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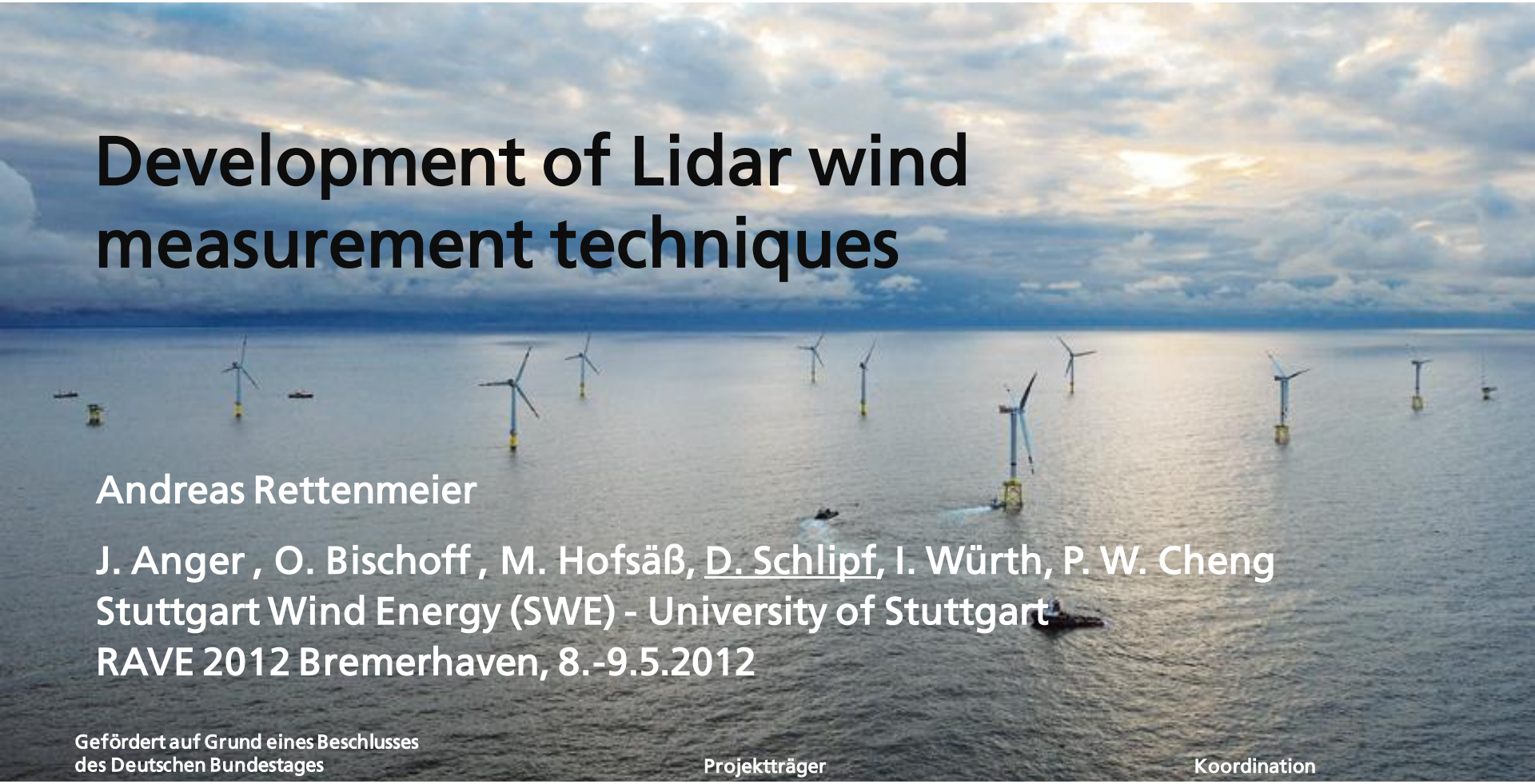

Development of Lidar wind measurement techniques

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Stuttgart Wind Energy (SWE) - University of Stuttgart

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Gefördert auf Grund eines Beschlusses des Deutschen Bundestages

