

# Sensor fusion for a blade surface-mount icing detector for wind turbines

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# Motivation

- Why **fusion**?
  - Both capacitive and optical icing detectors have shown to work but might have drawbacks.
- Why **blade-mount**?
  - Detect icing where it is relevant.
- Why **measure**, not estimate from weather conditions?
  - Get reliable information e.g. to trigger heating.

# State of the Art

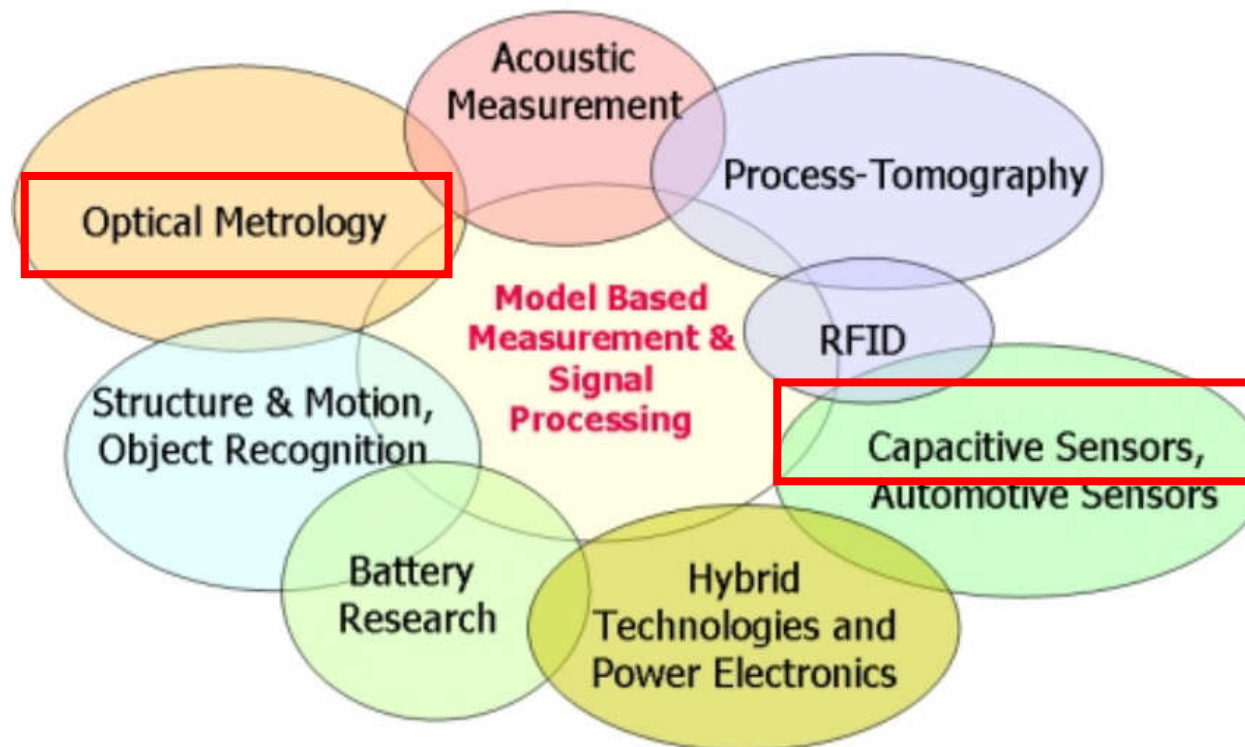
- **Weather monitoring and estimation**
  - Detection of icing e.g. by means of standard ice detectors
- **Ultrasonic and microwave thickness measurement**
  - Deterioration due to pollution is possible, power demand is high
- **Indirect Detection of aerodynamical changes**
  - Loss of power generation is an indicator, detection of vibrations
- **Measurement of rotor blade weight**
  - Averages over entire blade surface

