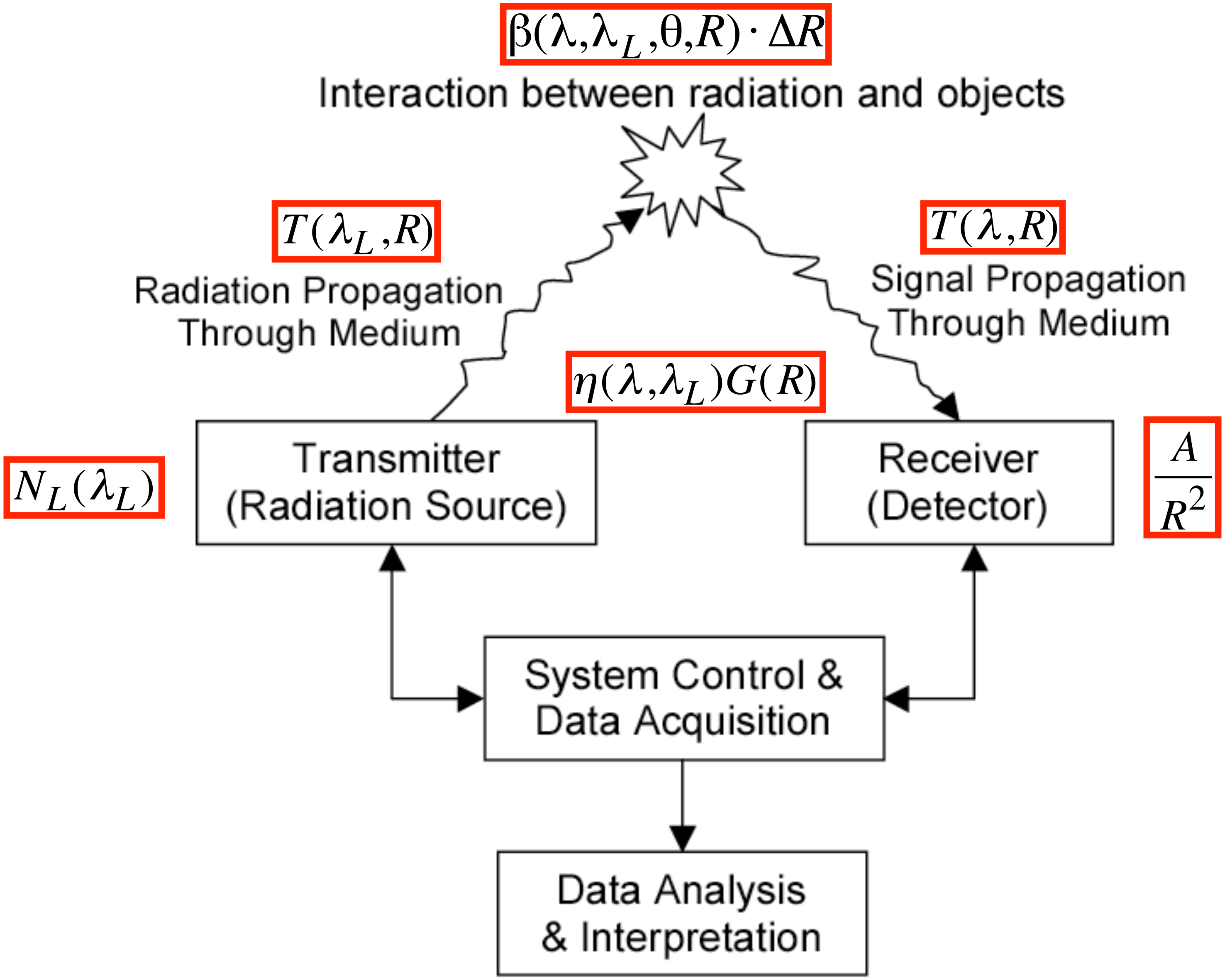
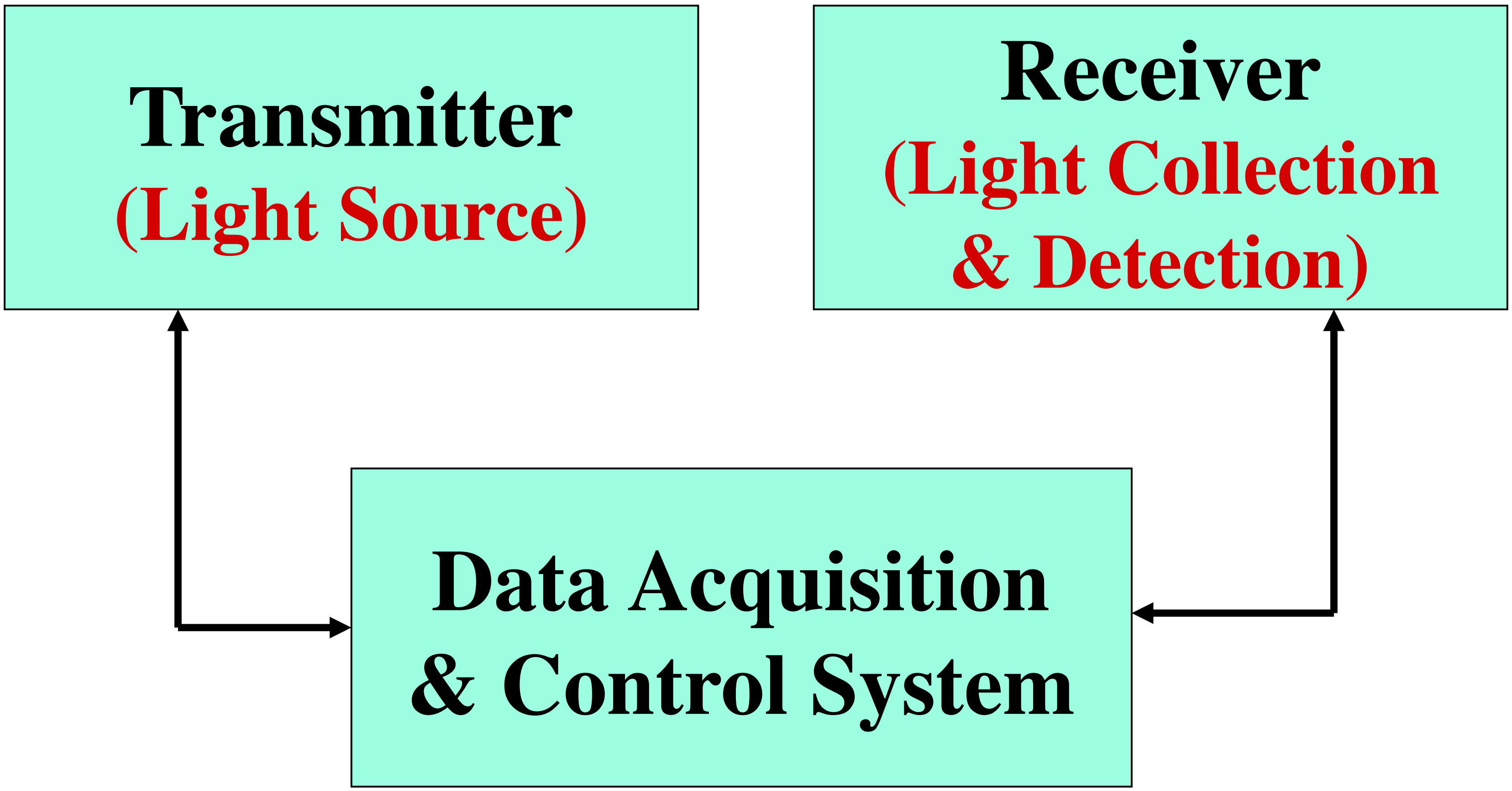
Lecture 07. Fundamentals of Lidar Remote Sensing (5)

