Progress in Measurement of Carbon Dioxide using a Broadband LIDAR.

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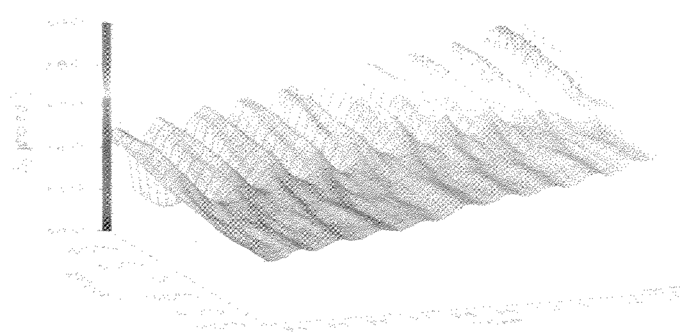
OUTLINE OF TALK

I. Introduction-ASCENDS
II. Why Broadband LIDAR?
III. How Does it Work?
IV. Conclusions



The Path Length Problem I

If the entire atmospheric column could be compressed into a box with a constant pressure of one atmosphere the box would be roughly seven kilometers thick. A change in the column by 1 part in 400 then would represent a change in the box thickness of 7000/400=17.5 meters. This means that a change in the optical path of light that is being used to measure the CO_2 column as small as 17.5 meters would produce a change in the column measurement of about 1ppm—the desired measurement precision. Clearly changes in terrain can produce path length deviations much larger than this so a successful CO_2 measurement must include some method of determining this path length. Simultaneous measurement of the O_2 column has been suggested since this also corrects for changes arising from meteorology. Atmospheric scattering can produce path length changes much larger than 17.5m and depending on the distribution of scattering particles and the elevation of the sun the changes can be either positive or negative.

THE ASCENDS MISSION

- The goal of Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission is to significantly enhance the understanding of the role of CO_2 in the global carbon cycle.
- The National Academy of Sciences recommended in its decadal survey that NASA put in orbit a CO_2 lidar to satisfy this long standing need.
- Existing passive sensors suffer from two shortcomings.
    - Their measurement precision can be compromised by the path length uncertainties arising from scattering within the atmosphere.
    - Also passive sensors using sunlight cannot observe the column at night.
- Both of these difficulties can be ameliorated by lidar techniques.

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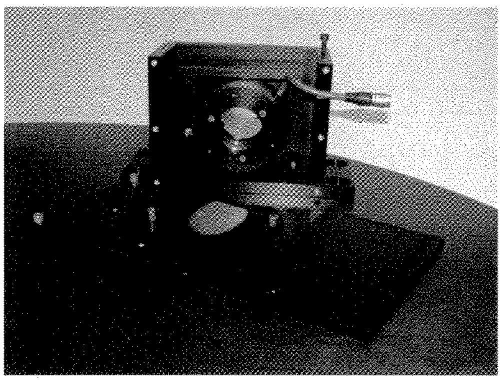
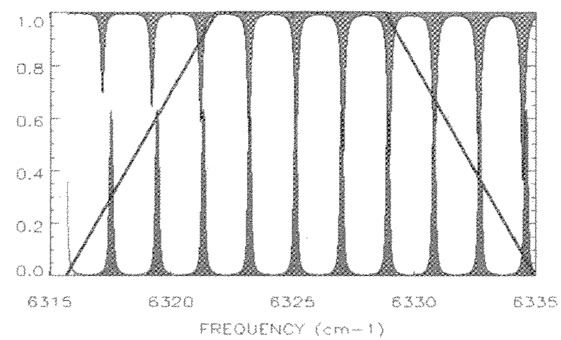


