

# Table of Contents

<b>Abstract</b>	i
<b>Acknowledgment</b>	iii
<b>Table of Contents</b>	v
<b>List of Figures</b>	viii
<b>List of Tables</b>	xi
<b>List of Common Abbreviations and Symbols</b>	xii
<b>1. Introduction</b>	<b>1</b>
1.1 Motivations	1
1.2 Outline of the Thesis	5
<b>2. Engine Combustion Fundamentals</b>	<b>9</b>
2.1 Engine Combustion Cycle	10
2.2 Combustion Stoichiometry	12
2.3 Fuel-Air ratio in the Mixture	13
2.4 The Governing Thermodynamics State Variables	14
2.5 Factors Affected by Fuel-Air Equivalence Ratio	17
2.5.1 Combustion Efficiencies	17
2.5.2 Pollutant Formation	19
2.6 Homogeneous Charge Compression Ignition (HCCI) Combustion	22
<b>3. Diagnostics Fundamentals</b>	<b>25</b>
3.1 Diagnostics using Tracer	25
3.2 Laser Induced Fluorescence (LIF)	27
3.3 Fluorescence Photophysics	30
3.3.1 Nomenclatures	31
3.3.2 Deactivation Pathways	36
3.3.3 Fluorescence Quenching	39
3.3.4 Kinetics of Photophysics	39
3.3.5 Fluorescence Quantum Yield	40
3.3.6 Stern Volmer Relation	41
3.4 LIF Thermometry	45
3.4.1 Two-lines Method	45
3.4.2 Thermalized Assisted Thermometry	46
3.5 Quantitative Concentration Measurement using Fuel-Air Ratio LIF (FARLIF)	47
3.6 Correcting Systematic Error	50

<b>4. Formaldehyde</b>	<b>51</b>
4.1 General Description	51
4.2 Physical Properties	52
4.3 Formaldehyde Spectroscopy	54
4.3.1 Absorption Spectrum	56
4.3.2 Emission Spectrum	57
4.4 Formaldehyde Photophysics	58
4.5 Two-lines Thermometry using Formaldehyde	62
<b>5 Experimentation</b>	<b>65</b>
5.1 Experimental Set-up	66
5.1.1 Heatable Pressure Chamber	66
5.1.2 Nd:YAG Laser System	66
▪ Principle of Frequency Conversion	
5.1.3 Fluorimeter	68
5.1.4 Camera System	69
▪ Image Intensifier	
▪ DIDEK Unit	
▪ Multiplexer	
▪ Filters	
5.1.5 Time-Delay Generator	72
5.1.6 Photodiode – Oscilloscope	72
5.1.7 Spectrograph System	72
5.1.8 Energy Monitor	73
5.1.9 The Acquisition System	73
5.2 Distribution System	73
5.3 Formaldehyde–Fuel Mixture	75
5.4 Fluorescence Lifetime Measurements	78
5.4.1 Fluorescence Decay Detected by High Speed Photodiode	79
5.4.2 Contiguous-Gated RLD Method	80
5.4.3 Optimized-Gated RLD Method	81
5.5 Absorption Cross-Section and Fluorescence Quantum Yield of Formaldehyde	83
5.6 Temperature Measurements Employing Formaldehyde LIF	84
5.7 Calibration for Fuel-Air Ratio LIF using Formaldehyde as Dopant	85
<b>6 Measurement Results</b>	<b>87</b>
6.1 General Investigation on the Measurement Systems	87
6.1.1 Energy Stability of 3 <sup>rd</sup> harmonic of Nd:YAG Laser	87
6.1.2 Linearity Check	88

6.2 Investigation on Formaldehyde Spectroscopy and Photophysics using a Fluorimeter	90
6.2.1 Formaldehyde Emission Signal: Spectra and Decayed Signal	90
6.2.2 Quenching Behavior due to Bath Gases and Temperatures	92
6.2.3 Investigation on Applicability of RLD and ORLD Lifetime Calculation	96
6.3 Photophysical Measurements using a Photodiode	98
6.3.1 Quenching Behavior due to Bath Gases	98
6.3.2 Quenching Behavior due to Temperature	99
6.4 Temperature Measurements using Two-line Thermometry of Formaldehyde	102
6.5 Measurement of Formaldehyde Absorption Cross-Section	105
6.6 Fuel-Air Ratio Measurement using Formaldehyde as Tracer	108
6.6.1 Investigation on the Fuel – Tracer Mixture	108
6.6.2 Calibration of Fuel-Tracer Mixture Concentration	108
<b>7 Summary and Outlooks</b>	<b>113</b>
<b>References</b>	<b>117</b>
<b>Appendices</b>	<b>127</b>
<b>Curriculum Vitae</b>	<b>133</b>