!YOUR TITLE ALL CAPS!

By Joel N. Johnson

A Dissertation

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

in Applied Physics and Materials Science

Northern Arizona University

!Month YYYY!

Ryan O. Behunin, Ph.D., Co-Chair

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Table of Contents

List of Tables

List of Figures

Dedication

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Preface

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Chapter 1

Introduction

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1.1 Spontaneous Brillouin Scattering

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1.2 Stimulated Brillouin Scattering

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1.3 Phase-matching

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1.4 Brillouin Gain of Materials

1.5 Raman Scattering

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1.6 Raman-like Brillouin Modes

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Chapter 2

Foundational Experimental Techniques and Instrumentation

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2.1 Experimental Techniques

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2.1.1 ways we can direct light in a photonic system

2.1.2 photonic devices and diagrams

2.1.3 ways we can select and isolate signals

2.1.4 heterodyne detection and the role of the LO

2.1.5 loss in a photonic system

2.1.6 free space optics and beam alignment

2.1.7 special fiber types and properties

2.2 Optical Instrumentation

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2.3 Electronic Instrumentation

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2.4 Noise and Background Handling

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2.5 Custom Software

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2.5.1 Description of Python Script for CABS Data Collection

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2.5.2 Description of Plotting Data in Go Program

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Chapter 3

Manuscript I: Laser cooling of traveling wave phonons in an optical fiber

3.1 Optomechanical Cooling and Heating

3.2 Cooling Platform: CS_2-Liquid Core Optical Fiber

3.2.1 Optomechanical Properties

3.2.2 Fabrication

3.2.3 Fabrication Iterative Refinement

3.3 Intention of the Pump-Probe Experiment

3.4 Experimental Setup

3.4.1 Main Experiment

3.4.2 Pump-Probe Experiment

3.5 Results

3.5.1 Main Experiment Results

3.5.2 Pump-Probe Experiment Results

3.6 Discussion

3.6.1 Application to Ground State Cooling

3.6.2 Standardized Cooling Metric

3.6.3 Syncronous Achievement by Max Plank Group

3.6.3.1 Platform: Tapered chalcogenide Photonic Crystal Fiber

Chapter 4

Manuscript II: A coherently stimulated phonon spectrometer

Joel N. Johnson[1,2], Nils T. Otterstrom[3], Peter T. Rakich[4], Ryan O. Behunin[1,2]

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4.1 Abstract

4.2 Introduction

State of brillouin microscopy Applications and usefulness Challenges: selection of backscattered signal conflated with Stokes field phase-matching requires probe wavelength to be exactly that of Stokes Wouldn't it be nice if we could break free of strict phase-matching requirements, therefore perfectly isolating the signal In this work

4.2.1 Theory of CABS

description of physics with scattered power equation

4.2.2 Phase-matching at short lengths

phase-matching bandwidth description with equation

4.3 Methods

4.3.1 Theory of CABS

full CABS theory arriving at scattered power

[1] Department of Applied Physics and Materials Science, Northern Arizona University, Flagstaff, AZ 86011, USA
[2] Center for Materials Interfaces in Research and Applications, Flagstaff, AZ 86011, USA
[3] Sandia National Laboratory, 1515 Eubank Blvd SE, Albuquerque, NM 87123, USA
[4] Department of Applied Physics, Yale University, New Haven, CT 06520, USA

4.3.2 Phase-matching bandwidth

phase-matching bandwidth theory

4.4 Results

4.4.1 Design of instrument

description of design figure: instrument apparatus design sensitivity measurements

4.4.2 From fiber-coupled to micrometer-scale free-space

figure: demonstration measurements 1mm uhna3 fiber 1mm CS2 bulk

comparison to stimulated brillouin and spontaneous brillouin?