- Basic Lidar Architecture
- Configurations vs. Arrangements
- A real example: Arecibo K Doppler Lidar
- Transceiver with HOE
- Lidar Classifications
- Summary

Physical Picture of Lidar Equation



Basic Architecture of LIDAR



Function of Transmitter

- A transmitter is to provide laser pulses that meet certain requirements depending on application needs (e.g., wavelength, frequency accuracy, bandwidth, pulse duration time, pulse energy, repetition rate, divergence angle, etc).
- Usually, transmitter consists of lasers, collimating optics, diagnostic equipment, and wavelength control system.
- For sophisticated lidars with spectral analysis capabilities, the lidar transmitter is usually the most challenging part. The properties of the lidar transmitter determine the performance of the lidar system.
- Most modern lidars use ns pulsed lasers, while some uses cw lasers with bistatic configuration or pulse coding.

Function of Receiver

- A receiver is to collect and detect returned photon signals while compressing background noise.
- Usually, it consists of telescopes, filters, collimating optics, photon detectors, discriminators, etc.
- The bandwidth of the filters determines whether the receiver can spectrally distinguish the returned photons.

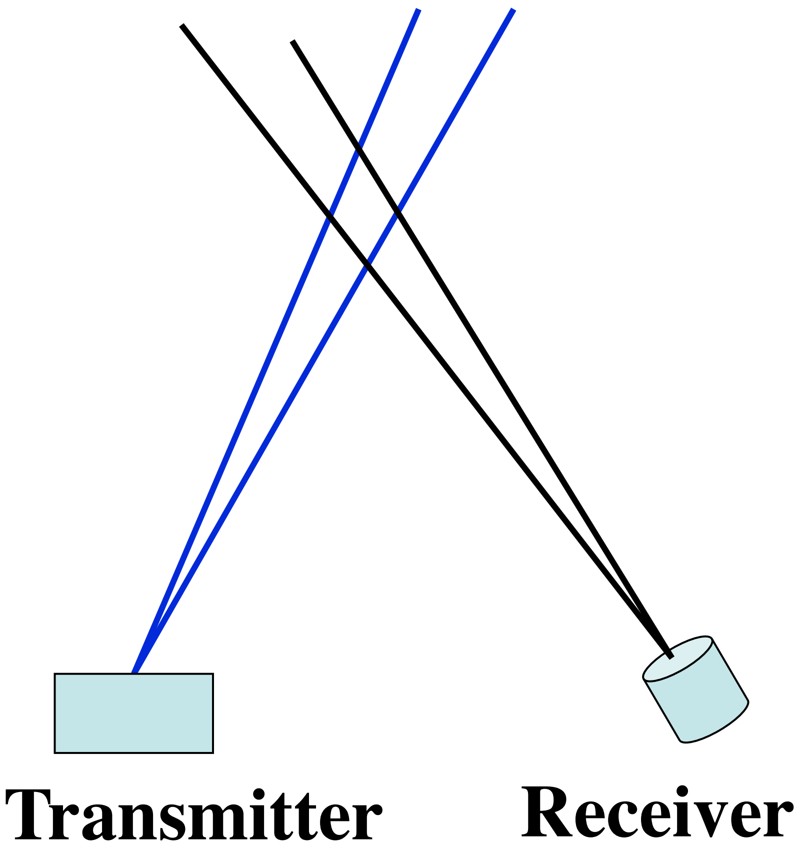
Function of Data Acquisition and Control System

- Data acquisition and control system are to record returned data and corresponding time-of-flight, provide system control and coordination to transmitter and receiver.
- Usually, it consists of multi-channel scaler which has very precise clock so can record time precisely, discriminator, computer and software.
- This part has become more and more important to modern lidars. Recording every single pulse return has been done by several groups, enabling various data acquisition modes.