# New Approach

- **Aim #1: „Direct“ measurement**
  - Measurement of icing on multiple points on the rotor blade surface
- **Aim #2: Scalability**
  - In principle, applicable to any surface
- **Aim #3: Low power consumption**
  - In particular: energy harvesting is feasible -> no wires
- **Aim #4: No change in aerodynamics**
  - Mounted e.g. within heating foil / on or under shell coat

# EMT's Key Competences

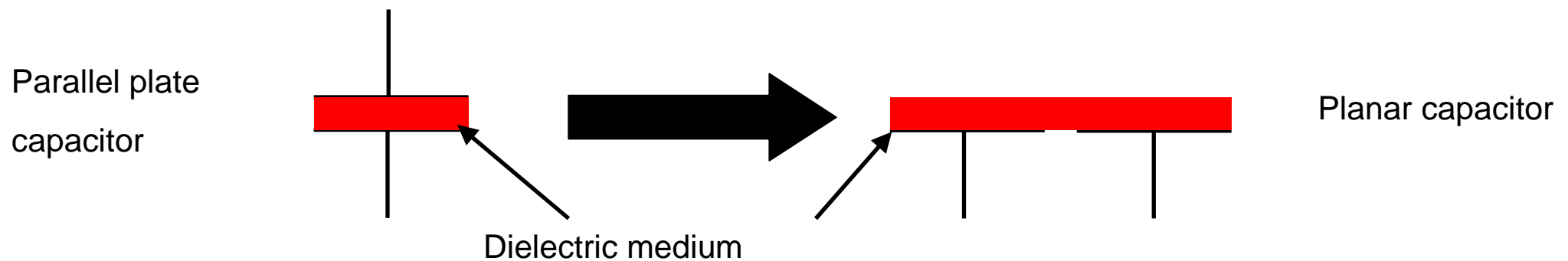
Which measurement principles are suitable?



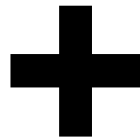
# Capacitive Sensing

Evaluation of the variable capacitance of a measurement capacitor, modification of

