It has been six years since the first issue of Windtech International, which featured the public release of a revolutionary and groundbreaking new technology – lidar. Today, we look back over those six years to see how the technology has fared and what the future holds. Remote sensing methods for measuring wind characteristics, such as lidar, are fast becoming widely adopted across the wind industry. By obtaining accurate wind profiles for wind resource assessment across a wider range of measurement heights than masts, such methods offer a potential for reducing both total project costs and data uncertainty risks.

By Ian Locker, Managing Director, ZephIR, and Alex Woodward, Product Development Manager, Natural Power

Introducing the New ZephIR 300

See the Wind, Measure the Power

In 2005 ZephIR, the first wind lidar system for the wind industry, became commercially available founded on decades of lidar expertise within QinetiQ, a UK research and development laboratory. Working with Risø DTU, Denmark's National Research Centre, the product was launched and stands today as one of the leading lidar devices with over six years of field experience and more than 450 system deployments ranging from -38°C Canadian winters through to +44°C African summers. ZephIR users range from developers, banks' engineers and consultancies, through to turbine manufacturers, research institutes and utilities.

ZephIR now resides within the leading renewable energy consultancy, Natural Power, where an experienced global wind engineering team has steered the technology and application of lidar to the next level. This next evolutionary step, ZephIR 300, represents a validated, traceable and affordable continuous wave (CW) lidar system, calibrated to an industry approved standard developed with GL Garrad Hassan, at the world's first dedicated lidar test site.

Figure 1. ZephIR 300 deployed in a complex flow environment, using Natural Power's dynamics™ for data conversion

The proven core technology, which remains essentially unmodified from the established ZephIR '175' systems, has been rigorously tested via IEC equivalent power performance measurements, extensive onshore/offshore campaigns and tall mast verifications up to 193 metres. By employing this same proven core system technology the fundamental proof of concept and validation work carried out over the past six years remains valid and applicable to the repackaged and refined ZephIR 300.

Introduction

The principle by which lidar measures velocity was described in earlier articles: 'Wind speed at light speed: laser radar', D Smith, Windtech International, November 2004, and 'Wind resource measurement by laser anemometry', M Harris, Windtech International, July 2007. An infrared beam of coherent radiation illuminates natural aerosols (particles of dust, pollen, droplets, etc.) in the atmosphere, and a small fraction of the light is backscattered into a receiver. Motion of the target particles along the beam direction leads to a change in the light's frequency through the Doppler effect. This frequency shift is accurately measured by mixing the return signal with a portion of the original beam, and sensing the resulting beats at the different frequency on a photo-detector.

Since a single lidar measurement only provides the component of wind speed along the beam direction, it is necessary for the direction of the beam to be altered in a scanning pattern in order to generate a measurement of the wind speed vector. ZephIR uses a conical scan pattern; as the beam moves, it intercepts the wind at different angles, thereby building up a series of measurements around a disc of air from which the wind speed vector can be derived.

Types of lidar

Not all lidars are the same. ZephIR 300 incorporates a very simple, rugged and reliable optical design, the basis of which is a CW fibre-based lidar. Following the many years of development within QinetiQ both CW and 'pulsed' lidar were considered and indeed used in a variety of applications. However, for the specific needs of the wind industry, CW lidar was adopted providing very clear benefits:

- **Sensitivity**: ZephIR's sensitivity remains constant at all heights ensuring high data availability in all conditions. The emitted laser beam is focused at each user-con figured height – the laser power does not change at each height or with range and so the sensitivity does not degrade. This sensitivity ensures ZephIR 300 has extremely high data availability at greater heights. We always considered that in developing a wind measuring system it would be a significant compromise to data integrity were there to be varying availability of data across the heights of interest. Wind engineers need to measure full and reliable shear profiles. Should the availa bility vary with heights, it essentially reduces the worth of the system to that of the 'weakest' measurement height.
- **Sample rate**: ZephIR 300 measures 50 data points every second across a full 360-degree scan providing the high sample rate advantageous in complex and fast changing air flows. This high sample rate has allowed us to use Natural Power's dynamics™ – a complex flow calibration tool – to give greater confidence in complex flow sites. dynamics™ is an online tool that first quantifies a site in terms of complexity and then provides a conversion factor to apply to the ZephIR data should there be a need to simulate what a single point cup anemometer would see at the measurement location. This can still be desirable, even though it has been demonstrated that by moving a fixed mast mounted cup anemometer in complex terrain by just a few tens of metres, signifi cant percentage points of difference can be seen in the measured wind speeds.
- **Accurate measurements at the heights that count**: ZephIR 300 has been tailored to provide highly accurate measurements across the entire rotor diameter and beyond – from 200 metres down to just 10 metres from ground level.

