https://ntrs.nasa.gov/search.jsp?R=20170010648 2020-05-09T23:06:16+00:00Z

A Methane Lidar for Greenhouse Gas Measurements

Haris Riris (GSFC), Kenji Numata(GSFC), Stewart Wu(GSFC), Brayler Gonzalez (GSFC), Mike Rodriguez (Sigma Space), Molly Fahey (GSFC), Randy (Stephan) Kawa (GSFC), Stan Scott (GSFC), Anthony Yu (GSFC), Mark Stephen (GSFC), Bill Hasselbrack (Sigma Space), Jianping Mao (UMD)

ESTF June 2017

Pasadena, CA

Supported by:

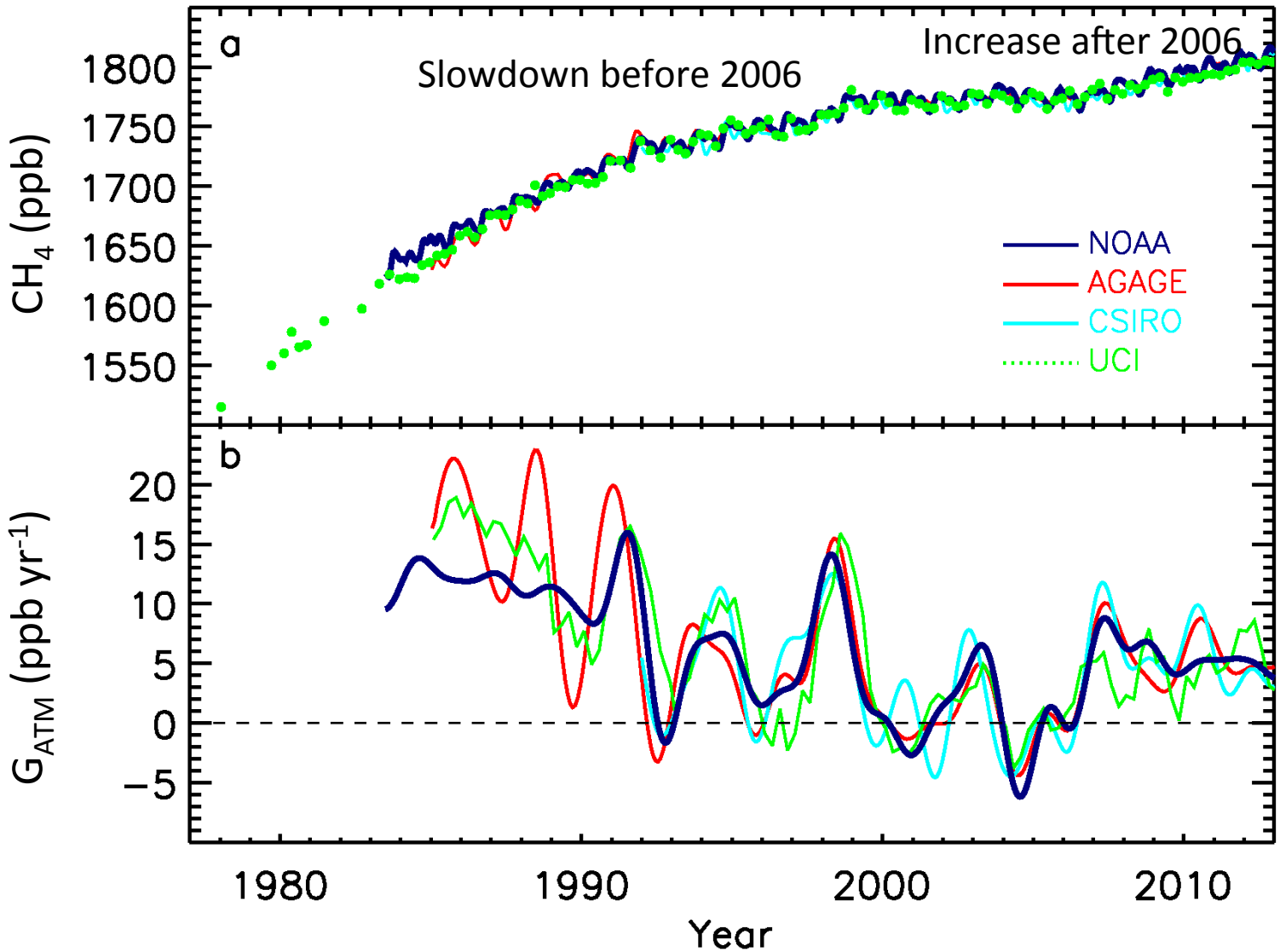
NASA ESTO ACT and GSFC IRAD programs

Haris.Riris@nasa.gov

Outline

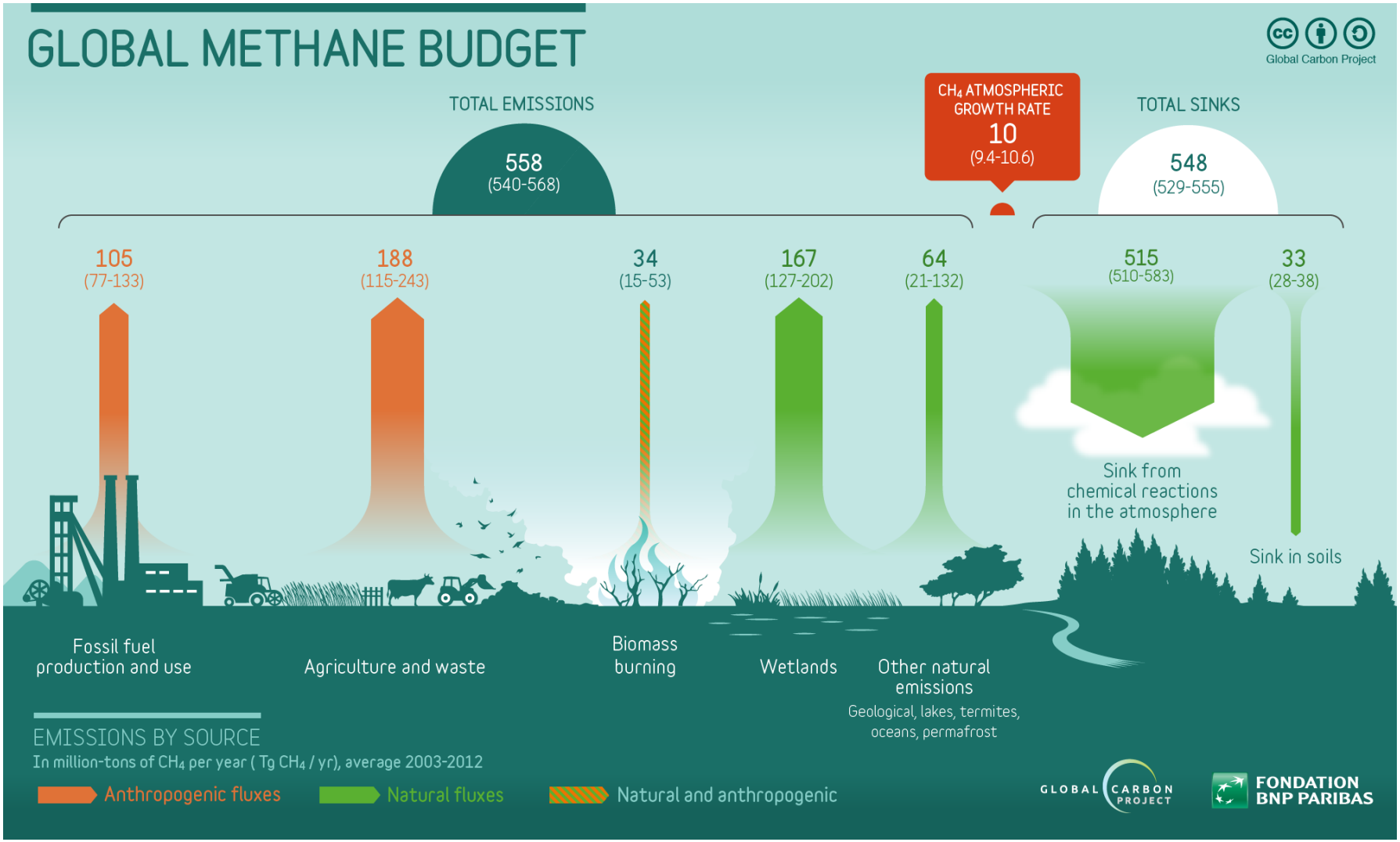
- Motivation - Why measure Methane?
- GSFC Measurement Approach
- Airborne Campaign Results
- Current Status
- Summary

Why measure Methane?



