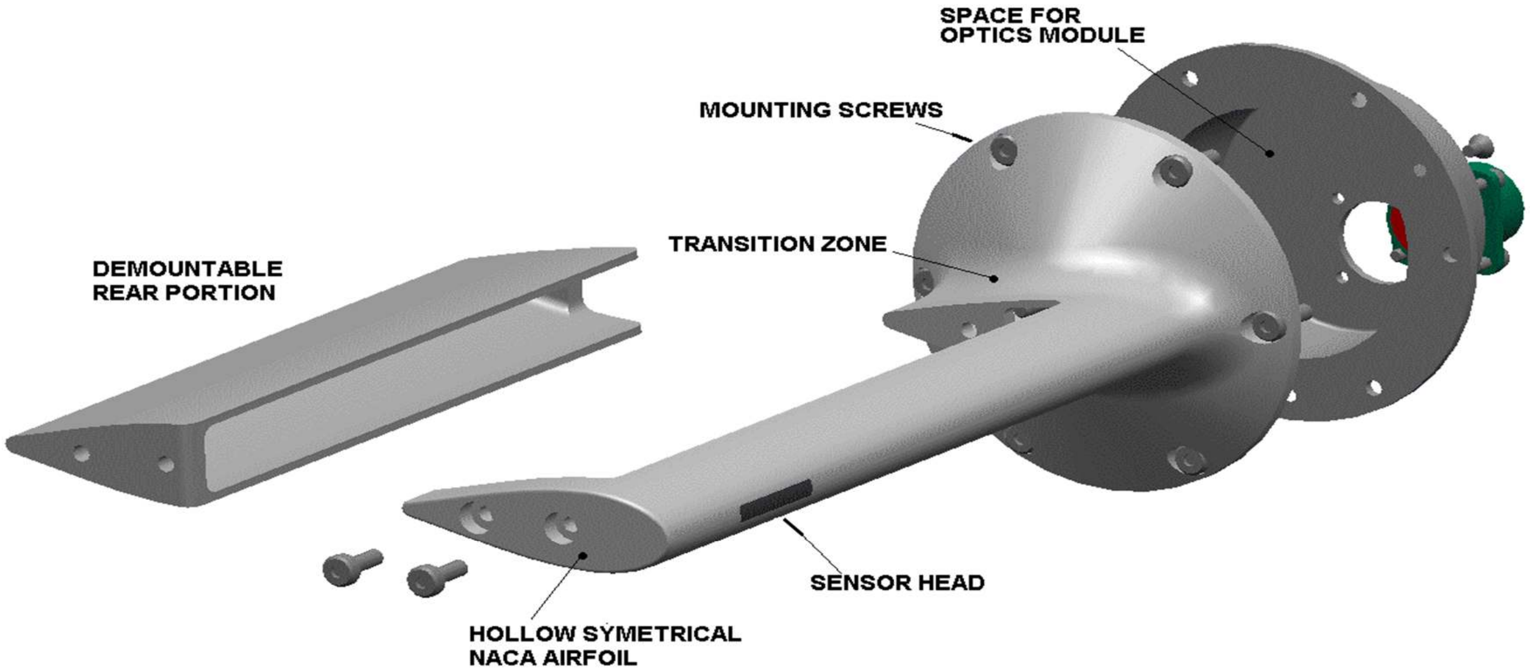
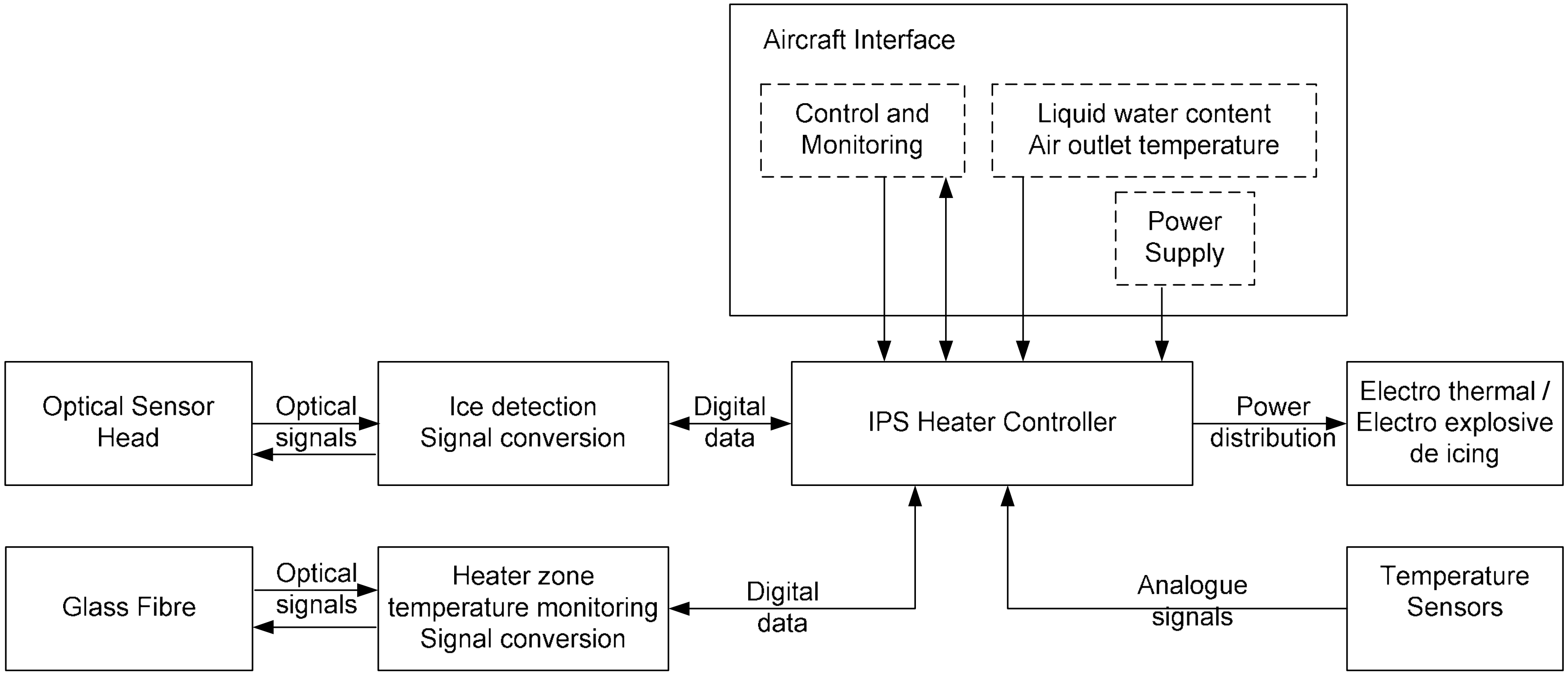
Initial Steps for Flight Trial

