Lecture 37. Lidar Architecture and Lidar Design

- Introduction
- Lidar Architecture:

    Basic Configurations and Basic Arrangements

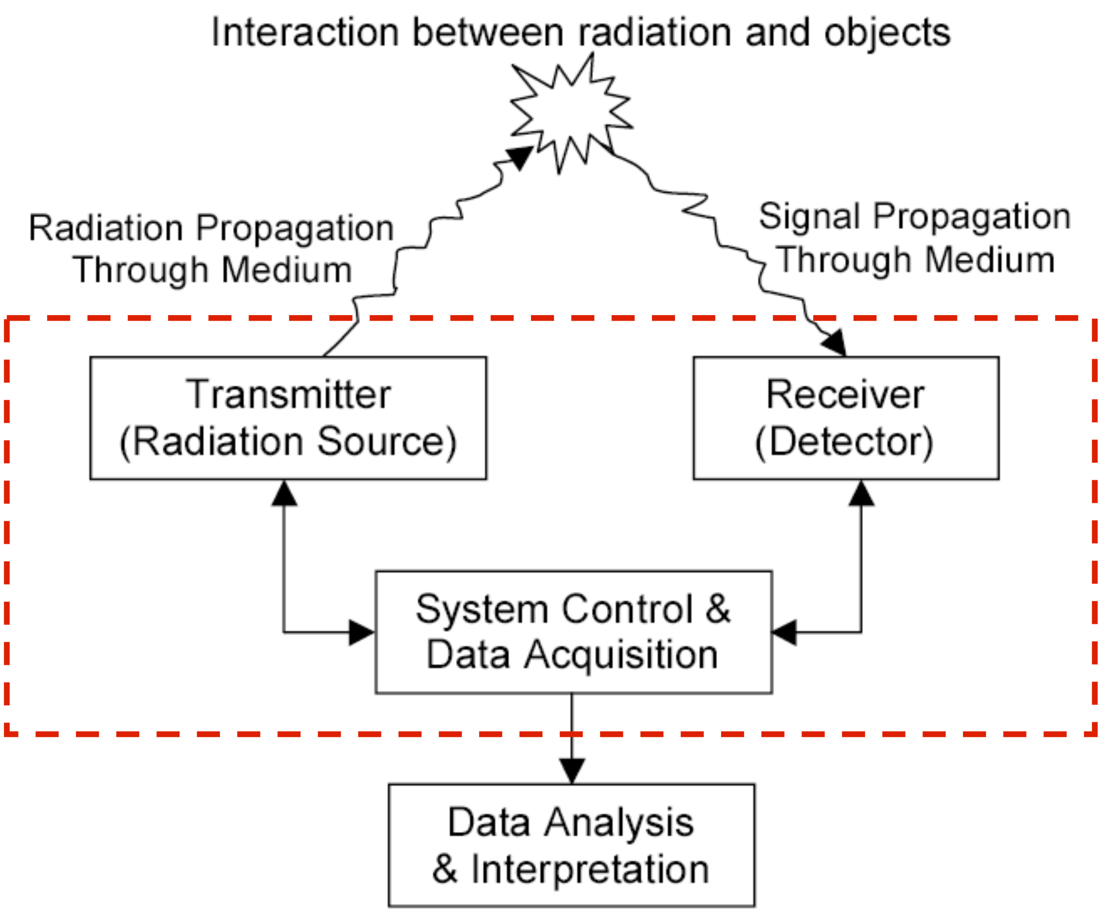
- Lidar Design:

    Basic Ideas and Basic Principles

- Summary

Introduction

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



Introduction

- Lidar design is based on the understanding of physical interactions and processes related and the lidar simulations to design a lidar system that meets our measurement goals.
- Lidar design includes

