

The background of the slide is a light blue, semi-transparent image showing a dense field of ice crystals. These crystals vary in shape, with many appearing as thin, needle-like or plate-like structures, characteristic of ice formed under certain atmospheric conditions. The overall texture is intricate and fibrous.

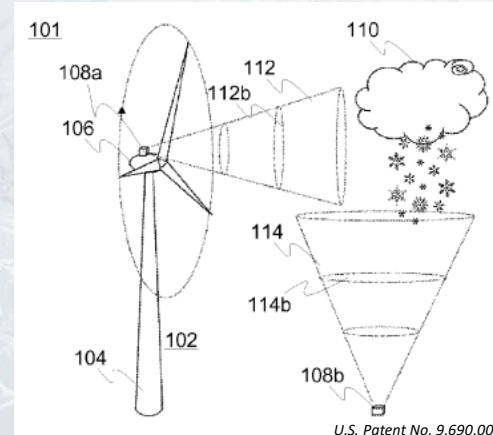
# **A simple low-cost optical ice-sensing surface for instrumental icing assessment**

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# Direct ice sensors

- Measures directly the presence of water particles in the air
- Measures meteorological icing
- Pros : High sensibility, high precision
- Cons : Instrumental icing has to be modelled, few information about ice characteristics



U.S. Patent No. 9,690,008.

[https://windren.se/WW2015/WW2015\\_10\\_802\\_Karlsson\\_VTT\\_Lidar\\_as\\_ice\\_detector.pdf](https://windren.se/WW2015/WW2015_10_802_Karlsson_VTT_Lidar_as_ice_detector.pdf)

