

MASTER'S THESIS

Real-time optical fibre sensing of phytoplankton for studies in size distribution and concentration

Cheng, Sau Kuen

Date of Award:
1996

[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

**Real-time Optical Fibre Sensing
of
Phytoplankton for Studies in
Size Distribution and Concentration**

CHENG Sau Kuen

**A thesis submitted in partial fulfilment of the requirements for
the degree of Master of Philosophy**

August 1996

Hong Kong Baptist University



JH
8-9-97
14245966
TH

ABSTRACT

Flow Cytometry is a powerful equipment for particle analysis in microbiology. The tight optical alignment of the cytometer limits its usage for *in situ* particle analysis in oceanography. A modified flow cytometer was proposed to overcome the alignment requirement. It incorporated the technology of optical fibre, laser Doppler velocimetry, laser induced fluorescence and digital signal processing. A laboratory version of the proposed system was built on an optical breadboard for feasibility testing. The laboratory setup was used to measure two species of phytoplankton (*Chlorella* and *Scenedemus*). The result indicates that reliable size measurement can be obtained by the modified flow cytometer. A series of experiments for measurement of particle size with different flow rates demonstrated that the equipment measured particle size independent on the particle velocity. The constrain of constant flow of sample fluid through the measurement volume in ordinary flow cytometer is relaxed. The system is suitable to be further develop into a practical *in situ* field instrument.

TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGMENT	ii
DECLARATION	iii
List of Figures.....	vii
1. INTRODUCTION.....	1
1.1 AIM OF THE PROJECT.....	1
1.2 EXISTING METHODS FOR MEASURING PHYTOPLANKTON SIZE DISTRIBUTION.....	3
1.2.1 Microscope Counting.....	3
1.2.2 Electronic Counter.....	4
1.2.3 Fluorometer.....	5
1.2.4 Flow Cytometers.....	6
1.3 THE PROPOSED MEASUREMENT SCHEME.....	7
2. THEORY.....	11
2.1 WAVE PROPERTIES OF LIGHT.....	12
2.1.1 Spatial Coherence.....	13
2.1.2 Temporal Coherence.....	13
2.1.3 Polarization.....	14
2.2 INTERFERENCE OF TWO BEAMS.....	15
2.3 THE WORKING PRINCIPLE OF LDDV.....	19
2.4 LASER INDUCED FLUORESCENCE (LIF) OF PHYTOPLANKTON.....	22
2.5 BASIC PRINCIPLE OF FLOW CYTOMETRY.....	24
2.5.1 Particle Scattering Measurement in Flow Cytometry.....	26
2.5.2 Fluorescence Signal in Flow Cytometry.....	27
2.5.3 Limitation of Existing Technology.....	27
2.6 THE DETERMINATION OF PARTICLE SIZE.....	29
2.7 DIGITAL SIGNAL PROCESSING.....	31
2.7.1 Advantages and Limitation of DSP.....	34
2.8 DIGITAL SIGNAL PROCESSING HARDWARE.....	35
2.8.1 ADC.....	35
2.8.2 Architecture of Digital Signal Processor.....	37
2.9 SIGNAL PROCESSING TECHNIQUE.....	38
2.9.1 Windowing.....	38
2.9.2 The FFT Spectral Analysis Algorithm.....	42

3. THE MEASUREMENT SYSTEM DESIGN	46
3.1 THE OPTICAL SETUP	47
3.1.1 <i>The Argon Laser</i>	48
3.1.2 <i>Optical Fibre</i>	49
3.1.3 <i>The Optical Head</i>	52
3.1.4 <i>The Fluid System</i>	53
3.1.5 <i>The Optical Signal Detection System</i>	54
3.2 THE SIGNAL PROCESSING SYSTEM	57
3.2.1 <i>The ADSP Mother Board</i>	58
3.2.2 <i>The MDSP Board</i>	60
3.2.3 <i>The Signal Processing Algorithm</i>	63
3.2.4 <i>The PC Computer</i>	66
3.3 SAMPLES PREPARATION	66
4. RESULTS AND DISCUSSION	68
4.1 THE EMISSION SPECTRUM OF THE PHYTOPLANKTON CELLS	68
4.2 IDENTIFICATION OF VALID EVENTS	69
4.2.1 <i>One Phytoplankton Passing Through the Measurement Volume</i>	70
4.2.2 <i>Multiple Phytoplankton Particle Passing Through the Measurement Volume</i>	72
4.2.3 <i>The Phytoplankton Particle Transverse out of Measurement Volume</i>	74
4.2.4 <i>Multiple Particles Pass Through and out of the Measurement Volume</i>	76
4.2.5 <i>Invalid Signal Elimination with Hamming Windowing</i>	78
4.3 EVALUATION OF THE PARTICLE VELOCITY FROM THE DOPPLER SIGNAL	80
4.4 EQUIPMENT PERFORMANCE OF SIZE DISTRIBUTION MEASUREMENT WITH THE CHLORELLA AND SCENEDEMUS	82
4.5 DISCUSSION	88
5. CONCLUSION AND FURTHER DEVELOPMENT	89
5.1 CONCLUSION	89
5.2 FURTHER DEVELOPMENT	89
6. REFERENCES	93
7. APPENDIX A - ELECTRONIC CIRCUIT DIAGRAM	96
7.1 A1-PMT PROTECTION CIRCUIT	96
7.2 A2 - IV CONVERTOR CIRCUIT	97