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ODIN*, A NEW APPROACH FOR METEOROLOGICAL AIRPORT SURVEILLANCE

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INTRODUCTION

Severe turbulence and low altitude wind shear are posing a significant threat to landing and departing aircraft. According to FAA and ICAO statistics, more than 600 persons lost their lifes between 1965 and 1985 in the United States alone.

In order to introduce new laser technology for low altitude wind measurement, KAYSER-THREDE is currently developing a groundbased wind lidar station for the detection of these hazardous meteorological phenomena in the airport terminal area within a range of more than 8 miles.

TECHNICAL CONCEPT

The core of the system is a heterodyne solid state Doppler lidar. This instrument has to be fully eyesafe due to its measurement configuration along the runway approach sector. Therefore a wavelength > 1.5 µm has been chosen. This requirement is principally limiting the selection of laser sources to the well established CO_2 laser at 10.59 µm or to the relatively new family of solid state lasers. For our system Tm:YAG as the laser material was selected due to less stringent technological demands. The functional block diagram of this lidar is depicted in Figure 1.

The laser system, comprising two diode-pumped Tm:YAG lasers (master- and slave oscillator), is operating in fully solid state configuration in order to achieve atmospheric sounding with high temporal resolution and rapid scanning capabilities. Laser material and transmitter wavelength have been chosen according to performance advantages and a relatively low atmospheric attenuation of only 0.16 dB/km (Targ, R. et al., 1991). Intensive numerical simulations have demonstrated that molecular absorption due to atmospheric constituents can be avoided by operating the laser at a wavelength of 2.02184 µm. The spectral region around this wavelength is exclusively populated by lines of water vapor and carbon dioxide.

OPTICAL LAYOUT

The master oscillator (MO), operating in single longitudinal cw mode, is thermally stabilized and wavelength controlled by an internal etalon. This laser is being developed by DLR-Optoelectronics within the frame of this program.

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*Optical Detection of Turbulence and Windshear In the Vicinity of Airports

The diode pumped Q-switched slave oscillator (SO), supplied by Coherent Technologies Inc. emitts light pulses of 500 ns duration with a pulse energy of 3 mJ at a pulse repetition frequency of 100 Hz. The output frequency of the SO is offset to the MO frequency by 105 MHz, using an internal acousto-optical modulator (AOM) in order to provide the reference frequency for heterodyne detection. The principal optical layout is depicted in Figure 2.

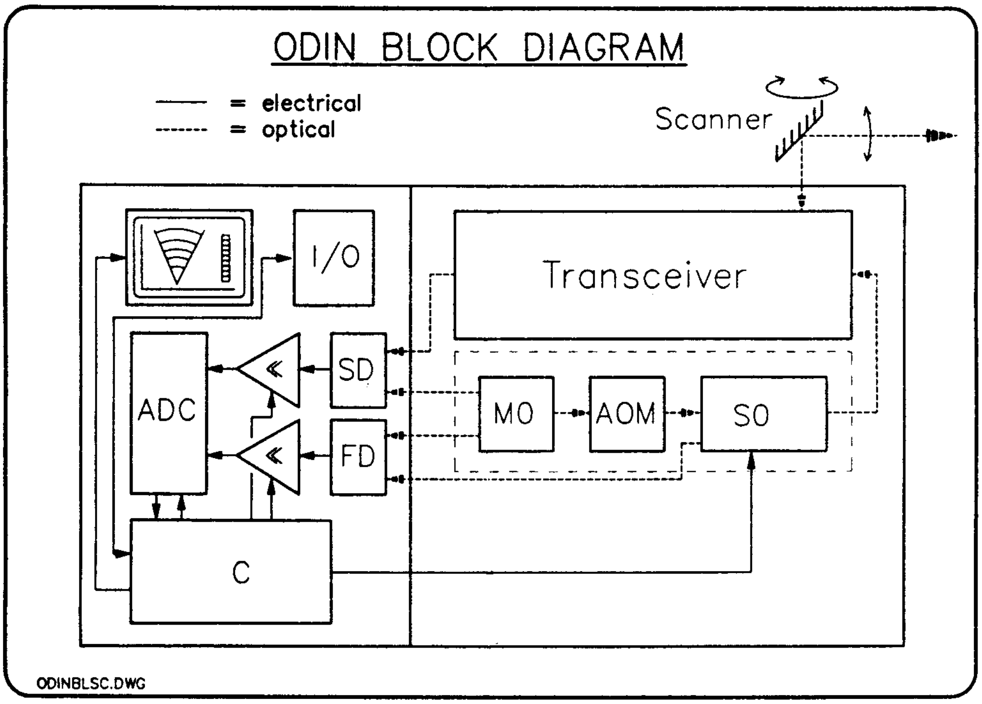

Figure 1: Functional block diagram of the Doppler Lidar ODIN. (MO: master oscillator, AOM: acousto-optical modulator for frequency offset, SO: injection seeded slave oscillator, SD: signal detector, FD: monitor detector, ADC: analog to digital converter, C: computer).