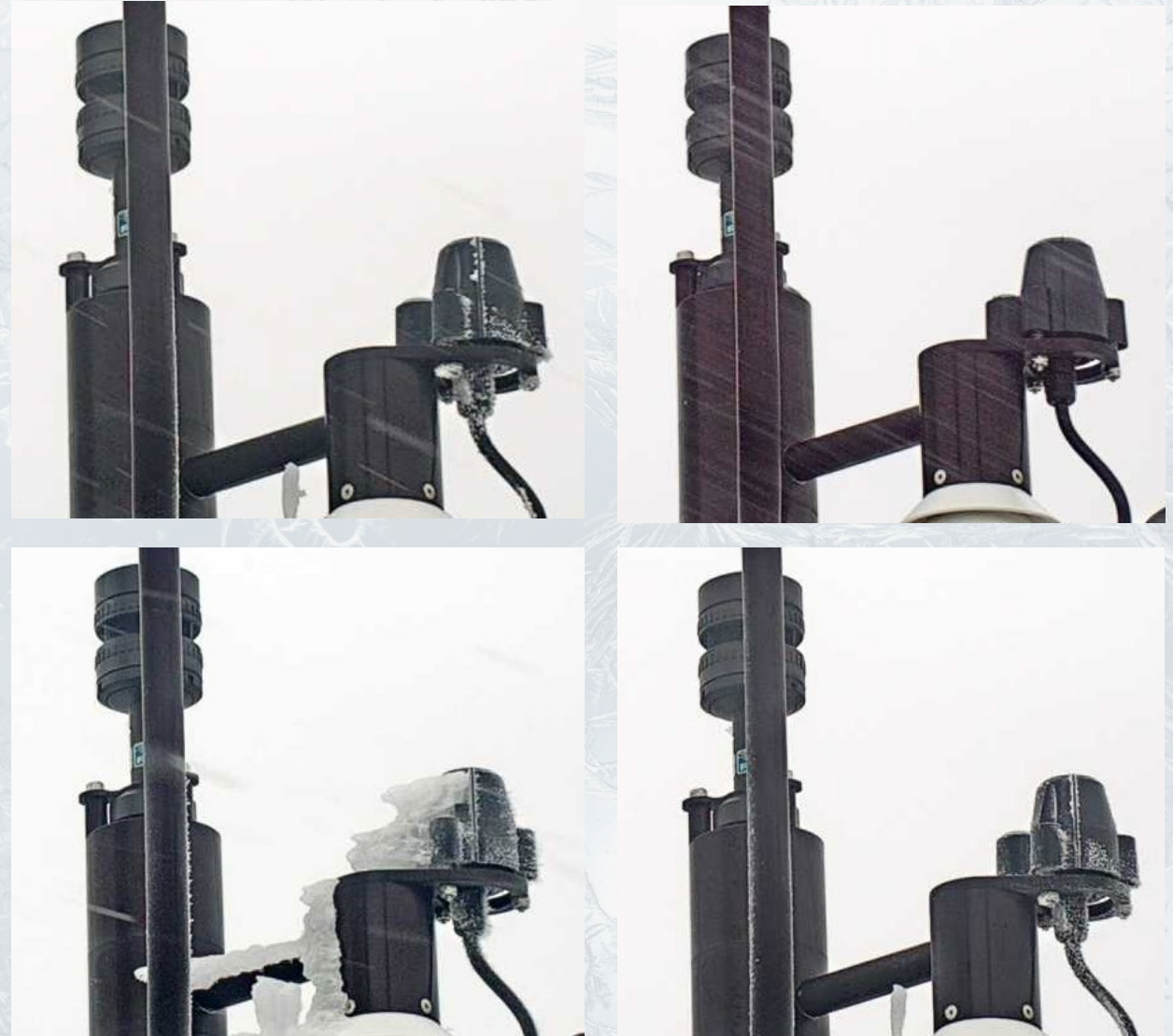


<https://www oulu.fi/icemet/research>



# Direct ice sensors

- Low adhesion wet snow
- Contributes to the heat transfer
- Does not result into large accretions
- Add a surface sensing device to discriminate events





# Indirect ice sensors

- Measures the effect of the ice accretions on structures
- Measures instrumental icing
- Pros : Instrumental icing assessment, accuracy for small accretions
- Cons : lower sensibility, higher latency time, prone to large accretions



[https://www.vgb.org/vgbmultimedia/392\\_Fin  
al+report-p-10476.pdf](https://www.vgb.org/vgbmultimedia/392_Fin<br/>al+report-p-10476.pdf)



[https://www.labkotec.fi/en/products/ice-detection-  
system](https://www.labkotec.fi/en/products/ice-detection-<br/>system)



[https://www.vgb.org/vgbmultimedia/392\\_Fin  
al+report-p-10476.pdf](https://www.vgb.org/vgbmultimedia/392_Fin<br/>al+report-p-10476.pdf)



# Indirect ice sensors

- Combinations of methods
- Add redundancy
- Reduce false alarms
- Increase sensibility





# Description of the technology

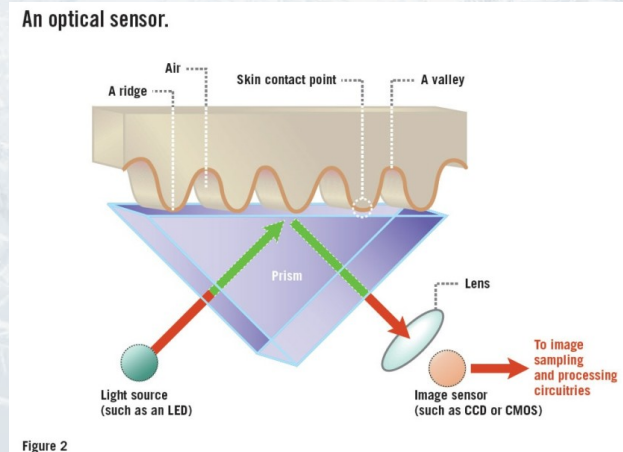
- Optical sensing surface
- Total internal reflection
- Presence of ice on the surface
- Refractive index of ice closer to glass
- Deflection and diffusion of light
- Ambient light compensation