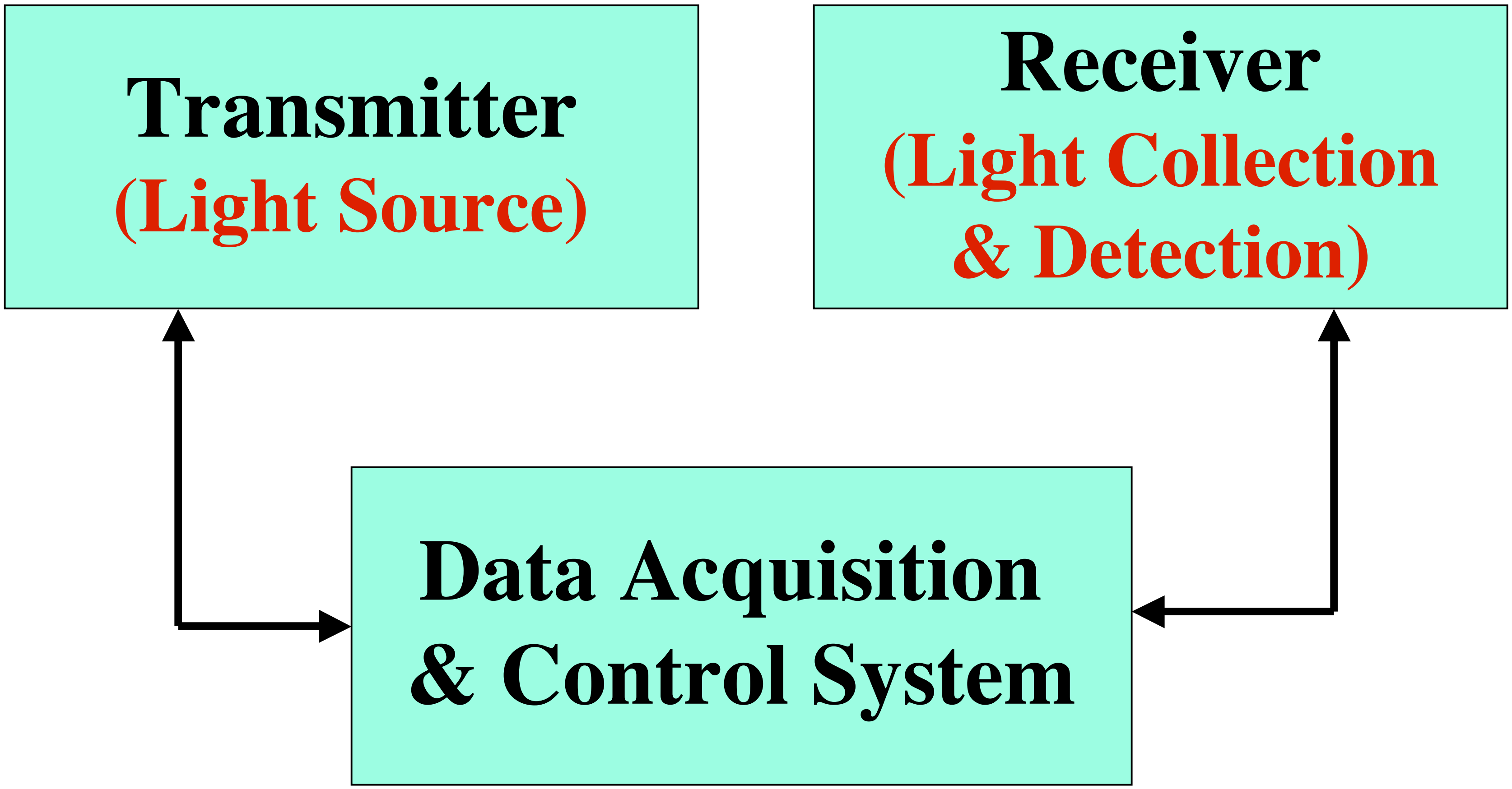
(1) Choice of what type of lidar to use, based on measurement objectives (subject), measurement requirements (accuracy, precision, and resolution) and operation requirements (reliability, stability, operation difficulty), considering physical interactions and processes involved (how well we know the details), potential signal levels, and available hardware, etc.

(2) Choice of what kind of wavelength, bandwidth, and diurnal coverage to use, based on potential return SNR, available hardware, etc.