Projektträger

Koordination

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

ptJ Projektträger Jülich Forschungszentrum Jülich

Fraunhofer IWES

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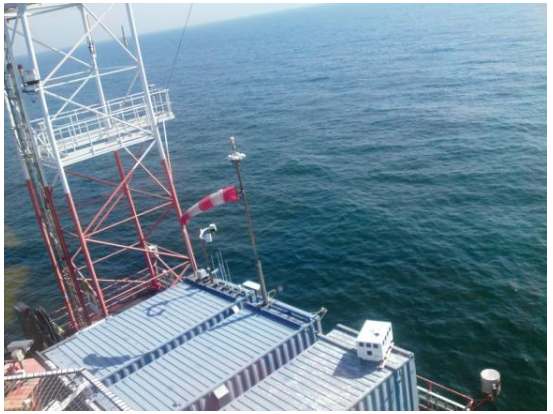
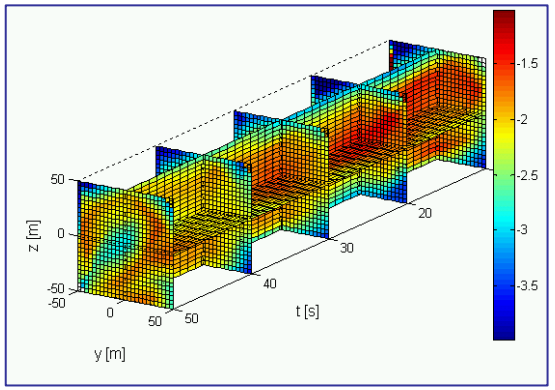




[Fig. SWE, DEWI]

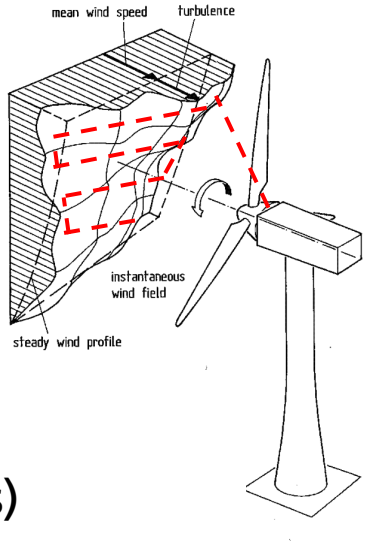
Motivation: Lidar technology
The new quality in wind measurement

Site evaluation & wind potential analyses

- Onshore: „complex terrain“, forest
- Offshore

Turbine development & research

- Higher temporal and spatial resolution of the wind field
- Power curve determination over the swept rotor area
- Loads, wake from other turbines
- Control (fatigue and extreme loads)



[Fig. BMU, Risø-DTU]

The projects and their aims

LIDAR I project (2007-2010)
- onshore -

- Lidar measurements ground- and nacelle-based
- Development of Lidar scanner
- Wake, p-v and control applications

LIDAR II project (2010-2013)
- on-/offshore -

- Lidar assisted control tests for load reduction and energy yield optimization
- Prototype of a robust, nacelle-based Lidar system, test in alpha ventus
- Methods of power performance behaviour of turbines with nacelle-based Lidar

OWEA project (2008-2011)
- offshore -

- 2 scanning Lidar devices offshore
- Nacelle-based Lidar measurements
- Comparison with FINO I data

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Project partners within LIDAR, LIDAR II & OWEA

Research Institutes

- Stuttgart Wind Energy (SWE) - Universität Stuttgart
- ForWind - Carl von Ossietzky Universität
- DLR: Institute of Atmospheric Physics

Measurement Institutes

- DEWI GmbH: German Wind Energy Institute
- Germanischer Lloyd Garrad Hassan

Wind turbine manufacturer

- AREVA Wind GmbH
- REpower Systems SE

Dissemination

- FGW e.V.: German Federation of Windpower

Ground-based Lidar measurements

SWE – Stuttgart Windenergie, Universität Stuttgart

ForWind – Universität Oldenburg

DLR- Deutsches Zentrum für Luft- und Raumfahrttechnik e.V.