LIDAR Configurations: Bistatic vs. Monostatic

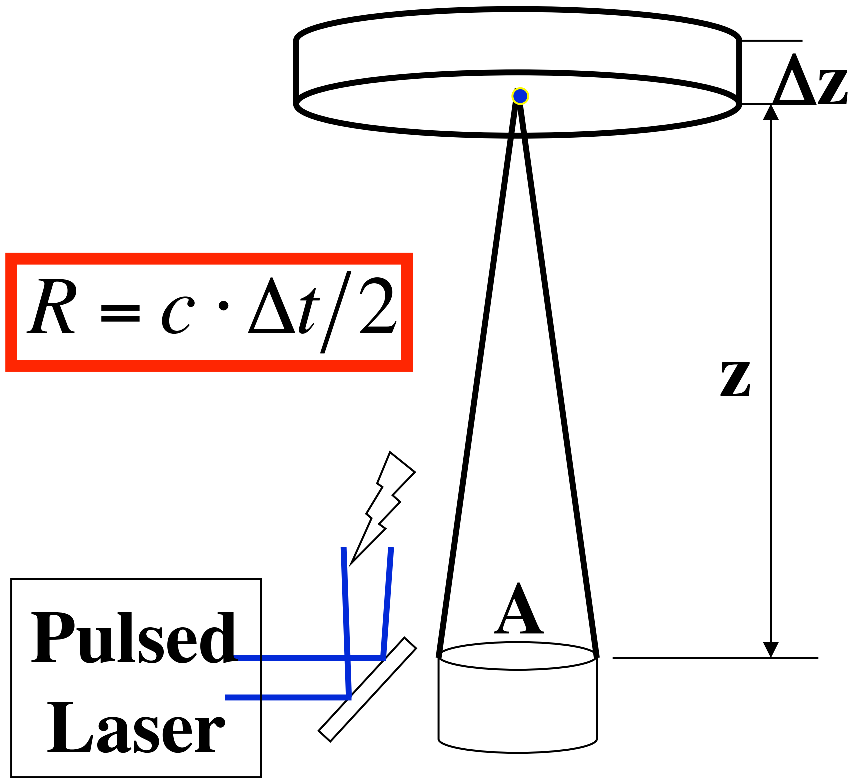
- Bistatic configuration involves a considerable separation of the transmitter and receiver to achieve spatial resolution in optical probing study.
- Monostatic configuration has the transmitter and receiver locating at the same location, so that in effect one has a single-ended system. The precise determination of range is enabled by the nanosecond pulsed lasers via time of flight (TOF).
- A monostatic lidar can have either coaxial or biaxial arrangement.