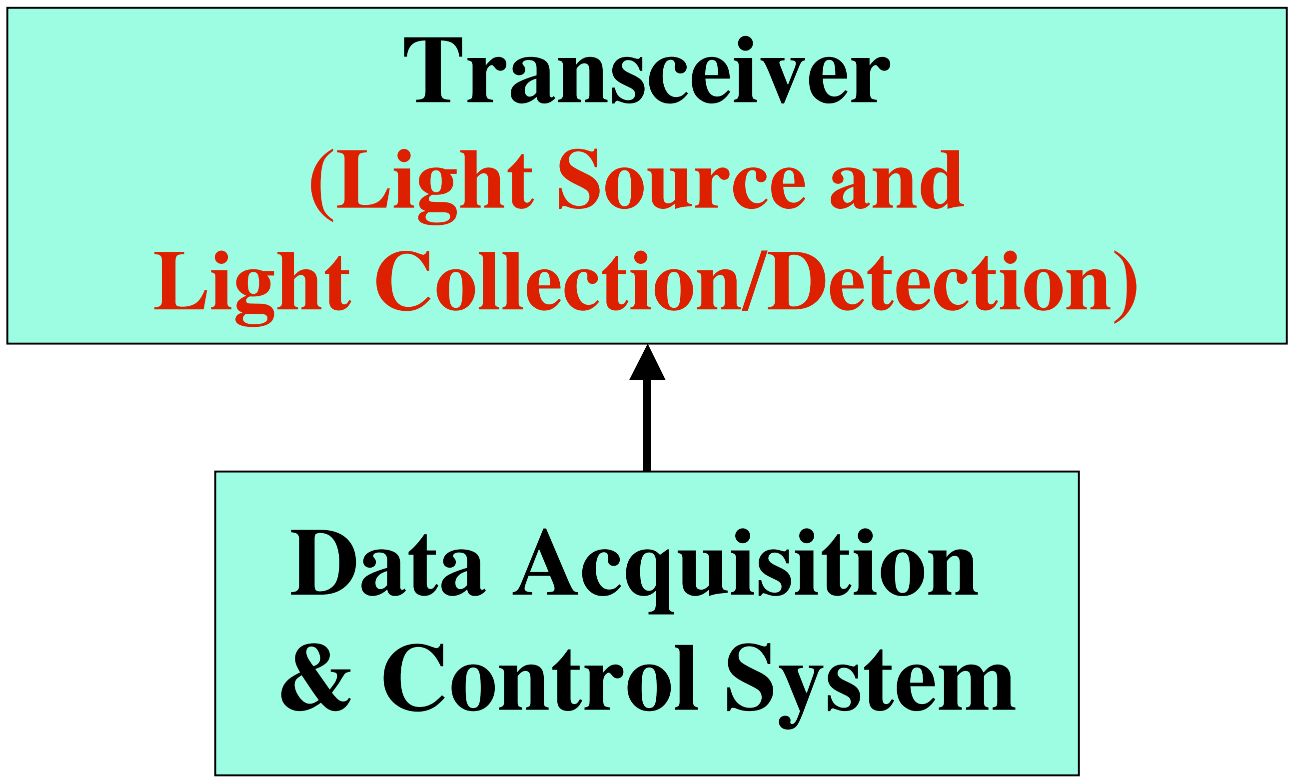
(3) Choice of what kind of laser, frequency control, receiver, detector, and filter to use, based on measurement requirements, available hardware, etc.

(4) Design the lidar system based on above choices, and run simulations or basic tests to predict the lidar performance.