- **capacitor's geometry**
- **permittivity of the dielectric medium**



# Capacitive: Pros and Cons

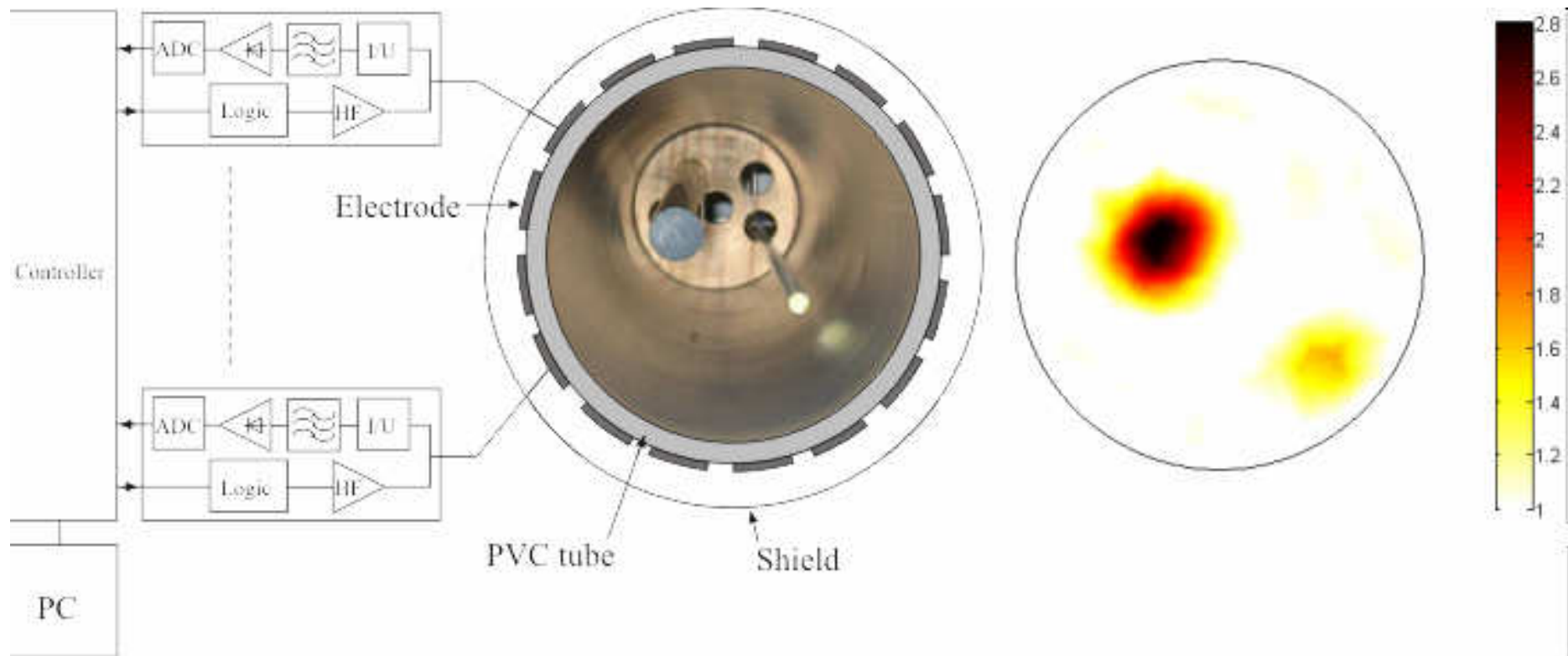


- ✓ High accuracy
- ✓ High resolution
- ✓ Temp. Range  $-40^{\circ}\text{C}$
- ✓ Wireless
- ✓ Low Power
- ✓ Thickness measurement



- x Small signal changes
- x Large offsets
- x Disturbers / EMC
- x Ambiguities
- x Model needed

