Lecture 37. Lidar Architecture and Lidar Design (1)

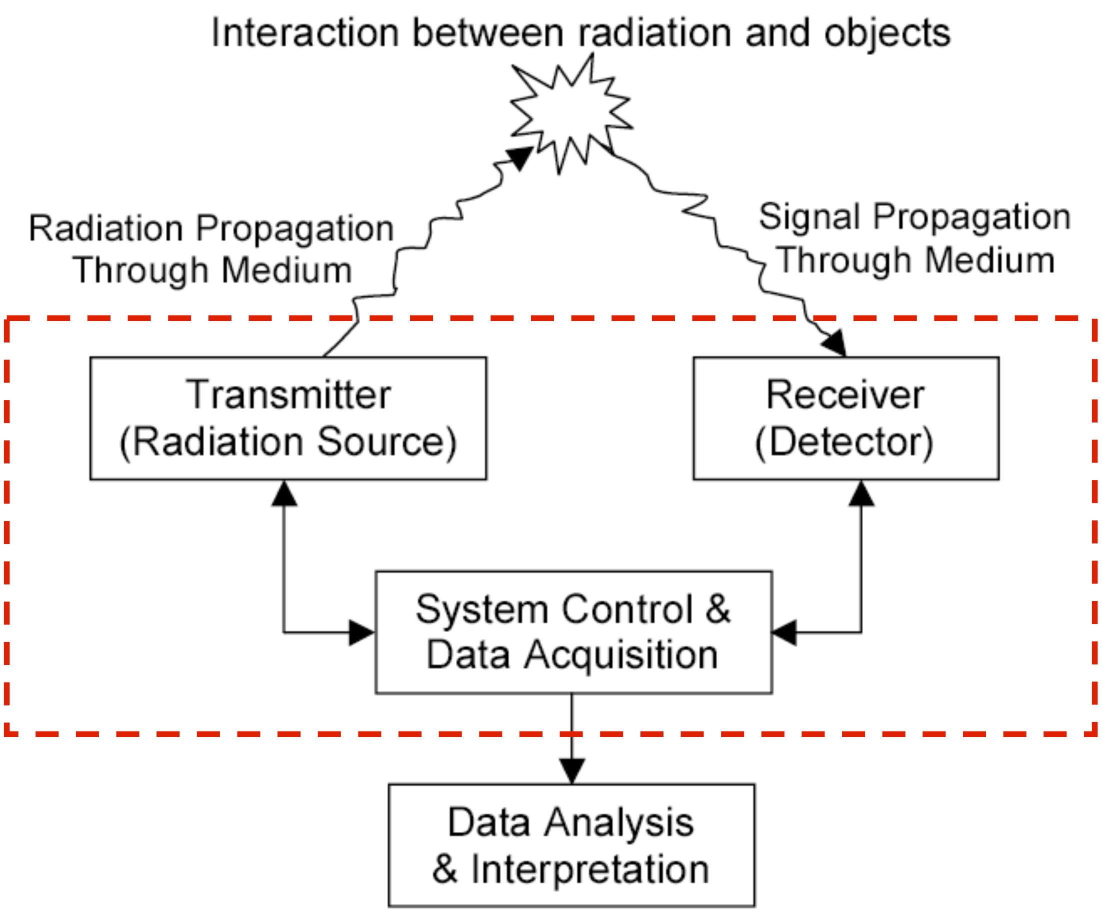
- Introduction
- Lidar Architecture:

  Configurations & Arrangements
- Examples of Real Lidars
- Lidar Design:

  Basic Ideas & Basic Principles
- Summary

Introduction

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



- Refer to Lecture 07 on lidar architecture fundamentals

Introduction

- Lidar design is to design a lidar system that meets our measurement goals. Lidar design is based on our understanding of the physical interactions and processes involved and utilizes the lidar simulations to assess the lidar performance, error and sensitivity analyses.

- Lidar design includes

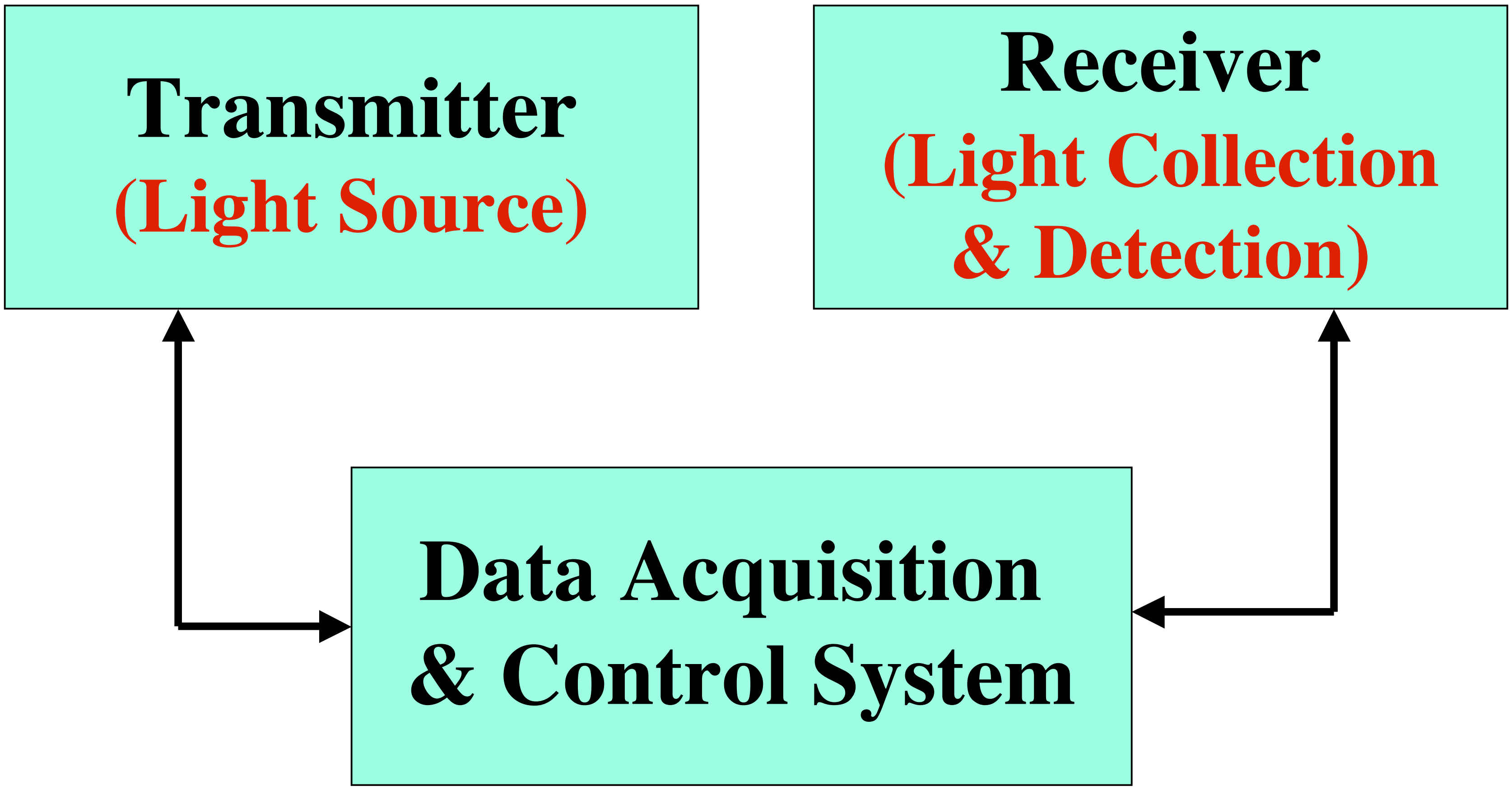
(1) Choice of what type of lidar to use, based on measurement objectives (subject), measurement requirements (accuracy, precision, and resolution) and operation requirements (reliability, stability, operation difficulty), considering physical interactions and processes involved (how well we know the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