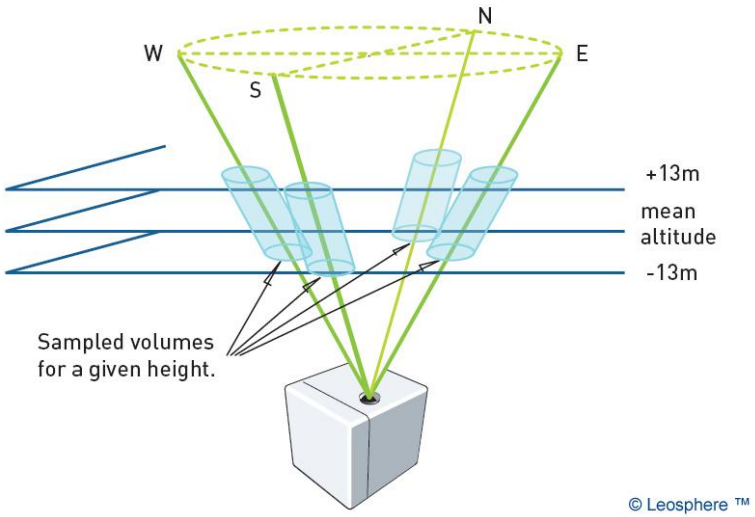
DEWI GmbH

AREVA Wind GmbH

Lidar Systems

Windcube™ system from Leosphere ™

- Range 40m – 220m
- Wavelength: 1,54 µm
- Pulse length: 26m
- Pulse energy: 10µJ



DLR long-range Lidar

- Range 500 m - 10 km
- Wavelength: 2.022 µm
- Pulse length: 75 m
- Pulse energy: 1.5 mJ

[Fig. Leosphere, DLR]

Lidar-Test in Bremerhaven and at FINO 1

AREVA Wind GmbH

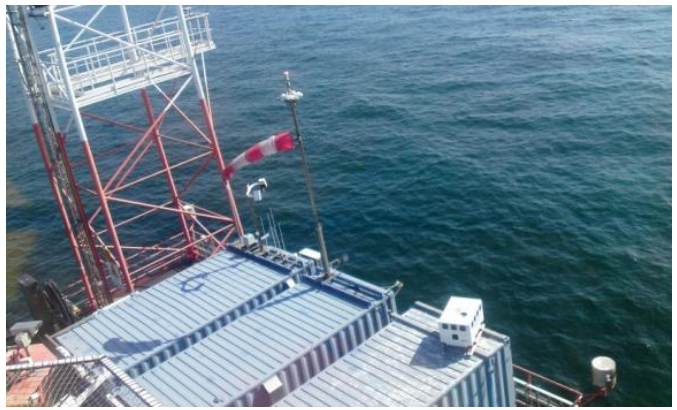
M5000 prototype

- Rated power: 5 MW
- 116 m rotor diameter
- 102 m hub height

Measurement project

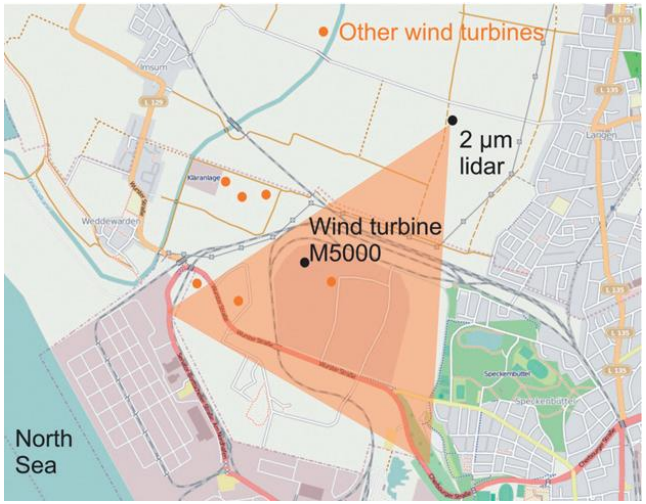
- April 2008 – March 2010
- Power curve and load measurement
- Met mast (102 m height)
- Meteorological sensors
- Data acquisition system
- Lidar device (ground, nacelle)

- **Location**: FINO1 platform
- **Period**: August 2009 - July 2010
- up to 44.190 10-min. data sets
- **Resolution**:
  - 10-min
  - 10 Hz (0.1 s) [FINO1]
  - ~0.83 Hz (1.2 s) [LIDAR]