# Method: Capacitance Tomography (ECT)





# Capacitive Icing Detection on OHTL

Capacitive Icing Sensor for  
OHTL

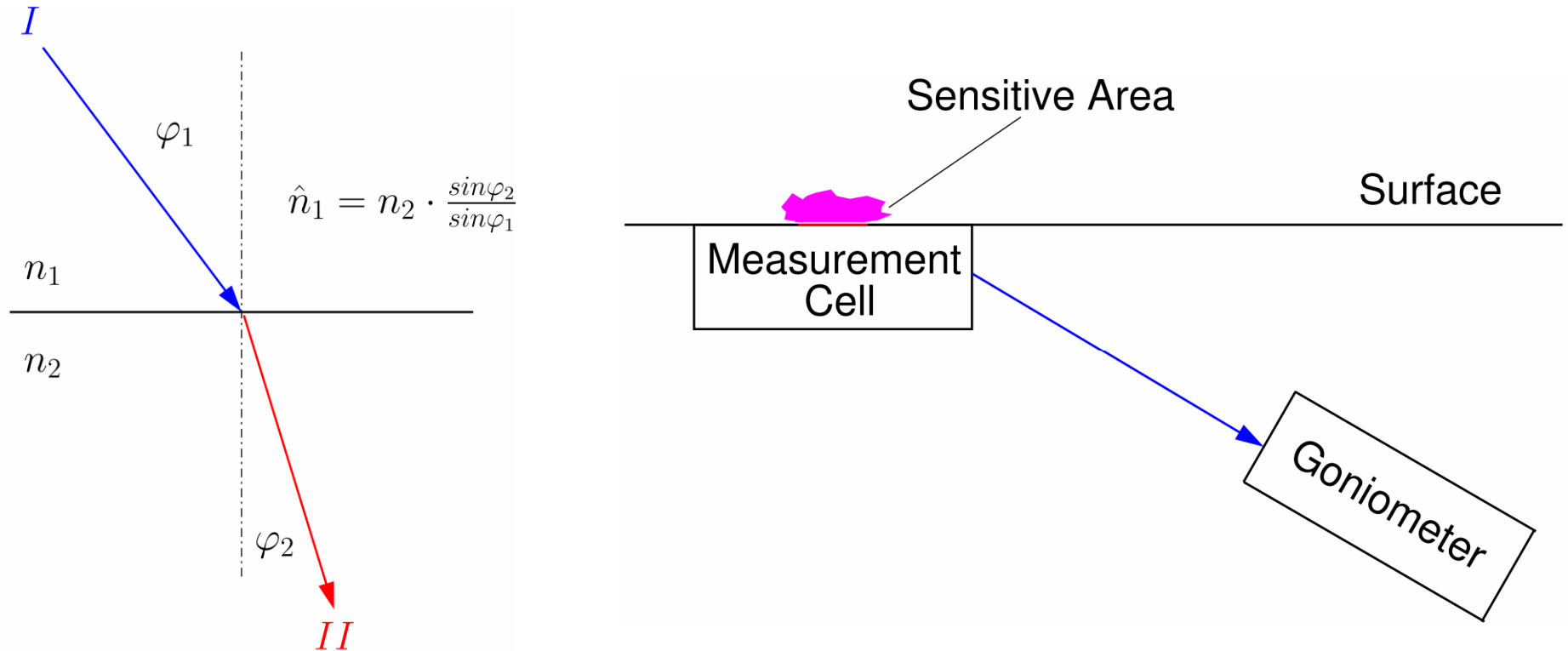
Field Test since 2009-2011

Commercial Product since  
2011

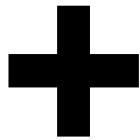


# Optical Icing Detection

- Make use of optical properties of ice, water and air



# Optical Icing Detection: Pros and Cons

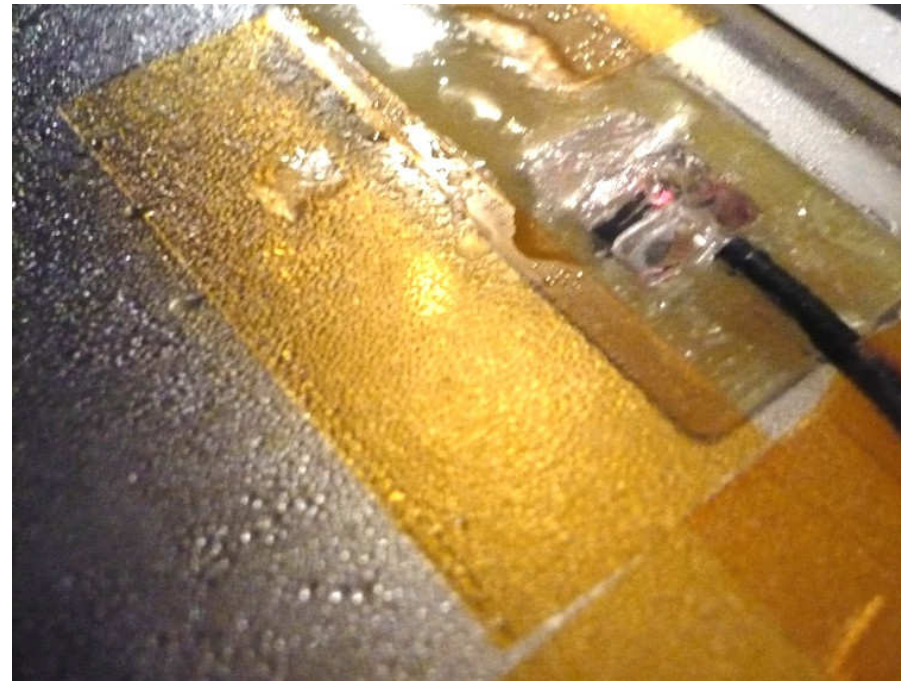


- ✓ High accuracy
- ✓ High resolution
- ✓ Robustness against disturbers
- ✓ Selectivity