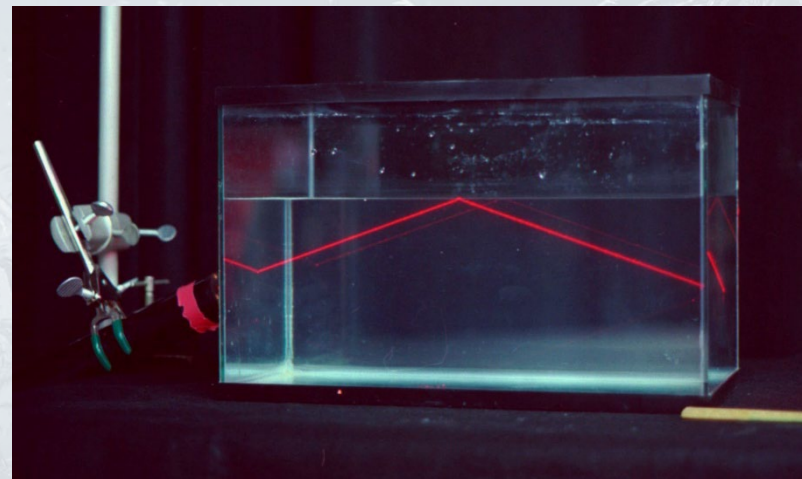


# Advantages

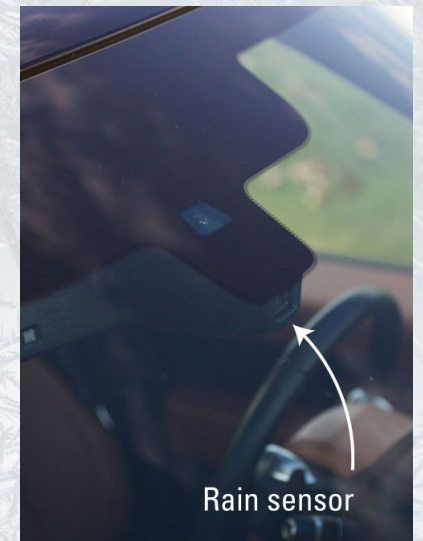
- Low cost
- Well known technology
- Ex: automatic whipers, fingerprint sensors
- Simple hardware
- Versatility, can take almost any form



<https://www.androidauthority.com/how-fingerprint-scanners-work-670934/>



<http://sites.fas.harvard.edu/~scidem/LightOptics/FishTankTIR/FishTankTIR.html>

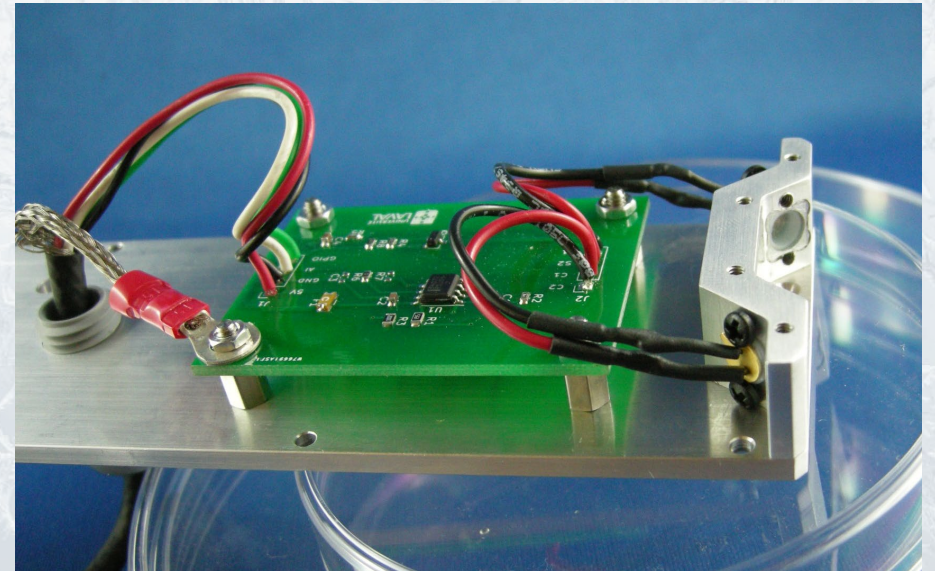


<https://www.safelite.com/windshield-auto-glass-technology/rain-sensors>



# Alpha prototype

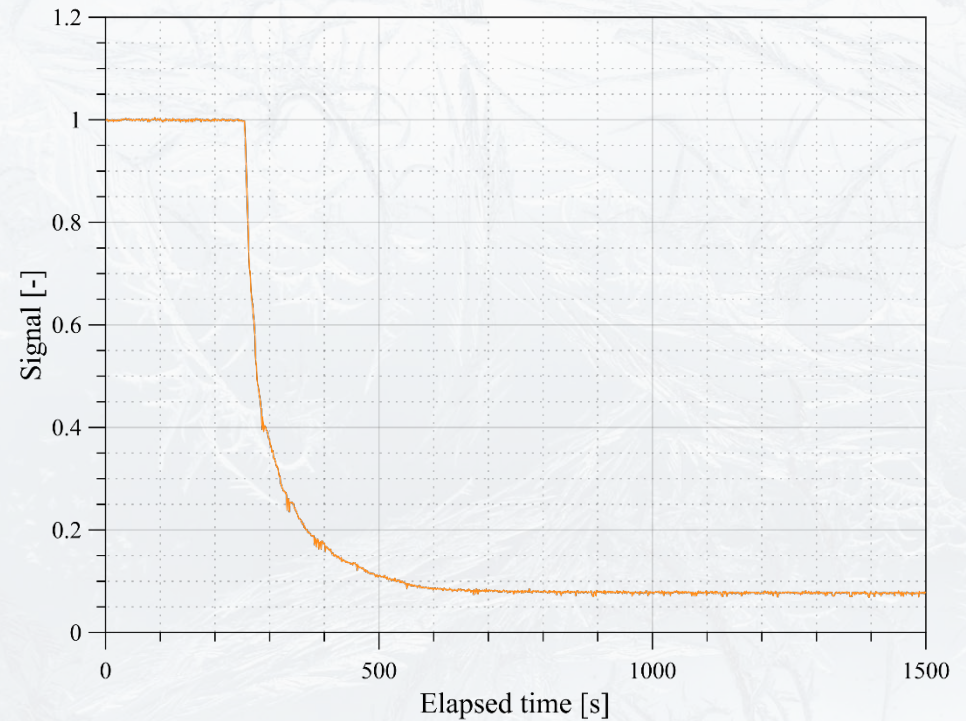
- Mounted on a MCMS
- Large sensing surface
- PDMS waveguide
- Discriminate wet snow