4.4.3 Relaxation of Phase-matching conditions

figure: phase-matching peak vs pump-probe separation 1cm uhna3, CS2 peak vs pump-probe separation 1mm uhna3, CS2

4.5 Discussion

4.6 Acknowledgements

4.7 Appendix

4.7.1 Equal contribution of P, S, Pr

figure: P, S, Pr equal contributors

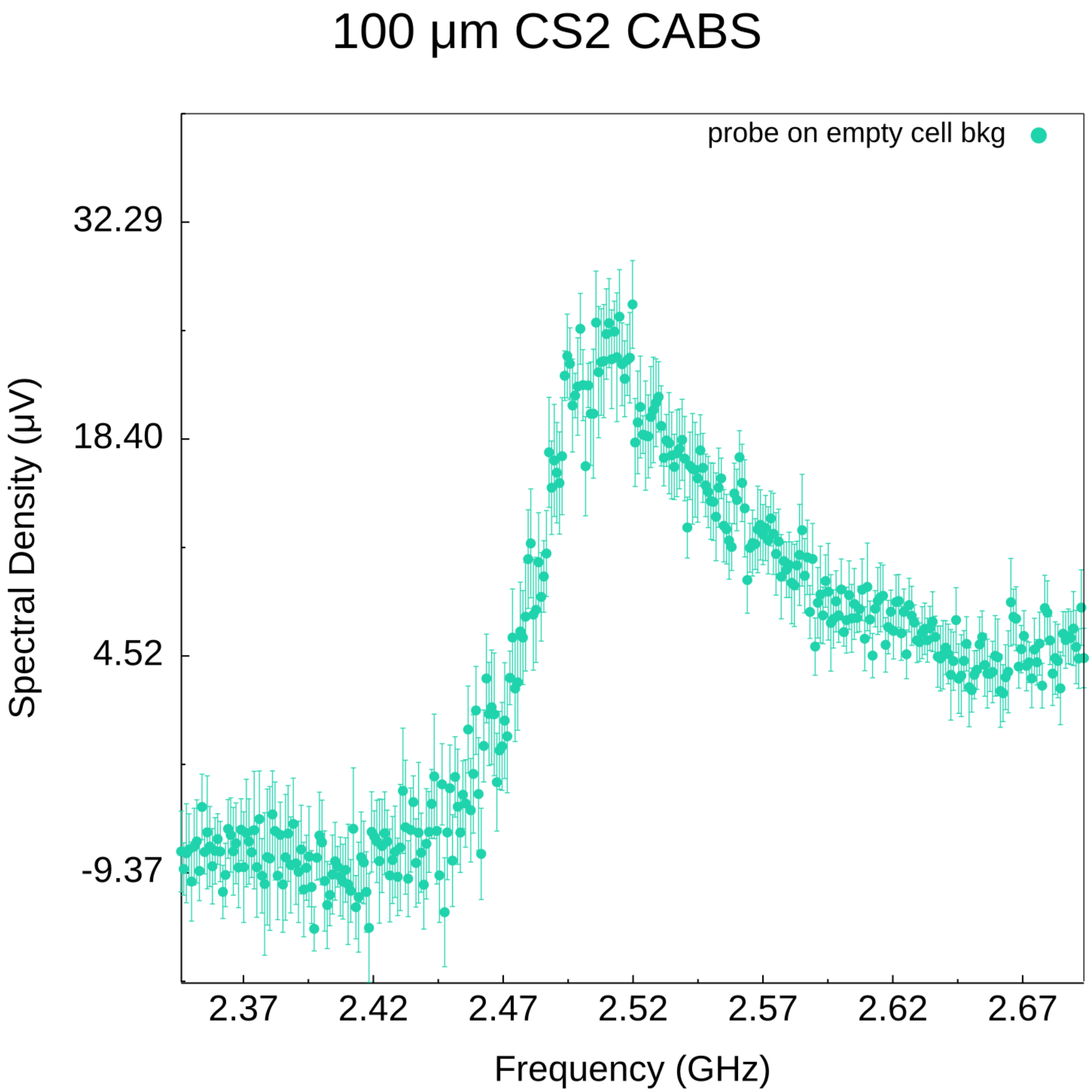

Figure 4.1: CABS measurement of 100um of CS2.

Chapter 5

Manuscript III: Brillouin-induced Raman modes

5.1 Abstract

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5.2 Introduction

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Table 5.1: Table caption.