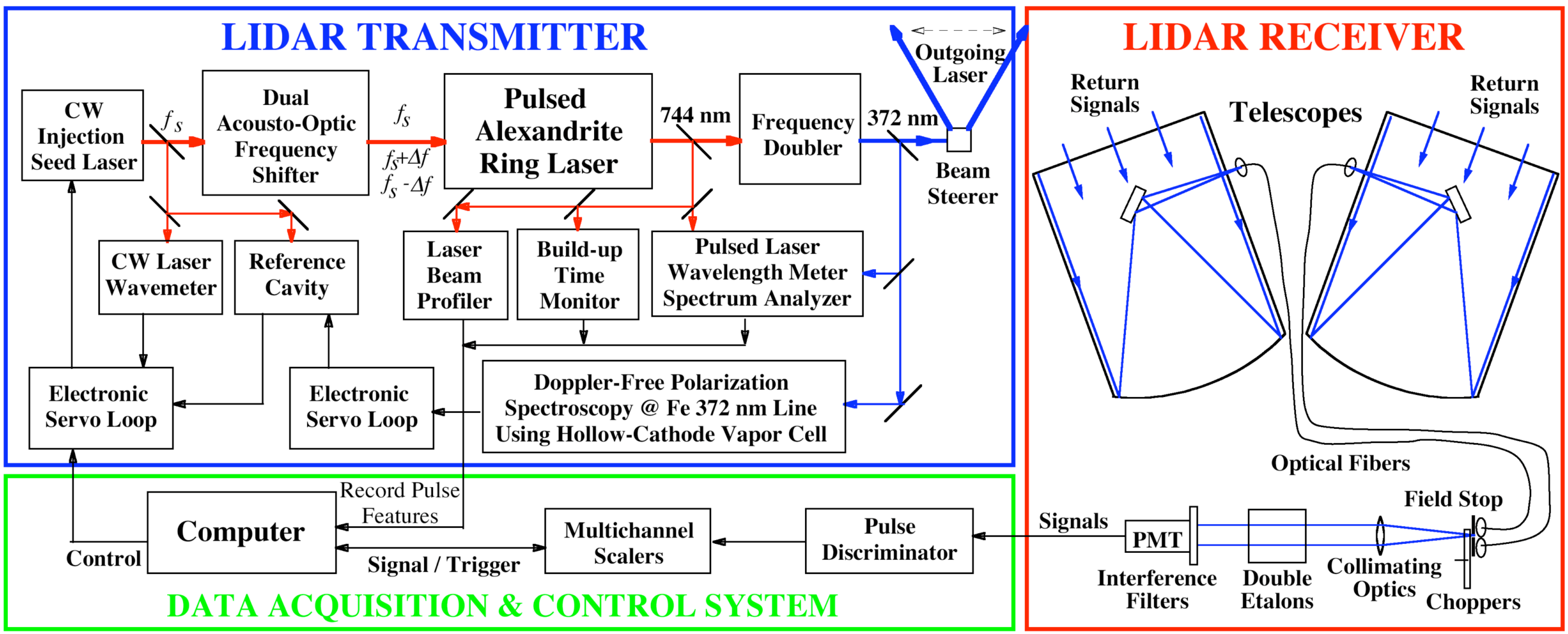
(3) Choice of what kind of laser, frequency control, receiver, filter, detector, DAQ to use, based on measurement requirements, available hardware, etc.

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

LIDAR Architecture



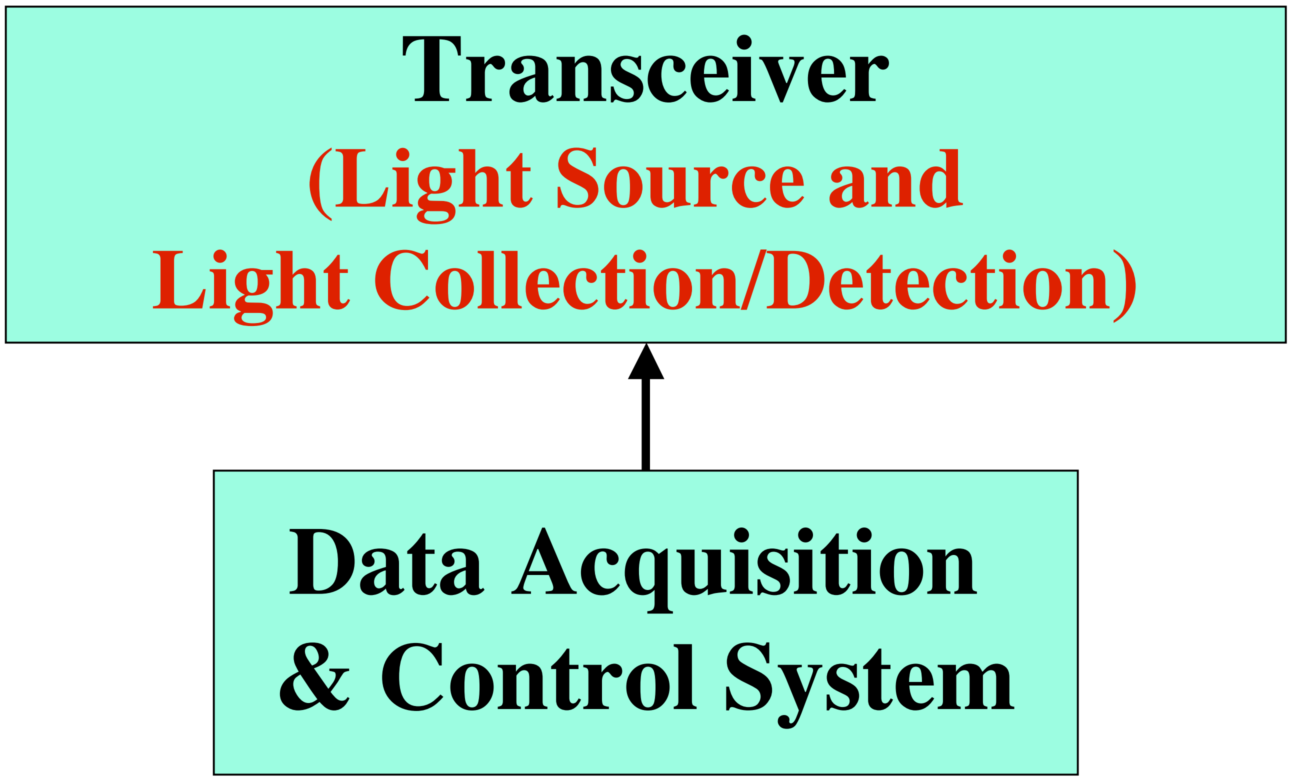
MRI LIDAR Architecture



- Functions for each sub-system:

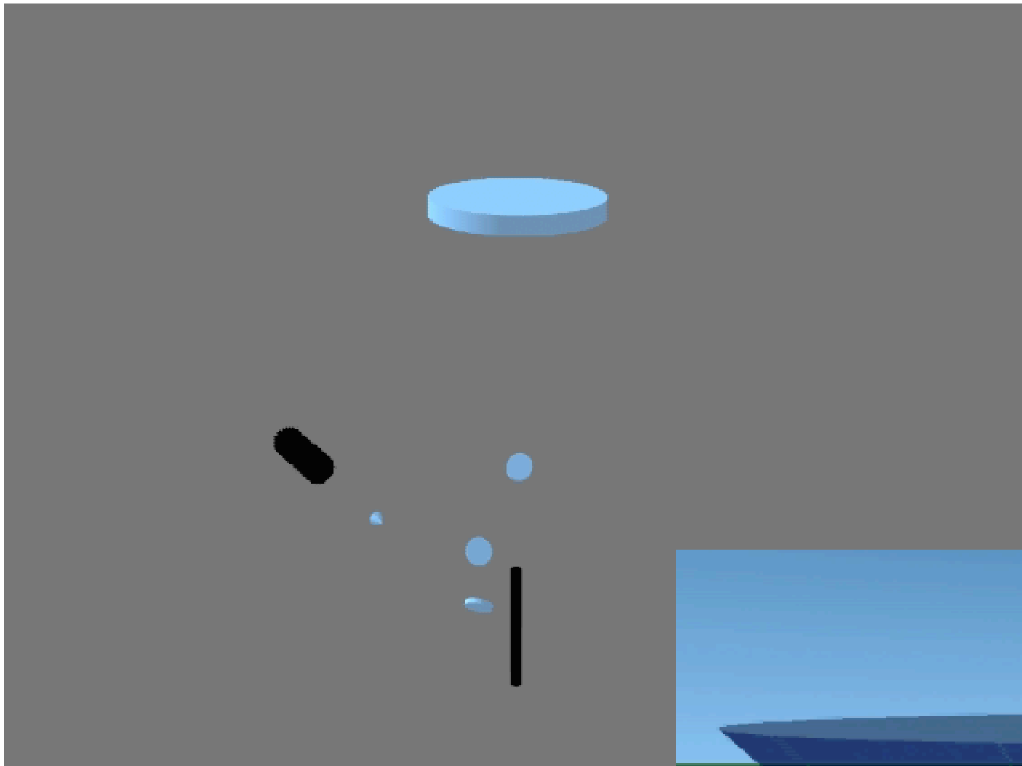
  transmitter, receiver, DAQ & control

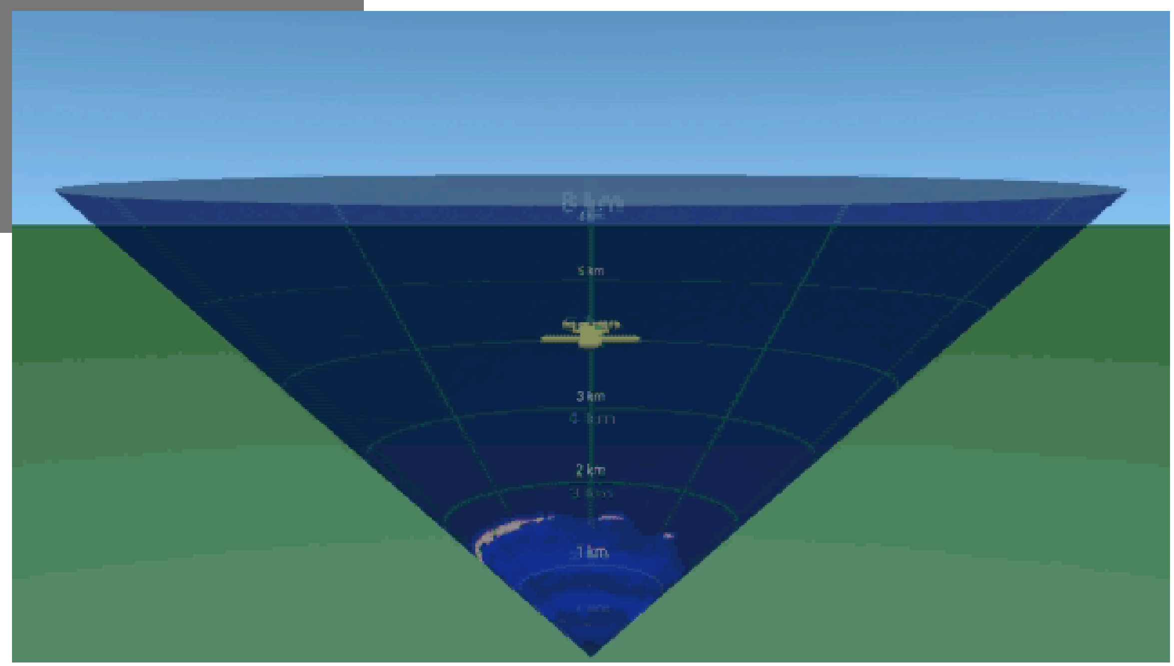
More Architecture of LIDAR



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

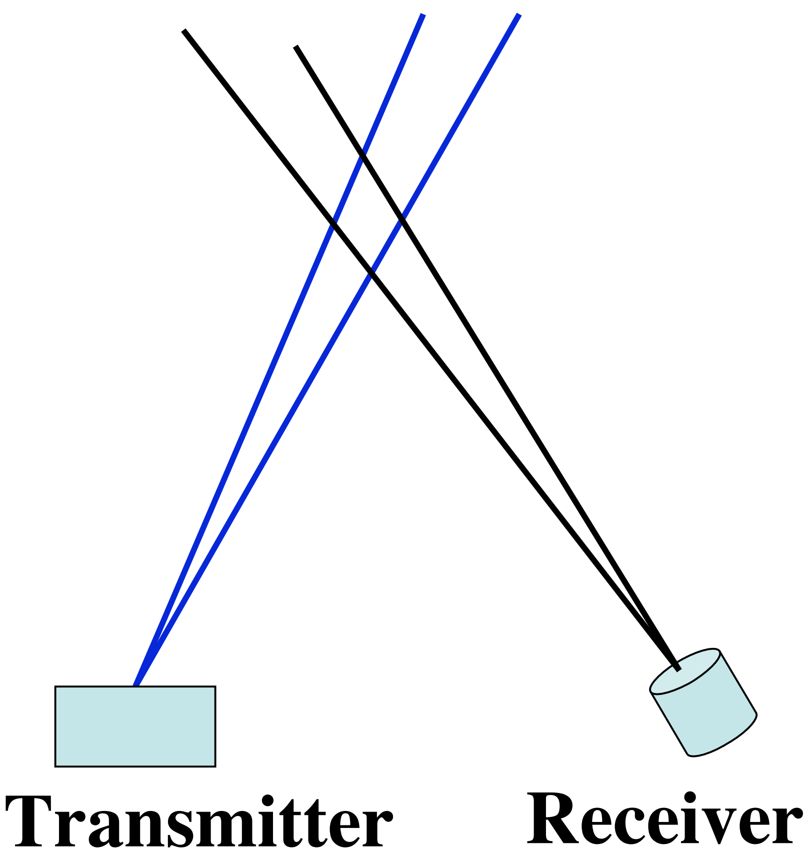
Lidar with Holographic Optical Element



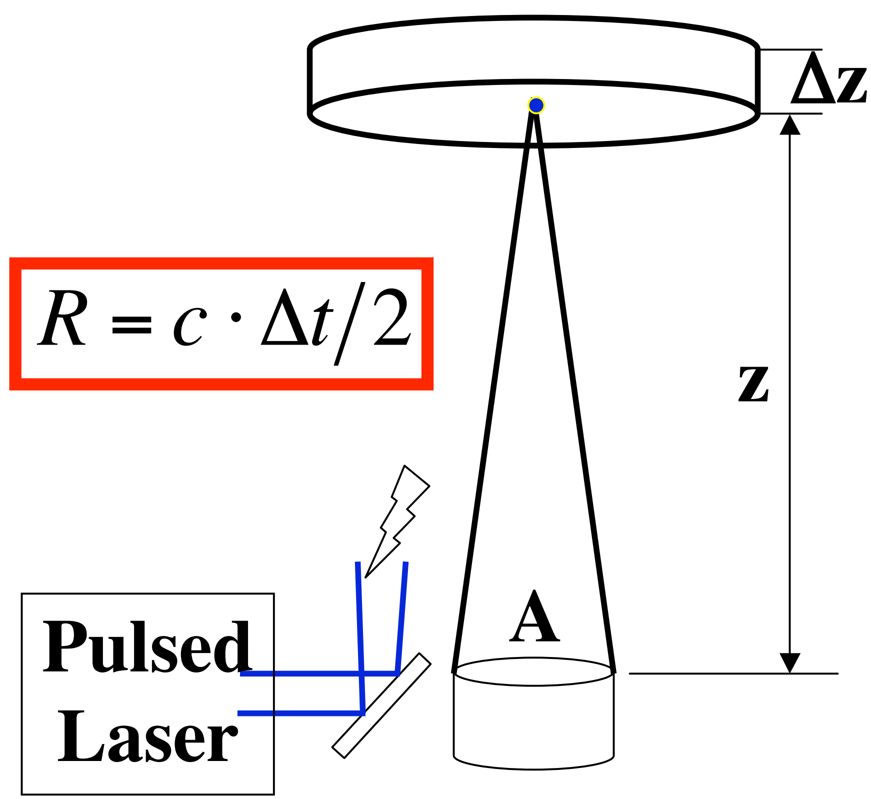


Courtesy of
Geary Schwemmer

LIDAR Configurations:
Bistatic and Monostatic



Bistatic Configuration

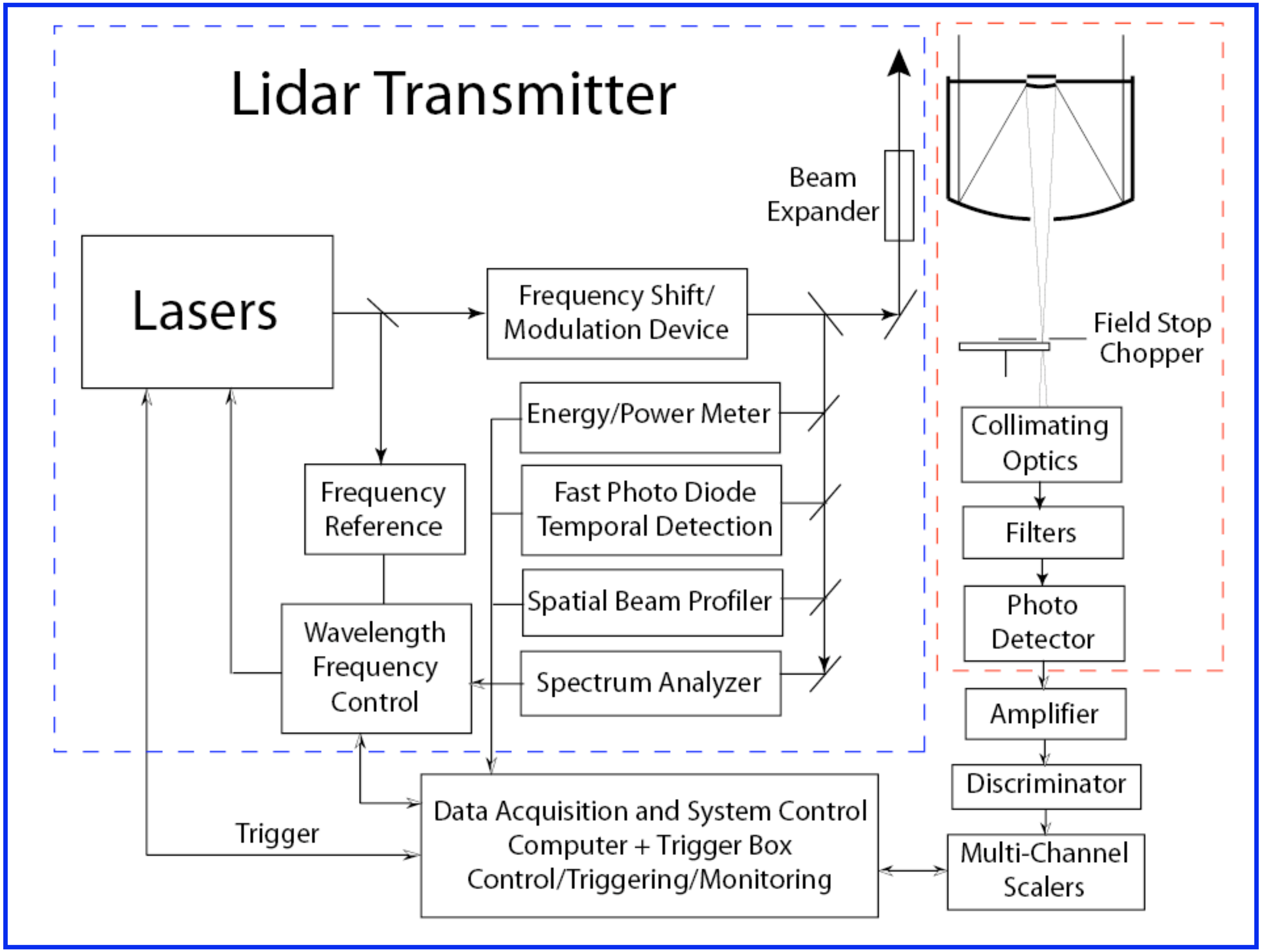


Monostatic Configuration

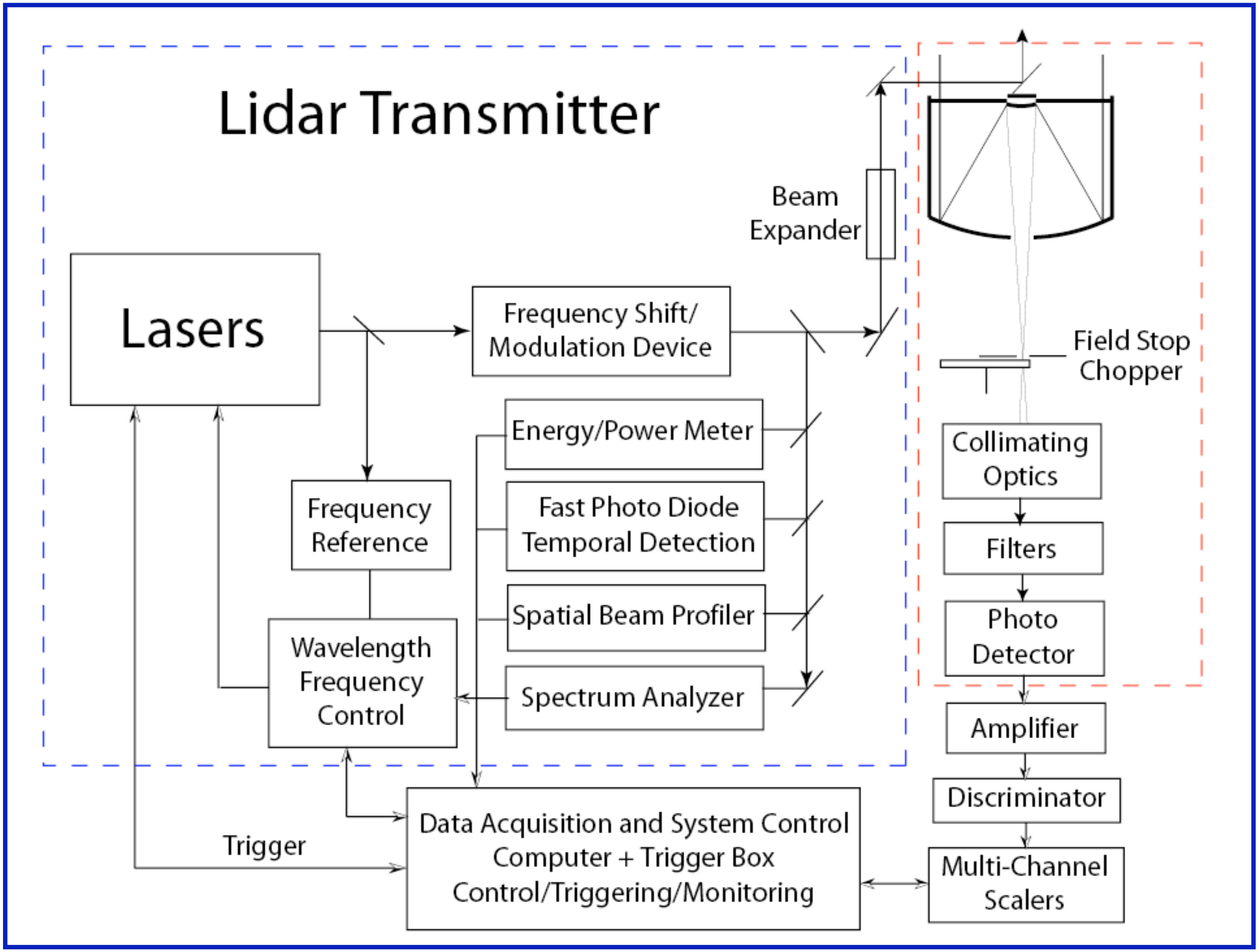
LIDAR Arrangements: Biaxial and Coaxial

- 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



Examples of Real Lidars

- CSU and UIUC dye-laser-based Na Doppler lidar

Sophisticated laser spectroscopy, transmitter and day-time receiver