Source: Saunois et al. 2016

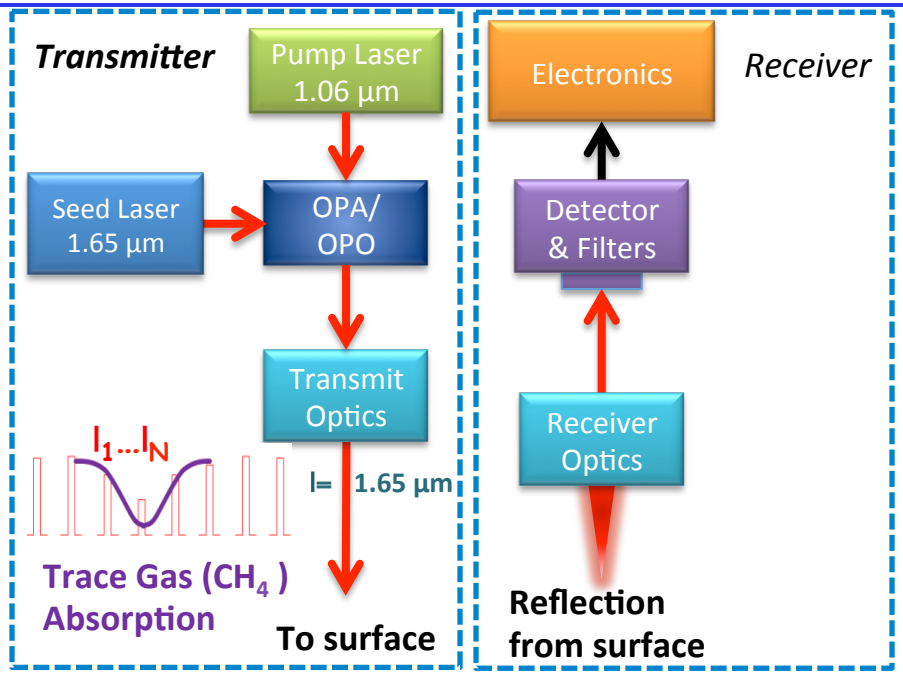
Global Methane Budget

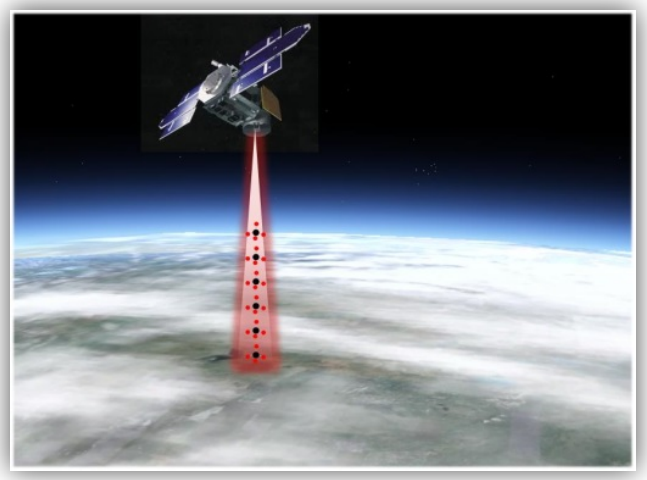


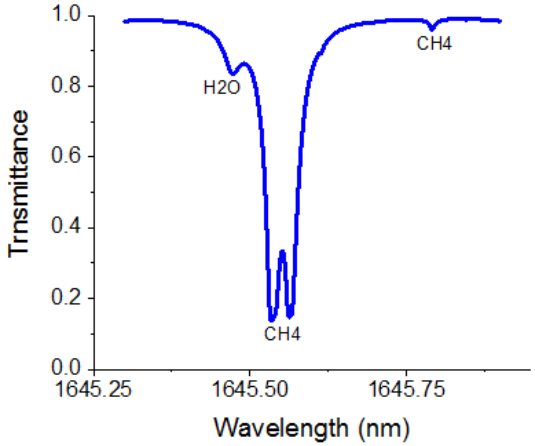
Source: http://www.globalcarbonatlas.org

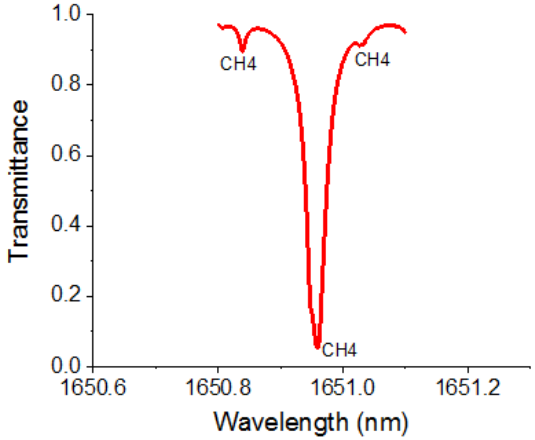
GSFC CH_4 IPDA Lidar

- ***Transmitter (Laser) technology***
  - Current (optimum) Wavelength for CH_4 Earth Detection: ~1.64-1.66 µm
  - Optical Parametric Oscillators (OPO) and Optical Parametric Amplifiers (OPA) are the "baseline" solutions for the transmitter.
  - Other options (Er:YAG and Er:YGG) now possible.
- ***Receiver (Detector) Technology***
  - DRS e-APD

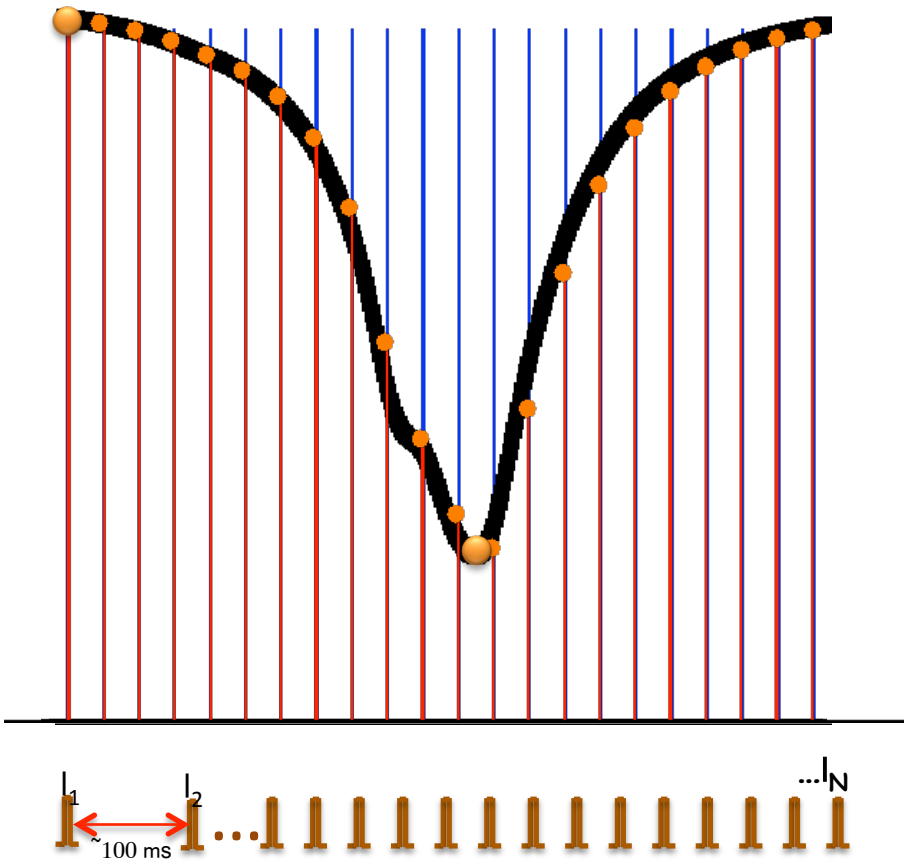






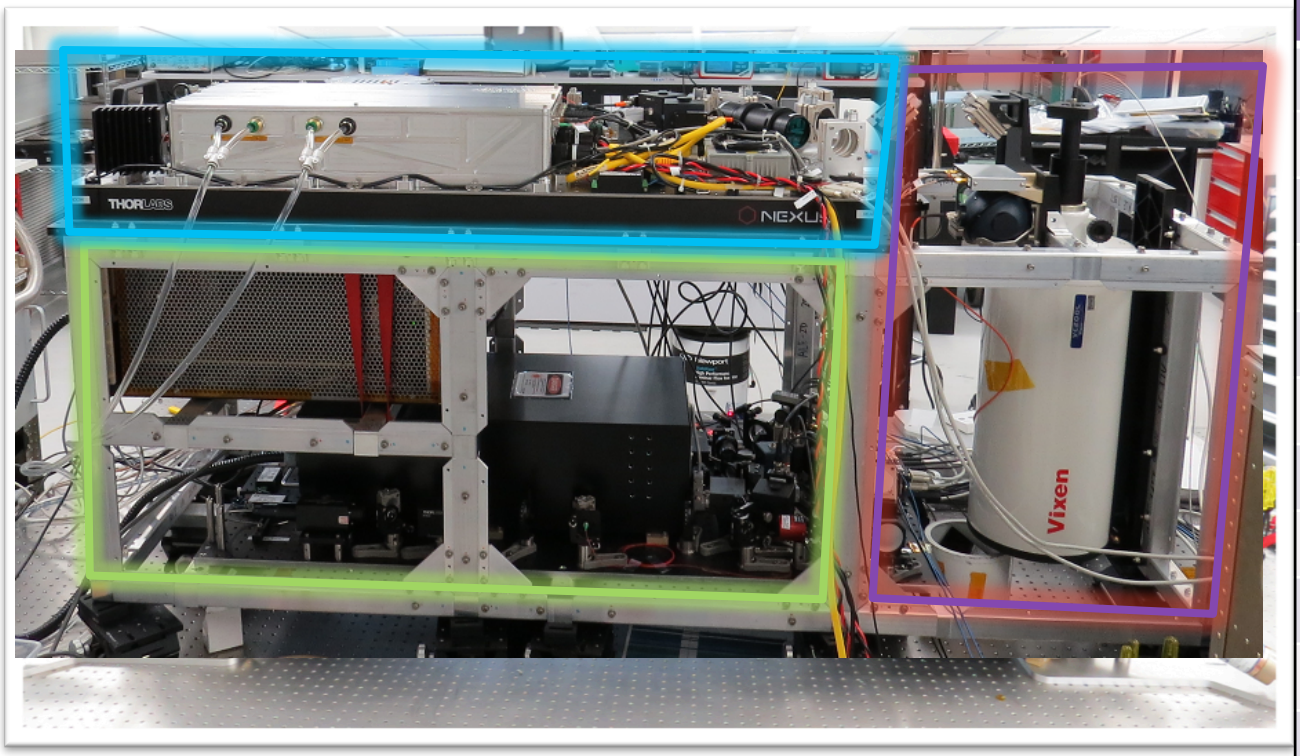


Why use multiple wavelengths?



"Ideal" Instrument – has only random noise which can be averaged indefinitely.
Two wavelengths can adequately sample the lineshape. Averaging always helps.
Real Instrument – has random and non-random noise which can NOT always be averaged.
Two wavelengths can NOT adequately sample the lineshape or reduce biases.

