A METHANE IPDA LIDAR USING OPTICAL PARAMETRIC LASER TECHNOLOGY

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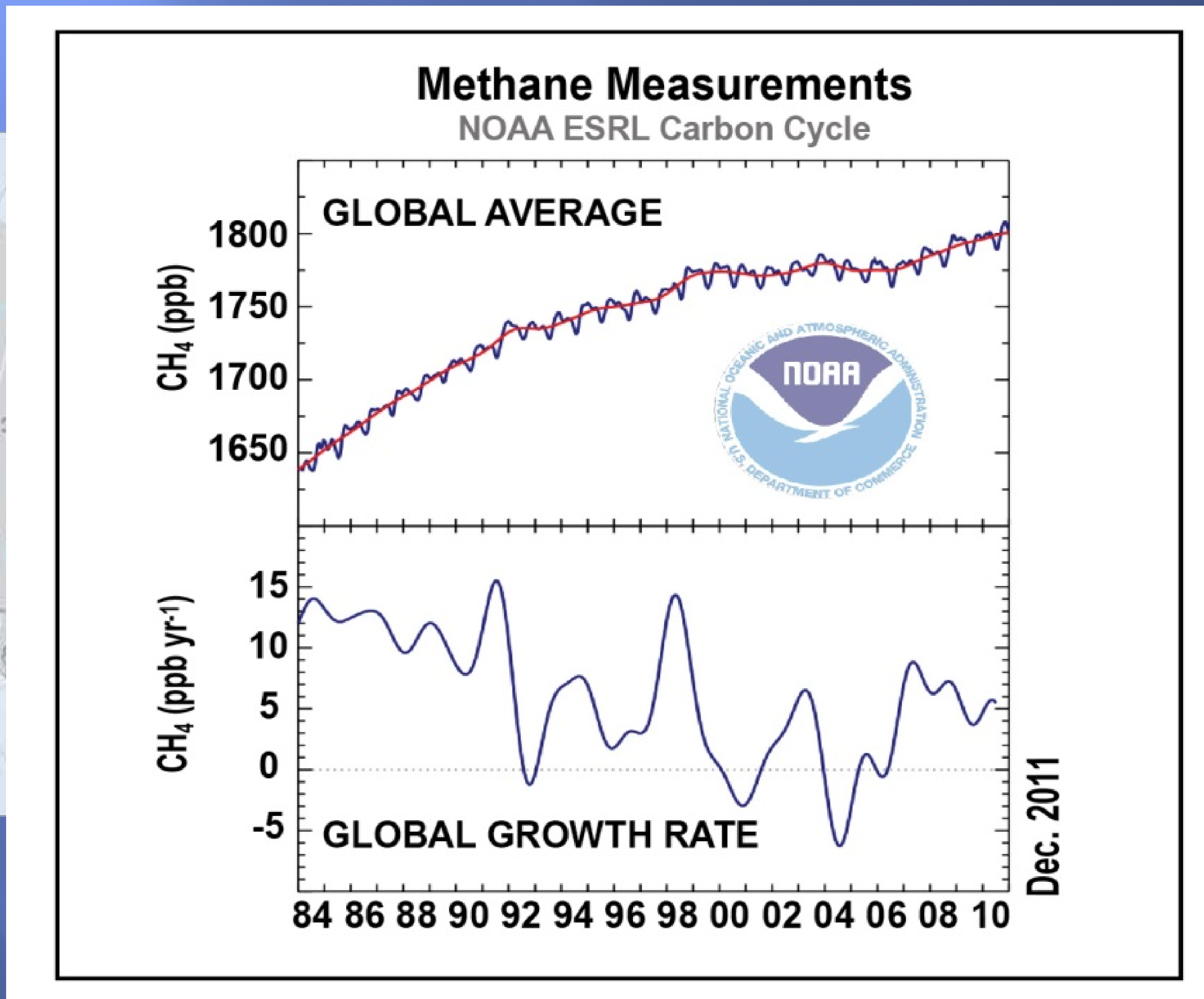
Outline

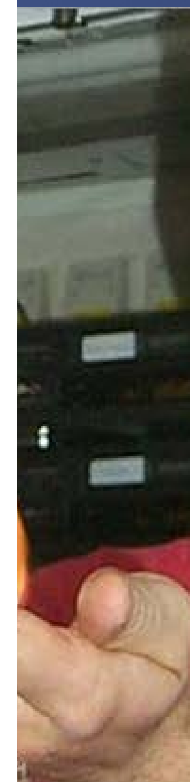
- Need for Methane Measurements
- Current Efforts
- GSFC Approach
  - Initial Results
  - Power scaling
  - Current Status
- Summary

Why measure Methane?

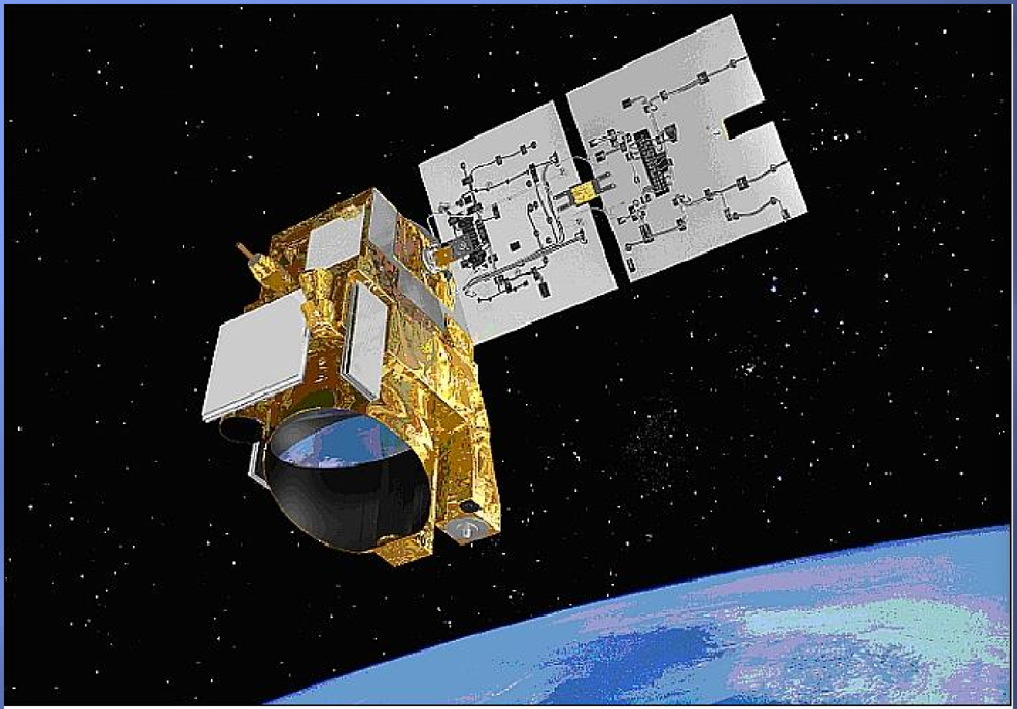
- CH_4 has strong radiative forcing (~x23 stronger than CO_2 on a per molecule basis). Carbon Budget needs accurate CH_4/ CO_2 sinks and sources.
- Large amounts of organic carbon are stored as CH_4 and CO_2 in the Arctic permafrost. Thawing Arctic permafrost soil, is a cause for concern as a rapid, positive greenhouse gas/climate feedback. In addition, large but uncertain amounts of CH_4 are sequestered as gas hydrates in shallow oceans and permafrost soils, which are also subject to potential rapid release.
- NASA Earth Science Decadal Survey: *"Ideally, to close the carbon budget, methane should also be addressed, but the required technology is not now obvious. If appropriate and cost-effective methane technology becomes available, methane capability should be added."*
- Methane is also an important biogenic trace gas ("life marker") for planetary science.