- Japanese solid-state-laser-based Na Doppler lidar

Mobile transmitter

- Arecibo K Doppler lidar

Alexandrite ring laser technology

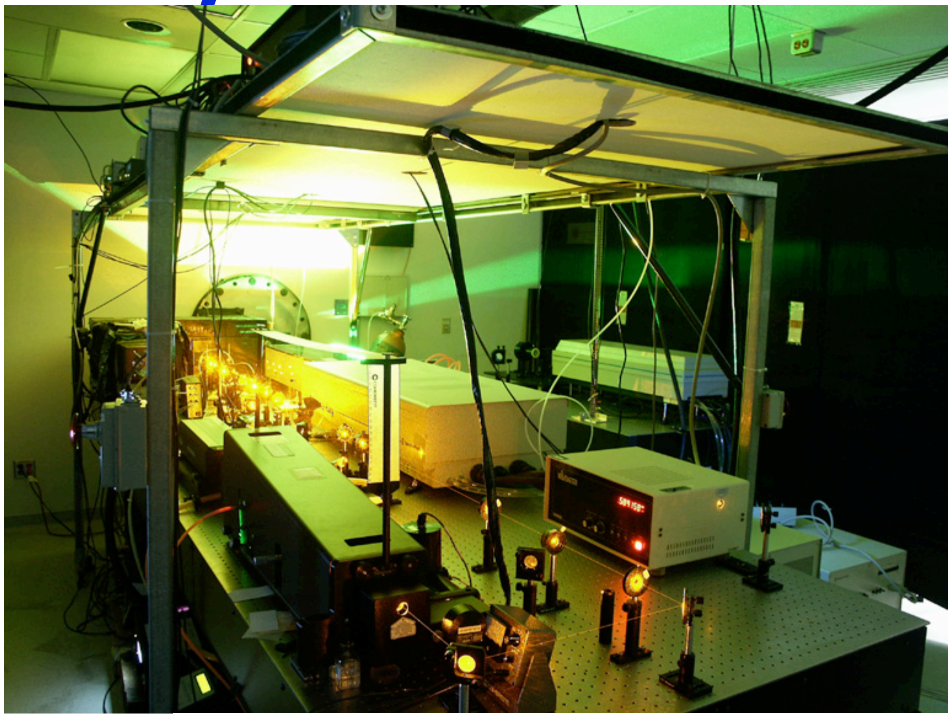
- ALOMAR (IAP) Rayleigh/Mie/Raman lidar

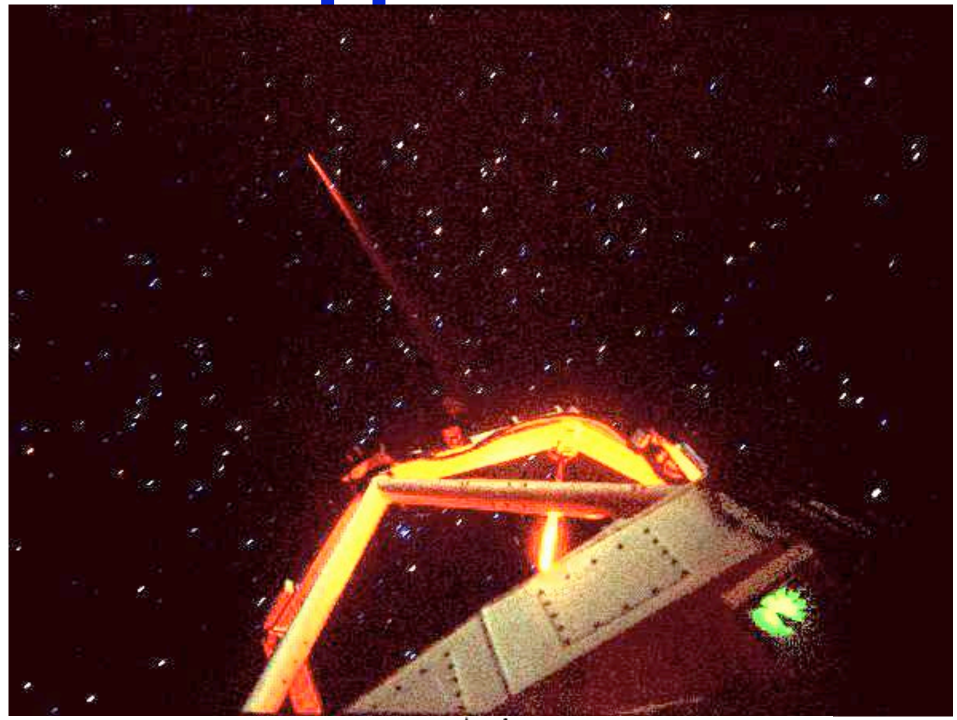
Sophisticated transmitter and receiver

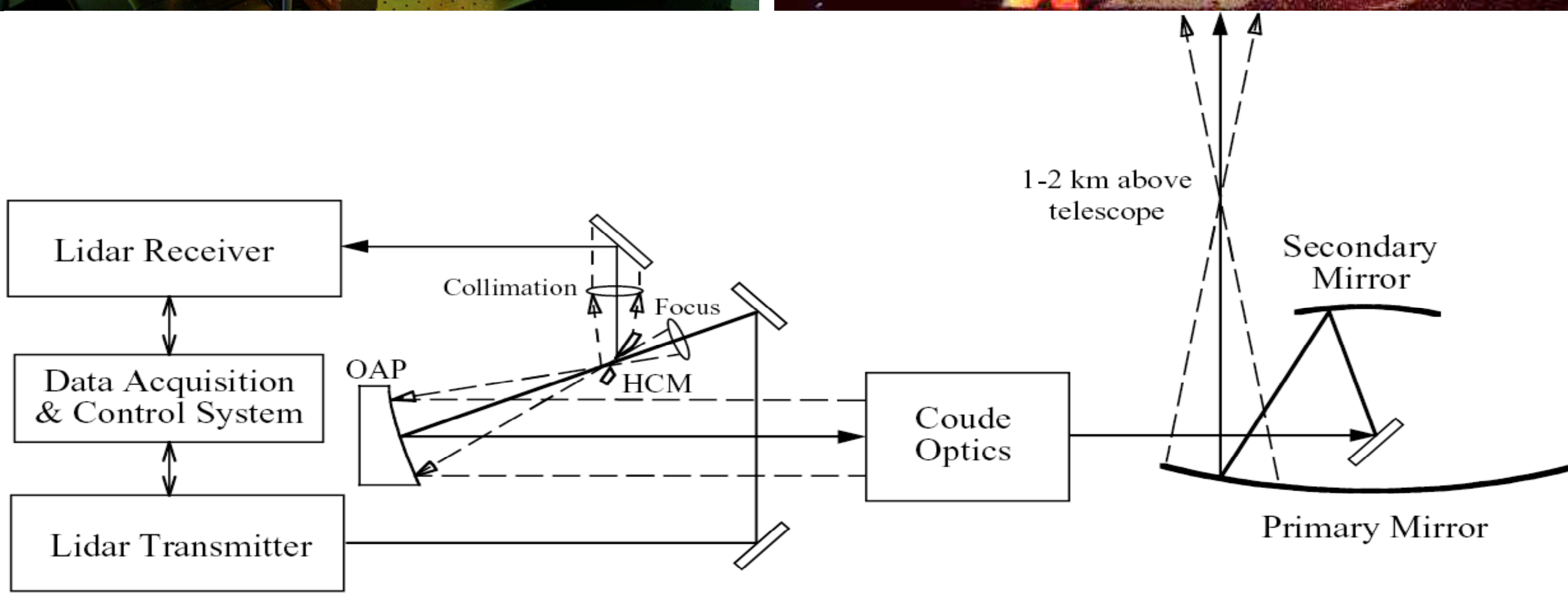
- University of Wisconsin high-spectral resolution lidar