Figure 2. Two ZephIR reference systems providing side-by-side correlations and ZephIR 300 prototype during the 18-month development and validation period

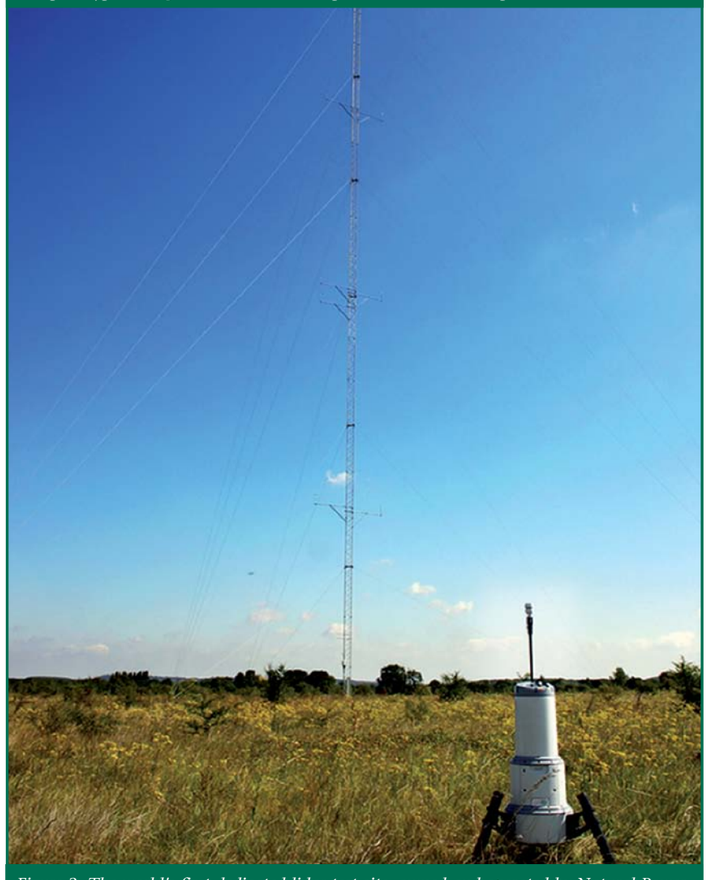

Figure 3. The world's first dedicated lidar test site, owned and operated by Natural Power

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Timeline

March 2003:	Turbine-mounted system (Nordex) for proof of principle
January 2004:	Ground-based prototype delivered to Risø DTU
September 2004:	Development of ZephIR begins
April 2005:	First production ZephIR available
March 2006:	Initial ten ZephIRs delivered worldwide
March 2007:	ZephIR joins Natural Power to increase industry acceptance
March 2008:	Production plant established delivering over 100 units
August 2008:	SeaZephIR demonstrator deployed for floating lidar proof of concept
Early 2009:	Calibration process defined with GL Garrad Hassan for all units
September 2009:	World first lidar measurements from a turbine spinner with Risø DTU with ControlZephIR
April 2009:	ZephIR 300 development begins
January 2010:	First commercial sales agreed for SeaZephIR
August 2010:	UK lidar and sodar test site established for independent ZephIR validations with GL Garrad Hassan
November 2010:	ZephIR 300 launched

Work has also been undertaken to demonstrate an extended 300-metre range and is part of an ongoing development programme. At lower heights, where wind shear typically changes more rapidly, ZephIR 300's optical design ensures that at these crucial heights, probe length (effective sample length) can be as small as just 7 cm.

benefited from customer exposure during more than 450 system deployments. From our unique position in the industry, offering rental systems and our managed data service – vuWind™ – we work with a range of ZephIR users understanding more closely their need for quality wind data. This, in addition to both a wind industry focus group consulted in early 2009 and Natural Power's own back groups concerned the 'usability' of remote devices and in addition how to ensure both traceability and repeatability of data.

The fundamental optics in ZephIR 300 have not been modified in the system since 2009 (to improve low wind speed resolution and increase the uppermost measurement height achievable). The reasons the core technology was selected all those years ago are as valid today as they were then. Clients did not want to start the clock ticking again for product acceptance and maturity; however, they do want to achieve greater usability and performance. Performance of ZephIR 300 is significantly improved, but, in addition, users will see great steps forward in functionality, communications, autonomy, service interval, temperature range of operation, power consumption, weight and also the support services offered by Natural Power. Our aim is to be a one-stop shop for gathering and analysing wind data, thus providing expert advice based on proven experience.

An 18-month development and validation programme within Natural Power has driven ZephIR 300 to be of single pod construction capable of operating from -40°C through to +50°C. It also has robust high-specification connections, and is small in size, low in power (69W), and fully CE compliant including approved 'true' Class 1 eye-safe laser classification (IEC 60825-1) and EMC compliance (EN61236 Industrial and EN55022 Class A standards). The system is provided with an 18-month warranty as standard and a worldwide network of service engineers are established to continue our close working relationship with clients. ZephIR 300 is easy to use, while also rugged to ensure its longevity in the field.

