Lecture 12. Temperature Lidar (3)
Na Doppler Lidar Architecture

- Review Doppler ratio technique
- Introduction
- Na Doppler lidar instrumentation
- Na Doppler lidar transmitter
- Na Doppler lidar receiver
- DAQ & control system
- Summary
Review of Doppler Ratio Technique

![Graph showing fluorescence signal from Na vapor cell compared to Doppler broadened spectrum at 187 K. The graph includes important frequencies annotated as $f_-$, $f_a$, and $f_+$. The fluorescence signal is indicated by a solid line, while the Doppler-broadened spectrum is represented by a dashed line. The mesopause return is indicated by triangles.](image)
Review of Doppler Ratio Technique

\[ R_T = \frac{N_+ + N_0}{N_a} \]

\[ R_W = \frac{N_+ - N_-}{N_a} \]

-100 m/s
-20 m/s
+100 m/s
280 K
120 K
200 K

Temperature: 200 K
**Introduction**

Lidar architecture is the art of lidar system instrumentation (including hardware and software).
Na Doppler Lidar Schematic

Dye-laser-based Na wind and temperature Lidar
Large-Aperture Na Doppler Lidar
Na Doppler Lidar Transmitter

- CW Frequency-Doubled Nd:YVO₄ Laser:
  - 532 nm
  - 4 W

- CW Ring Dye Laser:
  - 589 nm
  - 0.5-0.7 W

- Acoustic-Optic Frequency Shifter ± 630 MHz

- Optical Isolator

- Na Vapor Cell

- Photo Detector

- Pulsed Dye Amplifier:
  - 589 nm
  - 1.5-2 W

- Pulsed Frequency-Doubled Nd:YAG Laser:
  - 1064 nm
  - 5 mW

- CW Injection Seeder Laser:
  - 1064 nm
  - 5 mW

- Wavemeter
Na Lidar Transmitter

Ring Dye Laser

Nd:YAG

PDA
Ring Dye Laser
1. “Four mirror + Dye jet” form the laser resonance cavity.
2. Unidirectional lasing prevents spatial hole-burning.
3. Rhomb compensates the astigmatism effect.
4. Optical diode forces the unidirectional lasing.
5. BRF + ICA (etalons) select frequency and narrow bandwidth.
Frequency Selection in Ring Laser

- **Thin etalon** (FWHM=200 GHz)
- **BRF** (FWHM=2 THz)
- **Gain profile**
- **Thick etalon** (FWHM=5 GHz)
Na Doppler-Free Fluorescence Spectroscopy & Laser Freq Lock

Hardware

3-Level Explanation

[Diagram of Na Doppler-Free Fluorescence Spectroscopy & Laser Freq Lock, including Na Vapor Cell, Temperature Control, Sensor, Heater Current, Photo Diode, Ring Laser Light, and Diagram of Energy Levels |a⟩, |b⟩, |e⟩ with transitions D_{2a} and D_{2b}]

[Graph showing fluorescence signal from Na vapor cell and Doppler broadened spectrum at 187 K with peaks at f_c, f_a, and f_b]
Laser Frequency Scan and Lock

- Use computer to scan laser frequency and lock it to the $D_{2a}$ dip of the Na saturation-absorption spectroscopy.
**Acousto-Optical Modulator**

**Hardware**

![Diagram of Acousto-Optical Modulator](image)

**Explanation: Doppler shift or Photon/Phonon Annihilation**

(a) Incident Beam: \( \vec{k}_i \)

Diffracted Beam: \( \vec{k}_d = \vec{k}_i + \vec{k}_s \)

\( \omega_d = \omega_i + \omega_s \)

(b) Incident Beam: \( \vec{k}_i \)

Diffracted Beam: \( \vec{k}_d \)

Ultrasonic Transducer

AO Crystal

Electric Input

Sound wavefronts

\( \vec{k}_d = \vec{k}_i - \vec{k}_s \)

\( \omega_d = \omega_i - \omega_s \)
Pulsed Amplification

1. Amplified Spontaneous Emission (ASE)
2. Injection-seeded Nd:YAG laser
3. PDA chirp caused by pulsed amplification
Na W/T Lidar Receiver

Receiver
- Optical Telescope
- Chopper
- Collimating Optics
- Filters
- Photo-Multiplier Tube
Steerable Na W/T Lidar at SOR and Maui

Large-Aperture, Steerable Na Wind/Temperature LIDAR
Data Acquisition and System Control

- Ring laser control
- Trigger timing control
- PMT + Discriminator
- Multichannel scaler
Na Doppler Lidar System Control

Connection of Na Wind/Temperature Lidar System at MSSC

- **Computer**
  - A/D
  - I/O Box
  - Computer Control Bit In
- **States Shifter**
  - Delayed Trigger In
  - 50 Division
- **Frequency Divider**
  - Trigger In
  - Terminator
  - HighZ TTL
  - A.nl B
- **#1 DG535**
  - EXT. TRIG. IN
  - 50 TTL
  - 50Hz
- **#2 DG535**
  - INT. TRIG. 700Hz
  - TO A.nl B C.nl D
  - HighZ TTL
- **Command Frequency**
  - #1 Chopper Controller
- **Cooling Water & its Power Supply**
- **Frequency Doubled Pulsed Nd:YAG Laser Power Supply**
  - Lamp Trigger Input
- **Selector**
  - Q-Switch Sync. Output
- **14 Division Frequency Divider**
  - IN
  - 700Hz
  - OUT
- **#1 Chopper Controller**
  - Control
- **#1 Chopper for Blanking PMT**
  - Sync. Input
  - Chopper Driver (Multiply x4)
  - 200Hz
- **#2 Chopper for blanking Ring CW beam**
  - 50Hz
- **Sync. Input**
- **28 V Power Supply**
Summary

- Currently state-of-the-art Na Doppler lidar is the dye-laser-based Na wind and temperature lidar - “ring dye laser + pulsed dye amplifier” configuration.

- One main feature is the narrowband Na lidar transmitter with precise frequency control and narrow laser linewidth: Na Doppler-free fluorescence spectroscopy for frequency calibration and locking, acousto-optic frequency modulator for generating two wing frequencies with high stability and fast switching, pulsed amplification with very low ASE.

- The lidar receiver (broadband) and DAQ subsystems have various styles and forms. They are also progressing rapidly.

- Na Doppler lidar can be realized with other laser configurations, e.g., solid-state Nd:YAG laser frequency mixing, or alexandrite laser Raman shift, etc.