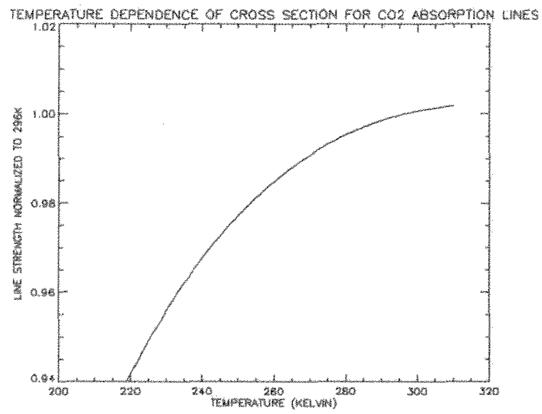


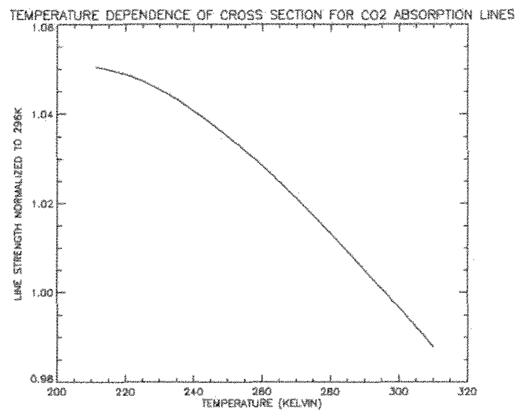
LIDAR SYSTEMS

- Lidar systems present Global measurement of carbon dioxide column with the aim of discovering and quantifying unknown sources and sinks has been a high priority for the last decade. These systems have their own set of problems however.
  - Temperature changes in the atmosphere alter the cross section for individual CO_2 absorption features.
  - Different atmospheric pressures encountered passing through the atmosphere broaden the absorption lines.
- Currently proposed lidars require multiple lasers operating at multiple wavelengths simultaneously in order to untangle these effects.

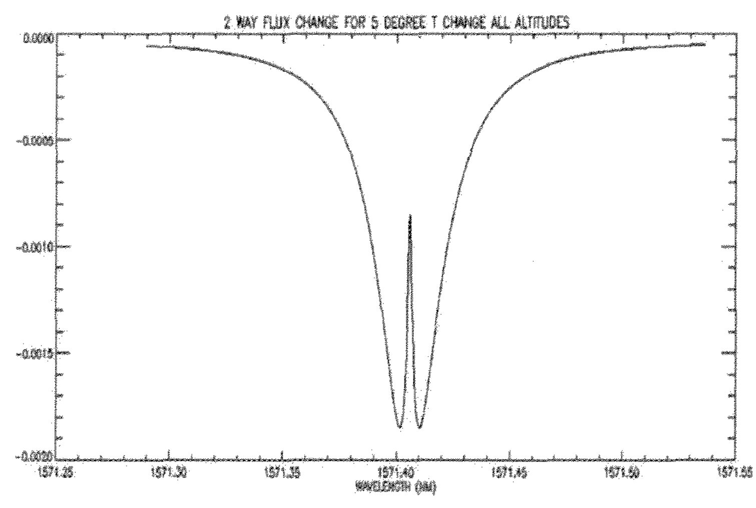
SPECTROSCOPY-TEMPERATURE EFFECTS

The line strengths change with the temperature of the atmosphere This can introduce errors in the column as large as 1ppm for a 2 degree K change in temperature. This means that using a single absorption line and relying on meteorological measurements or models to provide the temperature correction may not suffice for the CO_2 column measurement.