Basic Configurations of LIDAR Bistatic and Monostatic



Bistatic Configuration

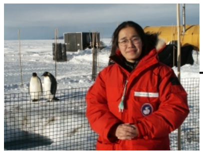
$$\boxed{R = c \cdot \Delta t/2}$$



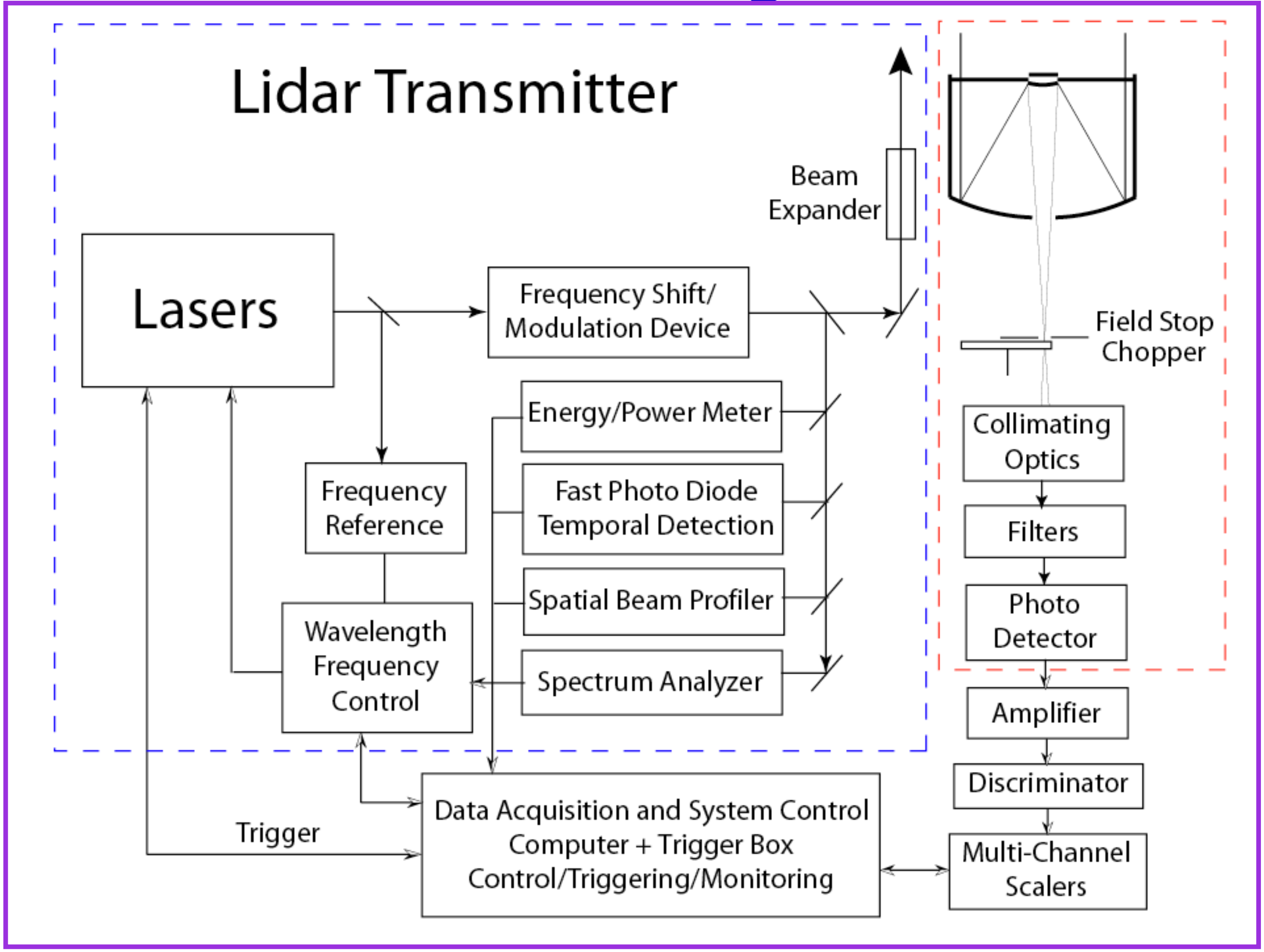
Monostatic Configuration

Coaxial vs. Biaxial Arrangements

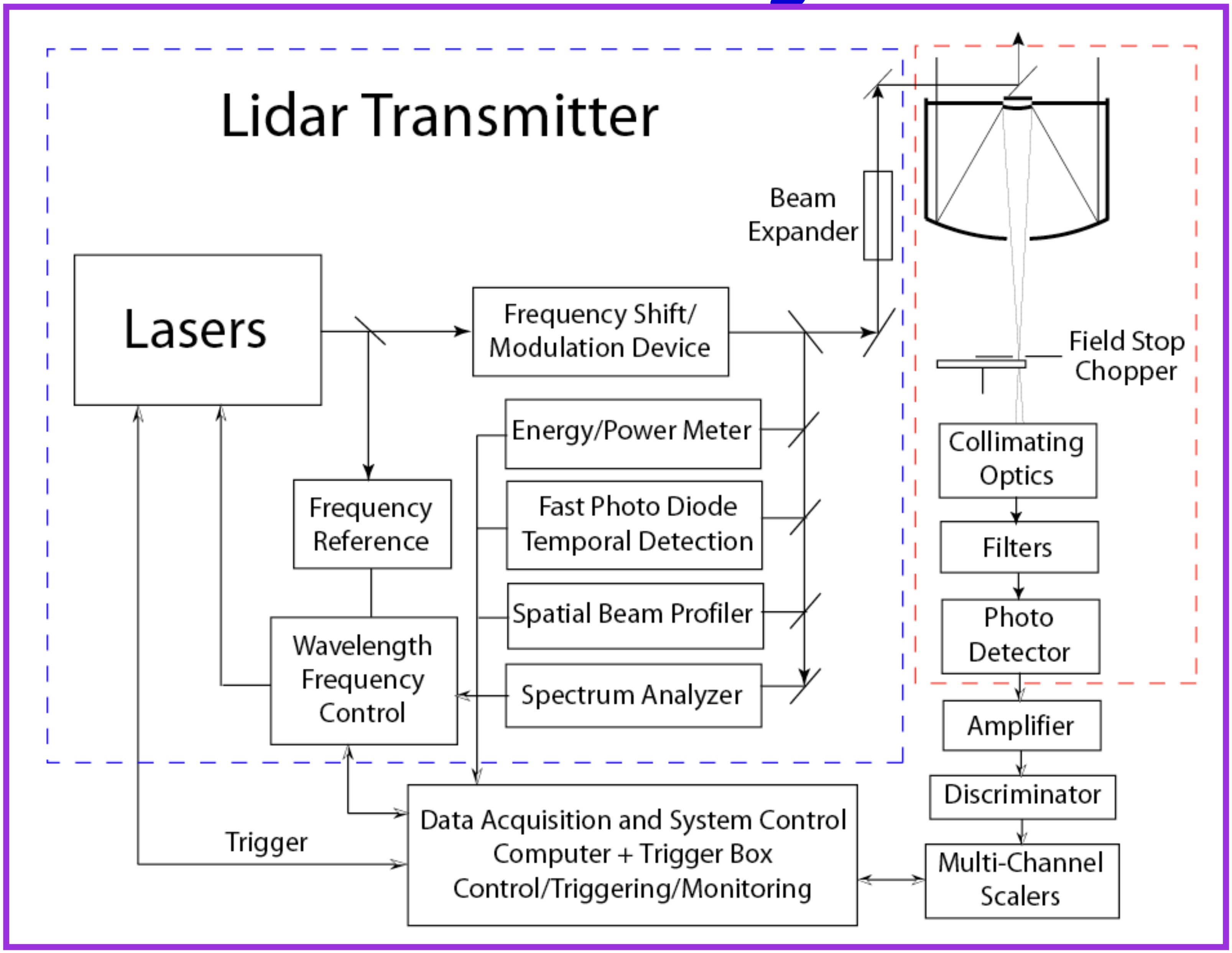
- In a coaxial system, the axis of the laser beam is coincident with the axis of the receiver optics.
- In the biaxial arrangement, the laser beam only enters the field of view of the receiver optics beyond some predetermined range.
- Biaxial arrangement helps avoiding near-field backscattered radiation saturating photo-detector.
- The near-field backscattering problem in a coaxial system can be overcome by either gating of the photo-detector or use of a fast shutter or chopper.