Basic Architecture of LIDAR

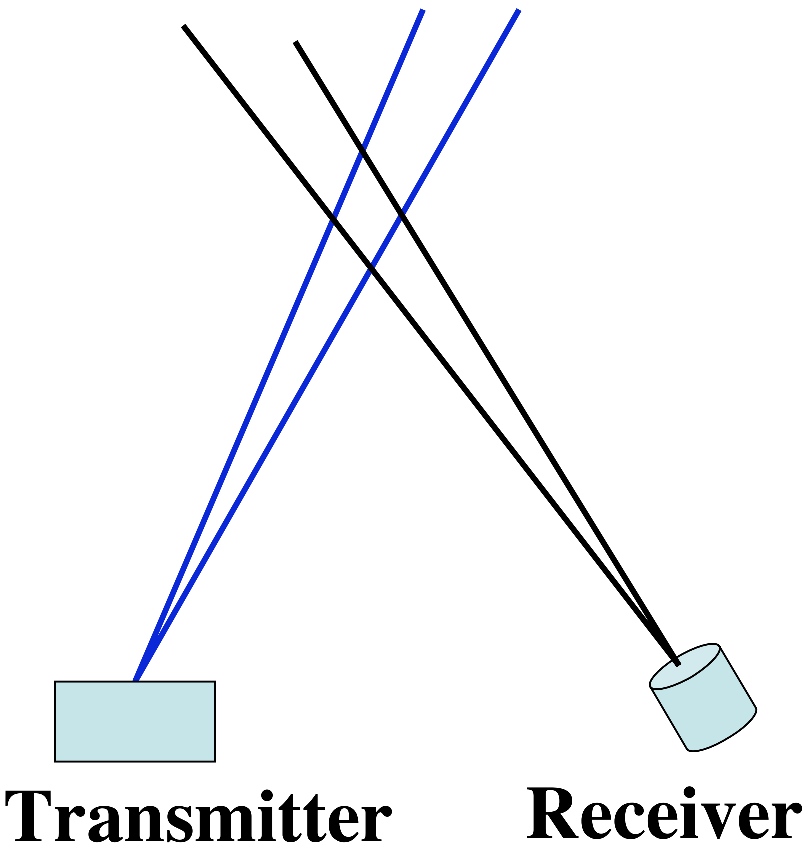


More Architecture of LIDAR

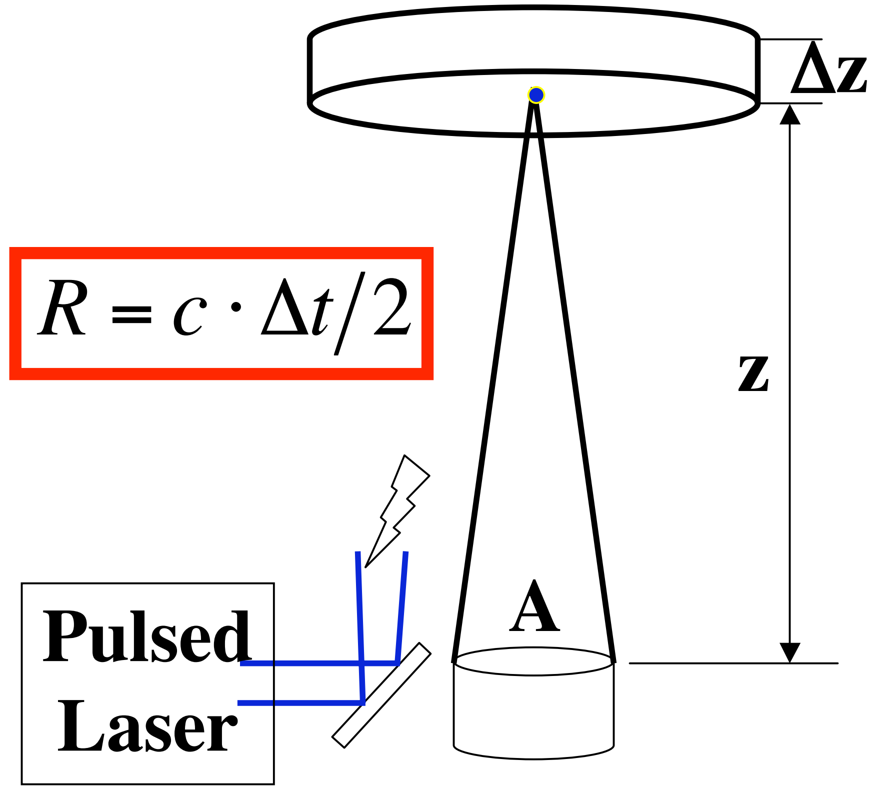


- Transceiver is becoming more and more popular for compact lidars for mobile systems like airborne and spaceborne lidars in the lower atmosphere detection.