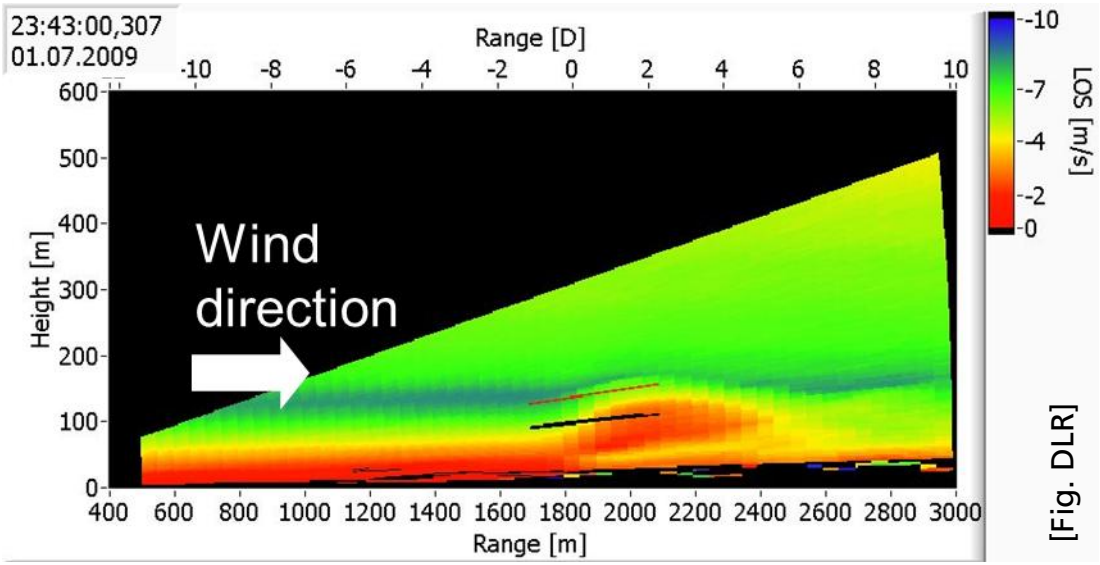


[Fig. SWE, DEWI]

DLR long-range Lidar Measurements



- Results of elevation scans
- 3km measurement range
- Low-Level-Jet determination



Nacelle-based Lidar measurements

SWE – Stuttgart Windenergie, Universität Stuttgart

ForWind – Universität Oldenburg

DEWI GmbH

Germanischer Lloyd – Garrad Hassan

AREVA Wind GmbH

REpower Systems SE

Motivation

Reasons for developing nacelle-based Lidar measurement techniques

- Increasing hub heights and rotor diameter of wind turbines
- Cost expansive certification procedures
- For on- and offshore purposes

Nacelle-based Lidar wind field measurements taking into account

- Whole swept rotor disc
- Wind direction (slow variation) → yaw correction
- Horizontal wind shear, vertical wind shear (fast variation)
- More free valid measurement areas (acc. IEC 61400-12-1)
  → Less sectors to exclude
  → Faster measurement campaigns (on- and offshore)

➔ **Measuring the incoming wind for**

- Wind turbine certification
  - Power performance testing
  - Load validation
- Predictive control strategies

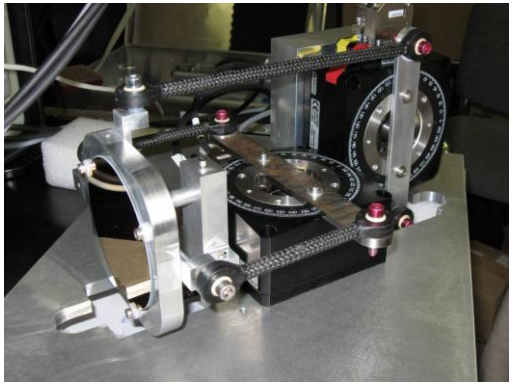
➔ **Measuring the turbines wake wind for**

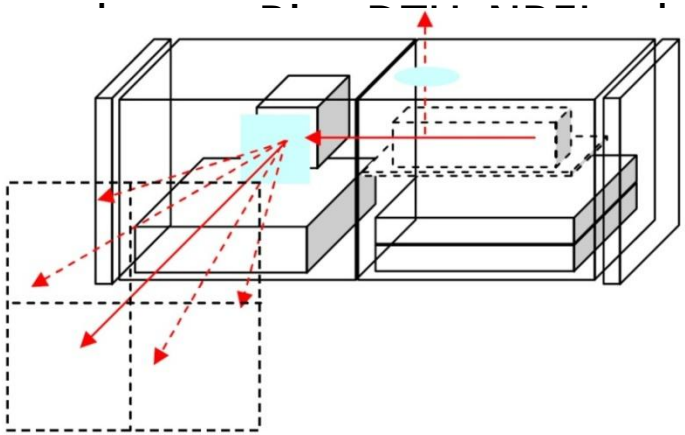
- Validation of wake models

[Fig. SWE]

Development of a Lidar Scanner

- Scanner and control software developed by SWE (within LIDAR project)
- Designed for nacelle-based applications
- Adapted to Windcube by AventLidar Technology
- Allows steering the laser beam in any direction
- Proof-of- concept demonstrated in various measurement campaigns on- and offshore (Br ha-ve