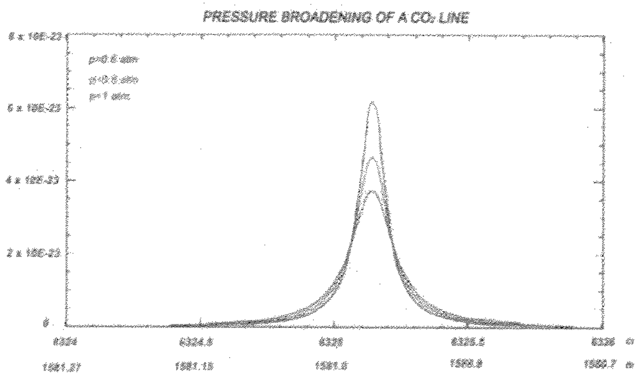


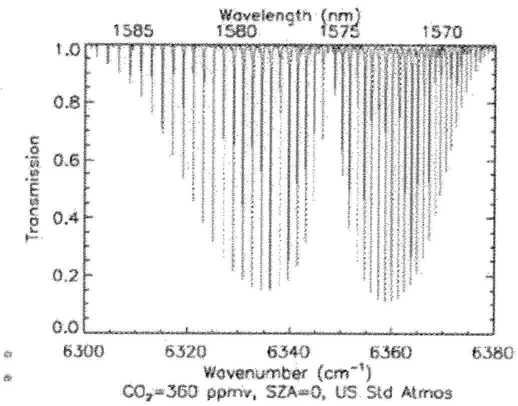
SPECTROSCOPY-TEMPERATURE EFFECTS



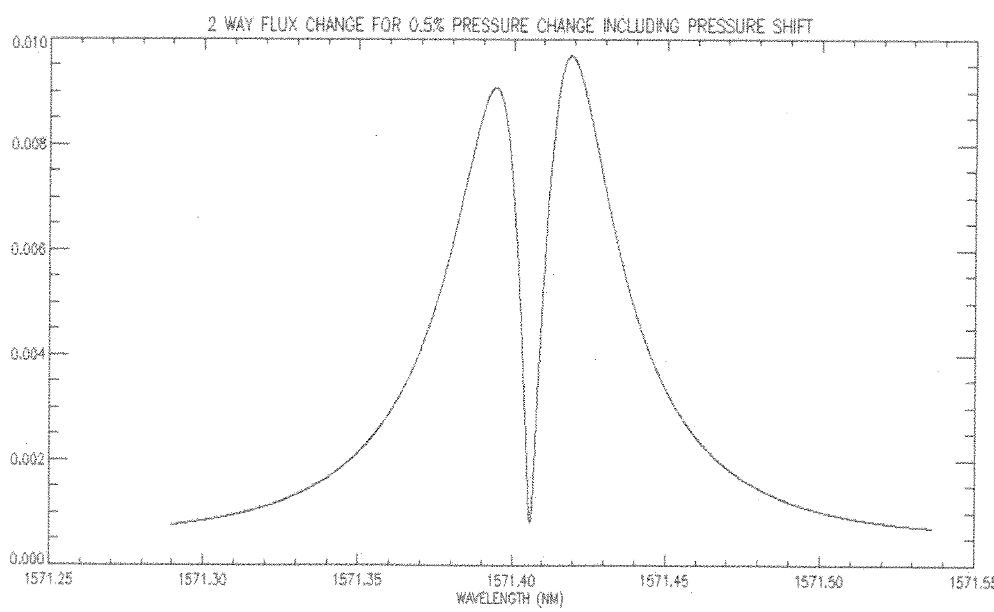
SPECTROSCOPY-PRESSURE EFFECTS

At the top of the atmosphere the width of a spectral line is dominated by the Doppler effect. Proceeding lower into the atmosphere collisional (pressure) broadening begins to manifest itself to a greater and greater extent. A shift in the center frequency also occurs as the result of collisions. There is only a minimal contribution to the absorption in the wing from the upper atmospheric CO_2 the effect of a surface source or sink will be a larger perturbation on the overall column absorption at these wavelengths.