Biaxial Arrangement



Coaxial Arrangement



"Fancy" Architecture of LIDAR

Transceiver
(Light Source
Light Collection
Lidar Detection)

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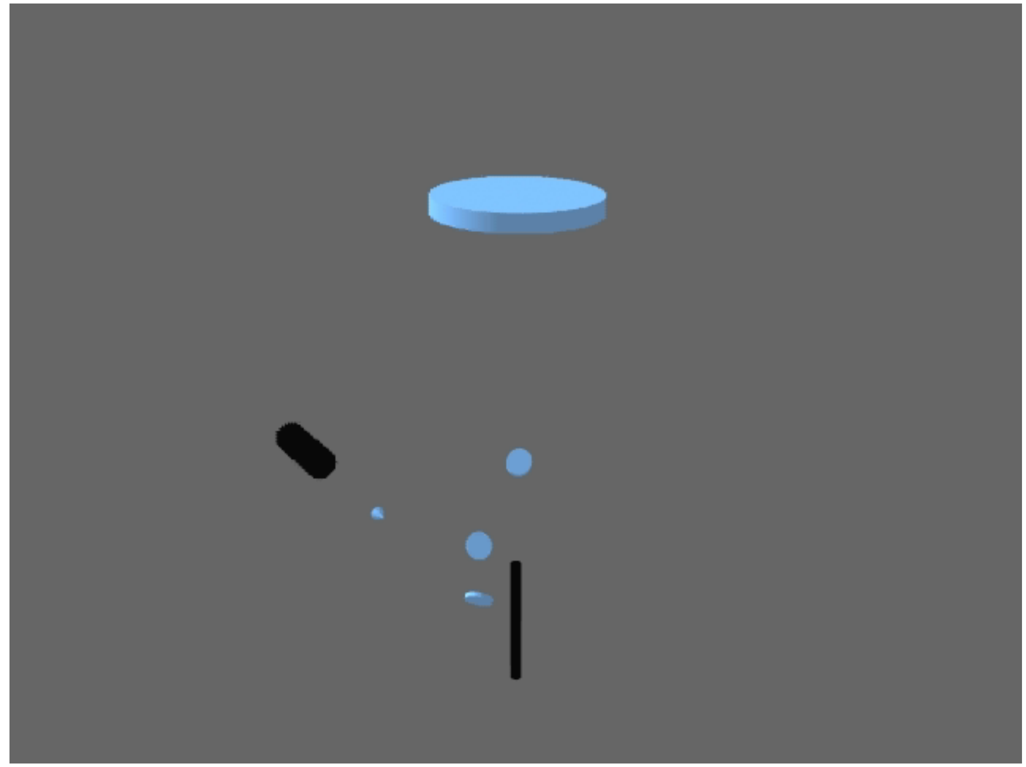
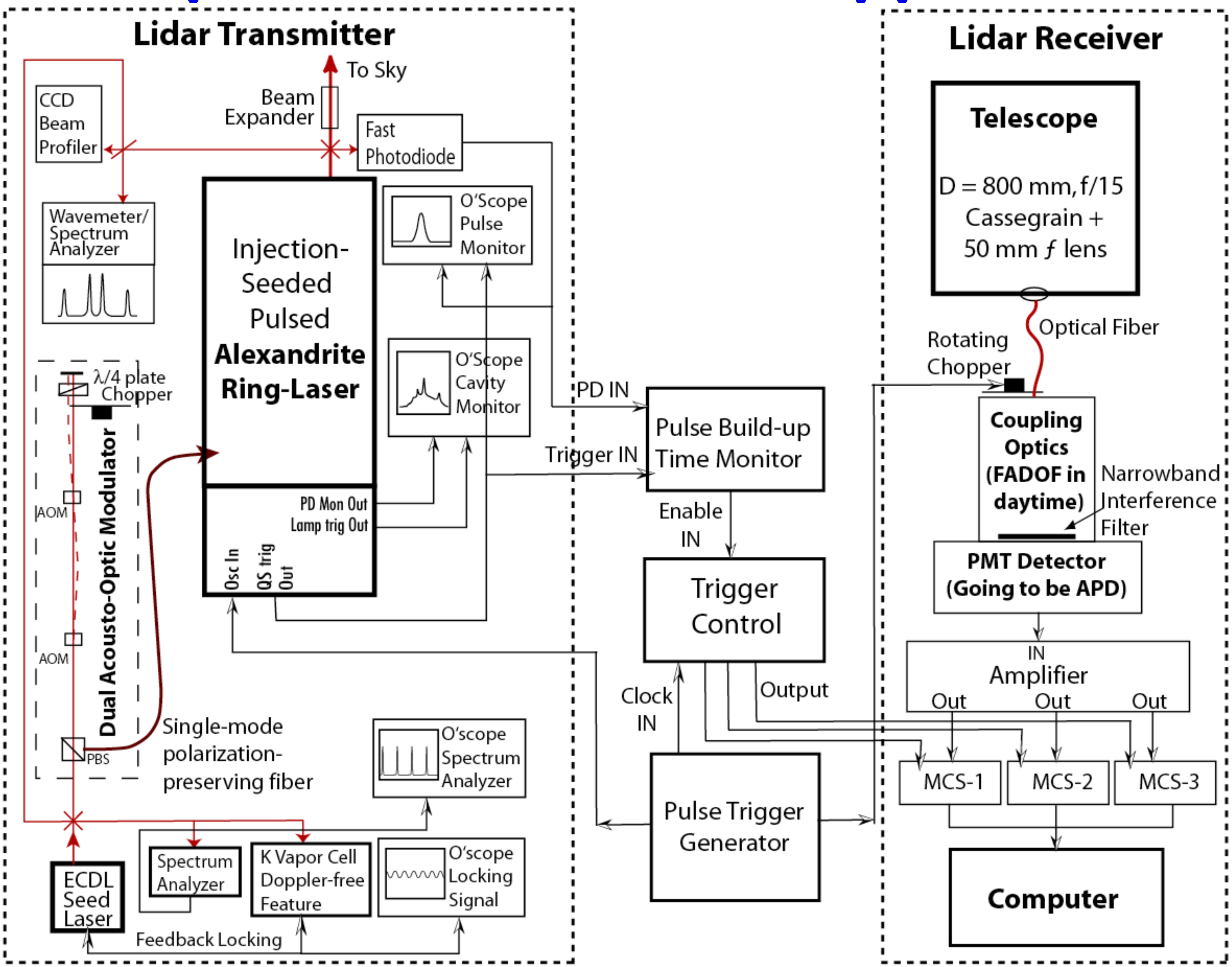
Data Acquisition
& Control System