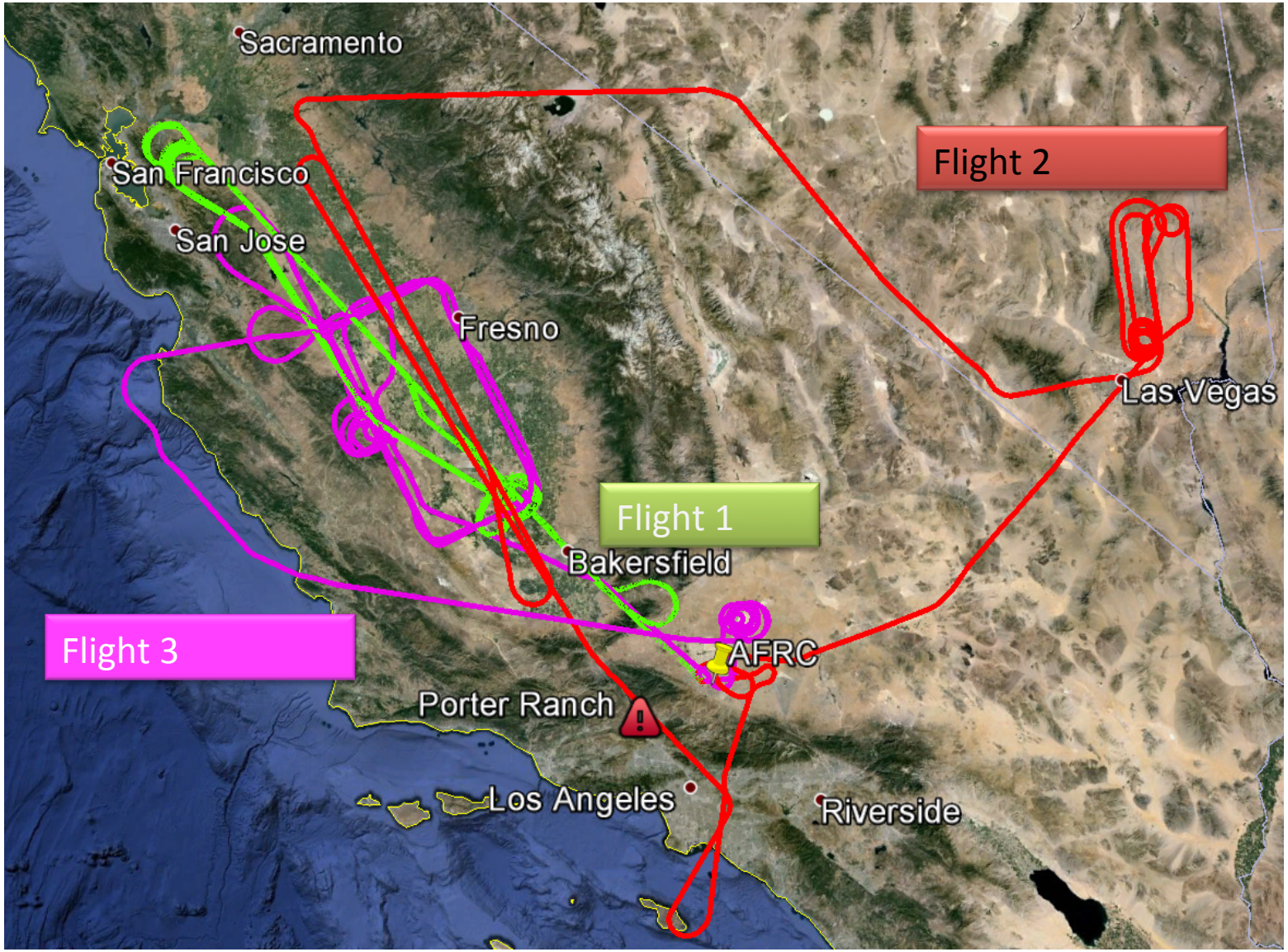
CH_4 Airborne Instrument



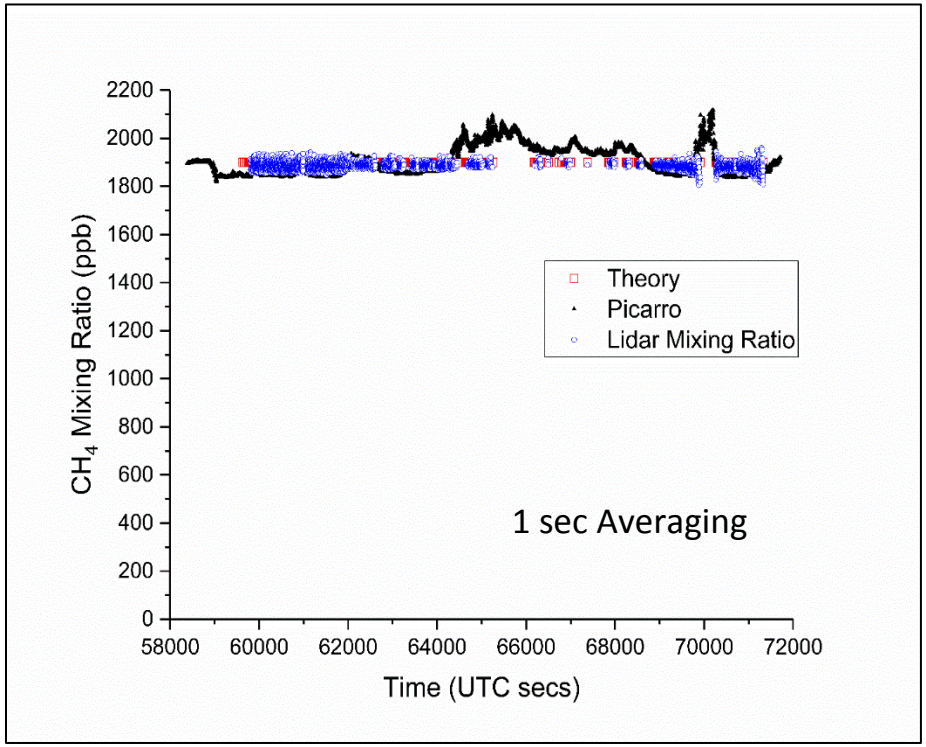
Parameter	Value (OPA/OPO)
Center l	1650.9 nm
Number of l	20/5
Pulse Width	~700/80 ns
Energy/pulse	~25/250 µJ
Bin width	4 ns
Divergence	~150 µrad
Receiver diam.	20 cm
Field of view	300 µrad
Receiver BP	0.8 nm (FWHM)
Averaging time	1/16 s *
Detector Resp.	~1-1.5 x 10^9 V/W