PRESSURE AFFECTS DIFFERENT PARTS OF AN ABSORPTION LINE DIFFERENTLY



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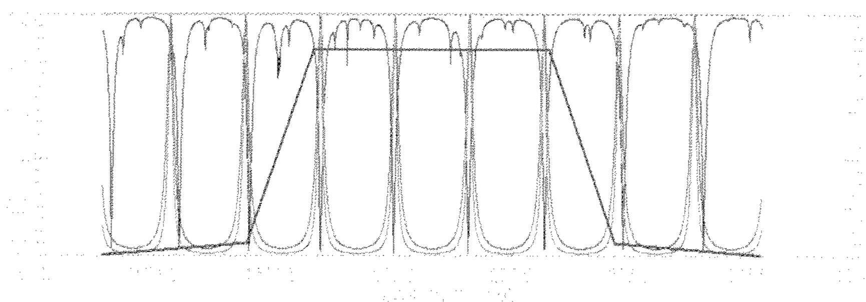
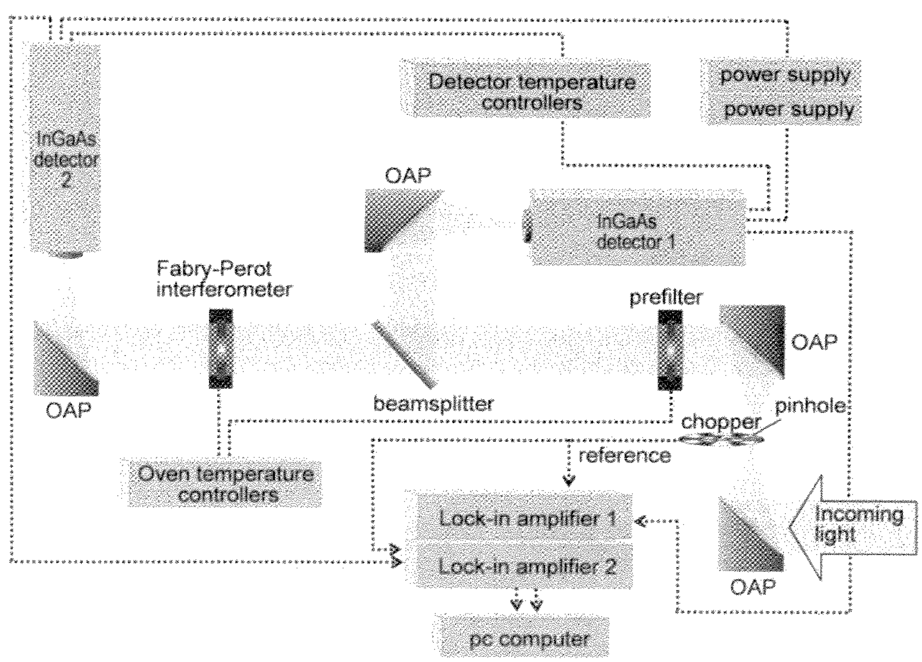
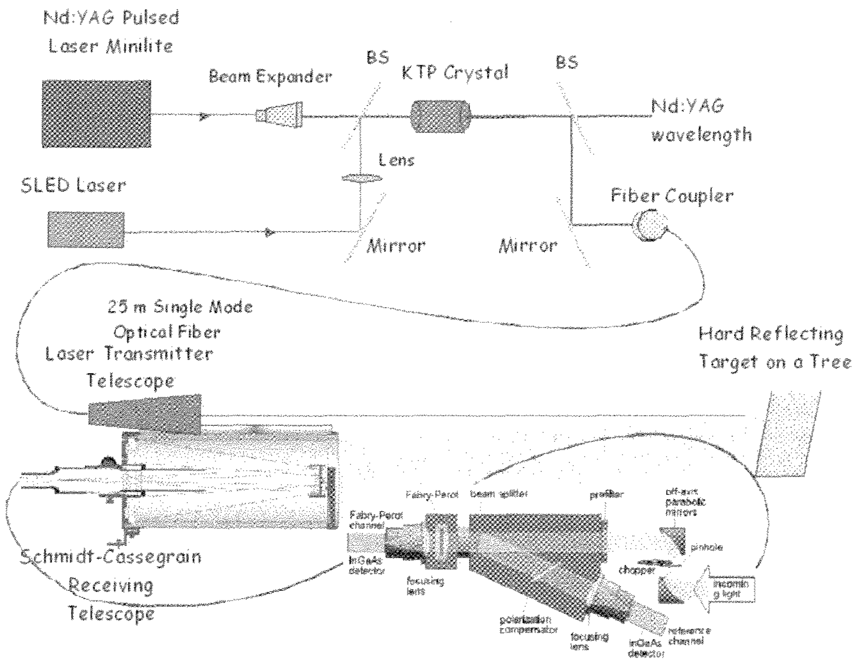