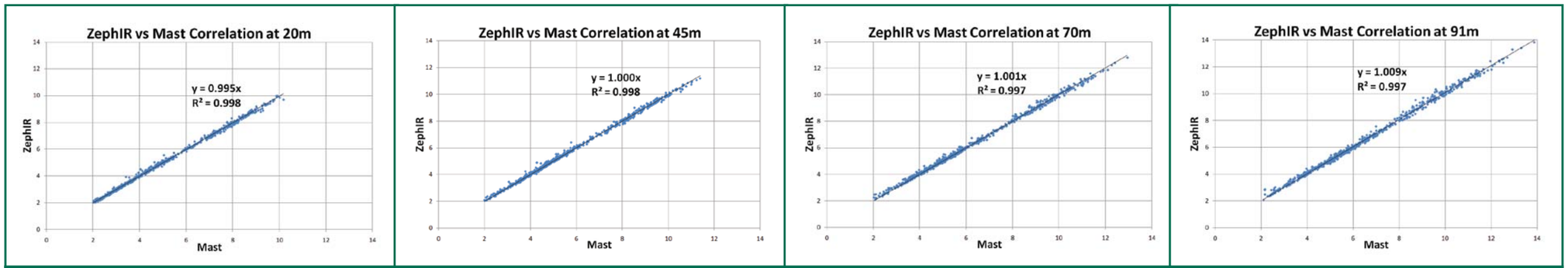

Figure 4. Correlation of 10-minute averaged horizontal wind speeds (m/s) at Natural Power's lidar test site

Listening to the Industry

It has certainly been a challenge to pioneer a change in behaviour across an industry that uses established traditional measurement techniques, but through this process we have well-established wind engineering team, has guided the development direction of ZephIR 300 to its recent release at the renewableUK 2010 conference in Glasgow, Scotland. The main input from the various feed-

Industry Accepted Validation

Banks' Engineer GL Garrad Hassan has worked with Natural Power in defining the principles of our validation process for all new systems providing the necessary traceability – a key element of formal energy prediction reports used by the financial community. Before shipping, each ZephIR 300 undergoes several stages of rigorous checks, also repeated as part of the routine maintenance whenever a unit returns to base. Each ZephIR undergoes an outdoor test to measure wind speed side-by-side against a Reference Unit that has been validated against several tall masts including Risø's Høvsøre test site and a 193-metre met mast in the USA. In addition Natural Power has established the UK's first lidar and sodar test site so that ZephIR 300 can also be delivered with either a Natural Power or GL Garrad Hassan validation report against the calibrated 90-metre met mast featuring calibrated Risø cups and Vector 100L cups based at 20, 45, 70 and 90 metres, a pressure sensor logger at 6 metres and a temperature sensor mounted at 80 metres.

Results

The plots in the figure 4 show comparisons between ZephIR and the met mast situated at Natural Power's test site. This side-by-side comparison of the ZephIR against the mast took place during 2010.

Excellent agreement between mast and ZephIR is maintained at all heights with less than a 1% difference in the gradients and R2 values extremely close to the optimum value of 1.0.

The Next Chapter

With the launch of ZephIR 300 we now look to our other product development streams – ControlZephIR, where we have ZephIR units involved in research programmes looking at lidar as a wind turbine control sensor, with tests and evaluations for both the OEM and retro-fit markets, and SeaZephIR (a patented floating ZephIR concept) which we have already agreed and delivered against the first commercial sales.

This combination of rugged optical design, user-friendly reliable product design and traceable high-quality data, positions ZephIR 300 as the leading commercially available remote sensing device.

The ZephIR team has now grown considerably; we have a production facility manufacturing units on a steady scale and have spent much of 2010 working to put a world network of service engineers in place to support our expanding customer base. Scientific research and product development activities within the group continue at pace. In 2011 the market will see many new supporting tools released as a result of the wind engineering input that has been received from Natural Power over the years since the technology was transferred into the group. It has been an extremely challenging yet rewarding six years in which we have seen the industry grow substantially and competition enter our market, confirming a very real need for alternatives to met masts, and our own efforts come to fruition as we release this evolution in lidar technology – ZephIR 300. ■

Biography of the Authors

Ian Locker is a Chartered Electronic Engineer with a Masters Degree in Business Administration. He has worked in the wind industry for 11 years and during that time has been responsible for QinetiQ's renewable energy business and is currently Managing Director of the ZephIR business within Natural Power.

Alex Woodward is a Product Development specialist with five years of direct experience within the wind industry. He has managed the recent development of ZephIR 300 at Natural Power and is responsible for all new product streams within the company.

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