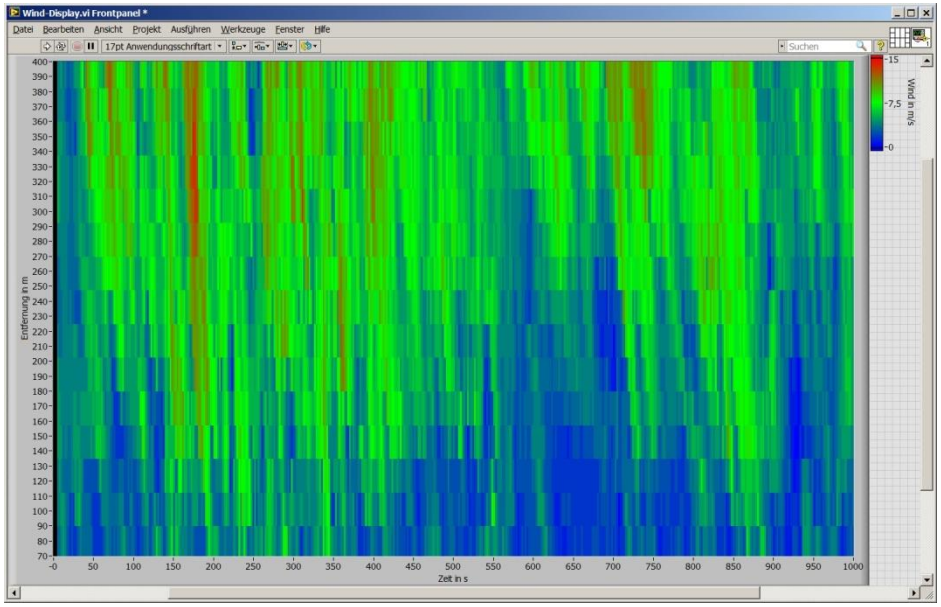


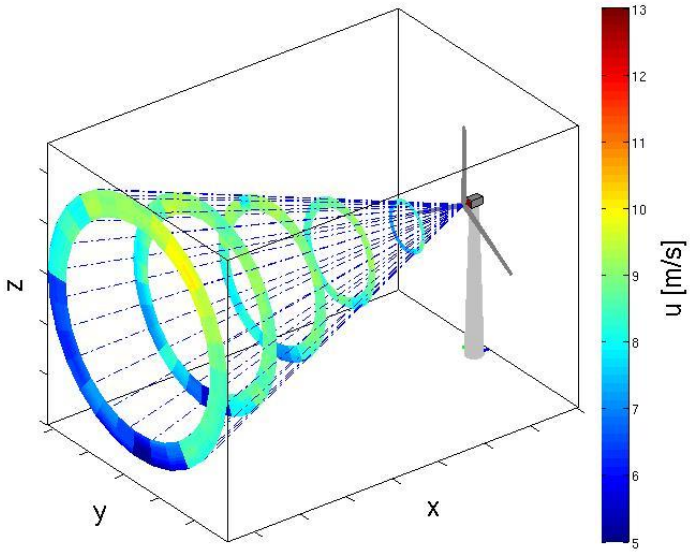


[Fig. Leosphere, SWE]