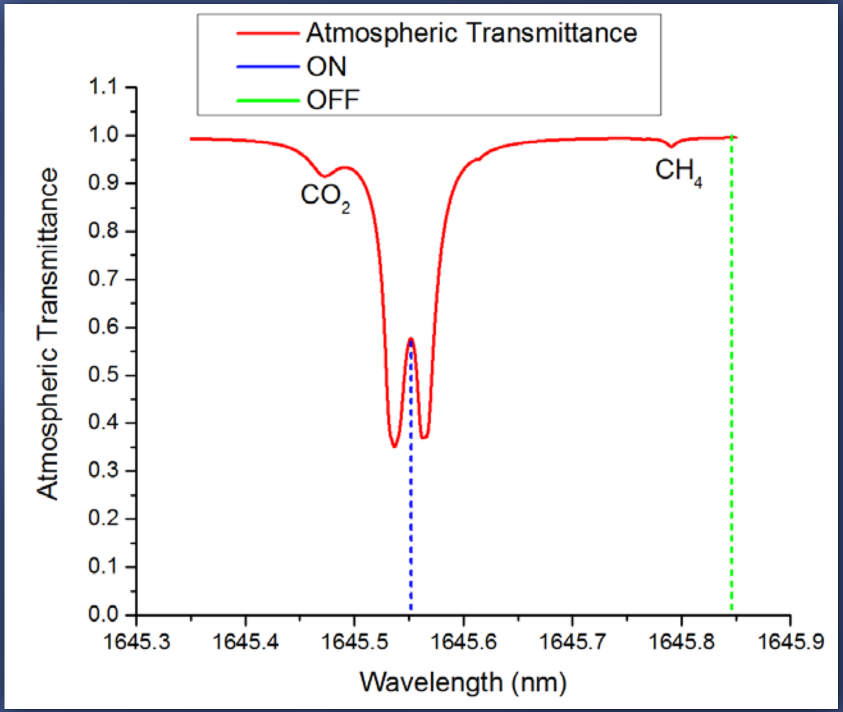
Rising Methane





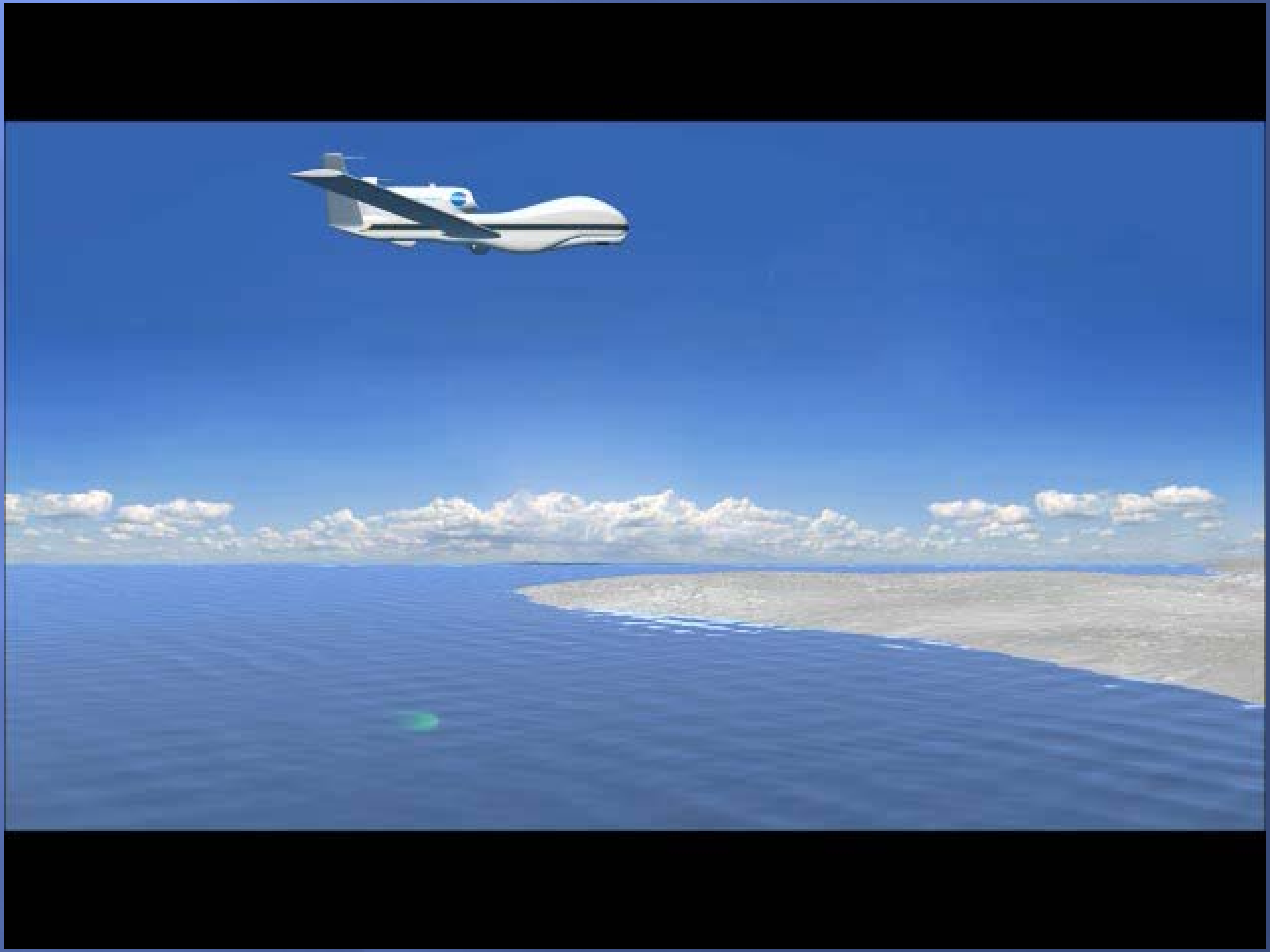
MERLIN (MEthane Remote Sensing LIDAR Mission) mission