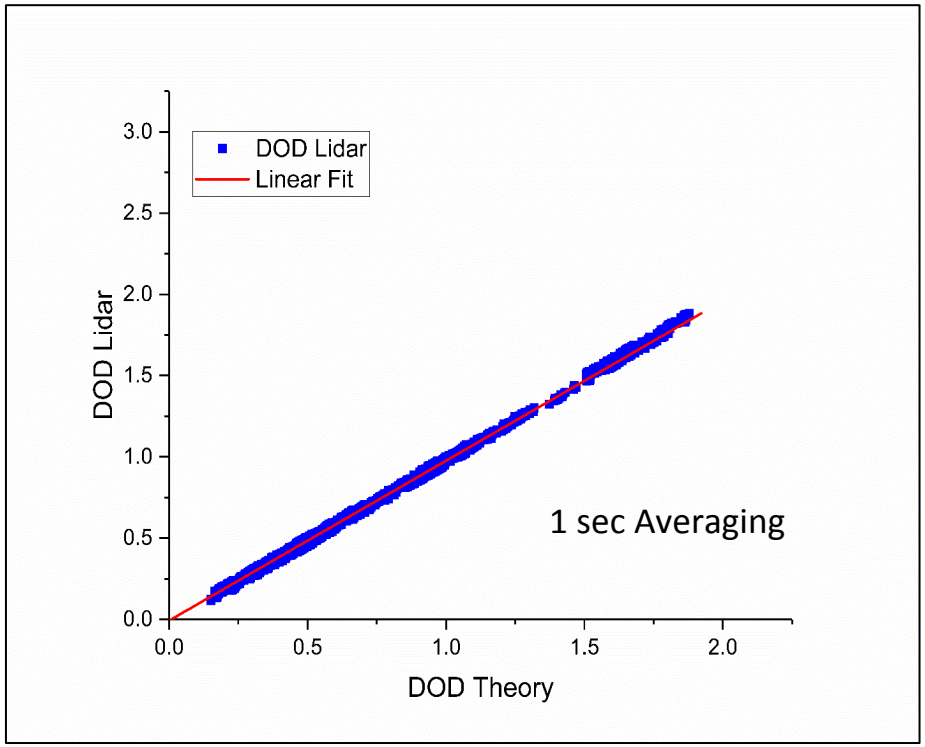
*Data analysis uses 1s averages

2015 Airborne Demonstration Flight Tracks



Flight 1-OPA

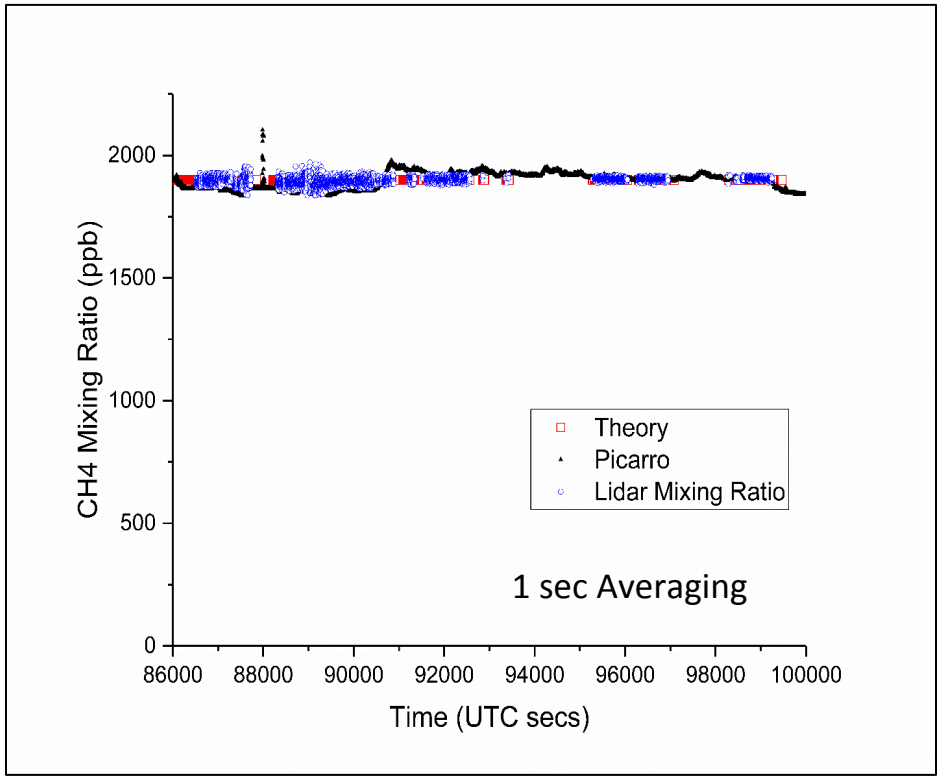


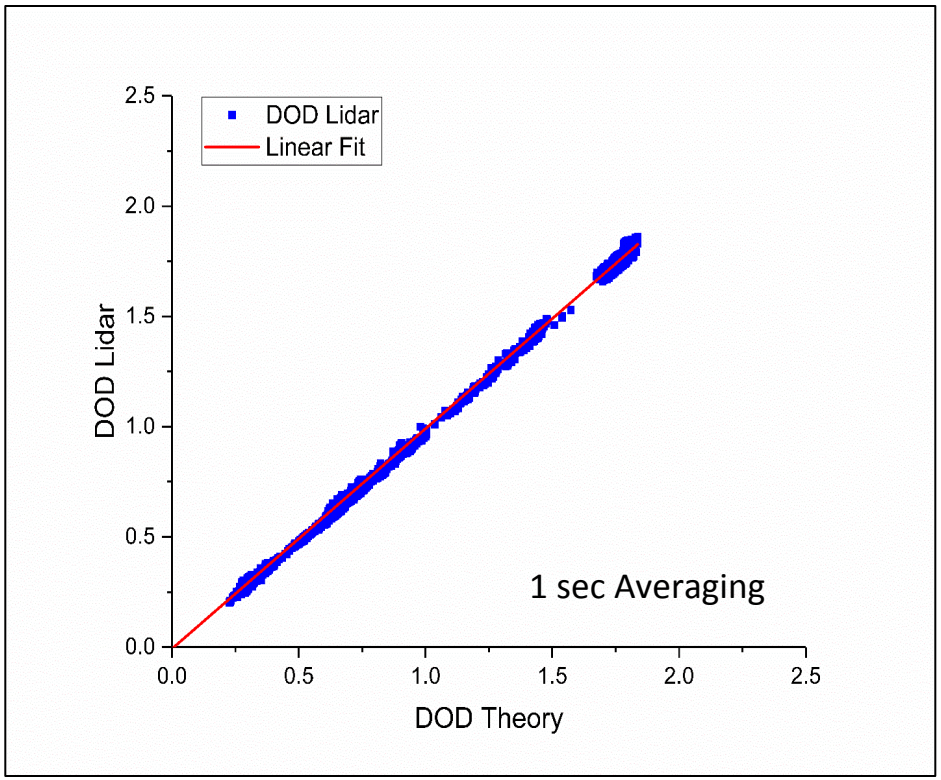


Precision: 14.9 ppb or ~0.8%

Slope= 0.98; offset=-0.007; R^2=0.994.

Flight 2-OPA

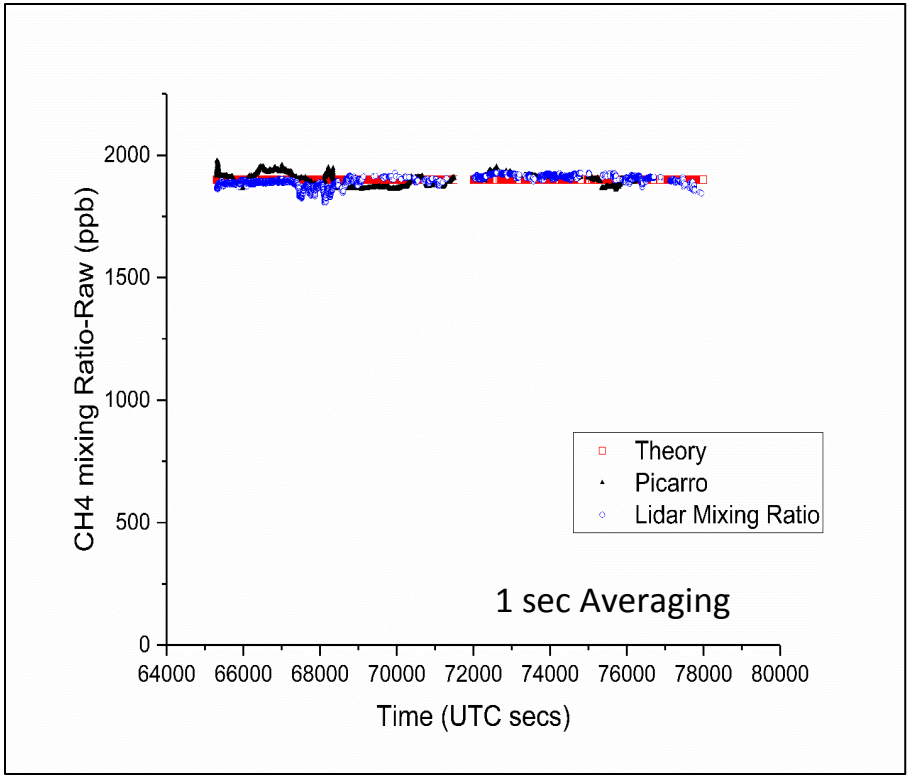


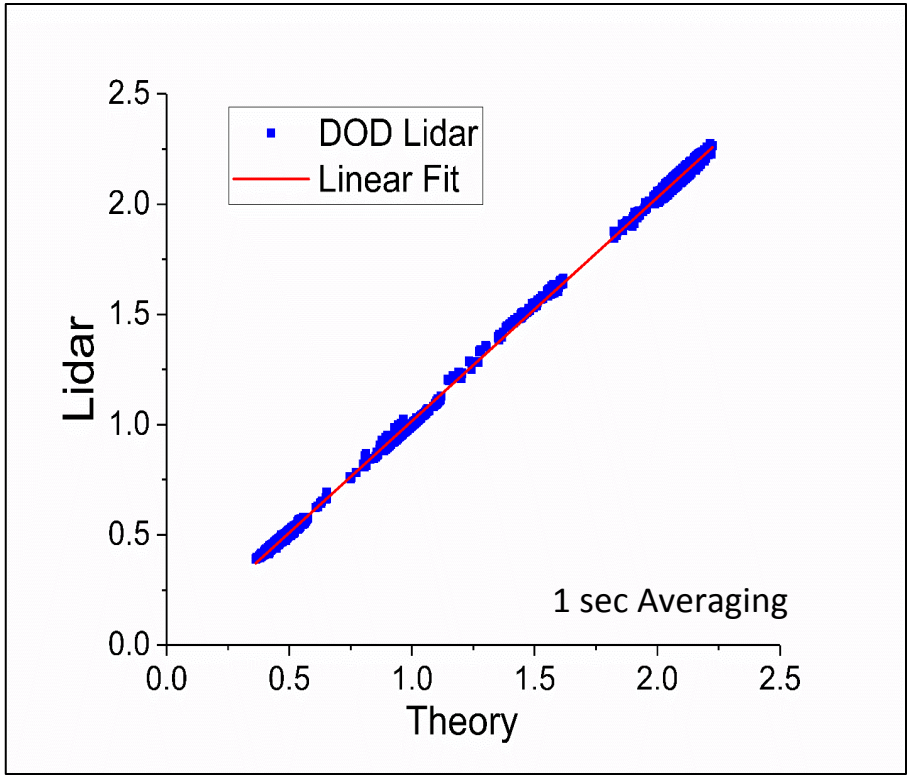


Precision: 13.4 ppb or ~0.7%

Slope= 0.998; offset=-0.007; R^2=0.990.

Flight 3-OPO





Precision: 21.4 ppb or ~1.1%

Slope= 1.01; offset=-0.003; R^2=0.999.

Airborne Demonstration Summary

- ✓ *Best* precision for:
  - ✓ OPA ~ 6-9 ppb; overall 12-15 ppb
  - ✓ OPO ~ 10-12 ppb; overall: 21 ppb
- ✓ 20 wavelengths (OPA) produced better fits than 5 (OPO).
- ✓ OPO correction needed for cross talk.
- ✓ DRS e-ADP works very well at 1651 nm and is linear over a remarkable range of signals and gain settings.
- ✓ New airborne instrument designed.

Current summary of laser efforts

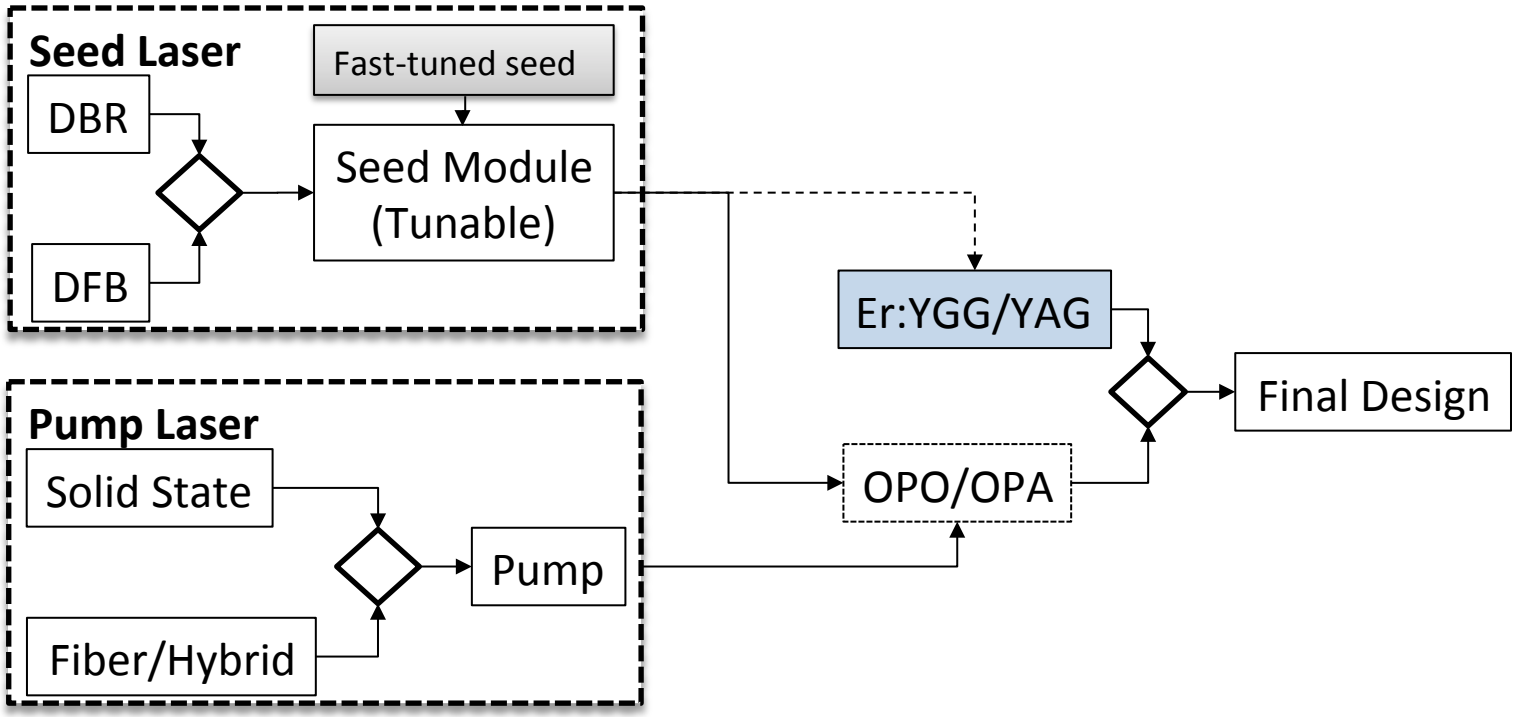
Transmitter Requirements:

High Energy (~600 µJ)