- The first test module is being constructed in the form of a traditional fuselage-mounted probe and is shown below.
- Using this configuration allows the same probe to be used in the IWT and flight trial, removing variability from the results.



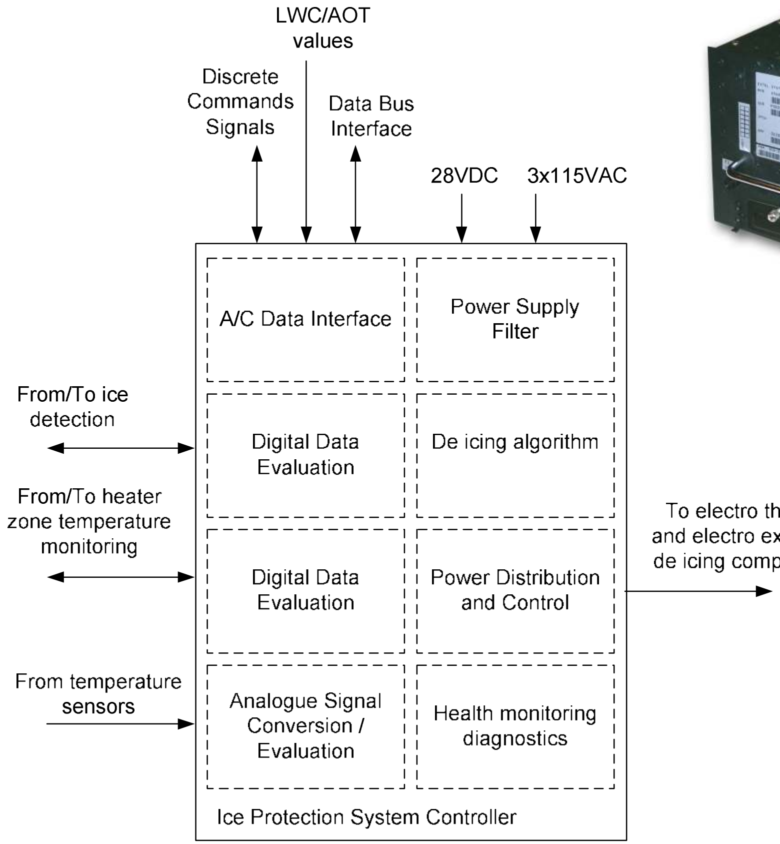
Integration of Control

- These modules form part of the overall ice protection control system and integration of these units into the aircraft control system needs to be considered.



Integration of Control

- Example Ice Protection System Controller as produced by Jenoptik ESW.



Ice Protection System Controller

Control Module Considerations

- Data Acquisition System
  - It is envisaged that this module will be sited within the aircraft EE bay.
  - The number of channels will depend upon the number of monitoring sensors and the sophistication of the ice protection control system.
  - The Optics Control Module with its embedded software is currently sited within the DAS.

Control Module Considerations

- Ice Protection Controller
  - It is envisaged that this module be sited in the aircraft EE bay.
  - Initiation of the electro-thermal anti-icing heaters is by an 'on-set of icing' trigger signal from the sensor and controlled via algorithm and temperature sensor.
    - Ultimately the temperature sensor will be based upon a distributive optical fibre system with multiple FOBG monitoring points.
  - The control of the de-ice heater element (or electro-expulsive system) is via ice-thickness threshold and "out of icing" signals from the sensor.

Conclusion

- The project is mature enough to demonstrate excellent results and has reached the stage where the final prototype configurations need to focus upon a platform demonstrator.