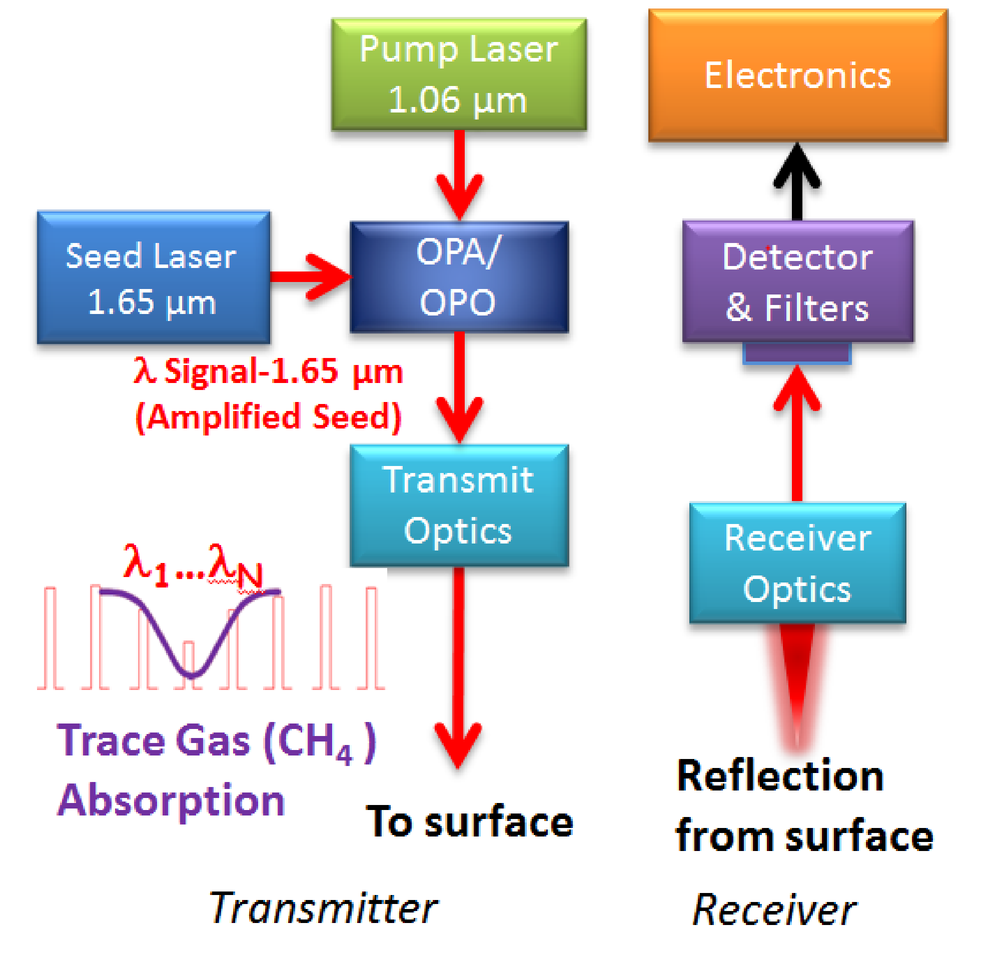


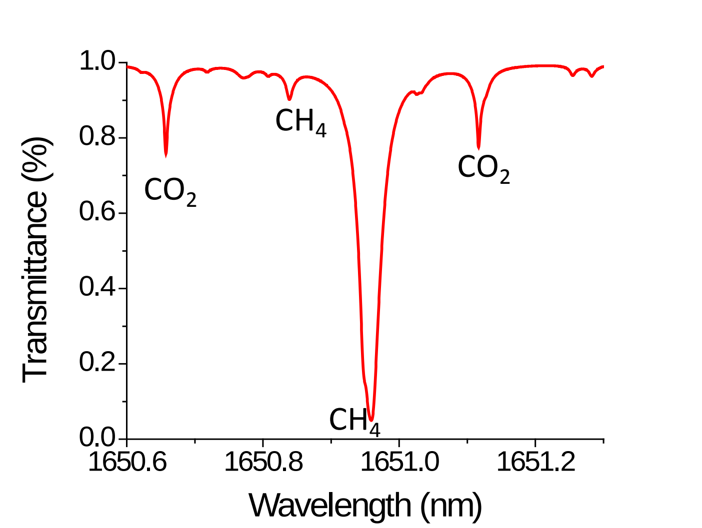
λ_{on} : 1645.552 nm
λ_{off} : 1645.846 nm

GSFC Approach - Integrated Path Differential Absorption Lidar-same as CO_2 IPDA lidar



GSFC IPDA Lidar Precision Goal: 10 ppb





Parameter	Value
Repetition Rate	10 KHz
Pulsewidth	6 nsec
Orbit altitude	400 km
Ground Speed	5 km/s
Laser Spot Diameter	48 m
Detector Quantum Eff.	70%
Telescope Diameter	0.5 m
Receiver Field of View	200 µrad
Surface reflectivity	0.31
Receiver Optical Bandwidth	0.8 nm
Averaging Time	1 sec
Energy	250-300 µJ

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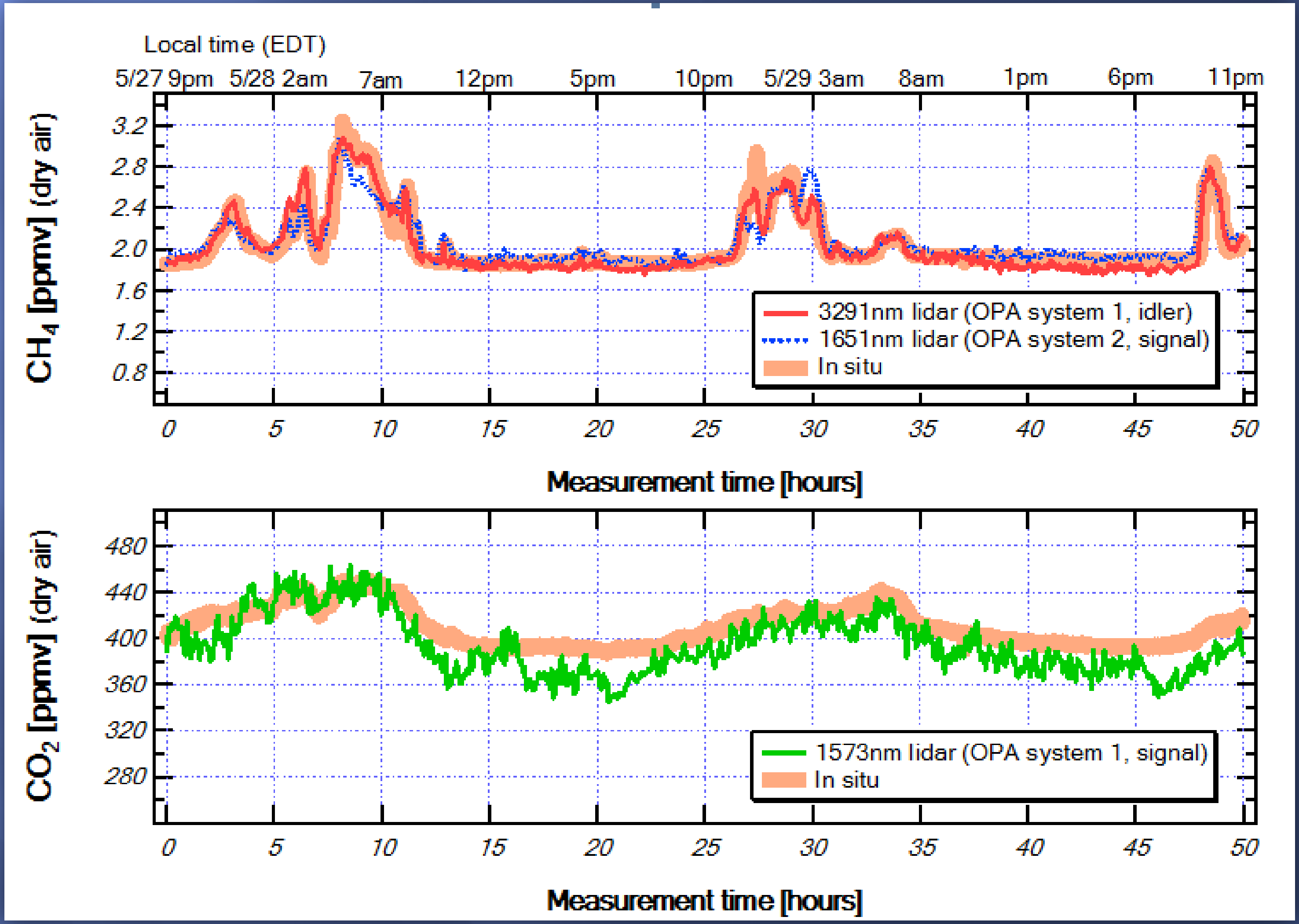
Ground Testing with two IPDA lidars using OPA – 3.29 µm and 1.65 µm