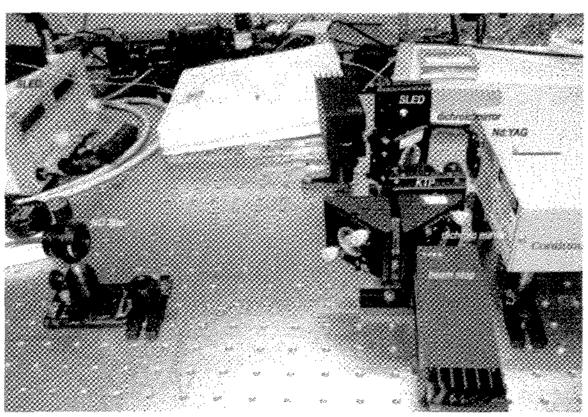
Schematic of one channel of the FP radiometer:

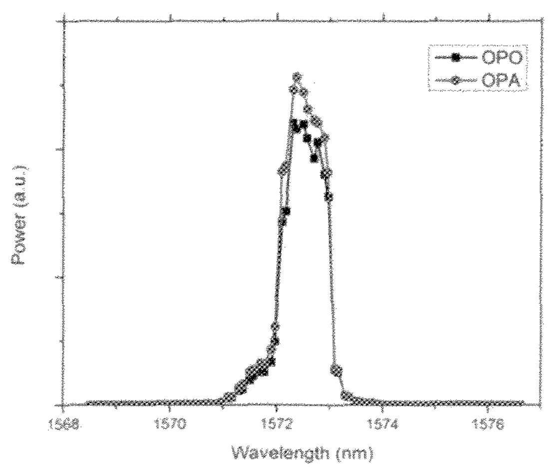


OVERVIEW OF 1.57 MICRON BROADBAND SYSTEM

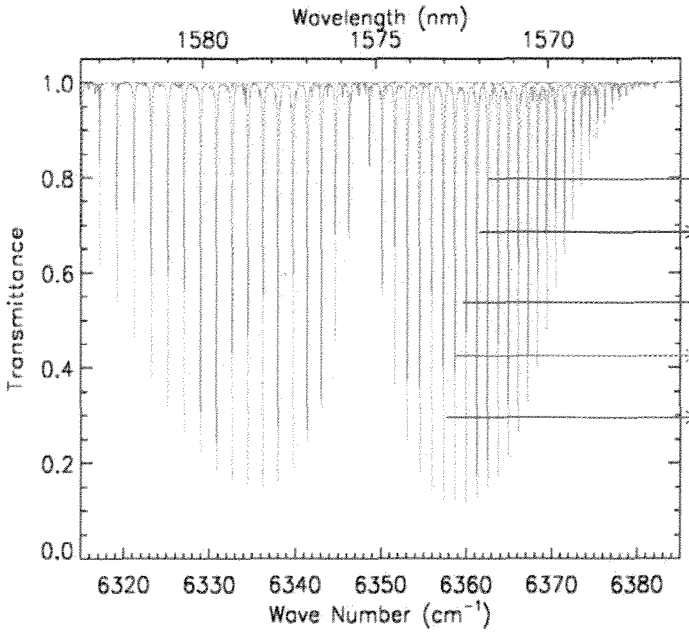


OPO/OPA BROADBAND SOURCE





220 mW AVERAGE POWER OUT TO DATE.