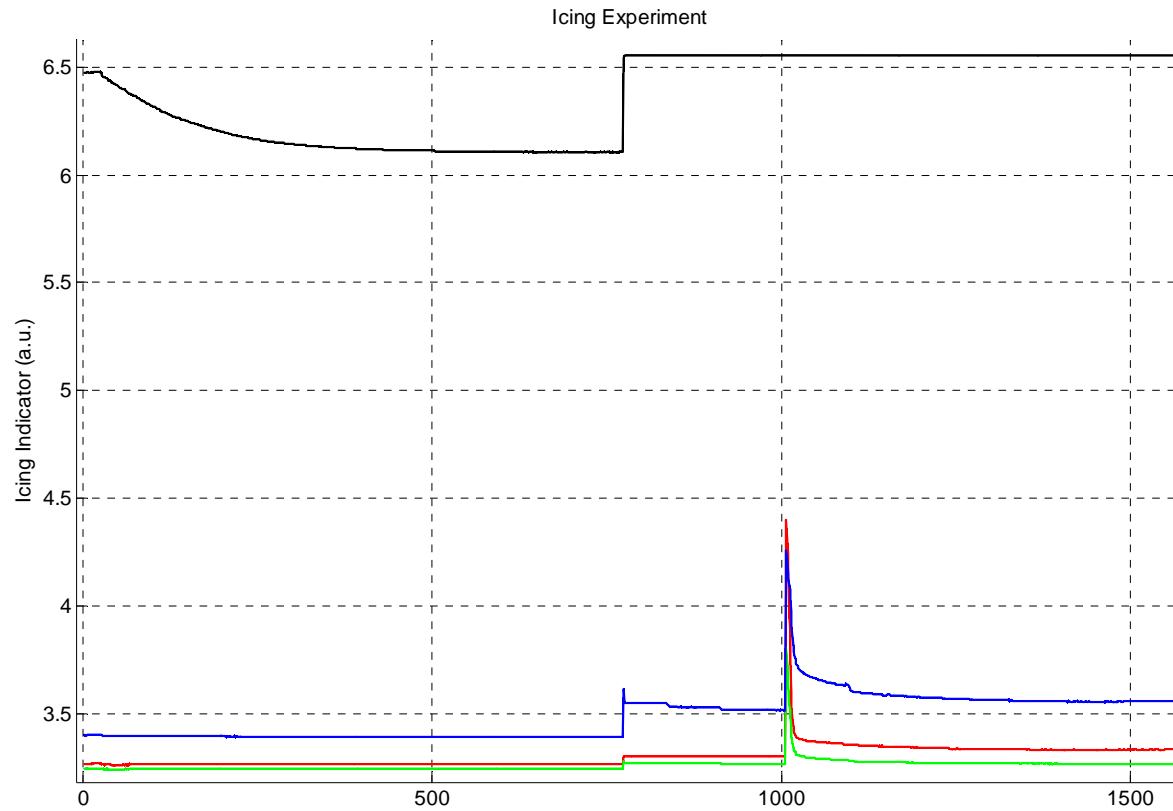


- x more power needed
- x pollution effects
- x lifetime of optical components
- x mechanical issues
- x no thickness measurement

# Lab Measurement Setup



# Icing Experiment Results



# Summary

- A capacitive measurement principle for the detection of rotor blade icing is feasible.
- Capacitance Tomography methods can be applied to estimate ice layer thickness and quality.
- Water (melting ice layers, rain and drying) can be clearly distinguished from any other state.
- Ice layers can be watched while growing, thickness can be determined.
- Sensor Fusion approach: Optical icing detection can eliminate ambiguities in capacitive measurement (improved ice/water discrimination)