

A Stabilized Master Laser System for Differential Absorption LIDAR

by

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Short Abstract

This thesis presents a Differential Absorption Lidar (DIAL) based on a simple yet accurate and robust dual master laser stabilization system built using optic fiber components. A water-vapor absorption cell stabilizes the on-line wavelength, while the off-line wavelength is beat-frequency stabilized using a 16 GHz bandpass filter. The Master Oscillator Power Amplifier (MOPA) uses a Tapered laser to form the transmitted pulse. Calibration and atmospheric measurements are demonstrated. The control system is built at the electronic component level, with schematics and code listings provided. The system can be expanded for stabilization of multiple lasers.

Abstract

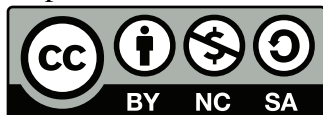
In this thesis, we present a prototype water vapour Differential Absorption Lidar (DIAL) instrument with accurate and precise wavelength control of master diode lasers. This stabilization system design has a number of novel elements that work towards a robust and low-cost autonomous DIAL observatory. With two continuous wave optical wavelengths stabilized, a pulse is formed using an Acousto-Optic Modulator (AOM) to switch light out of each control system to form the transmitted pulse. The control systems employ synchronous reference signal detection that suppresses system perturbations due to the optical switching, facilitating the use of deep dither modulation that aids in accurate stabilization to weak absorption lines. Furthermore, ratiometric detection in the control loop suppresses interference caused by back reflections in optical fiber components, as well as amplitude modulation of the laser diode due to injection current. In our system, the first laser is stabilized to an absorption line of a water vapour cell, while the second is beat-frequency stabilized relative to the first using a passive 16 GHz bandpass filter. This technique can be expanded to stabilize any number of reference lasers with respect to each other and to an absolute optical standard. The prototype DIAL uses a Tapered optical Amplifier (TA) to form 1 μ s 500 mW optical pulses with a repetition rate of >3 kHz for atmospheric transmission. Fourteen observation experiments were conducted over two years, with water vapour measurements obtained using a calibrated humidity sensor, using three saturated salt solutions as humidity references. The measured pulse extinction was used to calculate the effective absorption cross-section of the transmitter, and therefore used to calculate quantitative water vapour measurements from the DIAL observation data. It is hoped that this work will be useful to the further development and commercialization of this unique and powerful remote sensing technique.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide. I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying.

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SIGNED: DATE:

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List of software used in this work

Credit must also be given to the tools used to do and create this work.

- Labview
- Matlab, Octave and Mathematica
- Latex, Okular, Texstudio and Texmaker
- Inkscape, Xfig and Gimp
- Kicad and GEDA
- Linux, Ubuntu and KDE

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Acronyms

AERI Atmospheric Emitted Radiance Interferometer

AIRS Atmospheric Infra-Red Sounder

AMSU Advanced Microwave Sounding Unit

AOM Acousto-Optic Modulator

APD Avalanche Photo Diode

AR Anti Reflection

ARM Atmospheric Radiation Measurement facility

ASE Amplified Spontaneous Emission

ATMS Advanced Technology Microwave Sounder

AVHRR Advanced Very-High Resolution Radiometer

BOM Bureau Of Meteorology

BP Band-Pass filter

CHAMP CHALLENGING Minisatellite Payload

CODI COmpact water vapour DIal

CW Continuous Wave

DAQ Data AQUisition

DFB Distributed Feedback diode laser

- DIAL** Differential Absorption Lidar
- DLR** Deutsches Zentrum für Luft- und Raumfahrt
- DOE** Department Of Energy
- ECDL** External Cavity Diode Laser
- ESR** Equivalent Series Resistance
- FIR** Far Infra-Red
- FM** Frequency Modulation
- FOV** Field Of View
- FP** Fabry-Pérot
- FSR** Free Spectral Range
- FTIR** Fourier Transform Infra-Red (spectrometer)
- FWHM** Full Width at Half Maximum
- GDPFS** Global Data processing and Forecasting System
- GHG** Green-House Gas
- GIFTS** Geosynchronous Imaging Fourier Transform Spectrometer
- GNSS** Global Navigation Satellite System
- GOES** Geostationary Operational Environmental Satellite(s)
- GPS** Global Positioning System
- GRACE** Gravity Recovery And Climate Experiment
- GRAS** GNSS Receiver for Atmospheric Sounding
- HIRS** High-Resolution Infrared Radiation Sounder
- HITRAN** High resolution TRANsmission

HWHM	Half Width at Half Maximum
IASI	Infrared Atmospheric Sounding Interferometer
IHOP	International H ₂ O Project
IR	Infra-Red
LASE	Laser Atmospheric Sensing Experiment
lidar	LIDAR
LIDAR	LIght Detection And Ranging
LITE	Lidar In space Technology Experiment
LPF	Low Pass Filter
MODIS	Moderate-Resolution Imaging Spectroradiometer
MOPA	Master Oscillator Power Amplifier
MSLP	Mean Sea Level Pressure
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NWP	Numerical Weather Prediction
OPO	Optical Parametric Oscillator
OSA	Optical Spectrum Analyzer
PID	Proportionl Integral Differential
PIN	P-Intrinsic-N doped semiconductor
PMT	Photo Multiplier Tube

QPF	Quantitative Precipitation Forecasting
RAM	Residual Amplitude Modulation
RF	Radio Frequency
RH	Relative Humidity %
SG	Savitzky-Golay
SSM/I	Special Sensor Microwave Imager
STP	Standard Temperature and Pressure
TA	Tapered optical Amplifier
TPW	Total Precipitable Water
TRMM	Tropical Rainfall Measuring Mission
VCO	Voltage Controlled Oscillator
VCSEL	Vertical Cavity Surface Emitting Laser diode
VHF	Very High Frequency
WMO	World Meteorological Organization
WM	Wavelength Modulation