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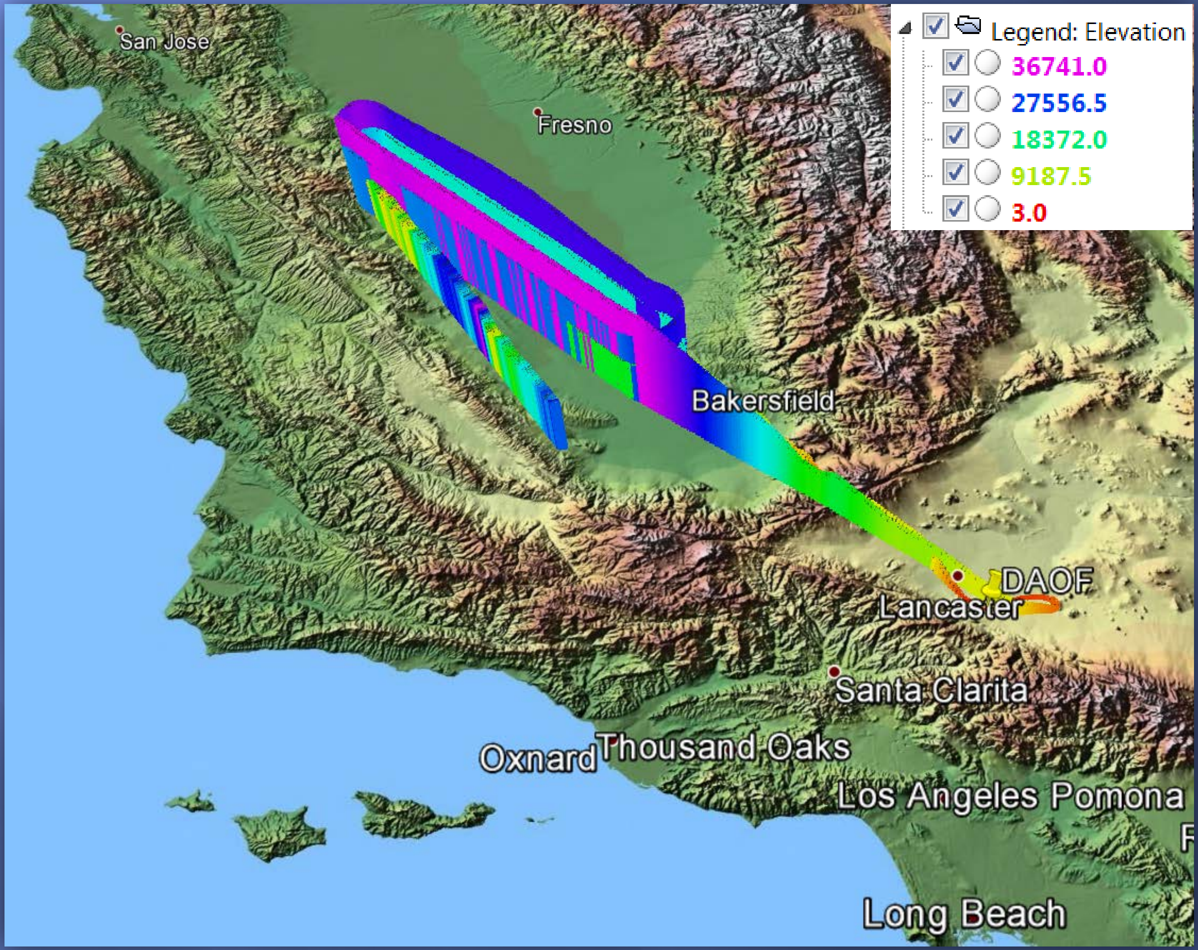
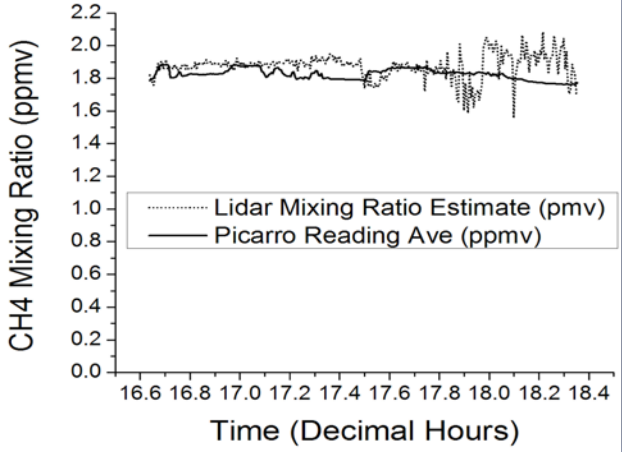
Airborne Tests in 2011 with an OPA and a PMT

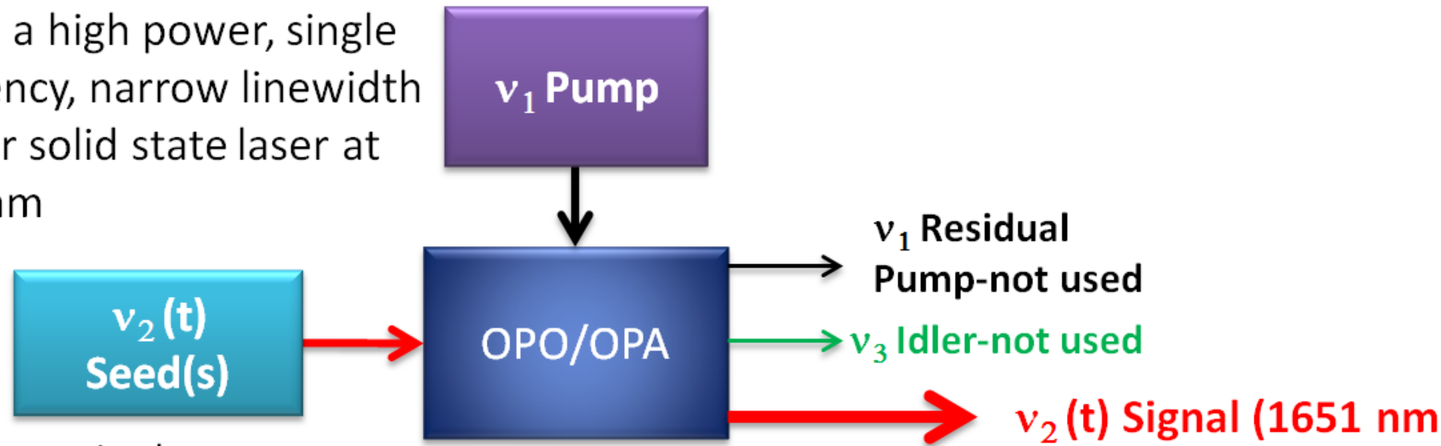




"Airborne measurements of atmospheric methane column abundance using a pulsed integrated-path differential absorption lidar", APPLIED OPTICS / Vol. 51, No. 34 / 1 December 2012