# Wind tunnel measurements

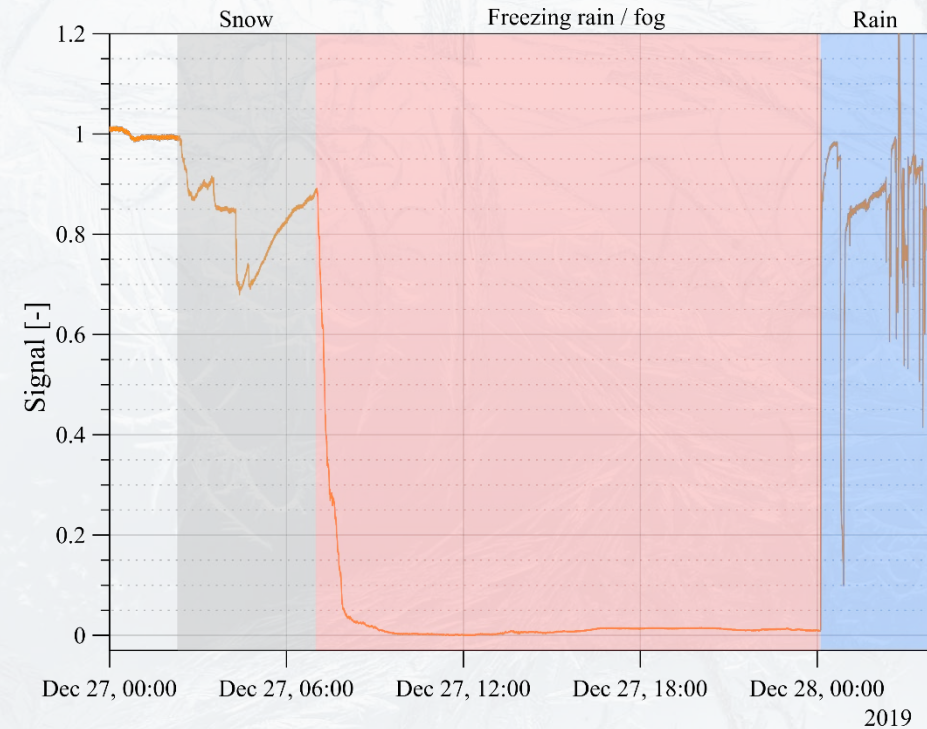
- Air temperature :  $-8^{\circ}\text{C}$
- High constant flow rate
- Rime ice
- Total accretion of 2mm
- Regular response