Basic Configurations of LIDAR
Bistatic and Monostatic



Bistatic Configuration

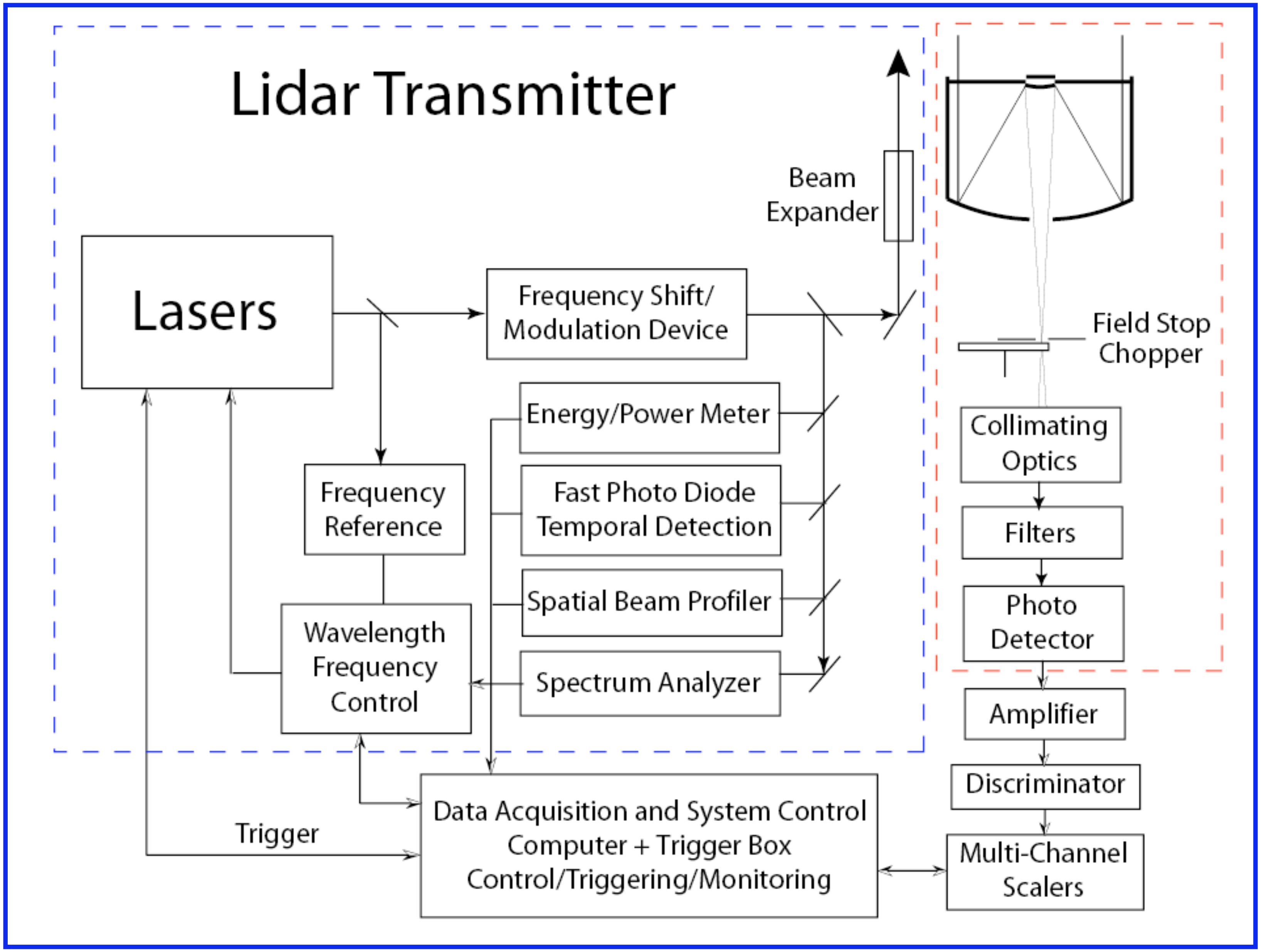


Monostatic Configuration

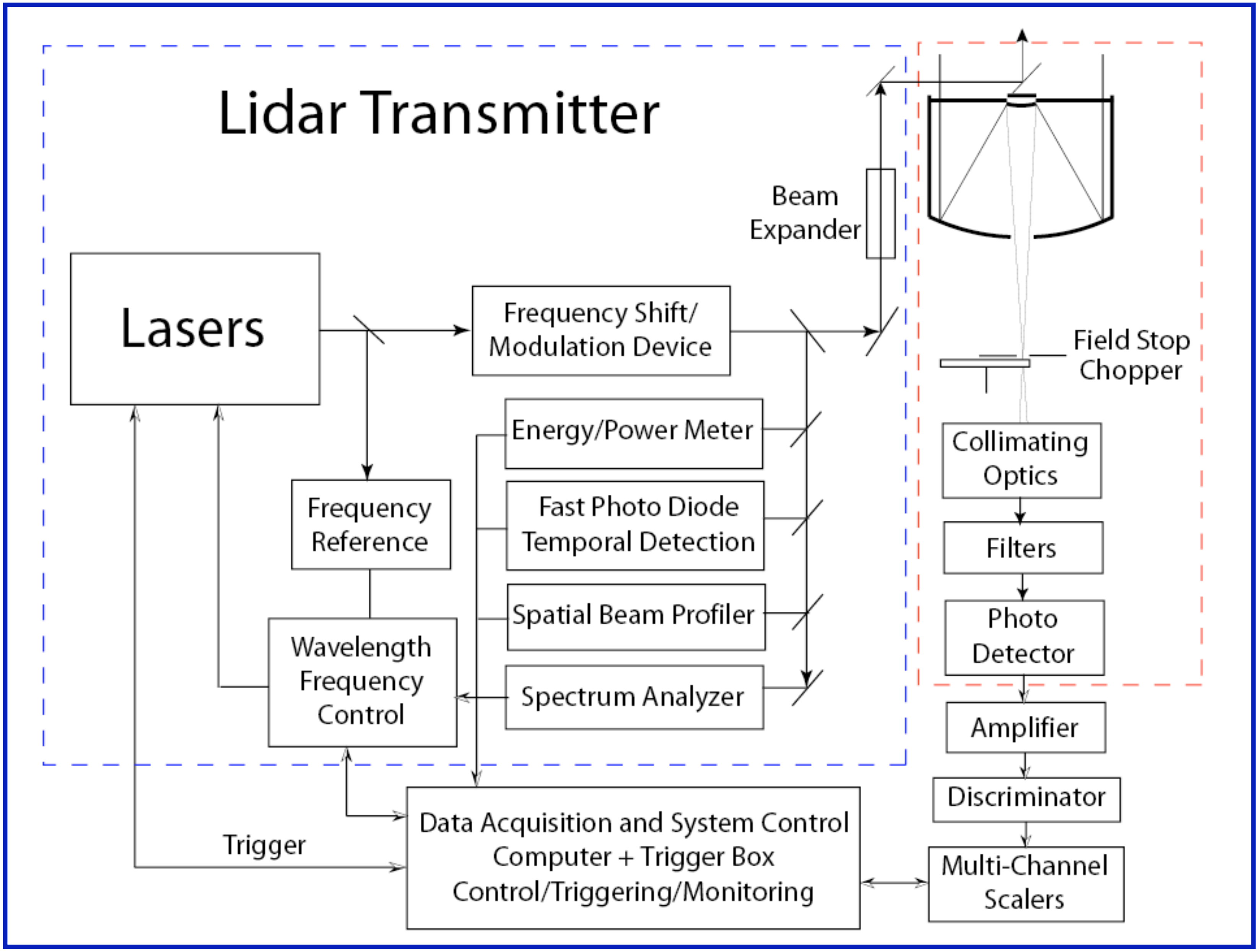
Basic Arrangements of LIDAR
Biaxial and Coaxial

- There are considerable amount of lidars using biaxial arrangements although they have monostatic configurations.
- In the biaxial arrangement, the laser beam and the receiver axis are separated, and 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 that may saturate photo-detector.
- In the coaxial arrangement, the axis of the laser beam is coincident with the axis of the receiver optics.
- Therefore, the receiver can see the laser beam since the zero range bin. (There are debates on this point!)
- 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 to block the near-field scattering.

Example of Biaxial Arrangement



Example of Coaxial Arrangement



Basic Ideas of Lidar Design

- The key of lidar design is the understanding of physical interactions and processes involved, the lidar simulations, and the choices of lidar type, configuration, arrangement, and hardware and software to meet the measurement goals (subject, accuracy, precision, and resolution).
- The basic procedure of lidar design includes

(1) Study of physical interactions, processes, and spectroscopy to find their applications in the lidar remote sensing.

(2) Choice of what type of lidar to use, based on measurement objectives and requirements (subject, accuracy, precision, resolution, reliability, stability, operation difficulty, etc).