Narrow linewidth

Tunable *(10-20 wavelengths)*

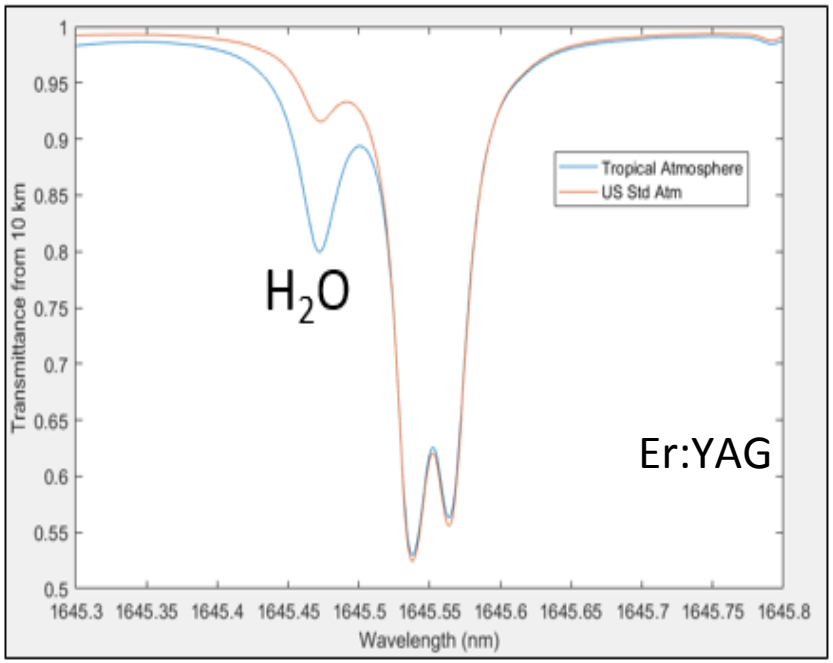
Robust

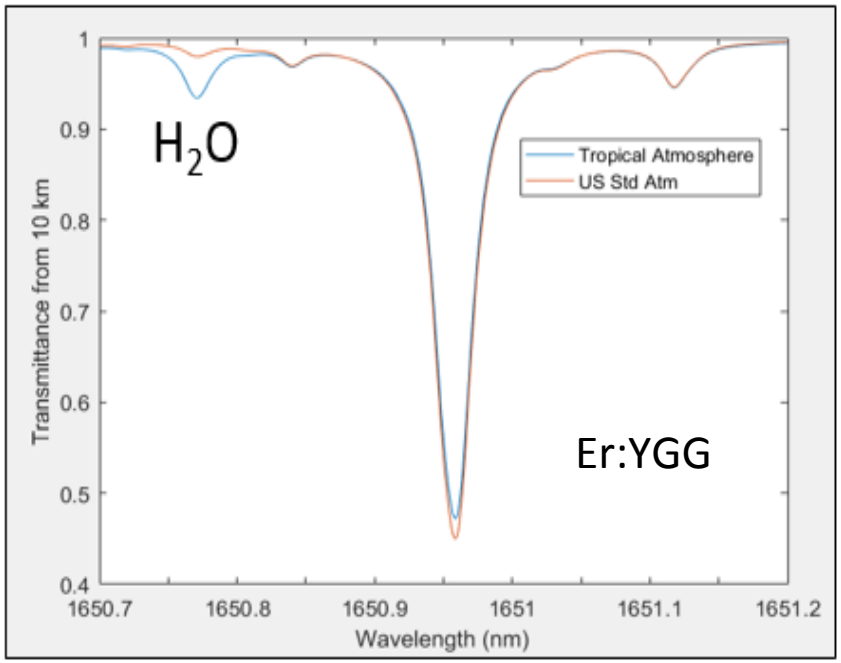


Other transmitter options: Er:YAG and Er:YGG

- Why consider other transmitter options?
  - OPAs and OPOs are parametric conversion techniques. They are complex and difficult to implement are sensitive to vibration.
  - Size/mass/cost of airborne/space instrument needs to reduced.
- Potential for "simpler" and more efficient solid-state" laser transmitter technology.
- ***Tuning and lasing at the right wavelength remain an issue.***

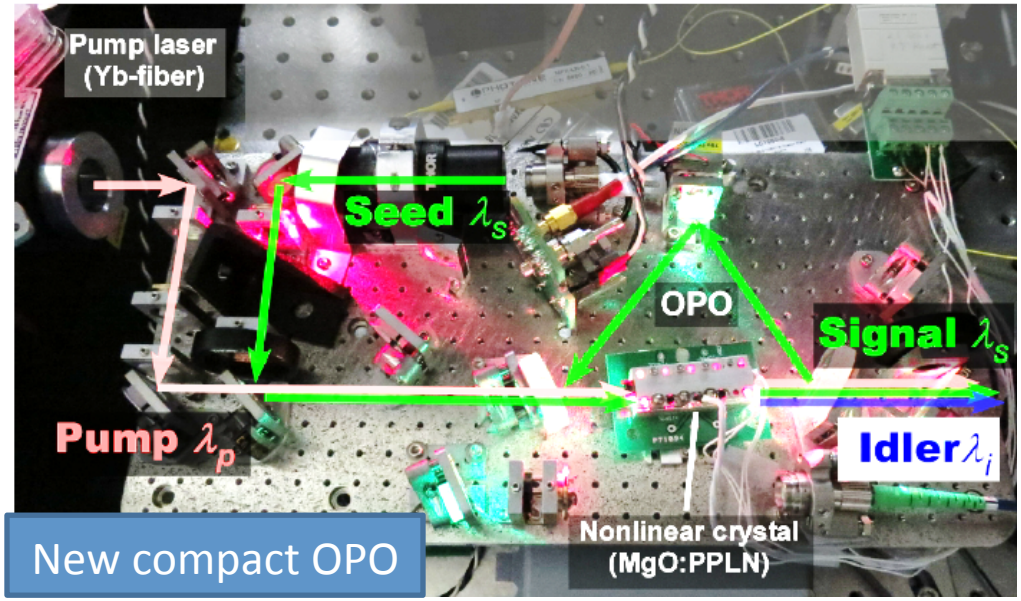
Er:YAG or Er:YGG ?



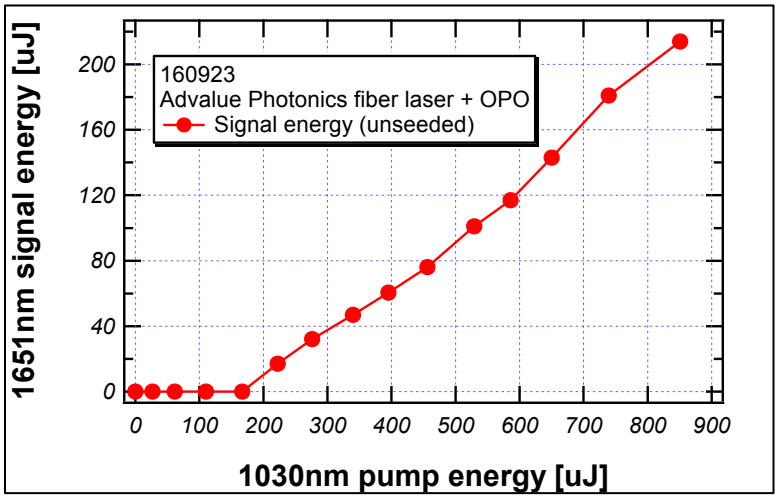


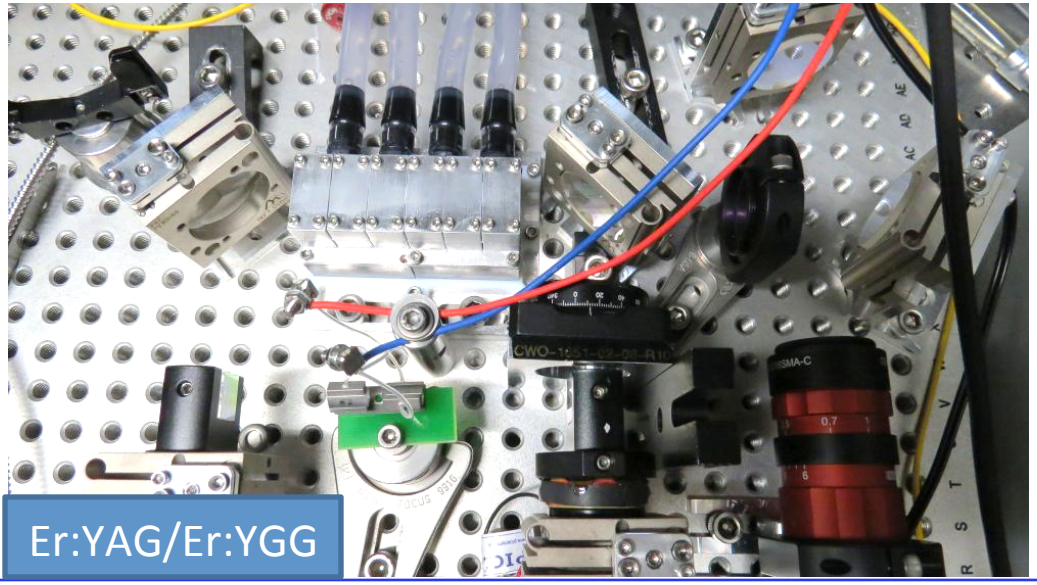
- Spectroscopy (temperature dependence, line mixing, etc.)
- Interferences from H_2O vapor.
- Power and Tunability requirements for the laser.