# Freezing rain measurements

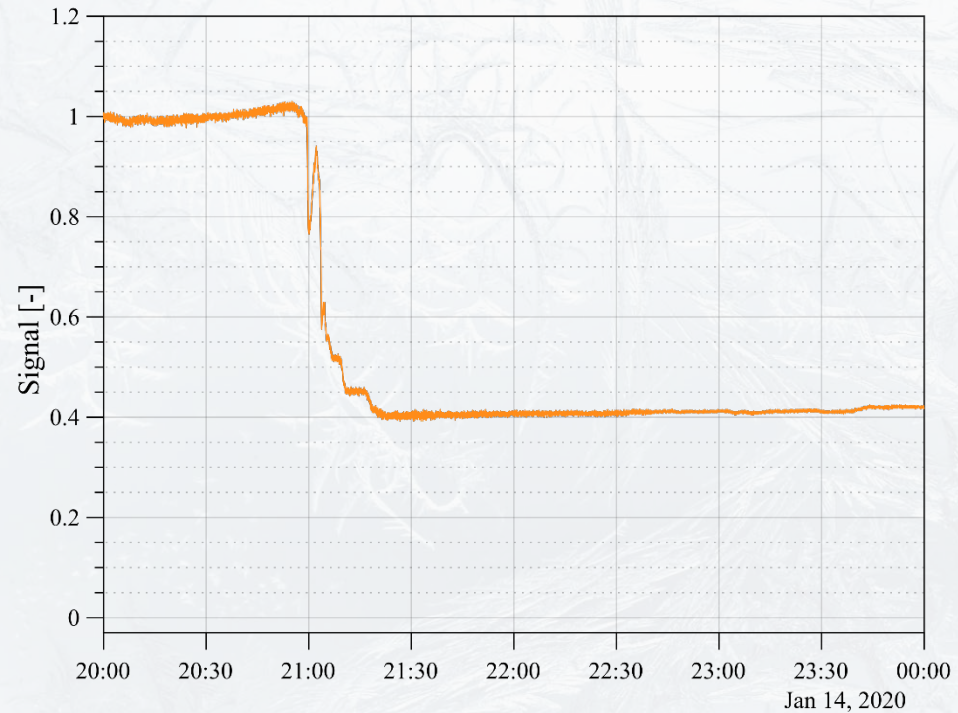
- Installed on a rooftop during a freezing rain event
- Increasing temperature
- Three phases clearly distinguishable





# Rime ice measurements

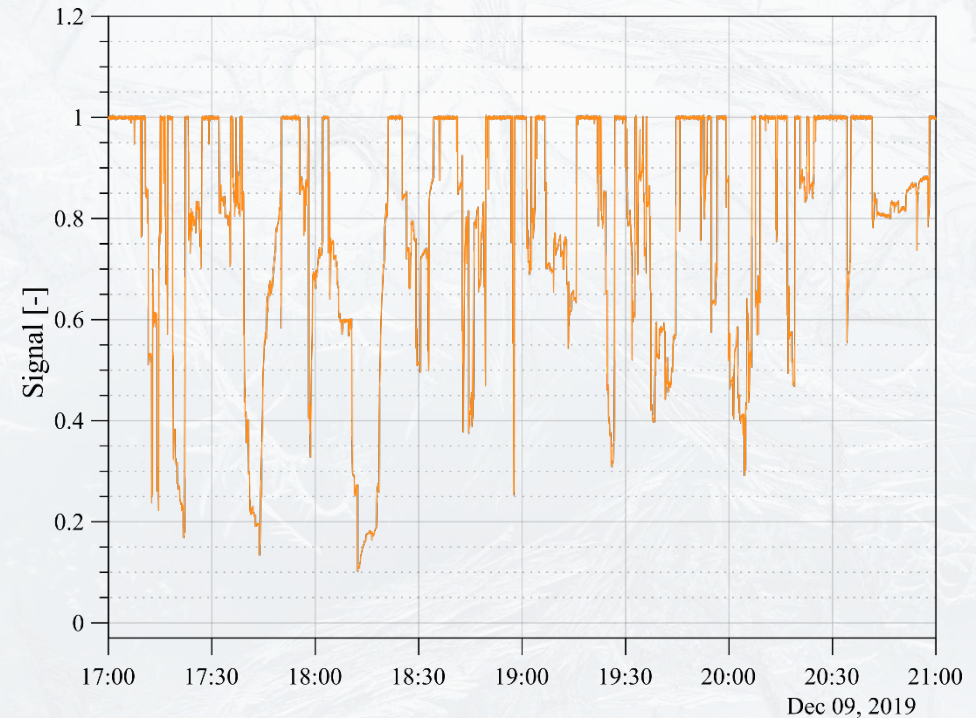
- Installed on a wind turbine
- Rime ice event
- Surface partially covered (low ice density)





# Discrimination of rain

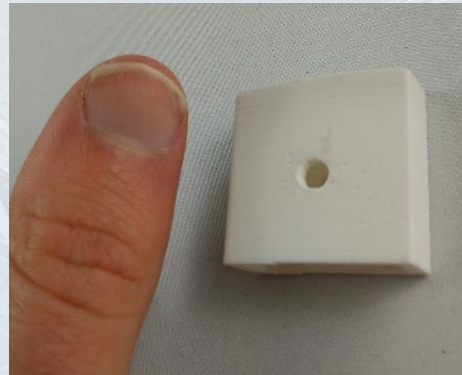
- Even without temperature measurement, rain produces a totally different signal





# Possibilities

- Prototype beta :
  - Way smaller
  - Cheaper
- Blade embedding
- Ice shedding techniques



[https://en.wikipedia.org/wiki/Optical\\_fiber](https://en.wikipedia.org/wiki/Optical_fiber)