

## MASTER'S THESIS

### Spatial and temporal probing of particle density in UV laser generated plasma and high pressure TE discharge plasma

Ng, Lun Chiu

*Date of Award:*  
1994

[Link to publication](#)

#### General rights

Copyright and intellectual property rights for the publications made accessible in HKBU Scholars are retained by the authors and/or other copyright owners. In addition to the restrictions prescribed by the Copyright Ordinance of Hong Kong, all users and readers must also observe the following terms of use:

- Users may download and print one copy of any publication from HKBU Scholars for the purpose of private study or research
- Users cannot further distribute the material or use it for any profit-making activity or commercial gain
- To share publications in HKBU Scholars with others, users are welcome to freely distribute the permanent URL assigned to the publication

**SPATIAL AND TEMPORAL PROBING OF PARTICLE DENSITY  
IN  
UV LASER GENERATED PLASMA  
AND  
HIGH PRESSURE TE DISCHARGE PLASMA**

**NG Lun Chiu**

**A thesis submitted on partial fulfillment of the requirements  
for the degree of  
Master of Philosophy**

**January, 1994**

**Hong Kong Baptist College**



Gift  
12-7-94  
313855

TH  
M. PHIL  
1994NS

## ABSTRACT

TH

\*Bib 9/94

Since the refractive index of plasma is very sensitive to the density of free electrons, a specially designed Michelson interferometer is established to probe the transient plasmas, generated by pulsed laser and by pulsed gas discharge, respectively. With a moving mirror in the interferometer and a phase comparator control system, the phase angle of the sinusoidal signal was tracked and the plasma was initiated whenever the detected phase angle matched a pre-defined value. The transient interference waveform produced as a consequence of the plasma formation was then synchronously captured. This modified set-up features minimal vibration isolation, fast response, powerful noise rejection, and a detection limit of a thousandth of a fringe shift.

Temporally and spatially resolved interference observations were performed for the LGP (laser generated plasma) from a solid sample by the ablation of a short uv laser pulse (15 ns, 308 nm) in vacuum and in gas environments. The sample materials are pure metal (copper), alloy (brass) and metallic oxide ( $Al_2O_3$ ), respectively. The velocity distribution of electrons, probable expansion velocity of its stream, and threshold of electrons ejection could all be determined with these interference measurements. The characteristics of the LGP are proven to be dependent upon the sample material as well as the pressure and the compositions of the atmosphere surrounding it. The shock wave and caging effect could be determined from the variation of the interference signal waveform as well. An example is the study of the LGP in an argon atmosphere. The angular distribution of the electron density is found to be isotropic.

Interference measurements were also performed on the HPTE (high pressure, transversely excited gas discharge) plasma occurring in a nitrogen laser chamber. It was found that the laser output energy was approximately proportional to the electron density of the discharge plasma, and the laser action starts with the rise of electron density.

## TABLE OF CONTENT

<b>ABSTRACT</b> .....	i
<b>ACKNOWLEDGMENT</b> .....	ii
<b>DECLARATION</b> .....	iii
<b>TABLE OF CONTENT</b> .....	iv
<b>LIST OF FIGURES</b> .....	vii
<b>LIST OF TABLES</b> .....	x
<b>CHAPTER 1: INTRODUCTION</b> .....	1
1.1 Significance of the LGP .....	1
1.2 Significance of the HPTE Discharge Plasma .....	6
1.3 Significance of the Electron Density Measurement .....	8
<b>CHAPTER 2: DIAGNOSTICS OF LGP AND HPTE PLASMAS</b> .....	15
2.1 Diagnostic of a LGP .....	15
2.1.1 Photographic Imaging .....	15
2.1.2 Spectroscopic Methods .....	20
A. Emission Spectroscopy .....	20
B. Absorption Spectroscopy .....	22
C. Laser-Induced Fluorescence (LIF) .....	22
2.1.3 Laser Beam Probing Methods .....	23
A. Beam Deflection .....	24
B. Interferometry .....	27
2.2 Diagnostic of a HPTE Plasma .....	29
2.3 Michelson Interferometry .....	31
<b>CHAPTER 3: INSTRUMENTATION</b> .....	34
3.1 Introduction to Problems .....	34
3.2 Phase Comparator Control System .....	37
3.2.1 Principles .....	37
3.2.2 Applications .....	40
3.3 Design and Construction .....	42
3.3.1 D.C. Motor-Driven Micrometer Lever Assembly .....	42
3.3.2 Electronic Circuitry of Phase Comparator Control System .....	43

<b>CHAPTER 4: STUDY OF PARTICLE DENSITY OF THE LGP</b> .....	48
4.1 Experimental Set-up .....	48
4.1.1 Overview .....	48
4.1.2 The production of the LGP.....	50
4.1.3 The Sample Chamber .....	51
4.1.4 The Moving-Mirror Michelson Interferometer .....	52
4.1.5 The Method of Capturing Raw Data .....	54
4.2 Raw Data Treatment .....	55
4.2.1 The Identification of Signal Portion .....	55
4.2.2 The Transformation to Fringe Shift .....	58
4.2.3 The Reliability of the Temporal Resolution .....	58
4.2.4 The Time Origin .....	60
4.3 Experimental Results .....	61
4.3.1 The Dependence of Laser Fluence in Vacuum .....	61
4.3.2 The Dependence of Probe Distance in Vacuum .....	68
4.3.3 The Dependence of Laser Fluence in Ambient Gas .....	74
4.3.4 The Dependence of Probing Distance in Ambient Gas .....	79
4.3.5 The Effect of Different Ambient Gases .....	83
4.3.6 The Transverse Scan .....	88
4.4 Discussions .....	92
4.4.1 The Measurement of the Ignition Threshold .....	93
4.4.2 The Time-of-Flight (TOF) Measurement .....	96
4.4.3 The Caging Effect .....	102
4.4.4 The Electron Density Function.....	103
<b>CHAPTER 5: STUDY OF THE HPTE DISCHARGE PLASMA</b> .....	114
5.1 Experimental Set-up .....	114
5.2 Calibration .....	120
5.3 Experimental Results .....	123
5.3.1 The Methodology of Signal Subtraction .....	123
5.3.2 The Dependence of Charging Voltage .....	128
5.3.3 The Dependence of Pressure .....	130
5.4 Discussions .....	132
5.4.1 The Background Fluorescence .....	132
5.4.2 The Interferometer Signals .....	134
5.4.3 The Temporal Relation between Laser Pulse and Electron Density ...	136
<b>CHAPTER 6: CONCLUSION AND FURTHER WORK</b> .....	140
6.1 Conclusion .....	140
6.2 Further work .....	143
6.3 Practical Application.....	144

<b>APPENDICES</b> .....	146
<b>A. The Circuit Diagrams of the Phase Comparator Control System</b> .....	146
<b>B. The Specifications of the Questek Excimer Laser</b> .....	150
<b>REFERENCES</b> .....	151
<b>VITA</b> .....	156