Development of a robust Lidar

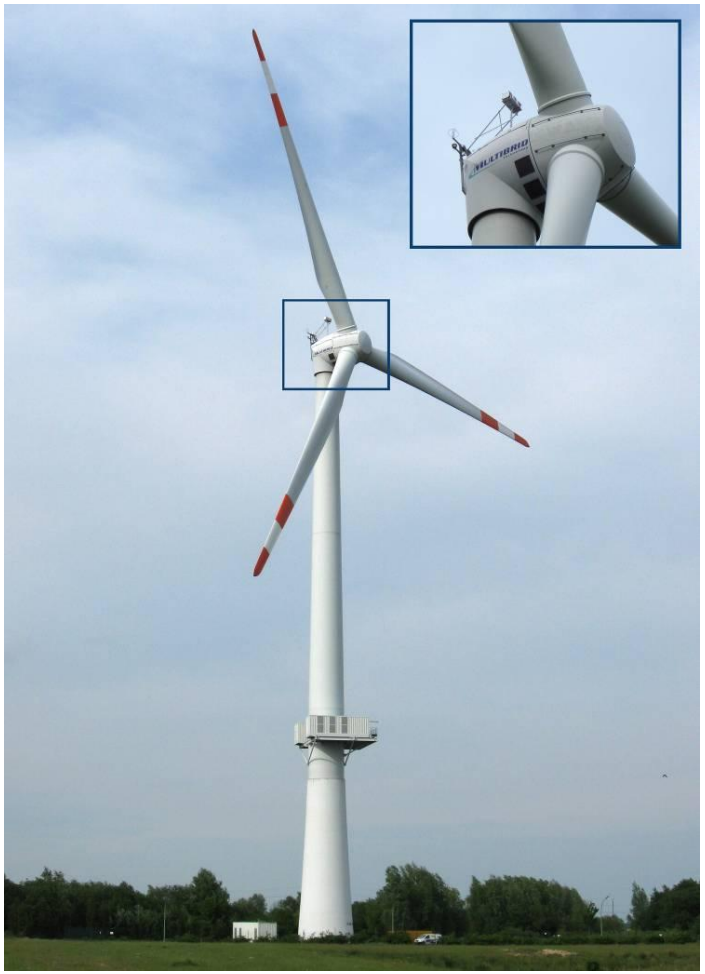
- Under development, by Forwind-Oldenburg (within LIDAR II project)
- Designed for nacelle-based applications
- Proof-of- concept demonstration onshore and offshore at alpha ventus (planned)



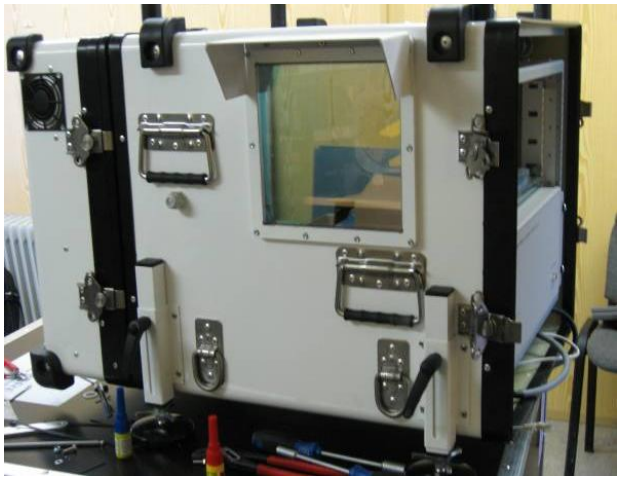


[Fig. Forwind-OL]

Experiment setup - Bremerhaven



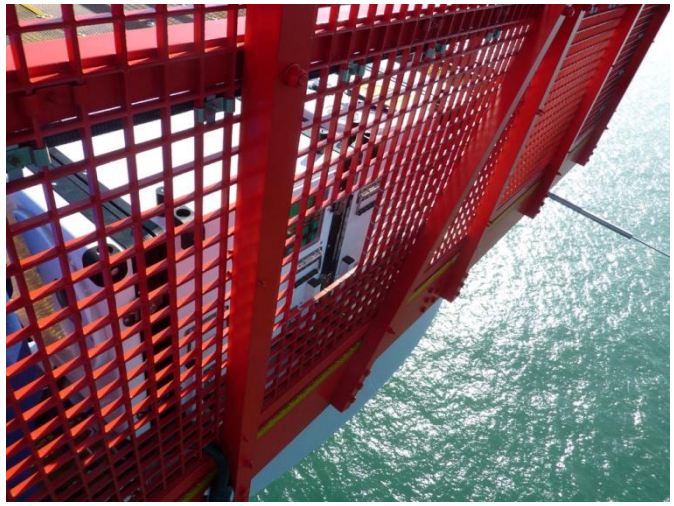
LIDAR system installed on the nacelle (May 2009-March 2010)