Transceiver with holographic optical element (HOE)

Courtesy to Geary Schwemmer

Example: Arecibo K Doppler Lidar



[Friedman and Chu, JGR, 2007]

Lidar Transmitter

- A pulsed alexandrite ring laser
  injection seeded by
  an external cavity diode laser
- Seed laser frequency
  is locked to K D1a Doppler-free feature
- Twin dual-pass acousto-optic modulators
  shift seed laser to two wing frequencies
- Diagnostic equipment: CCD beam profiler, fast photo diode, spectrum analyzer, and oscilloscopes,
  monitor the spatial, temporal, and spectral features of the lasers to ensure fidelity operation.

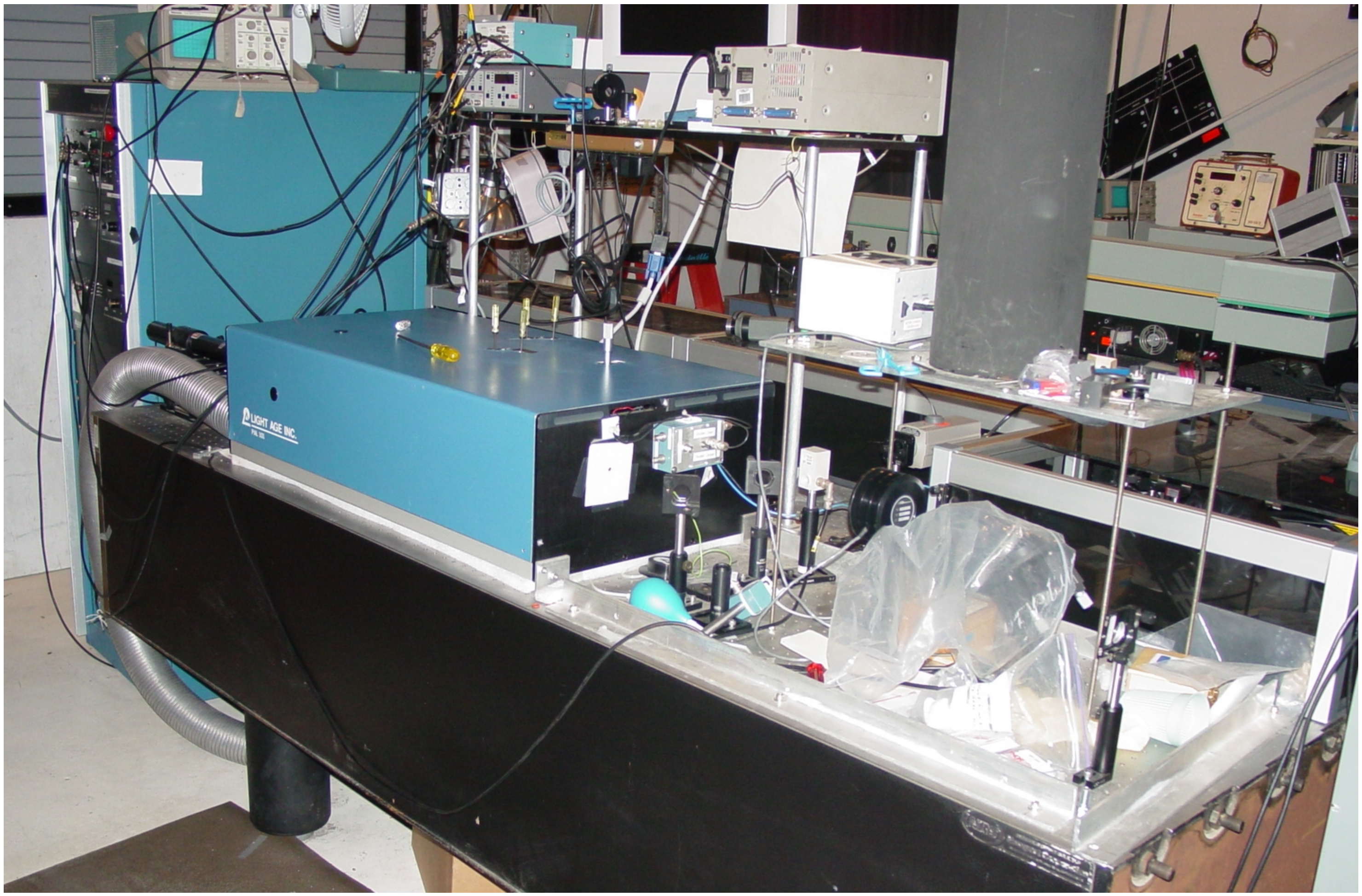
Lidar Receiver

- A Cassegrain optical telescope
  80-cm in diameter
- An optical fiber
  couples signals to receiver chain
- A rotating chopper
  blocks lower atmosphere return
  to avoid saturating photo detector
- Coupling/collimating optics
- An interference filter and a Faraday filter
  compress bkg while transmits signals
- A photomultiplier tube (PMT)
  detects photons in photon counting mode