Sophisticated transmitter and receiver

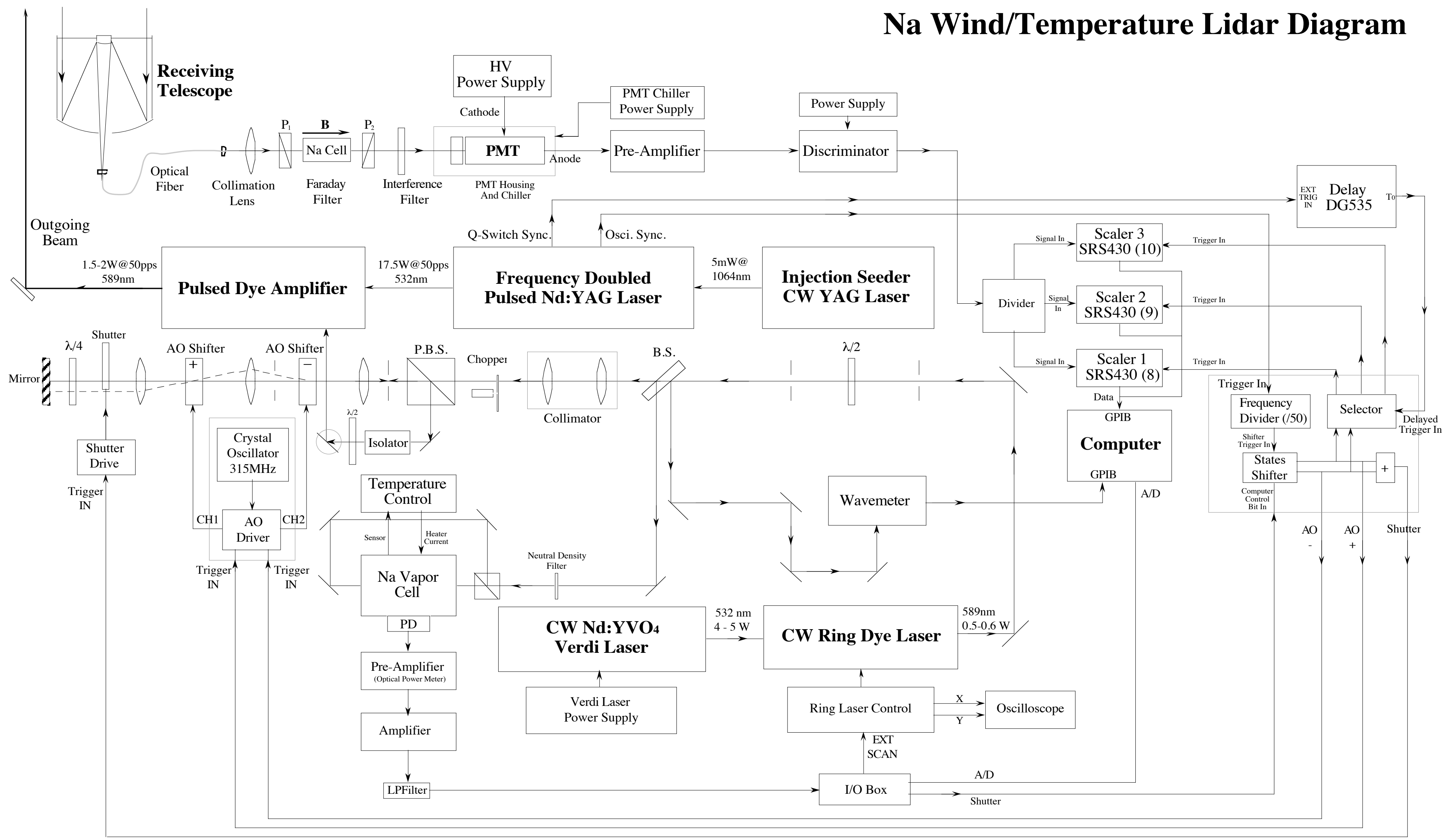
Dye-Laser-Based Na Doppler Lidar





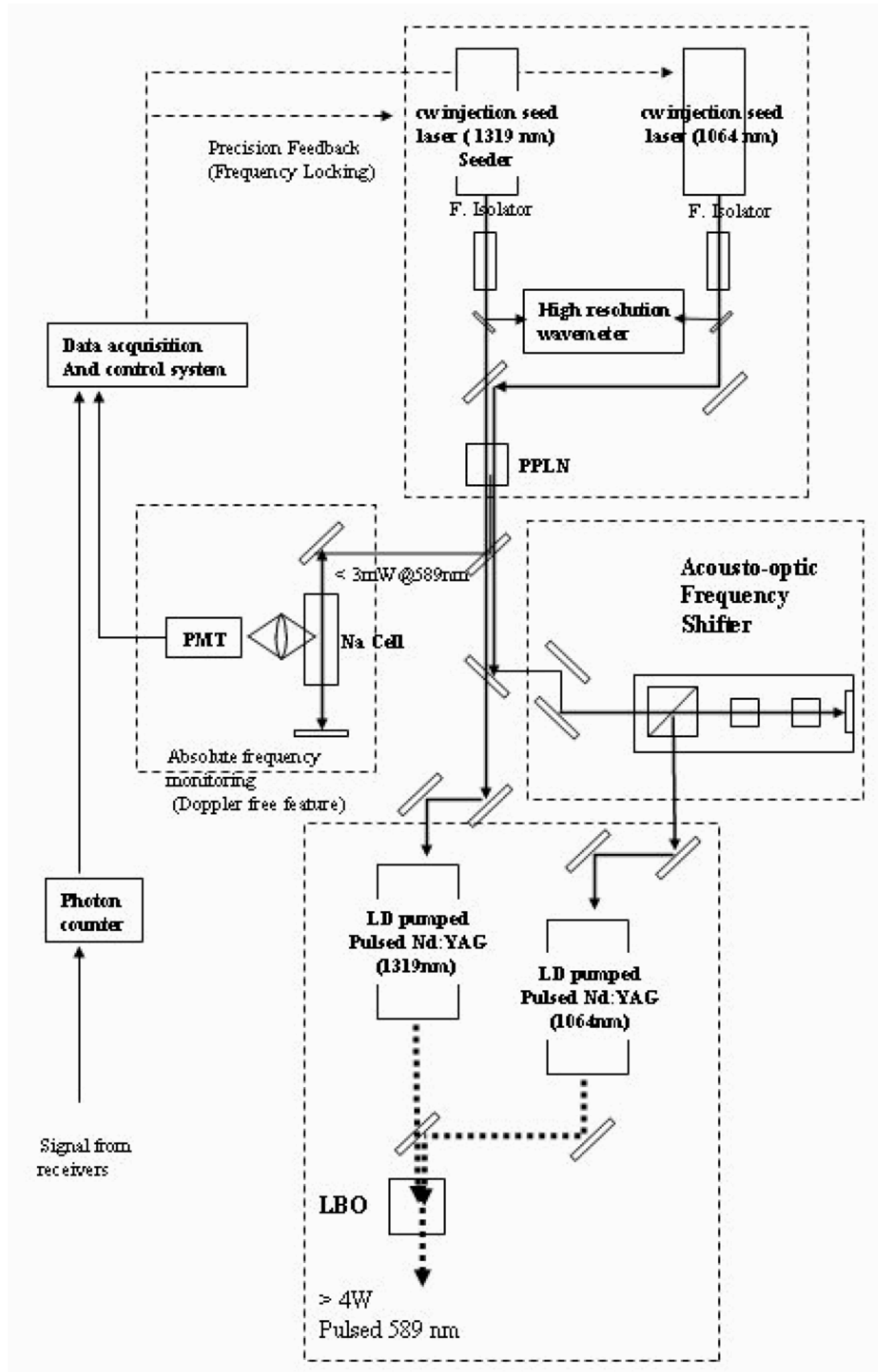


Na Wind and Temperature Lidar

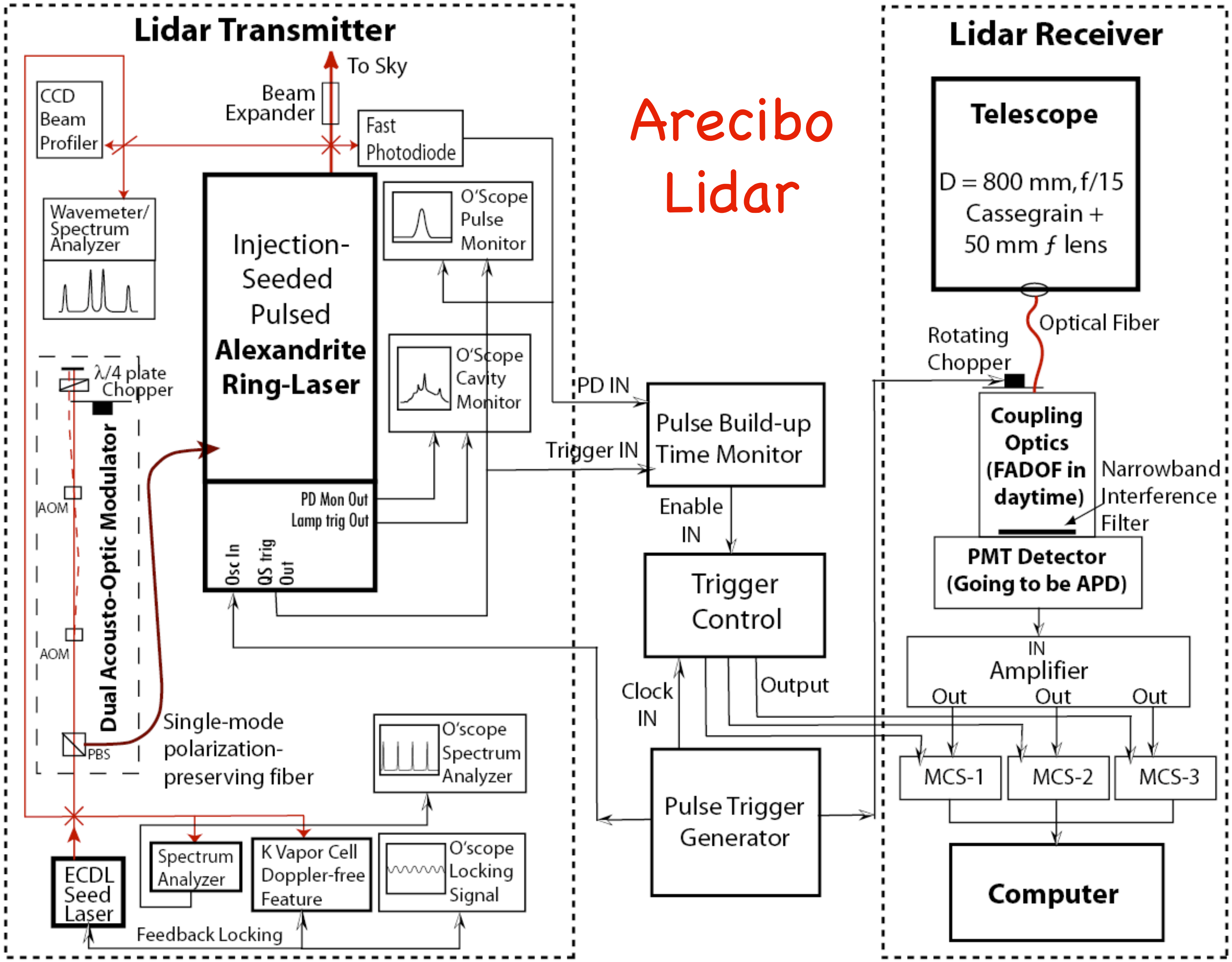


Solid-State Na Doppler Lidar Based on Diode-Laser-Pumped Nd:YAG Lasers

[Kawahara et al., ILRC, 2008]

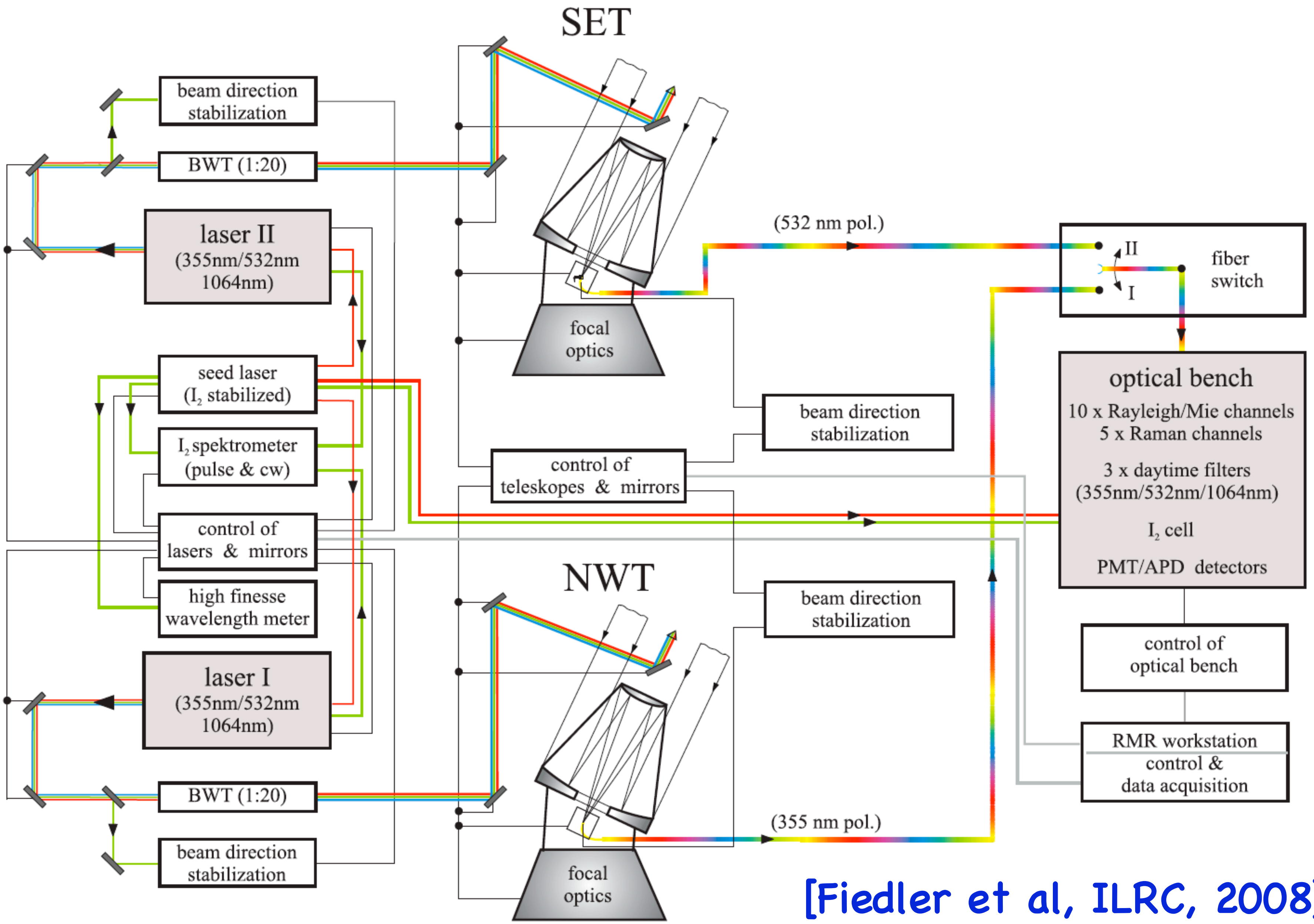


K Doppler Lidar Instrumentation



[Friedman and Chu, JGR, 2007]

ALOMAR RMR Lidar @ Andoya



[Fiedler et al, ILRC, 2008]

ALOMAR RMR Lidar Transmitter

- The ALOMAR RMR lidar is optimized for maximum receiving signal to measure atmospheric temperatures, winds and aerosols simultaneously. Therefore it is a complex twin-lidar system consisting of two power lasers, two receiving telescopes, and one optical bench for spectral separation and filtering of the light received from the atmosphere.