Lidar scanner

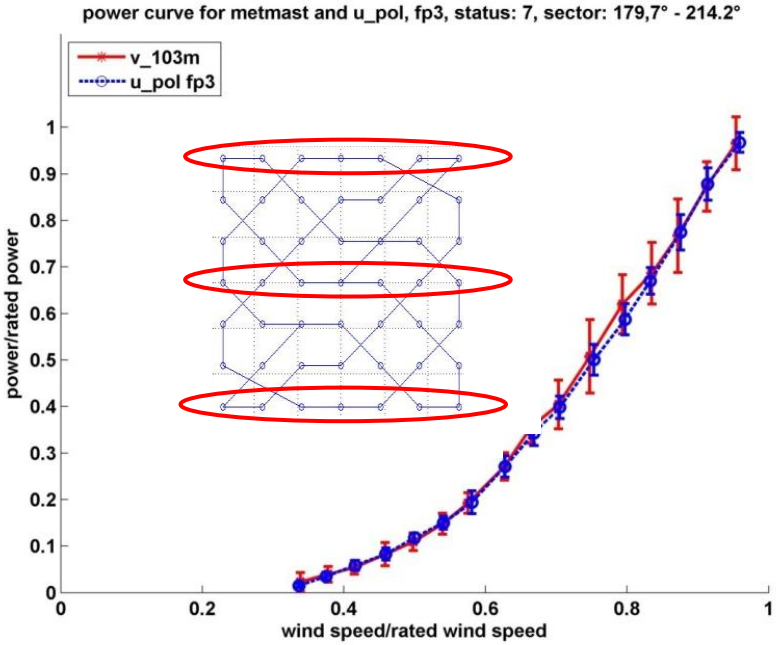
[Fig. SWE]

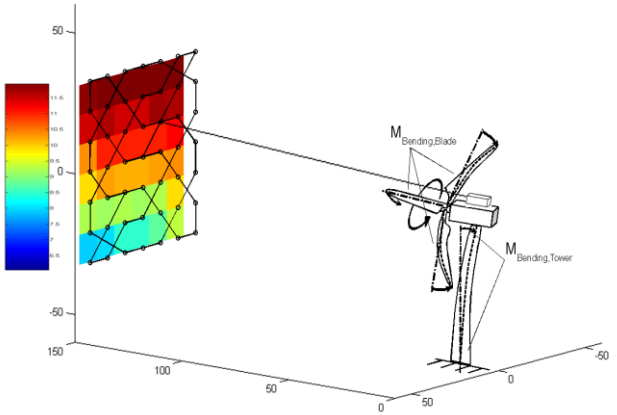
REpower 5M & AREVA Wind M5000 – inflow and wake

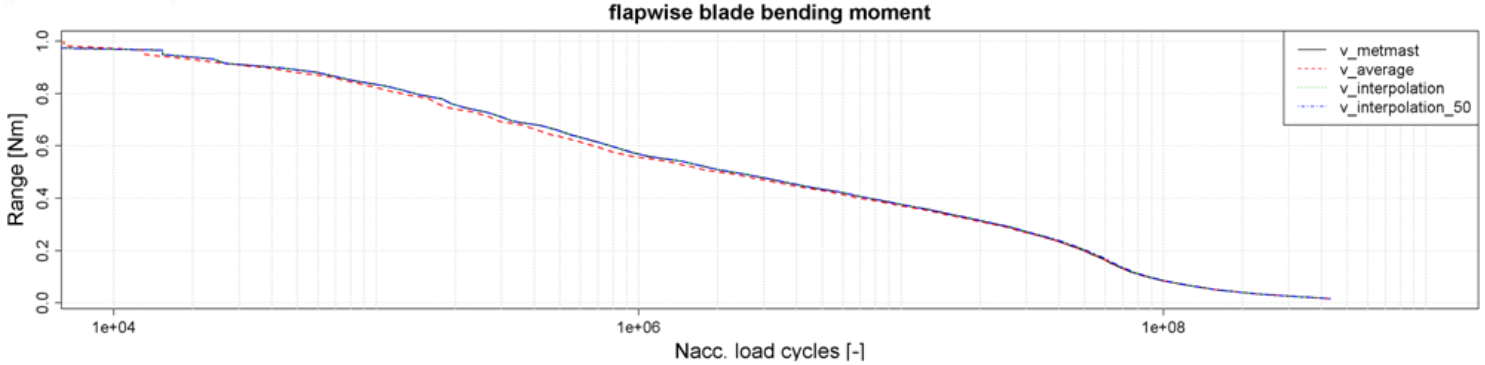


[Fig. ÊDWI, GH-GL]

Power curve determination and Statistical Load Estimation







[Fig. SWE]