New Transmitters: Compact OPO and Er:YAG/Er:YGG



New compact OPO

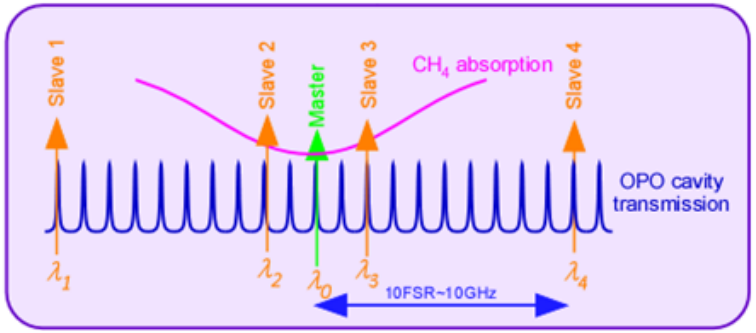


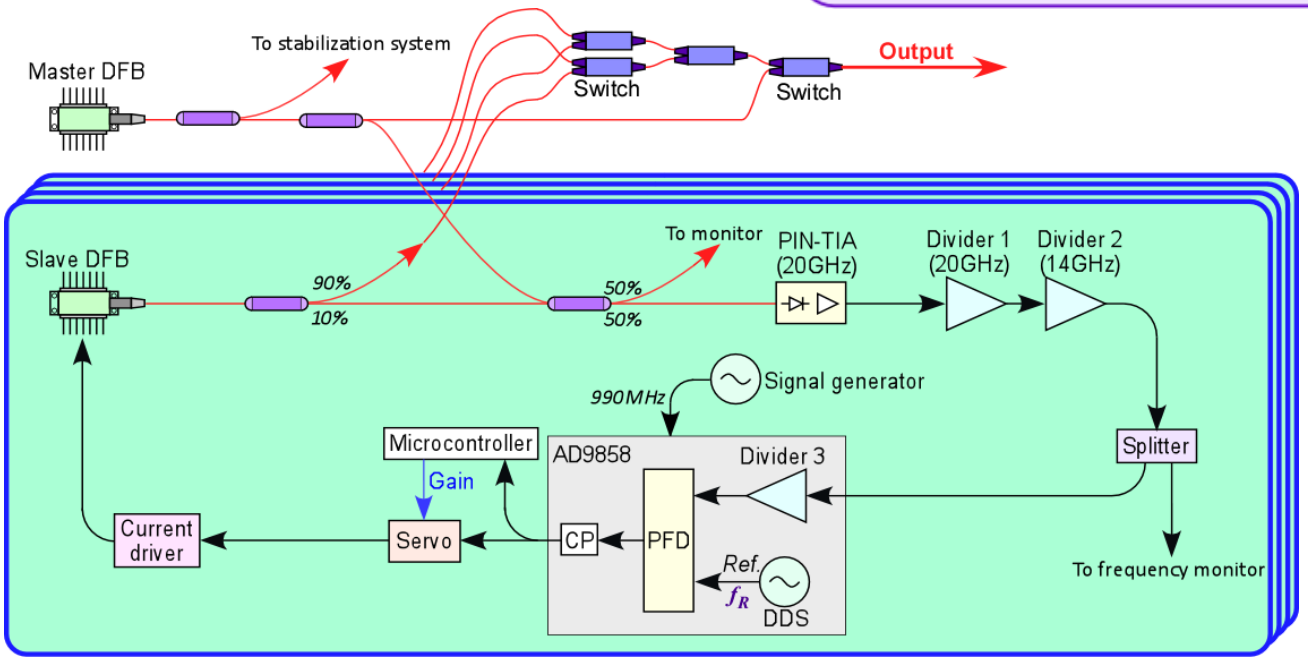


Er:YAG/Er:YGG

Existing OPO (Er:YAG/YGG) Tuning

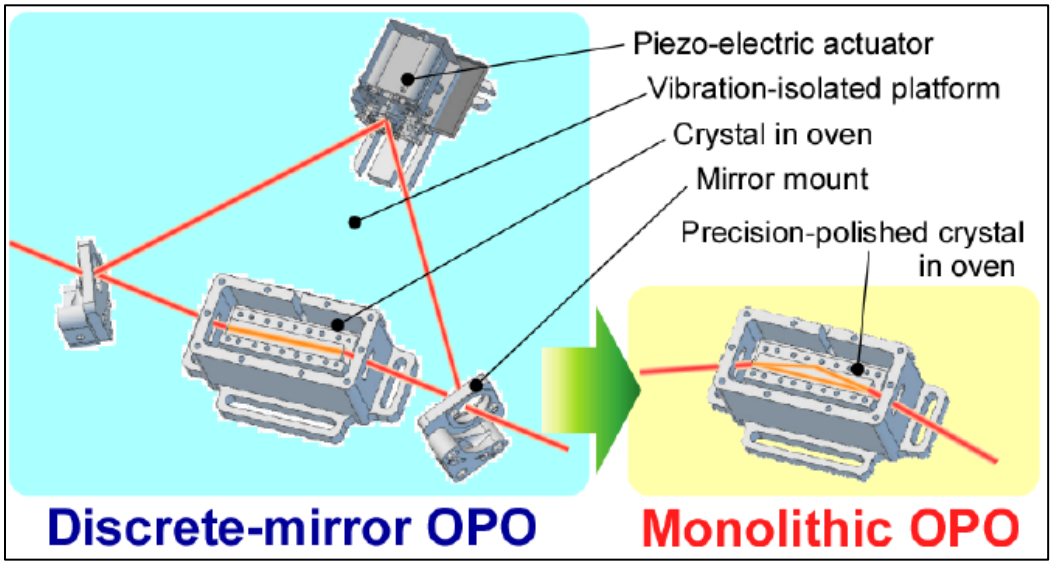
- 5 wavelength system for injection seeding
  - 5 lasers
  - 4 OPLLs
  - 4 optical switches
  - 4 fast detectors

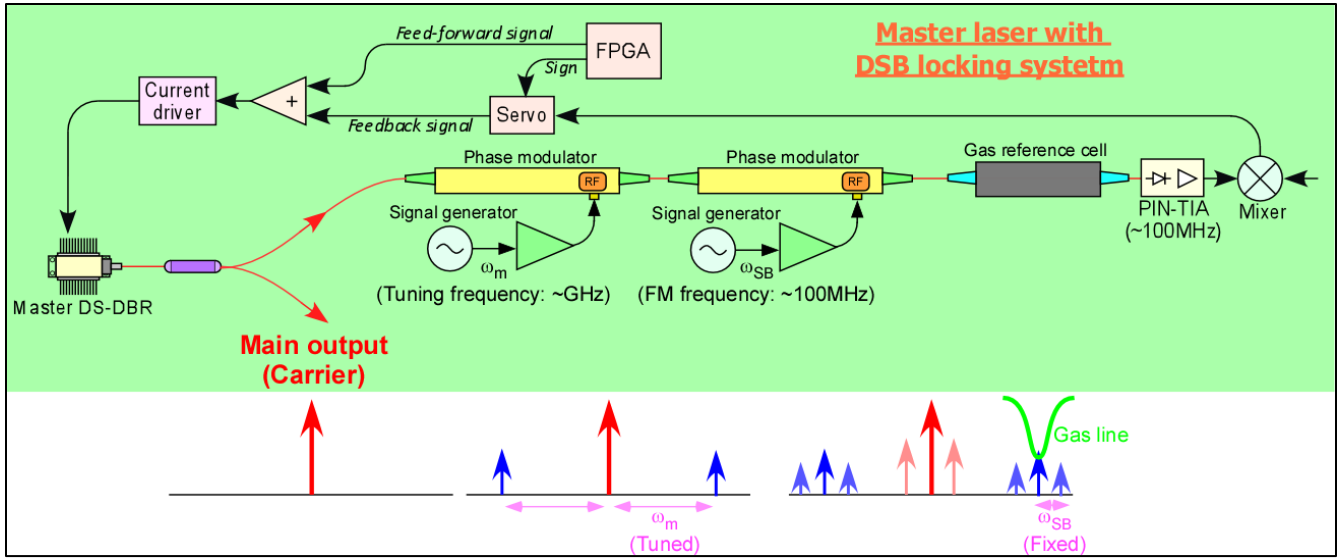




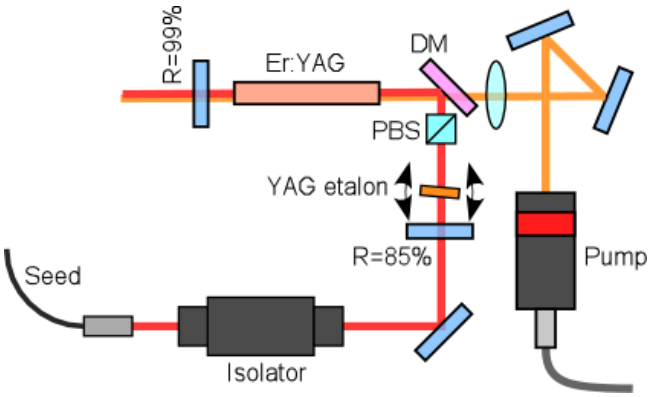
New tuning concepts and monolithic OPO

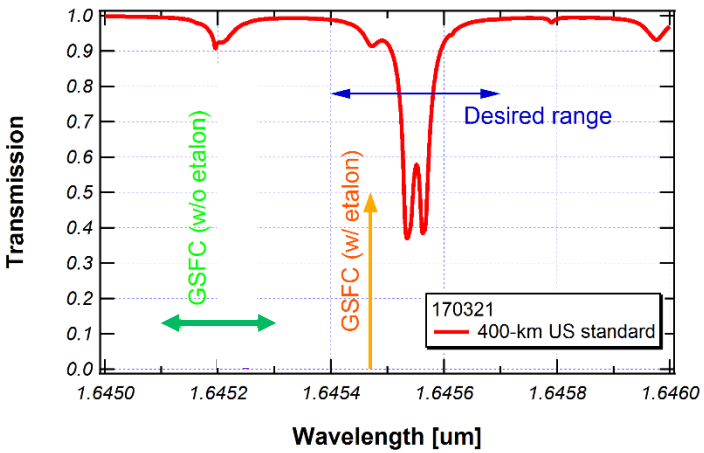
- Simplify the existing multi-laser (wavelength) system
- Two proposed schemes:
  - Dual Sideband (DSB): requires Game Changing DBR deliverable
  - Single Sideband (SSB)
  - Both showing promising results