Laser Transmitter Components

Pump: a high power, single frequency, narrow linewidth fiber or solid state laser at 1064 nm



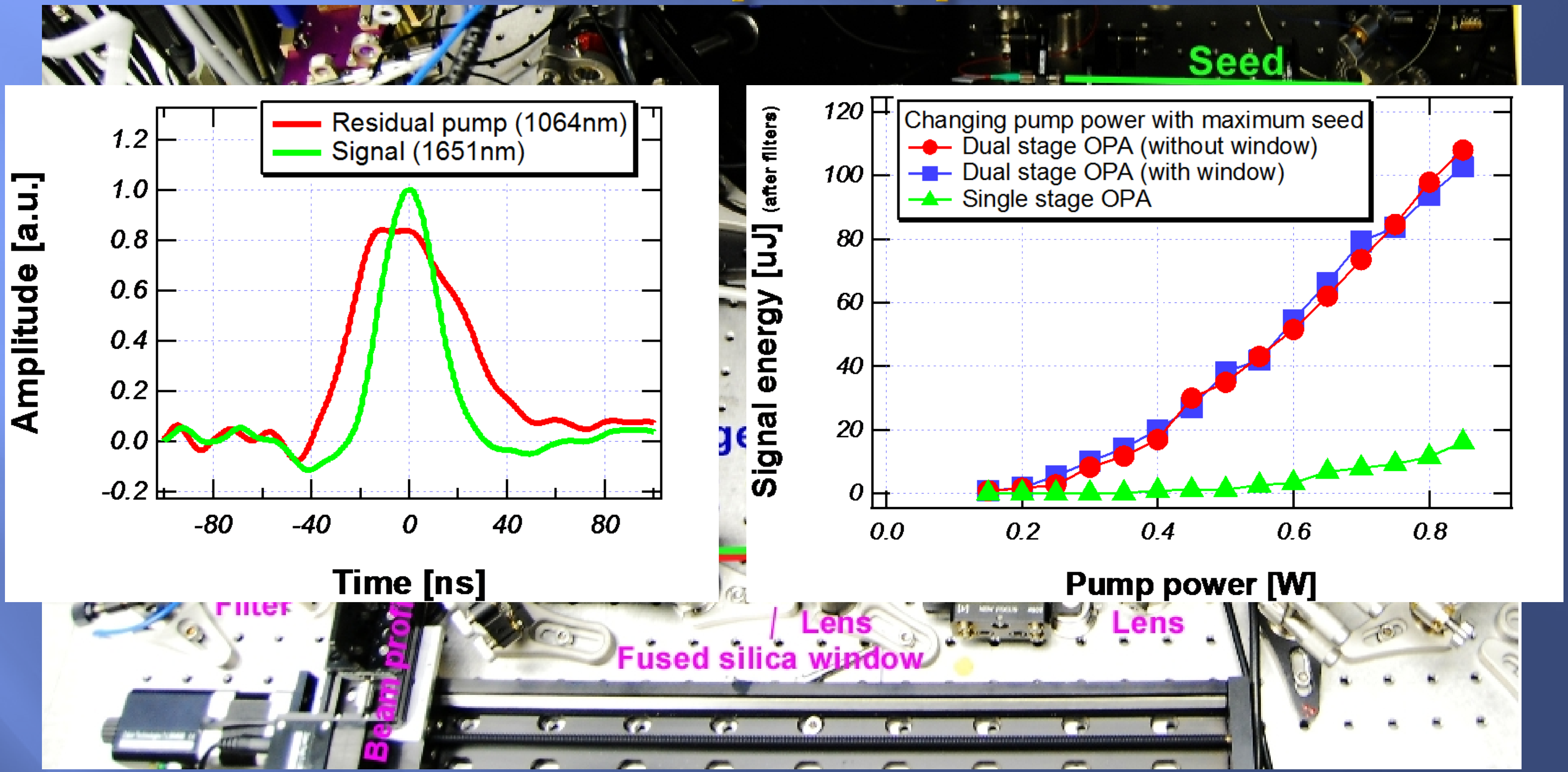
Seed: a low power, single frequency diode laser at 1651 nm.

Optical Parametric Oscillator (OPO) or Optical Parametric Amplifier (OPA).
A non-linear crystal that amplifies the seed laser to the energy needed for space (250-300 μJ) ***without*** degrading the spectral characteristics