There are CO_2 absorption lines located at

1571.7,

1572.0,

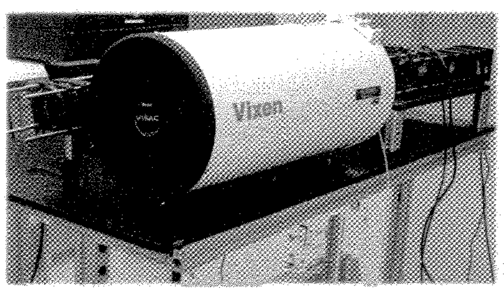
1572.3,

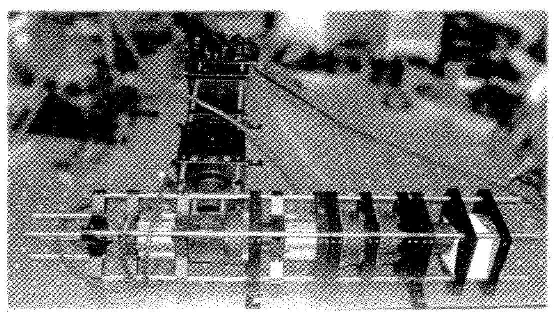
1572.65,

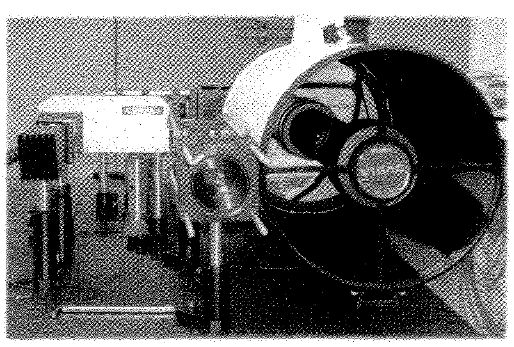
and 1573.0 nm

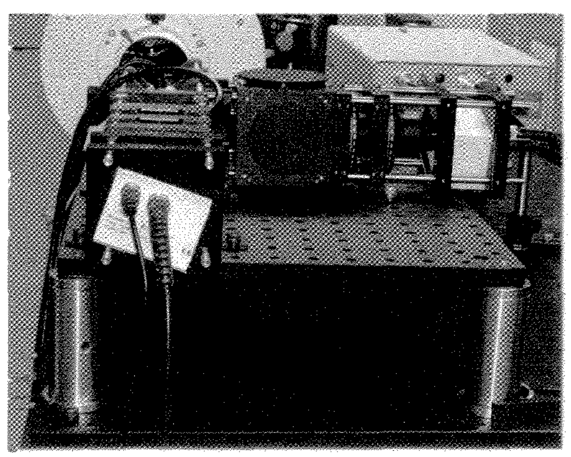
that will absorb light from this transmitter.