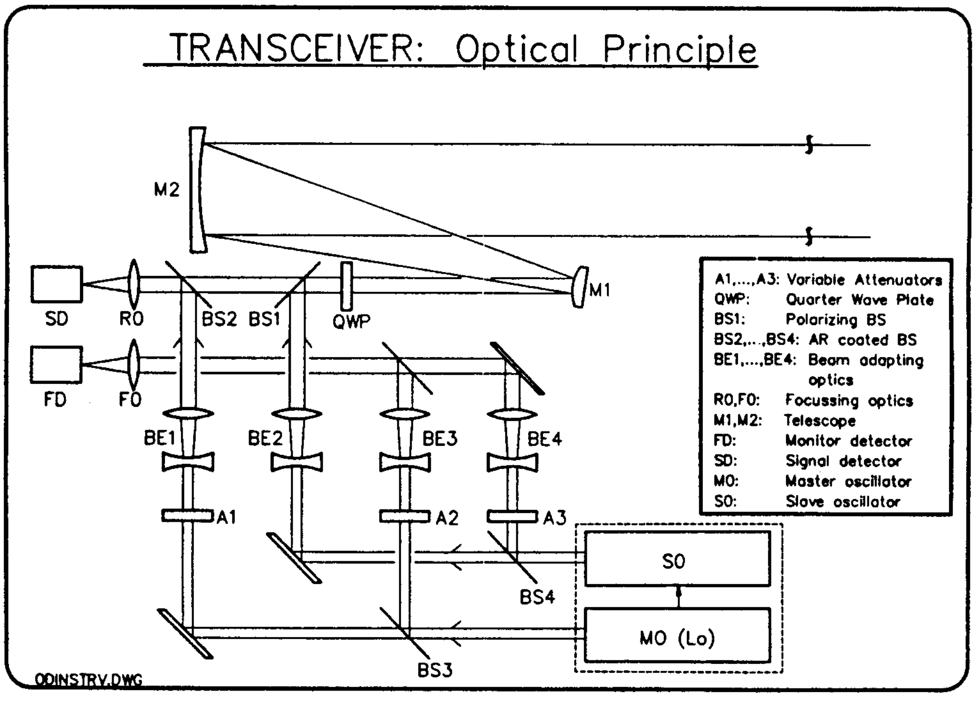

Figure 2: Optical circuit diagram of the ODIN-transceiver.

Frequency stabilized operation of the SO is performed by injection seeding the MO beam into the SO. The monitor detector (FD) is fed by radiation of the MO and of the SO and is thus generating an internal i.f. signal of 105 MHz. The frequency of the emitted laser radiation is monitored by the monitor detector FD and is used to compensate for frequency shifts of the SO from pulse to pulse in the velocity estimation.

The emitted laser radiation is expanded by a 100 mm aperture Dall-Kirkham telescope and is directed into the target area by a computer controlled two-axis scanning optics which allows probing the full hemisphere around and above the lidar station.

The emitted laser radiation is scattered by ambient wind borne aerosols, providing the return signal. The frequency of the scattered signal is shifted depending on the line-of-sight (LOS) velocity of these particles relative to the lidar. The frequency shift Δf, observed by the receiver of the system is quantified by the relation

$$\Delta f = 2 \cdot f_o \cdot \frac{v}{c}$$

where f_O denotes the frequency of the emitted laser radiation, v is the LOS-velocity of the scattering aerosols and c is the speed of light.

This backscattered signal is collected by the same Dall-Kirkham optics, thus acting as a transceiver and is focussed onto the signal detector (SD) in conjunction with a fraction of optical MO power to generate the heterodyne beat signal. The frequency spectrum of the detector signal is amplified and periodically analyzed by the data evaluation hardware and software.

SYSTEM DEVELOPMENT

During the first phase of the instrument development it is foreseen to use the Fast Fourier-Transform (FFT) algorithm in order to derive the different components of the electronic signal spectrum. The results of this off-line data analysis will be a first representation of range resolved LOS-components of wind velocity to study the performance of this Doppler lidar.