Power (Energy) Scaling

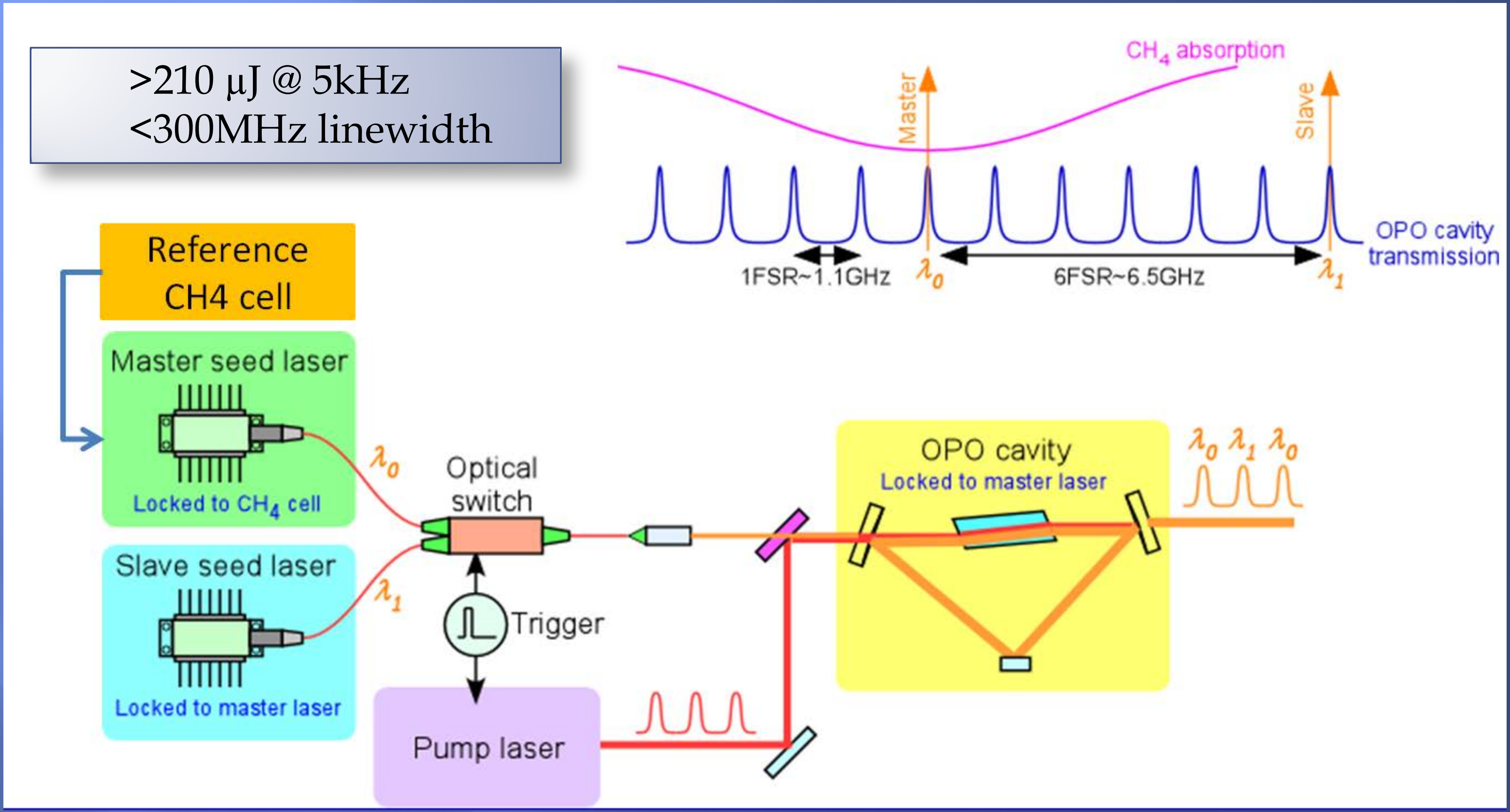
- Need ~300 μJ and narrow linewidth to achieve 10 ppb (~0.5%) random error.
- *OPA: Easy to align, easy to tune, power scaling hard to achieve while maintaining narrow linewidth. OPA samples the CH_4 line at several wavelengths using a single, continuously tuned seed laser.*
- *OPO samples the CH_4 line at several discrete wavelengths using multiple seed lasers. Complicated to align and tune; power scaling easier to achieve while maintaining narrow linewidth.*

Current Status of OPA using custom pump laser



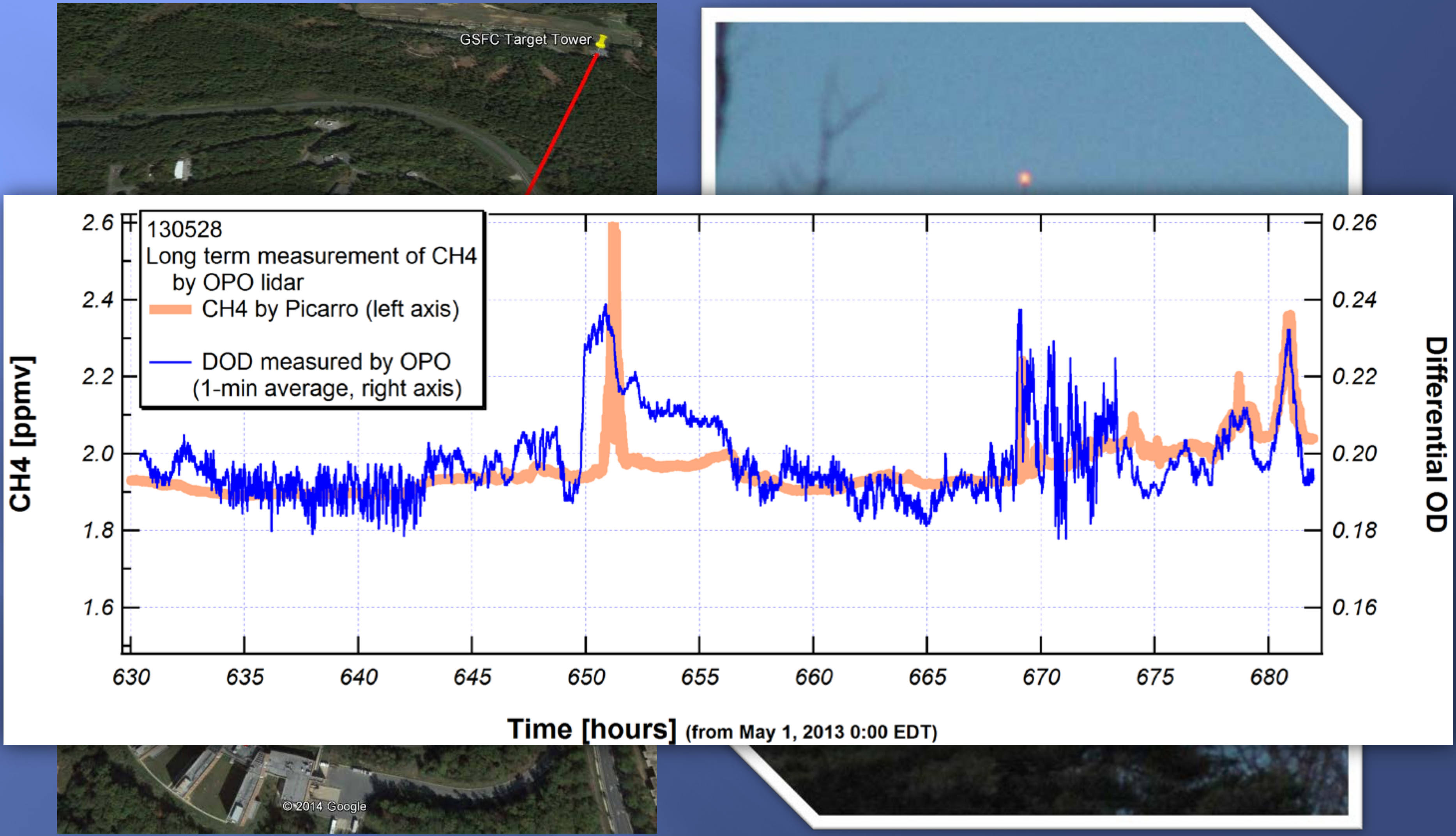
Output signal energy: ~140 μJ after ~70 % transmission filter = 200 μJ
BUT linewidth is ~ several GHz