- The power lasers are pulsed Nd:YAG lasers emitting the fundamental (1064 nm), second (532 nm), and third (355 nm) harmonic wavelengths simultaneously. Both power lasers are seeded by a single external cw laser, which is frequency stabilized to iodine absorption spectroscopy, to generate laser pulses of high spectral stability. Using beam direction stabilization systems the laser beams are guided into beam widening telescopes for reduction of the beam divergence by a factor of 20. After that the beams with 20-cm diameters are guided by a second set of beam direction stabilization systems into the atmosphere.

- For collection of the backscattered light two quasi-Cassegrain telescopes with 1.8-m primarymirrors are used which can be tilted up to 30◦ off-zenith while covering an azimuth range of 90◦ each. They are installed in such a way that one telescope is able to access the north-to-west quadrant (NWT), the other one the south-to-east quadrant (SET). The light received from the atmosphere is guided by optical fibers to the input of the optical bench. For investigations of the polarization characteristics of the light in the visible and ultraviolet spectral range, polarizers are integrated in the focal optics of the receiving telescopes.

ALOMAR RMR Lidar Receivers

- At the input of the optical bench a rotating segmented mirror (fiber switch) is used to feed the light of both telescopes synchronized to the laser pulses into the single set of receiving optics.
- In the following, the light is separated and filtered by spectral range and intensity to produce 15 different channels:
- 1064 nm (two channels, Rayleigh-/Mie-scattering on air molecules & aerosols),
- 532 nm (three channels, Rayleigh-/Mie-scattering on air molecules & aerosols),
- 355 nm (three channels, Rayleigh-/Mie-scattering on air molecules & aerosols),
- 608 nm (two channels, N2 vibrational Raman-scattering excited by 532 nm),
- 387 nm (one channel, N2 vibrational Raman scattering excited by 355 nm),
- 530.4 nm and 529.1 nm (two channels, N2 + O2 rotational Raman-scattering excited by 532 nm).
- Two additional channels at 532 nm are placed behind an iodine absorption cell for analyzing the Doppler shift.
- Using photomultipliers (PMT) and avalanche photodiodes (APD) the light is converted into electrical signals which are altitude resolved by counters and processed and stored on a computer.

[Fiedler et al, ILRC, 2008]

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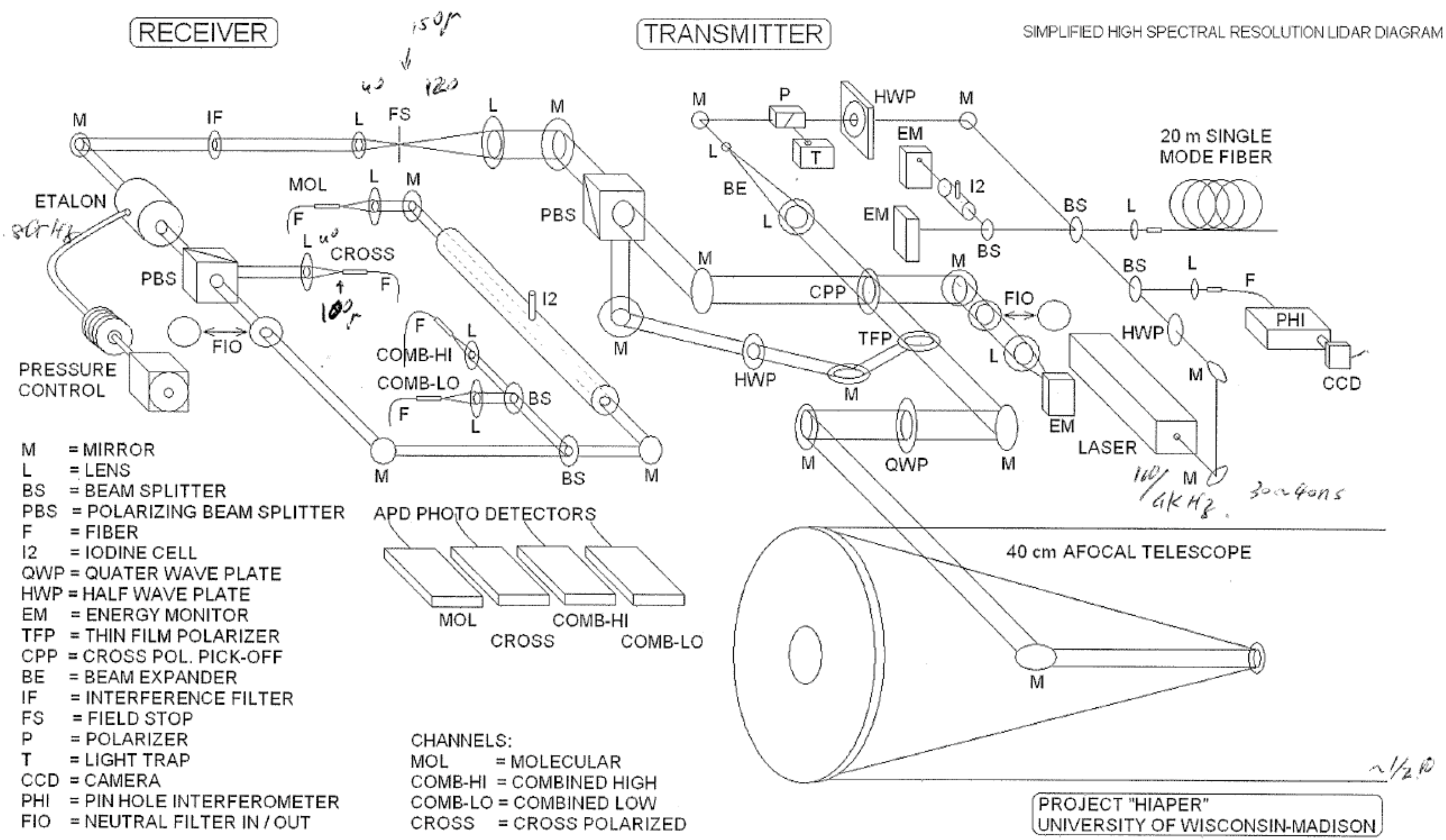

Courtesy of Dr. Edwin E. Eloranta, University of Wisconsin

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, hardware and software to meet the measurement goals (subject, accuracy, precision, resolution, coverage).
- 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, filter, and DAQ to use, based on measurement requirements, available hardware, etc.

(4) Design the lidar system based on above choices, and run simulations or basic tests or prototypes 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
- Frequency stability 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?

Further Considerations

- Doppler shift and how much?

- 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.
- 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.
- Learning existing lidar systems is a good approach to understand the lidar architecture in depth, especially experiences and issues. It will help the design of a new lidar system.
- Lidar design is based on the understanding of physical interactions and processes involved, the lidar simulations, and the choices of lidar type, configuration, arrangement, hardware and software to design a lidar that meets the measurement goals (subject, accuracy, precision, resolution, reliability, coverage, etc).