Recent developments and results of NICT Doppler Wind LIDARs

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5. Summary
1. Introduction

- Coherent Doppler Lidar
  - Research and development of spaceborne coherent Doppler lidar.
    - Ground-based coherent Doppler lidar.
    - Airborne coherent Doppler lidar.
    - Eye-safe laser experiments for spaceborne system.

- Incoherent Doppler Lidar
2. Coherent Doppler Lidar

- Study of computational algorithm for wind speed and wind direction (ground-based system, airborne system).
- Experimental study of coherent Doppler lidar from moving platform (airborne system).
- Accumulation of experience for the development of spaceborne system (airborne system).
- Developments of a half joule sub-scale laser for risk reduction and demonstration of spaceborne system.
## Specifications of Coherent Doppler lidar

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<th>Transmitter and Receiver</th>
<th>Scanner and Signal processing</th>
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<td><strong>Transmitter</strong></td>
<td><strong>Ground-based system</strong></td>
</tr>
<tr>
<td>Laser</td>
<td>Scanning axis</td>
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<tr>
<td>Wavelength</td>
<td>Scanning elements</td>
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<tr>
<td>Pulse energy</td>
<td>Scanning range</td>
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<tr>
<td>Pulse width (FWHM)</td>
<td>Effective clear aperture</td>
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<tr>
<td>Pulse Repetition</td>
<td>Pointing accuracy</td>
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<tr>
<td>Polarization</td>
<td>Speed</td>
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<td>Ground-based mobile</td>
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<tr>
<td><strong>Receiver</strong></td>
<td><strong>Signal processing</strong></td>
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<tr>
<td>Telescope diameter</td>
<td>Resolution</td>
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<tr>
<td>Detector</td>
<td>Sampling frequency</td>
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<td>Data point</td>
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<td>FFT-point</td>
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<td></td>
<td>Range resolution</td>
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<td></td>
<td>Maximum range</td>
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<td></td>
<td>Minimum range</td>
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<td>Storage</td>
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Ground-Based/Mobile System

Research vehicle and cargo transporter

Inside the cargo space with the main body of the lidar colored blue
Airborne System

Doppler Lidar

95GHz Cloud Radar

NIES Lidar (1064, 532 P/S pol)
Airborne Experimental Results

Wind profiles measured by the airborne coherent Doppler lidar and the Windprofiler on February 15, 2006.

- 1500 laser pulse accumulation
- 9 directions (VAD)

October 3, 2006
3. Incoherent Doppler Lidar

NICT Lidar at Poker Flat, Alaska.

- Rayleigh Lidar (November 1997 - )
  - Structure and dynamics of the middle atmosphere.

- Multi-wavelength lidar (March 2003 - )
  - Aerosols, clouds and water vapor in the troposphere and stratosphere.

- Incoherent Doppler lidar (August 2005 - )
  - Wind in the stratosphere.
# Specifications of Incoherent Doppler Lidar

<table>
<thead>
<tr>
<th>Transmitter</th>
<th>Fabry-Perot Interferometer</th>
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<tbody>
<tr>
<td>Laser</td>
<td>Type</td>
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<tr>
<td>Wavelength</td>
<td>Capacitance-stabilized Etalon</td>
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<tr>
<td>Pulse energy</td>
<td>Effective aperture</td>
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<tr>
<td>Pulse width (FWHM)</td>
<td>Etalon gap</td>
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<tr>
<td>Pulse Repetition</td>
<td>Free spectral range</td>
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<tr>
<td>Polarization</td>
<td>Reflectivity</td>
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<tr>
<td>Divergence</td>
<td>15 cm</td>
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<td>25 mm</td>
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<td></td>
<td>6 GHz</td>
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<td>90 %</td>
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<table>
<thead>
<tr>
<th>Telescope</th>
<th>Detector</th>
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<tbody>
<tr>
<td>Diameter</td>
<td>Type</td>
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<tr>
<td>F number</td>
<td>Equi-area ring detector</td>
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<td>Field of view</td>
<td>Channel</td>
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<td>24 (300MHz/Ch)</td>
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<td>Quantum efficiency</td>
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<td>10 %</td>
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<tr>
<th>Signal processing</th>
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<tr>
<td>Range resolution</td>
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<tr>
<td>I/O interface</td>
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</table>
Block Diagram of Incoherent Doppler lidar
Experimental Result at NICT (Koganei, Tokyo)
4. Current and future projects

- Ground-based coherent Doppler lidar.
  - Diversion of Tm,Ho:YLF sub-scale laser from spaceborne system to ground-based system (50-100 mJ, 20-30 Hz).
  - Sensing network project (urban area of Tokyo).
    - Coherent Doppler lidars, Windprofiler (1.3 GHz).
Spaceborne coherent Doppler lidar.

- Tm,Ho:YLF sub-scale laser experiments for the ISS-JEM/CDL (2J, 10Hz).
  - Slave OSC (6mJ, 10Hz) ➔ End pump AMP(100mJ, 10Hz) ➔ Side pump AMP(500mJ, 10Hz).
- ISS-JEM/CDL.
  - Review of medium- and long-term programs (JAXA).
  - Free flyer (500mJ+40cmΦ) or Small satellite (500mJ+40cmΦ).
  - One of the candidates for the optical remote-sensing satellite (？).

NICT(and JAXA) 2μm Coherent Doppler lidar

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500mJ+40cmΦ  Free flyer feasibility/availability/operational
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or

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200mJ+20cmΦ  Small satellite feasibility study
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Global environmental monitoring program

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<td>Sensor</td>
<td>Active radio sensor (Precipitation Radar)</td>
<td>TRMM/PR</td>
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<td>Passive radio sensor (Microwave radiometer)</td>
<td>Aqua/AMSR-E</td>
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<td>Active radio sensor (Scatterometer)</td>
<td>ADEOS-II/AMSR</td>
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<td>Passive optical sensor (Radiometer)</td>
<td>ADEOS-II/GLI</td>
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<td>Active radio sensor (Cloud Radar)</td>
<td>ADEOS-II/LCR</td>
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<td>Passive optical sensor (Infrared spectrometer)</td>
<td>GOSAT (Greenhouse gas monitoring)</td>
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<td>Active optical sensor (Lidar)</td>
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- **Existing Proj**:
- **New Proj**:

- Advanced infrared spectrometer
- GOSAT II(??)
- GOSAT (Greenhouse gas monitoring)
- Sensor
  - Passive radiosensor
    - Microwave radiometer
  - Active radiosensor
    - Scatterometer
    - Cloud Radar
  - Passive optical sensor
    - Radiometer
    - Infrared spectrometer
  - Active optical sensor
    - Lidar

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5. Summary

- Airborne experiments were made to demonstrate the feasibility of the coherent Doppler lidar from moving platform in 2004 and 2006.

- Wind profiles were successfully obtained from the surface to the altitude of up to about 7 km. The results obtained by the airborne coherent Doppler lidar were agreement with those measured by other instruments.

- NICT Doppler lidars (and 95GHz cloud radar) can contribute to the validation of the ADM-Aeolus.

- Moderate output conductive cooled, 2μm solid-state lasers is developed for ground-based and airborne Doppler lidars and a differential absorption lidar.

- Development of high pulse energy and high efficiency eye-safe laser for space applications will be continued:
  - Contribution to R&D of airborne and ground-based/mobile Doppler lidar.
  - Study of measurement of wind, CO₂ and H₂O (DIAL) with spaceborne coherent lidar.