

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

ABSTRACT	i
ACKNOWLEDGMENT	ii
DECLARATION	iii
TABLE OF CONTENT	iv
LIST OF FIGURES	vii
LIST OF TABLES	x
CHAPTER 1: INTRODUCTION	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
CHAPTER 2: DIAGNOSTICS OF LGP AND HPTE PLASMAS	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
CHAPTER 3: INSTRUMENTATION	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

CHAPTER 4: STUDY OF PARTICLE DENSITY OF THE LGP	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
CHAPTER 5: STUDY OF THE HPTE DISCHARGE PLASMA	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
CHAPTER 6: CONCLUSION AND FURTHER WORK	140
6.1 Conclusion	140
6.2 Further work	143
6.3 Practical Application.....	144

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