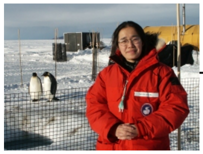
DAQ and Control System

- Amplifier
  to amplify PMT signal
- Discriminator
  to judge whether it is real photon signal
- Multichannel scaler
  to record data along time bins
- Computer with DAQ card and code
  to control system and record data
- Trigger control
  to coordinate the entire system
- Pulse build-up time monitor
  to preclude signals from bad pulses

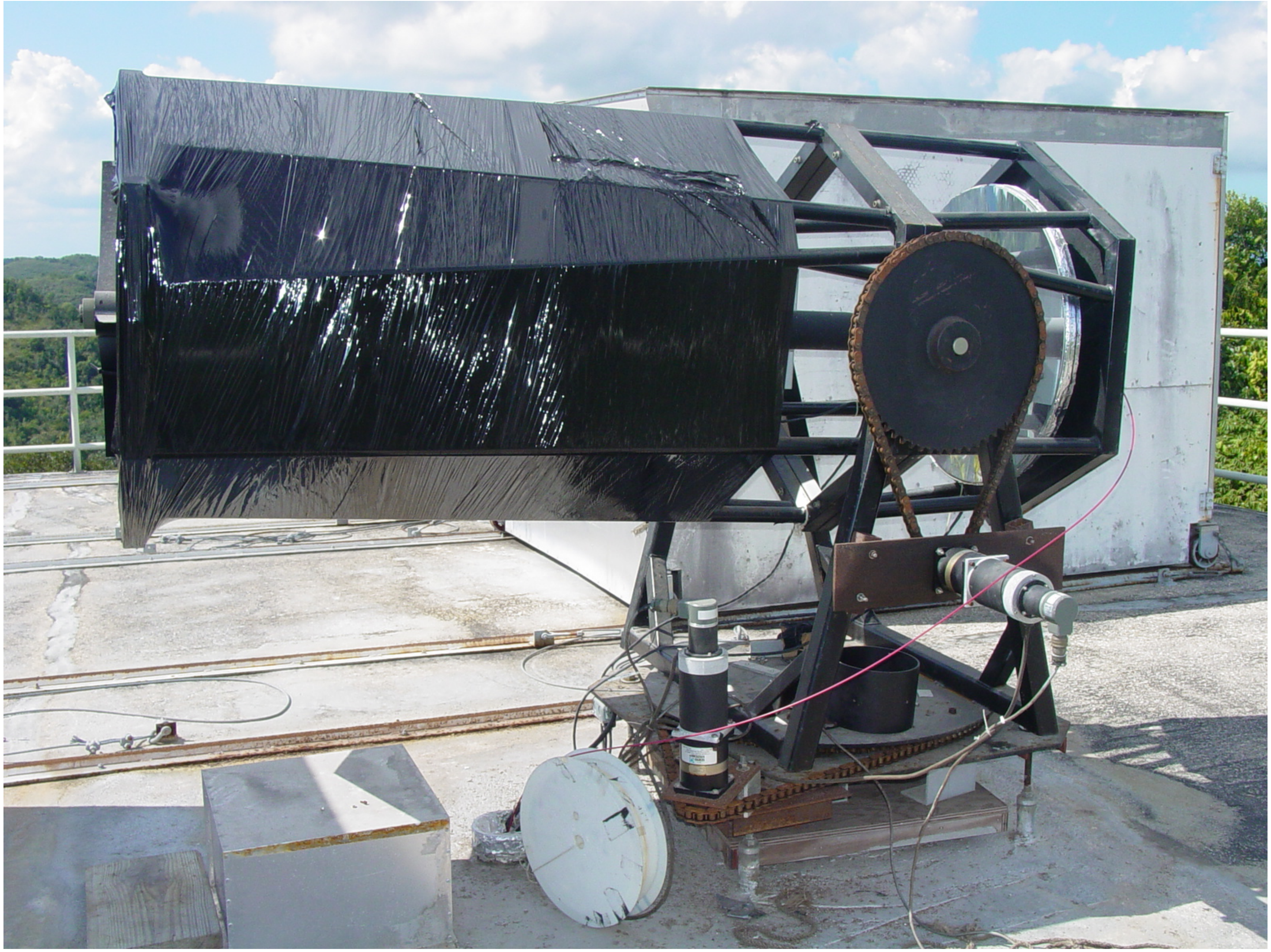
Alexandrite-Laser-Based K Doppler Lidar Transmitter