(2) Choice of what kind of wavelength, bandwidth, and diurnal coverage to use, based on potential return SNR, available hardware, etc.

(3) Choice of what kind of laser, frequency control, receiver, detector, and filter to use, based on measurement requirements, available hardware, etc.

(4) Design the lidar system based on above choices, and run simulations or basic tests to predict the lidar performance.

Considerations on Lidar Design

- Bistatic or monostatic?
- Biaxial or coaxial?
- Geometrical overlap
- Uplooking or downlooking?
- Care about scattering or only timing?
- Wavelength for transmitter and receiver
- Tunable or not?
- Bandwidth for transmitter and receiver
- Power/energy consideration
- Bin width – pulse duration time, repetition rate
- Nighttime or full diurnal capability?
- Volume, mass, cost, reliability, robustness, operation, etc?

Configuration & Arrangement

- Most modern lidars use monostatic configuration with either biaxial or coaxial arrangement.

- The choice of biaxial or coaxial arrangement is usually determined by the detection range. If near-field range is desired, coaxial arrangement is preferred as it provides full overlap of receiver field-of-view with laser beam. If near-field range is not desired, biaxial arrangement may help prevent the saturation of photo-detector by strong near-field scattering. Scanning capability can also come into play for the selection of biaxial or coaxial.

- Groundbased lidars are usually uplooking, while spaceborne lidars are usually downlooking. Airborne lidars can be either uplooking or downlooking, depending on application needs.