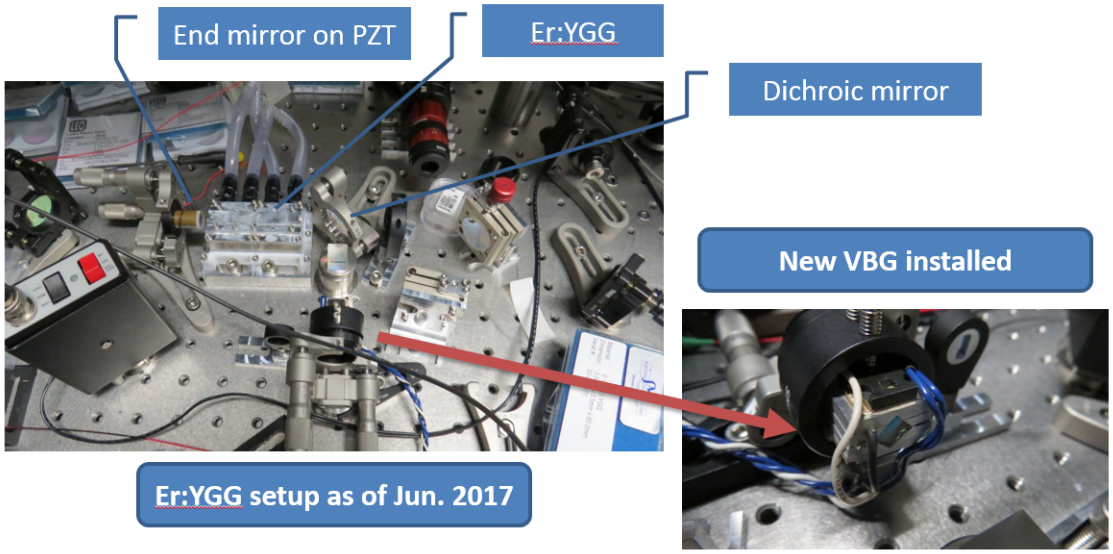




Er:YAG and Er:YGG

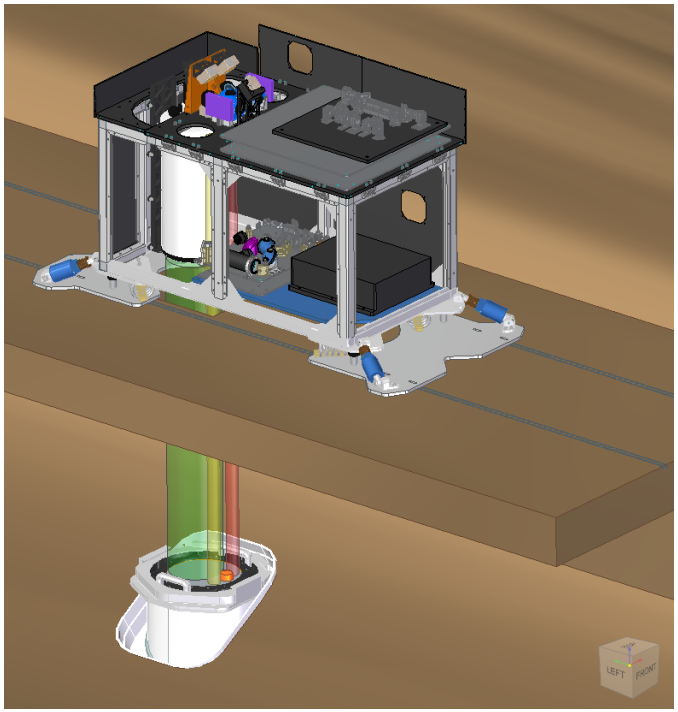


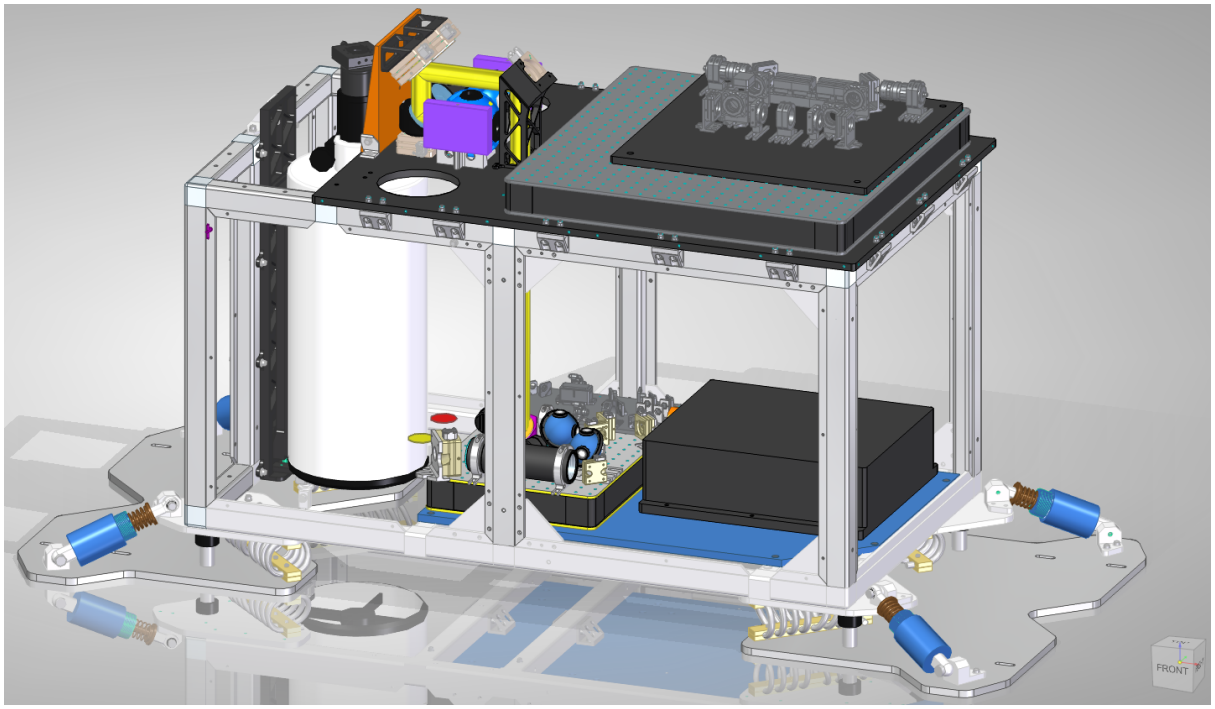




Both Er:YAG and Er:YGG require a wavelength-selecting element to lase at the right wavelength.
Tuning becomes exceedingly complicated if we need to tune both the seed/cavity and the wavelength-selecting element

New (improved) airborne sensor





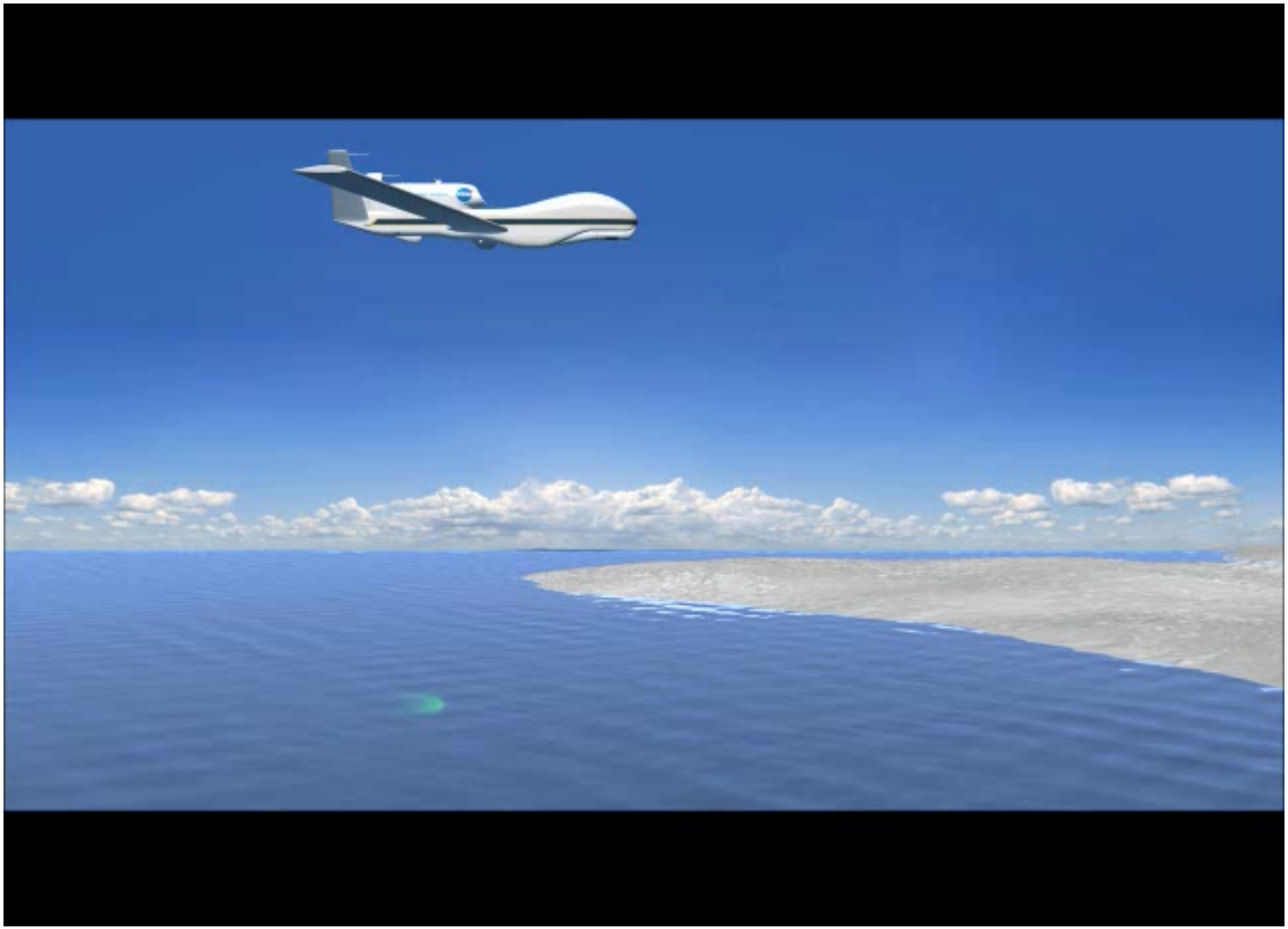
- New transceiver uses Er:YAG/Er:YGG and new, compact OPO (AdValue pump laser)
- Two beams can be fired simultaneously (unlike the earlier version)
- Smaller than the earlier version but still too big to fly on small aircraft
- Vibration isolation maintained