	Parameter	Value	Description
Lookup Variables	lat	-85°–85°	Latitude (35 bins in 5° increments)
	ALBEDO	0.05–0.225	Bolometric albedo (6 bins in 0.035 increments)
	SLOPE	0°–90°	Surface slope (19 bins in 5° increments)
	SLOAZI	0°–360°	Surface azimuth (19 bins in 20° increments)
	DELLS	4°	L_s step size (90 bins spanning 0°–360°)
Thermal Parameters	EMISS	0.96	Emissivity
	thick	0.05	Upper layer thickness [m]
	DENSITY	1100	Upper layer density [kg/m^3]
	DENS2	1800	Lower layer density [kg/m^3]
	lbound	18	Interior heat flow [mW/m^2]
	PhotoFunc	0.045/albedo	Photometric function (Keihm-style)
Temperature-dependent parameters	SphUp0/SphLo0	602.88098583	Specific heat capacity expressed as 4th-order polynomial ($c0 + c1 \cdot T + c2 \cdot T^2 + c3 \cdot T^3$)
	SphUp1/SphLo1	235.98988249	
	SphUp2/SphLo2	-29.59742178	
	SphUp3/SphLo3	-3.78707193	
	ConUp0	0.00133644	Upper layer conductivity expressed as 4th-order polynomial ($c0 + c1 \cdot T + c2 \cdot T^2 + c3 \cdot T^3$)
	ConUp1	0.00073150	
	ConUp2	0.00033250	
	ConUp3	0.00005038	
	ConLo0	0.00634807	Lower layer conductivity expressed as 4th-order polynomial ($c0 + c1 \cdot T + c2 \cdot T^2 + c3 \cdot T^3$)
	ConLo1	0.00347464	
	ConLo2	0.00157938	
	ConLo3	0.00023930	
Model Setup Parameters	body	Moon	Target body
	k_style	Moon	Conductivity style (Moon for airless bodies)
	LKofT	T	Temperature-dependent conductivity
	FLAY	0.01	First layer thickness [m]
	RLAY	1.3	Layer thickness multiplier
	N1	26	Number of layers
	N24	288	Timesteps per day (5 min steps)
	DJUL	0	Start date

Chapter 6

Manuscript IV: Nanoscale Brillouin scattering

6.1 Abstract

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	SLOAZI	0°–360°	Surface azimuth (19 bins in 20° increments)
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	DENS2	1800	Lower layer density [kg/m^3]
	lbound	18	Interior heat flow [mW/m^2]
	PhotoFunc	0.045/albedo	Photometric function (Keihm-style)
Temperature-dependent parameters	SphUp0/SphLo0	602.88098583	Specific heat capacity expressed as 4th-order polynomial ($c0 + c1 \cdot T + c2 \cdot T^2 + c3 \cdot T^3$)
	SphUp1/SphLo1	235.98988249	
	SphUp2/SphLo2	-29.59742178	
	SphUp3/SphLo3	-3.78707193	
	ConUp0	0.00133644	Upper layer conductivity expressed as 4th-order polynomial ($c0 + c1 \cdot T + c2 \cdot T^2 + c3 \cdot T^3$)
	ConUp1	0.00073150	
	ConUp2	0.00033250	
	ConUp3	0.00005038	
	ConLo0	0.00634807	Lower layer conductivity expressed as 4th-order polynomial ($c0 + c1 \cdot T + c2 \cdot T^2 + c3 \cdot T^3$)
	ConLo1	0.00347464	
	ConLo2	0.00157938	
	ConLo3	0.00023930	
Model Setup Parameters	body	Moon	Target body
	k_style	Moon	Conductivity style (Moon for airless bodies)
	LKofT	T	Temperature-dependent conductivity
	FLAY	0.01	First layer thickness [m]
	RLAY	1.3	Layer thickness multiplier
	N1	26	Number of layers
	N24	288	Timesteps per day (5 min steps)
	DJUL	0	Start date

Chapter 7

Discussion & Conclusion

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Appendix A

Acronyms

AGU American Geophysical Union

Appendix B

Supplementary Information for Chapter 3: Manuscript I

References

Boyd, R. W. 2020, Nonlinear optics (Academic press)