Bandwidth Consideration

- Possible combinations of transmitter and receiver

Transmitter		Receiver	Lidar types
Broadband Transmitter	+	Broadband Receiver	Conventional Mie, Rayleigh, Raman Scatter lidar, Broadband Resonance Fluorescence lidar, Differential Absorption lidar
Narrowband Transmitter	+	Broadband Receiver	Narrowband Resonance Fluorescence Doppler lidar, Differential Absorption lidar
Narrowband Transmitter	+	Narrowband Receiver	Coherent Doppler lidar, Direct-Detection Wind lidar, Rayleigh Doppler lidar. High-Spectral-Resolution lidar
Broadband Transmitter	+	Narrowband Receiver	Potential broadband resonance fluorescence temperature lidar, Potential Rayleigh and Raman temperature lidar

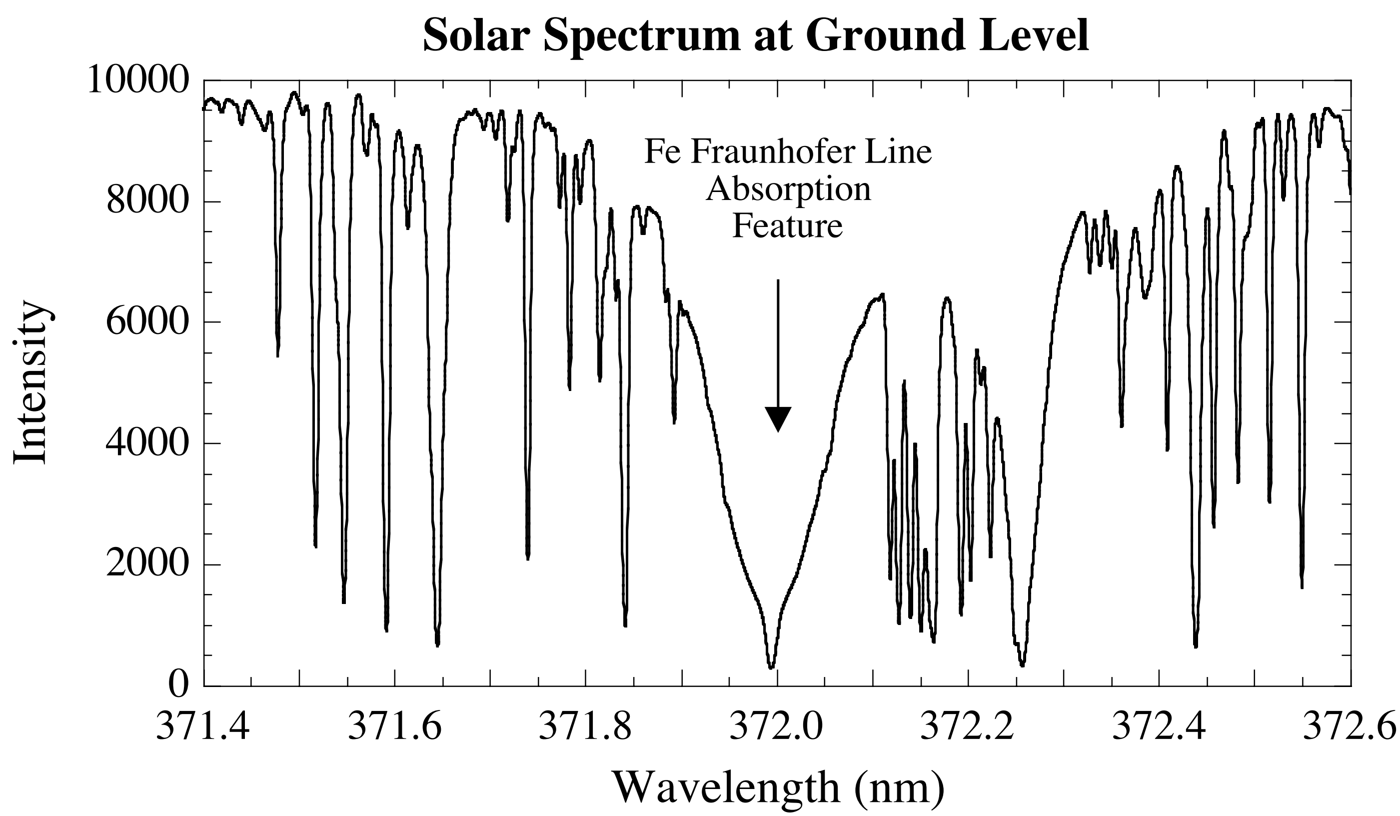
Wavelength Consideration

- Three main factors to determine wavelength selection: First, the detection subject – whether a specific wavelength is required, e.g., Na or Fe atomic transition wavelength, or H_2O differential absorption wavelength. Second, the solar spectrum intensity – low solar radiation is desirable to benefit signal-to-noise ratio (SNR) in daytime. Usually UV solar radiation is lower than visible and IR. Third, transmission of laser light through the medium (e.g., atmosphere or water). In addition, available hardware is often to be the major limitation.