Summary

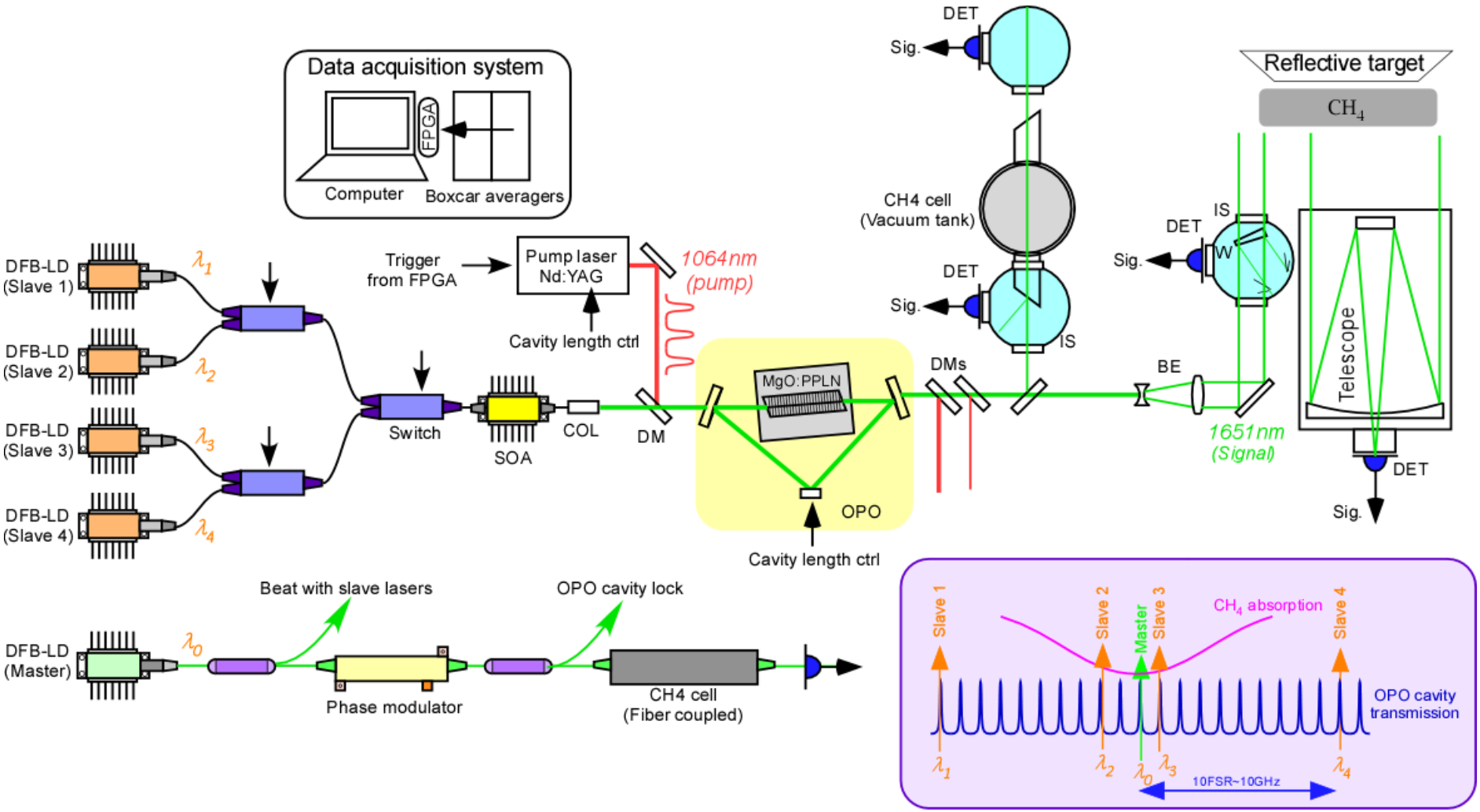
- ✓ Demonstrated CH_4 airborne measurements using two lidar transmitters (OPA and OPO).
- ✓ Many different approaches and options for the laser transmitter are being investigated.
- ✓ Demonstrated power scaling with several options.
- ✓ Will incorporate Freedom Photonics seed laser deliverable and decide on final configuration.
- ✓ Looking for opportunities to fly!
- **We would like to thank ESTO and GSFC IRAD for their support.**

BACKUP

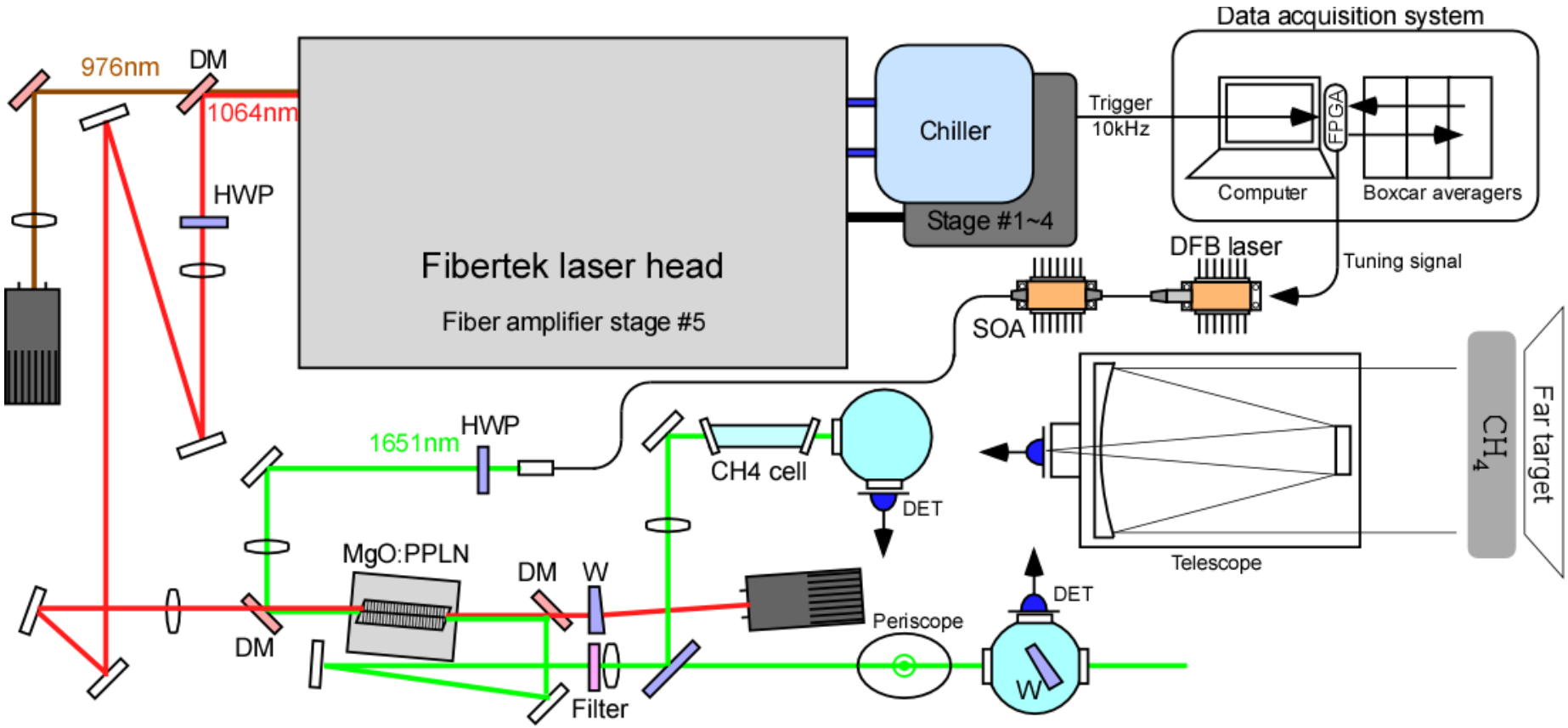
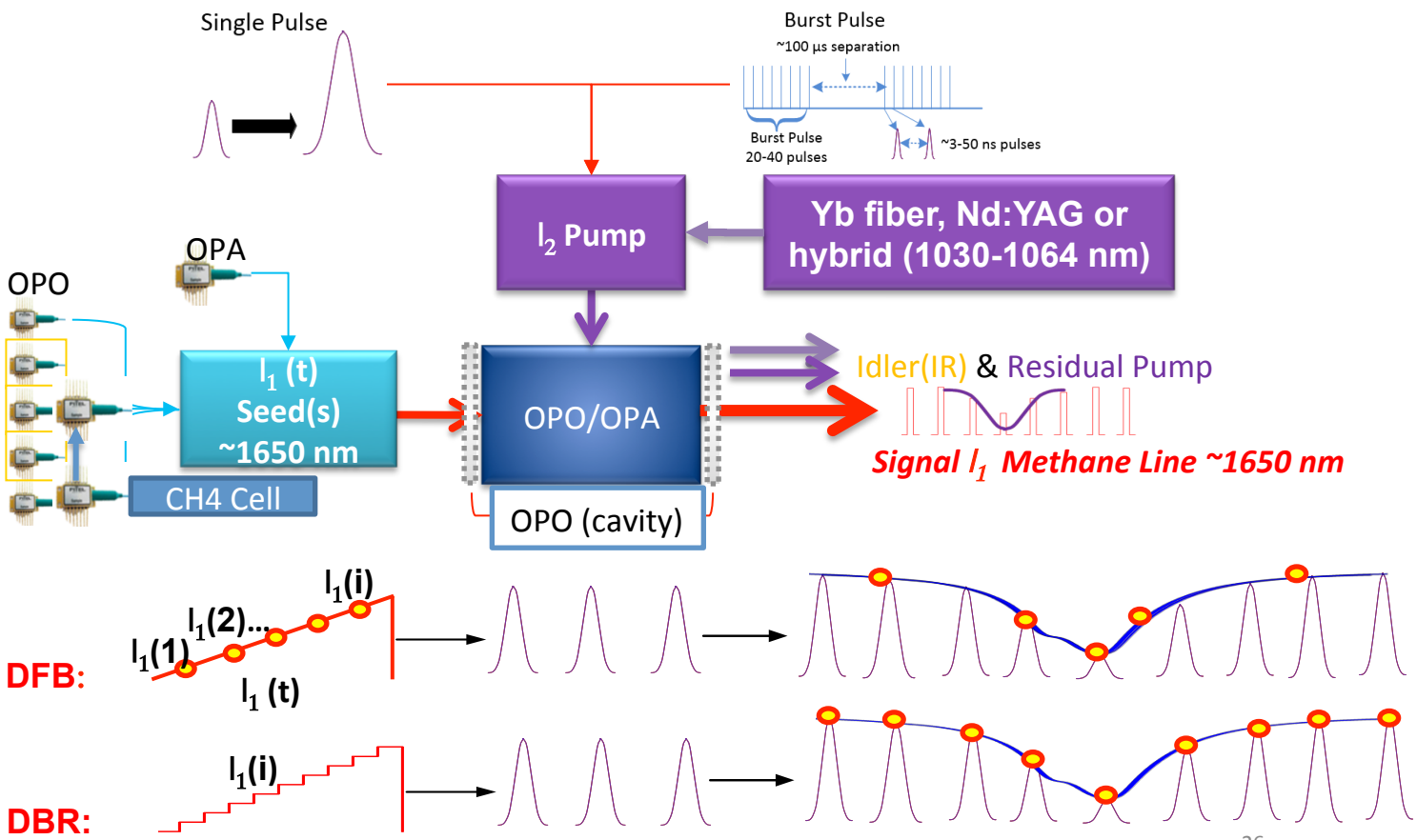
GSFC CH_4 Lidar with Integrated Path Differential Absorption Lidar (IPDA)



Setup for 5-wavelength OPO



OPA Open-path measurement setup



CH_4 Laser Transmitter: OPO-OPA