Current Status of OPO using custom pump laser

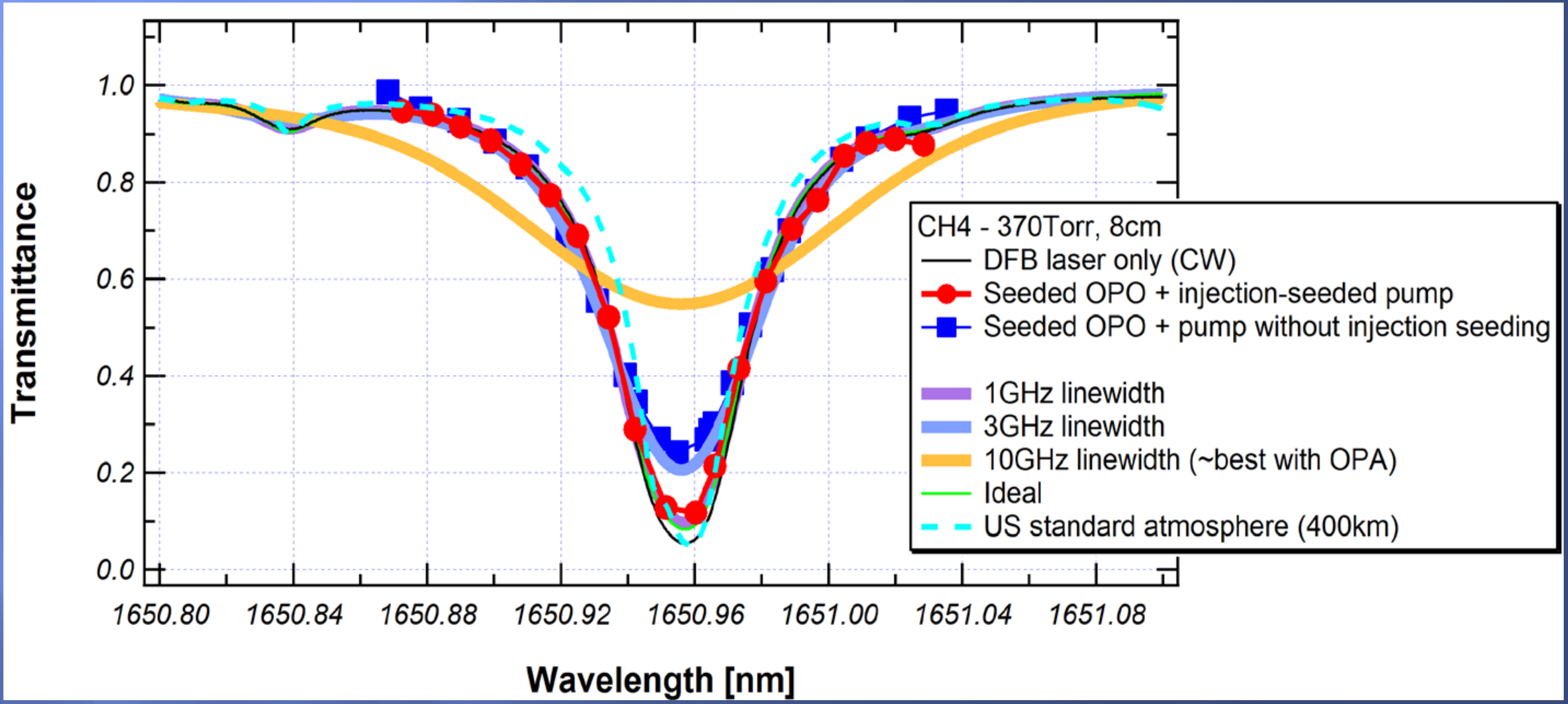


"Fast-switching methane lidar transmitter based on a seeded optical parametric oscillator", Appl. Phys. B. Feb. 2014

Current Status of OPO using custom pump laser – open path measurements



Why is the linewidth important?

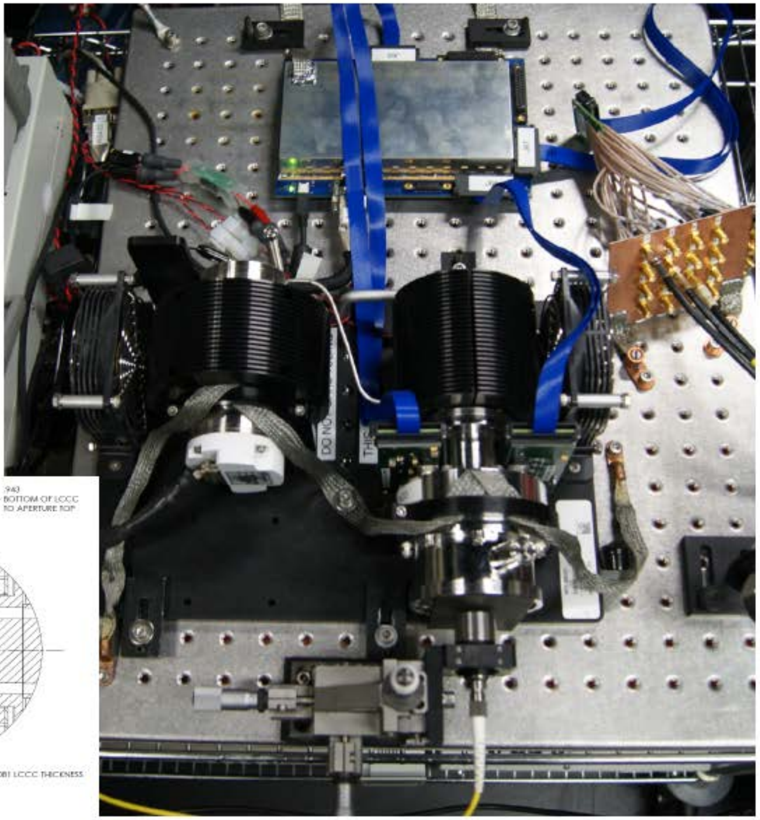


Detector Development

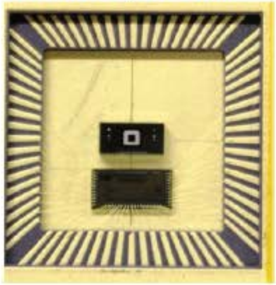
HgCdTe e-APD 4x4 Array Test Results at GSFC

GSFC

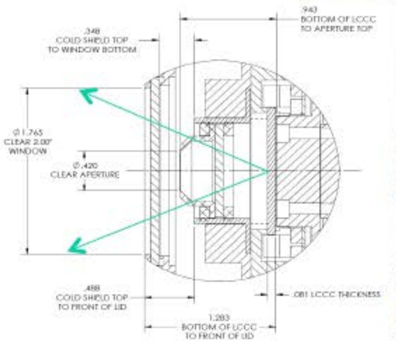
- First 4x4 HgCdTe e-APD array for the CO2 lidar received in April 2013 and met requirements



FPA on chip carrier



F/1.5 Dewar Cold Shield with Cold Filter



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Summary

- CH_4 and CO_2 are the two most important greenhouse gases.
- Active (laser) measurements of CH_4 are needed to improve coverage of important regions of the Earth, such as the Arctic permafrost
- The laser transmitter is currently the most challenging technological hurdle.
- At GSFC we hope to achieve high precision CH_4 measurements using a 4-wavelength OPO and a sensitive detector.