In the following phase a work station computer system for rapid on-line data analysis, including pulse-pair and poly-pulse-pair data analysis will be employed. Results will then be presented as a colour coded map with a range resolved presentation of the ambient wind field. It is planned to accomplish these phases by the end of 1995. Figure 3 shows the range resolved results of a computer simulation of the complete system (Werner et al., 1993), based on performance data as shown in Table 1. The atmospheric input data include mid-latitude summer model atmosphere height profiles of pressure, temperature, turbulence, aerosol number density, aerosol backscatter, water vapor and carbon dioxide concentration, superinposed by a microburst at 8 km distance from the lidar.

After integration in a mobile environment (20' container) and completion of final tests it is planned to transfer the system to Oberpfaffenhofen, the home airbase of DLR Optoelectronics for a three month field campaign. This airport, equipped with ILS facilities and frequently being used by commuters and research aircraft will serve as an ideal final testbed for this Doppler lidar. Here the system can be operated extensively within aviation environment; however still without the stringent security regulations of commercial airports. Further development and improvement of system capabilities is foreseen for implementation of this system at airports for routine operation.

CONCLUSION

A groundbased Doppler lidar is being developed by KAYSER-THREDE GmbH and DLR Institute for OPTOELECTRONICS to monitor the low altitude wind field within airport terminal area. It is the aim of this project to develop an instrument that provides warning to approaching or departing aircraft in the presence of severe turbulence or wind shear conditions.

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References:

Targ, R. et al., Appl. Opt. 30, 1991
Werner, Ch., et al., private communication, 1993

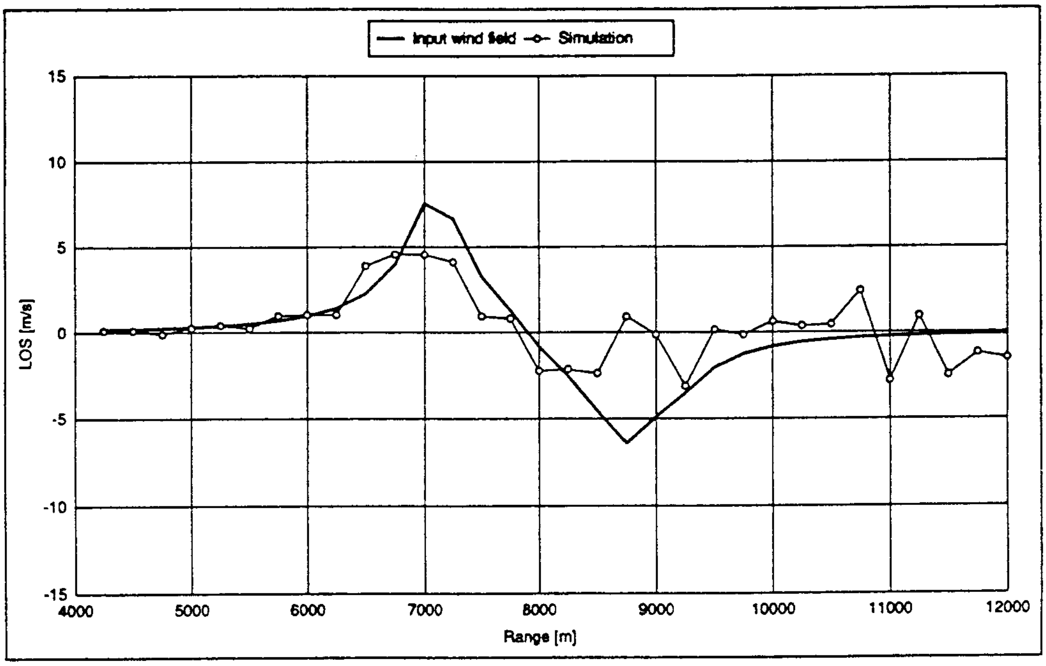

Figure 3: Performance simulation of ODIN with a predefined wind field, including a microburst at 8000 m distance from the lidar. (Wavelength: 2.02184 µm, pulse energy: 3 mJ, system height: 2 m AGL, elevation angle: +3 deg., signal averaging: 10 pulses, Doppler processor: Poly pulse pair).

Table 1: Preliminary technical data of the Doppler lidar.

Laser Wavelength	2.02184 µm
Pulse Energy	3 mJ
Pulse Duration	0.5 µs
Pulse Repetition Frequency	100 s^{-1}
Telescope Aperture	0.1 m
Scanner Type	two mirrors, two axis
Elevation Range	0° - 90°
Azimuth Range	0° - 360°
Platform	Ground-based in a mobile 20' container