BROADBAND SYSTEM HARDWARE

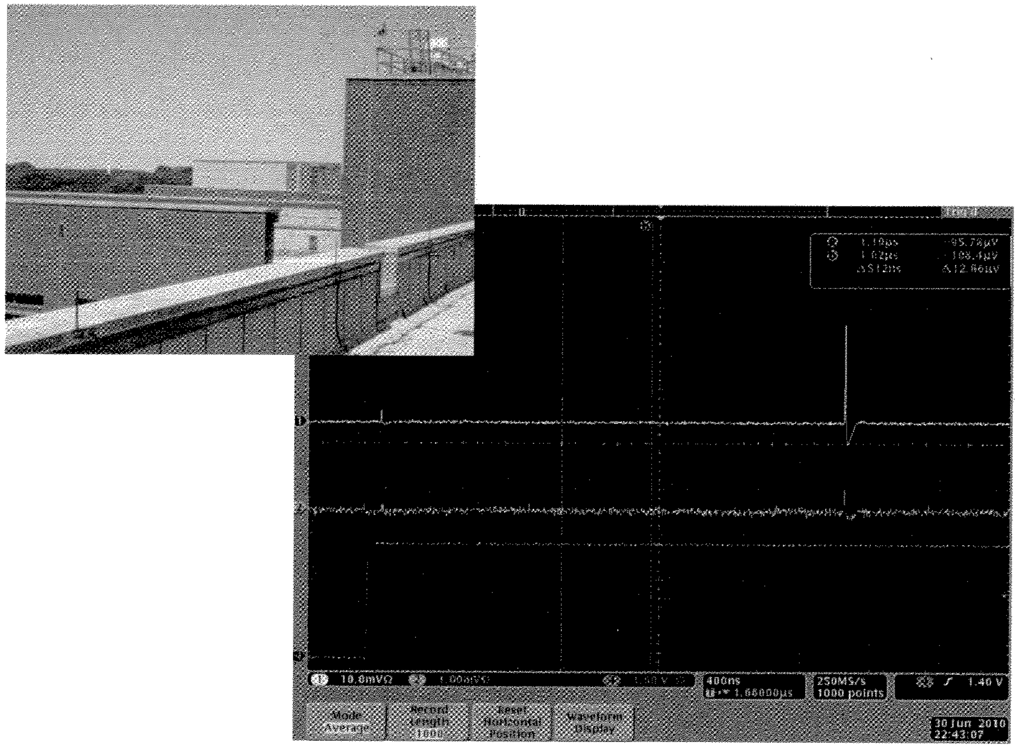








BROADBAND SYSTEM FIRST LIGHT



Tm FIBER LASER IS INTRINSICALLY RUGGED AND HAS VERY HIGH ELECTRICAL TO OPTICAL CONVERSION EFFICIENCY

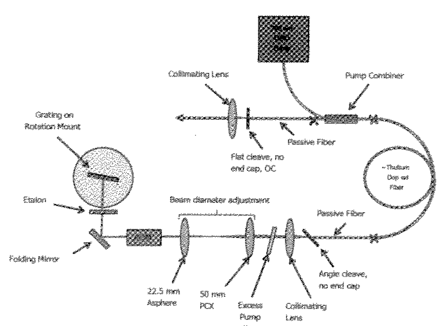
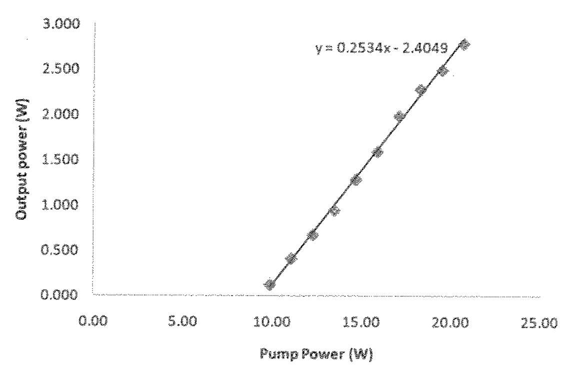


Figure 7: Schematic of current Tm fiber laser system



Current system produces 2.8 Watts

Conclusions

- Innovative active system using advanced source technology development– will enable precise daytime or nighttime measurements of column CO_2
- Directly responds to NRC DS ASCENDS mission
- Number of lasers is reduced compared to competing technologies which reduces the complexity of sensor and thus the cost and risk of failure,
- Knowledge gained from previously developed passive sensor decreases the risk and cost of the present lidar system development
- The instrument can play a significant role as an intercomparison instrument for OCO (Orbiting Carbon Observatory) if it is rebuilt and launched as well as other laser based instruments under development for participation in ASCENDS.

Conclusions

- It can play a role as an airborne instrument in its own right in addressing the problems of scale arising from differences between point observations by the existing ground based CO_2 network and wider area measurements obtained by satellites
- Developed 2.0 micron broadband system as well and will compare performance of both systems to choose optimal approach for ASCENDS
- Have begun development of approach that uses array detectors instead of APD. This approach will have lower noise than APD and may simplify design of the detector optical train.

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