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Simulation

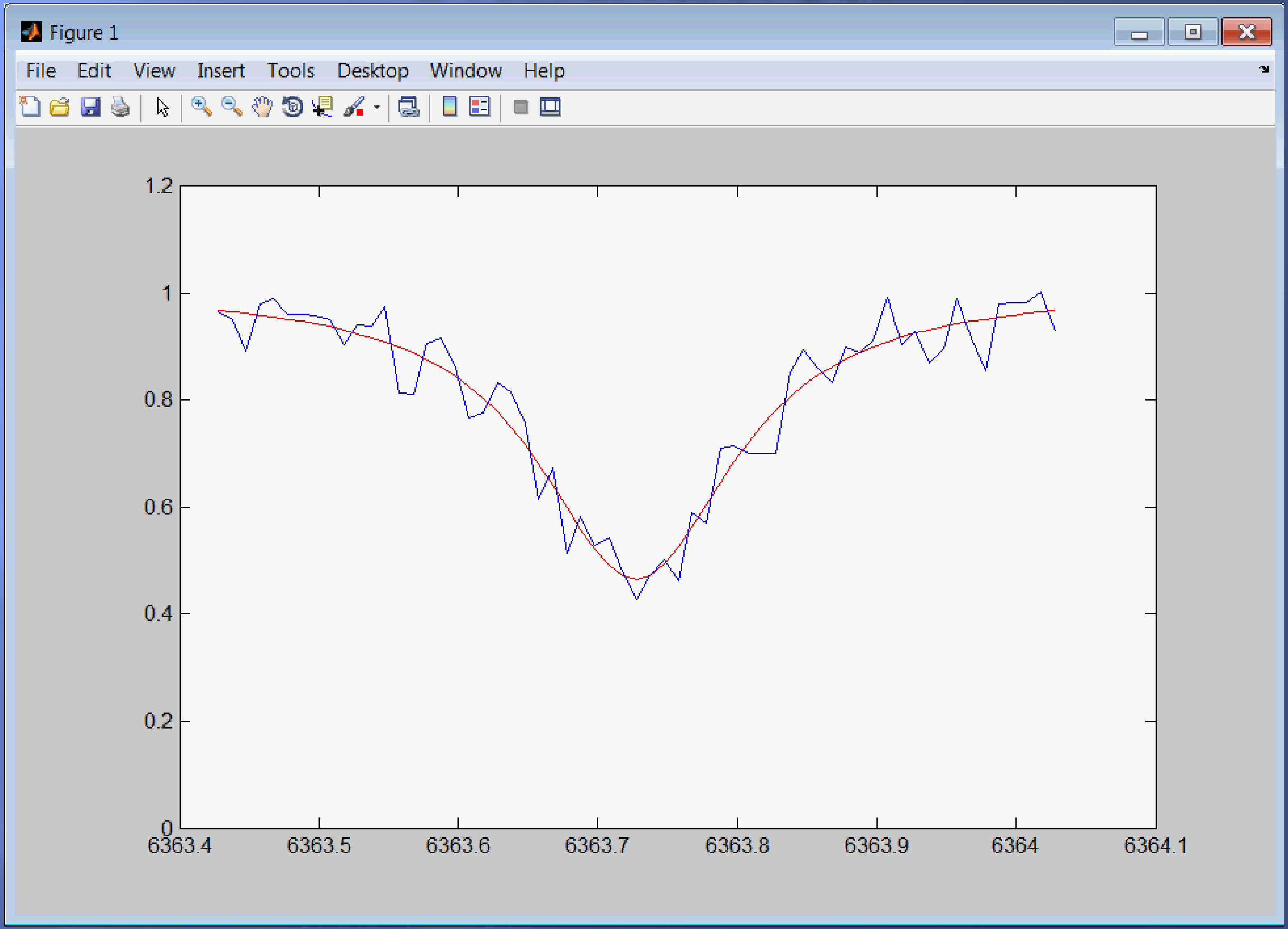

Figure 1
File Edit View Insert Tools Desktop Window Help
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0.2
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6363.5
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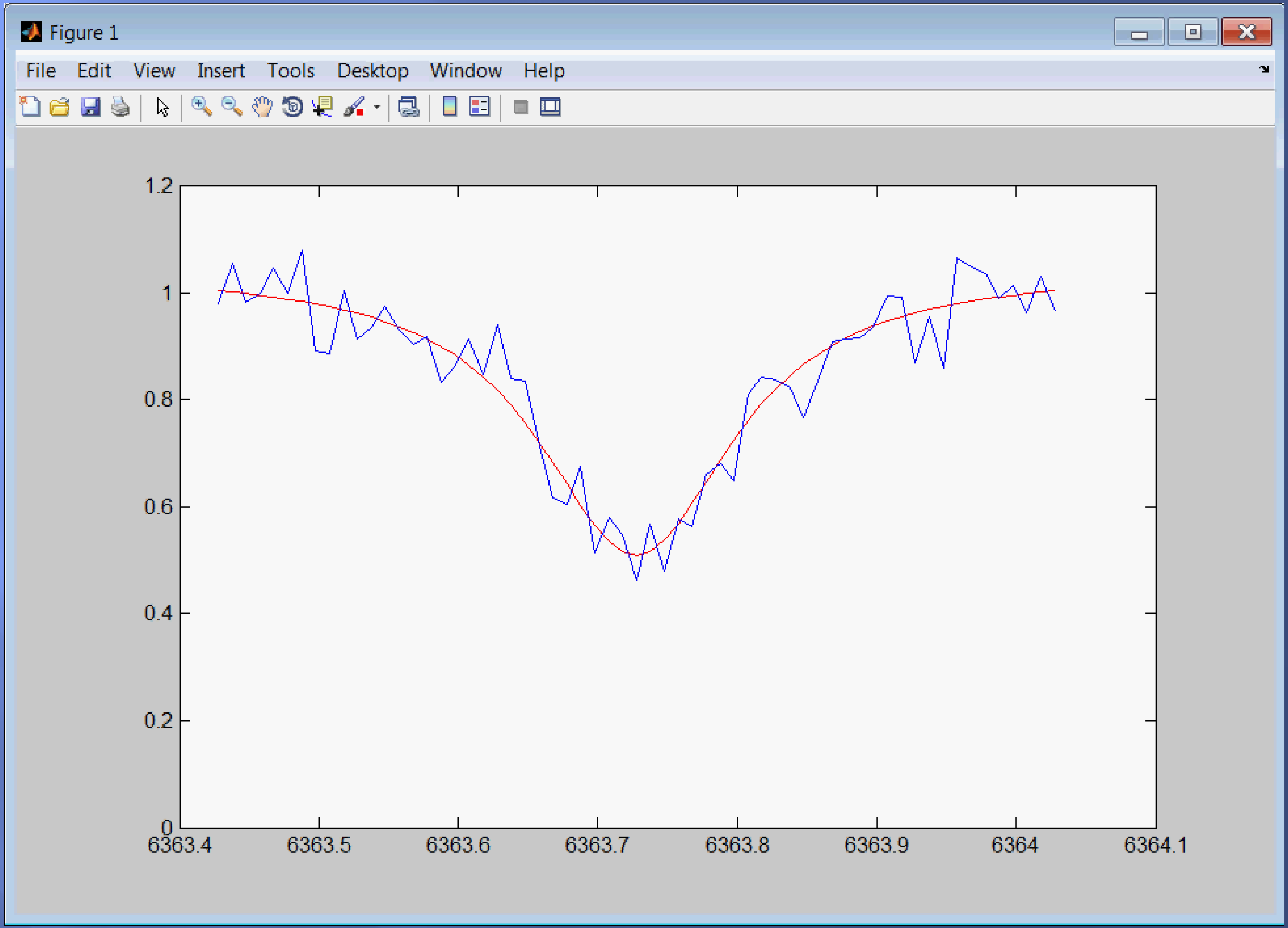
6363.8
6363.9
6364
6364.1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