Credit and courtesy to Dr. Jonathan Friedman

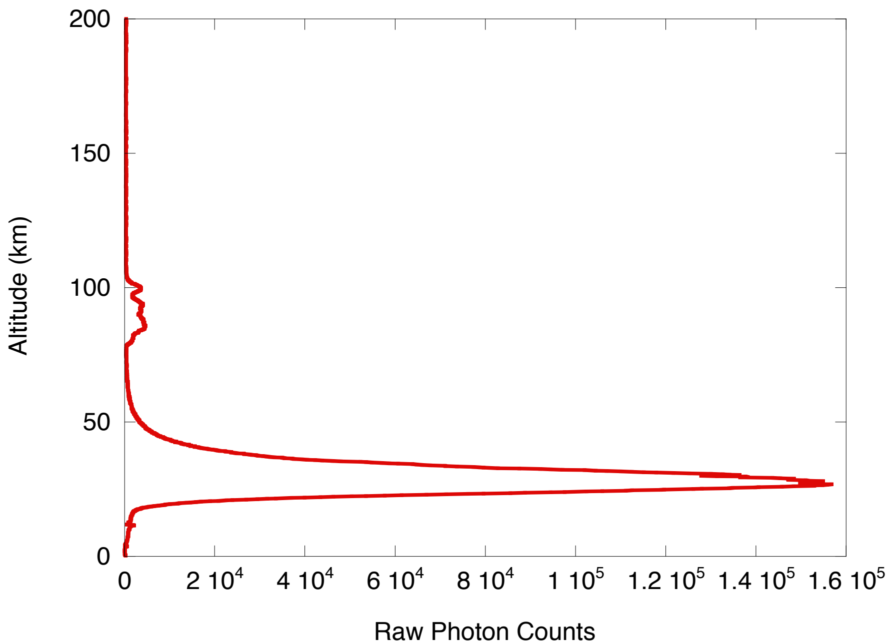


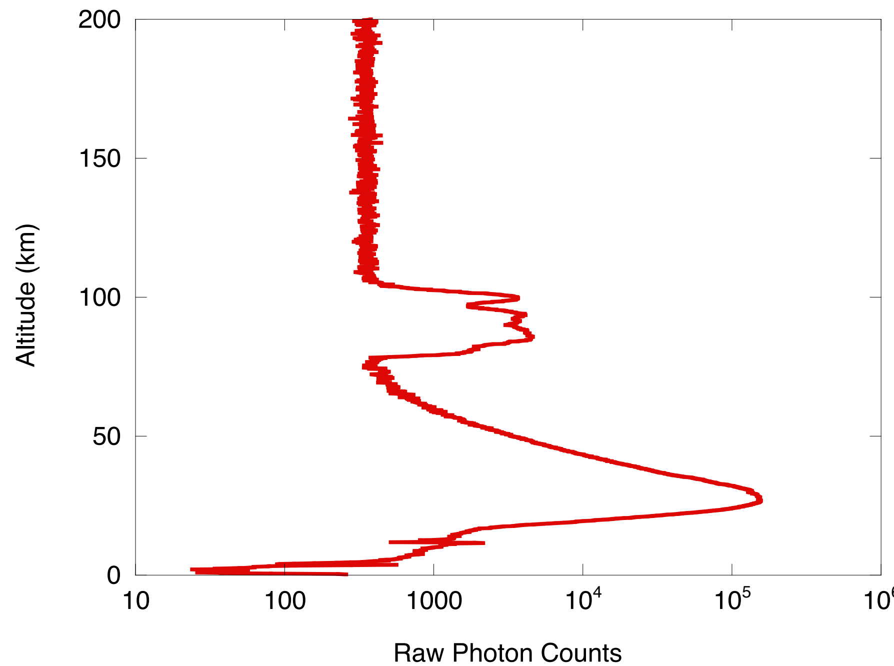
Arecibo 80-cm Telescope



Courtesy to Dr. Jonathan Friedman

Rawdata Profile of K Lidar





Linear Scale

Log Scale

Classifications of Lidar

There are several different classifications on lidars

e.g., based on the physical process;
(Mie, Rayleigh, Raman, Res. Fluorescence, …)
based on the platform;
(Groundbased, Airborne, Spaceborne, …)
based on the detection region;
(Atmosphere, Ocean, Solid Earth, Space, …)
based on the emphasis of signal type;
(Ranging, Scattering, …)
based on the topics to detect;
(Aerosol, Constituent, Temp, Wind, Target, …)

… …

Physical Process	Device	Objective
Elastic Scattering by Aerosols and Clouds	Mie Lidar	Aerosols, Clouds: Geometry, Thickness
Absorption by Atoms and Molecules	DIAL	Gaseous Pollutants
		Ozone
		Humidity (H_2O)
Inelastic Scattering	Raman Lidar	Aerosols, Clouds: Optical Density
		Temperature in Lower Atmosphere
Elastic Scattering By Air Molecules	Rayleigh Lidar	Stratos & Mesos Density & Temp
Resonance Scattering/ Fluorescence By Atoms	Resonance Fluorescence Lidar	Temperature, Wind Density, Clouds in Mid-Upper Atmos
Doppler Shift	Wind Lidar	Wind, Turbulence
Laser Induced Fluorescence	Fluorescence Lidar	Marine, Vegetation
Reflection from Surfaces	Target Lidar Laser Altimeter	Topography, Target

Classification on Platform

Spaceborne lidar	Satellite, Space Shuttle. Space Station
Airborne lidar	Jet, Propeller Airplanes Unmanned Aerial Vehicle (UAV) Kite
Groundbased lidar	Stationary Contanerized moved with truck
Shipborne lidar	Icebreaker, Ships
Submarine lidar	Submarine

Detection Regions

Atmosphere lidar	Various types From various platforms
Hydrosphere lidar	Various types From various platforms
Solid Earth lidar	Airborne or Spaceborne Laser altimeter
Target lidar	Various type With or without Imaging function

Emphasis on Signal Type

Scattering Lidar

Besides time delay, more interested in signal strength, spectra, etc

Ranging/Profiling Lidar

Mainly concern Time delay between transmission and reception

Various Topics

Aerosol/Cloud lidar

Constituent lidar

Temperature lidar

Wind lidar

Target lidar

… … … …

Lidar Classifications on Challenge

Middle and Upper Atmosphere Lidar	Long range - weak signal Accurate knowledge about atoms Accurate knowledge of transmitter Accurate knowledge of receiver Demanding requirements on lasers
Lower Atmosphere Lidar	Many factors involved together Aerosols play a key role, also add the difficulty to lower atmosphere
Target lidar	Precise determination of altitude is a great challenge, as many factors are involved.

Summary

- Basic lidar architecture includes transmitter, receiver and data acquisition and control system. Each has special functions. There are bistatic and monostatic configurations, and coaxial and biaxial arrangements.
- We use a real lidar - the Arecibo K Doppler lidar - as an example to examine the basic concepts of lidar picture and lidar architecture.
- High level lidar systems are sophisticated, mainly on the transmitter (laser) aspect. But receiver and DAQ also strongly affect system performance.
- Lidar classifications may have many different categories, depending on what we want to emphasize.