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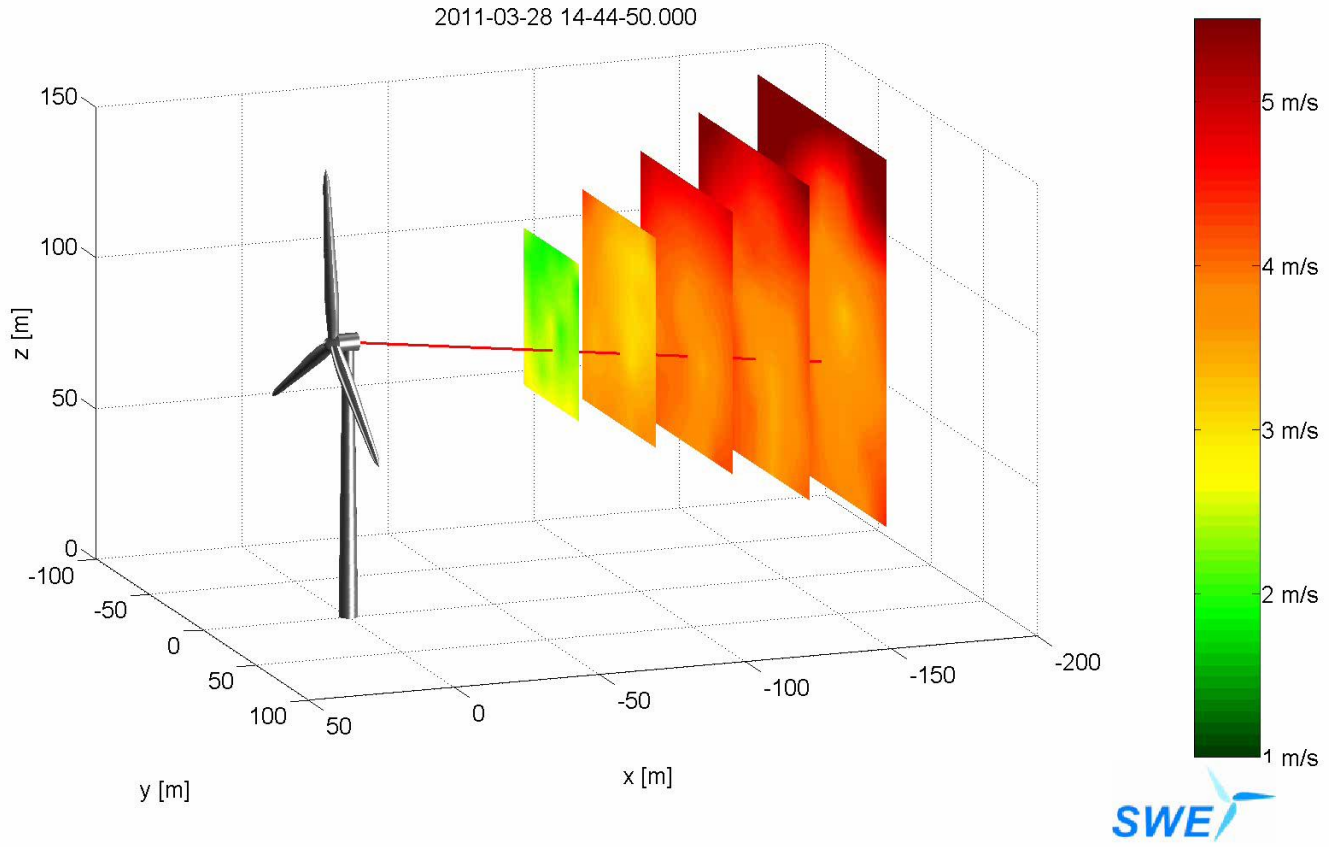
Results of nacelle-based near wake measurements (AREVA M5000, AV7, alpha ventus)



[SWE]

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Conclusions & Outlook

- Development of a scanning Lidar system
- Development of wind turbine applications using a Lidar for
  - power curve determination (ground- and nacelle-based)
  - wind turbine control (predictive control strategies)
  - wake wind field analysis (wake modelling and measurement)
- Offshore test of Lidar device on FINO 1
- Lidar measurements on two offshore wind turbines in “alpha ventus”,

- Further development and test of robust Lidar device
- Proof-of-concept of predictive control

Thank you for your attention!

Feel invited for further presentations on Lidar technology

Session 5: Wind turbine control and wind farm flow

5.1 **Lidar-assisted wind turbine control**
Project: RAVE - LIDAR, RAVE - LIDAR II
D. Schlipf et al., Stuttgart Wind Energy (SWE), University of Stuttgart

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5.5 **Analysis of wake-induced wind turbine loads**
Project: RAVE - OWEA
J.J. Trujillo, B. Kuhnle, H. Beck, ForWind - University of Oldenburg

Session 6: Site conditions

6.4 **Statistics of extreme wind events and power curve monitoring**
Project: RAVE - LIDAR, RAVE - OWEA
Dr. M. Wächter, ForWind - University of Oldenburg