- Fraunhofer lines in solar radiation are a set of several hundred dark lines appearing against the bright background of the continuous solar spectrum and produced by absorption of light by the cooler gases in the Sun's outer atmosphere at frequencies corresponding to the atomic transition frequencies of these gases, such as atomic H, Fe, Na, K, Ca, Mg, Li, etc, or by oxygen of the Earth's atmosphere.

Fraunhofer Lines

- Fraunhofer lines are named after the German physicist Joseph von Fraunhofer (1787-1826).
- Lidar operating at the wavelengths in deep Fraunhofer lines benefits from the lower solar background



http://bass2000.obspm.fr/solar_spect.php?PHPSESSID=b1fb4b5e30286b1698ae5b2f330b3318

Nighttime-Only & Full Diurnal

- This is mainly a consideration on background suppression.
- Even for nighttime-only operation, interference filters are necessary to suppress background (like moon or star or city light) and ensure safe operation of photo detectors.
- Daytime operation needs extra suppression on much stronger solar background, when compared to nighttime-only operation. Not only extra spectral filters with very narrow bandwidth are needed, but also spatial filter or minimized field-of-view is necessary to largely suppress the solar background. Of course, this is also limited by layer saturation or geometrical overlap issues.
- Two major narrowband spectral filters: F-P etalons and atomic/molecular spectral filters (like Faraday filter or iodine filter).

Lidar Types & Hardware

- Conventional Mie, Rayleigh, Raman lidar:
- Broadband resonance fluorescence lidar:
- Narrowband resonance fluorescence lidar:
- Broadband differential absorption lidar:
- Narrowband differential absorption lidar:
- Coherent Doppler lidar:
- Direct-detection wind lidar:
- Rayleigh Doppler:
- High-spectral-resolution lidar:

Transmitter & Receiver

- Depending on application needs and lidar types, there may be several possible combinations of transmitter and receiver to satisfy the same goal. Choose the best one depending on science need, technical feasibility, cost, performance, reliability, etc.
- To choose tunable lasers or not depends on the application needs, e.g., resonance fluorescence and DIAL lidars need to be tunable, while conventional Mie, Rayleigh, and Raman scattering lidars only need fixed wavelengths.
- Selection of pulse energy, repetition rate, and duration time, mainly concerns the SNR, measurement resolution, as well as cost, volume, mass, etc to the entire system.
- Selection of telescope area, type, configuration; detector type, size, quantum efficiency, maximum count rate; filter type, size, bandwidth, transmission, mainly concerns the SNR, measurement resolution, as well as cost, volume, mass, etc to the entire system.

Further Considerations

- Record every pulse or not?
- Bin width or resolution
- Record system parameters or not?
- Timing control

- Mobile or not?
- Need precise beam point control or not?
- Need real time data reduction or not?

- Eye safe or not?
- … …

Summary

- Lidar architecture is the art of lidar instrumentation, concerning the lidar hardware and software, lidar configuration and arrangement, etc.
- Basic lidar architecture consists of lidar transmitter, receiver, and data acquisition and control system. Some have merged transceiver. Basic lidar configurations are bistatic and monostatic configurations. Basic lidar arrangements are biaxial and coaxial arrangements.
- Lidar design is based on the understanding of physical interactions and processes involved, the lidar simulations, and the choices of lidar type, configuration, arrangement, and hardware and software to design a lidar that meets the measurement goals (subject, accuracy, precision, and resolution, reliability, etc).
- Besides basic architecture, configuration, and arrangement, more considerations should be given to the selection of wavelengths (specific request and solar spectrum intensity), bandwidth of transmitter and receiver (application needs - spectral resolved or not, nighttime-only or full diurnal cycle), laser power/energy, repetition rate, pulse duration time, receiver area, detector efficiency and capability, data acquisition software, and system timing and coordination control. Cost, volume, mass, reliability, etc will also be important when come to reality.