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14. ABSTRACT In recent years with the advent of high Q optical and mechanical micro-cavities, it has been possible to observe coupling between optical radiation and the mechanical modes in moveable structures in fine detail. Light when confined within a resonator exerts radiation pressure on the mechanical structure which gives rise to the effect of dynamic back-action. This leads to, among other things, parametric instability and opto-mechanical back-action cooling. Recently the dynamic manifestations of radiation pressure forces on micro- and Nano-mechanical objects have become an experimental reality. These observations have created a great deal of interest in exploiting these					
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UU	UU	UU		19b. TELEPHONE NUMBER 202-416-1484	

Report Title

Final Report: Organization of 2012 Cavity Optomechanics Incubator Meeting

ABSTRACT

In recent years with the advent of high Q optical and mechanical micro-cavities, it has been possible to observe coupling between optical radiation and the mechanical modes in moveable structures in fine detail. Light when confined within a resonator exerts radiation pressure on the mechanical structure which gives rise to the effect of dynamic back-action. This leads to, among other things, parametric instability and opto-mechanical back-action cooling. Recently the dynamic manifestations of radiation pressure forces on micro- and Nano-mechanical objects have become an experimental reality. These observations have created a great deal of interest in exploiting these effects to study fundamental properties of light and mechanical systems and research in this topic has grown quickly over the past few years to include areas such as optical micro and nano-mechanical resonators, entanglement, generation of squeezed states of light, measurements at or beyond the standard quantum limit, single photon non-linearities, and fundamental sources leading to decoherence. In this incubator meeting, we examined the emerging areas referred to as cavity opto-mechanics and cavity quantum opto-mechanics with the goal of discussing the latest advances which define the state of the art, and exploring the opportunities afforded by this new technology to better understand coupled systems and the quantum phenomena encompassing both optical and mechanical systems.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME

PERCENT SUPPORTED

FTE Equivalent:

Total Number:

Names of Post Doctorates

NAME

PERCENT SUPPORTED

FTE Equivalent:

Total Number:

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	National Academy Member
Prof. Markus Aspelmeyer	1.00	No
Prof. Pierre Meystre	1.00	Yes
FTE Equivalent:	2.00	
Total Number:	2	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

Names of Personnel receiving masters degrees

<u>NAME</u>
Total Number:

Names of personnel receiving PHDs

<u>NAME</u>
Total Number:

Names of other research staff

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

The format of the Cavity Optomechanics Incubator Meeting consisted of a series of two-hour long round tables discussions, each opened by one invited 45-minute overview presentation that helped frame the discussion in a balanced way, followed by brief, 3 slides presentation-long by interested participants and an open discussion

Topics discussed:

1. On-Chip Optomechanics: new ideas for classical and quantum information processing architectures (e.g. classical: optical nonlinearities, optical memory; quantum: coherent light-matter interfaces, quantum memories, single-photon nonlinearities); coupled systems such as arrays; manybody physics, etc.

Overview: Dr. Oskar Painter, Caltech

2. Multimode Phonon Physics: time dependent systems, phonon pulses, pulsed optomechanics; toward quantum acoustics, etc.

Overview: Dr. Kurt Jacobs, Boston University

3. Coherent Light-Matter Interfaces: mechanical to optical, mechanical to spins, mechanical to matter-wave fields; BECs, ultra cold atoms, hybrid systems, etc.

Overview: Dr. Olivier Arcizet, Grenoble

4. Tests of Fundamental Theories: fundamental sources of decoherence, predictions of quantum gravity. What can large masses do for you? Is it useful to have Planck mass objects operating in the quantum regime? What can large accelerations do for you?

Overview: Dr. Oriol Romero-Isart, Max-Planck Institute for Quantum Optics, Garching

5. Theoretical Challenges and New Directions: new types of couplings, nonlinear effects, single phonon physics, quantum control, nonclassical states, etc.

Overview: Dr. Aash Clerk, McGill University, Montreal

6. Experimental Challenges and New Directions: new systems, larger systems, graphene, mechanical nonlinearities, etc.

Overview: Dr. Tobias Kippenberg, EPFL Lausanne

7. Mechanical Sensing/Metrology in the Quantum Regime: what are the prospects?

Overview: Dr. Keith Schwab, Caltech

Final Report on 2012 Cavity Optomechanics Incubator Meeting

Submitted to:

Dr. Paul M. Baker

Atomic and Molecular Program Manager
Army Research Office (ARO)
4300 S. Miami Blvd.
Durham, NC 27703-9142

From:

Principal Investigator: Elizabeth A. Rogan

Optical Society of America
2010 Massachusetts Ave NW
Washington, D.C. 20036

Meeting

30 September - 2 October 2012
OSA Headquarters
Washington, DC

Post-Meeting Stats:

Incubator Meeting	Hosts	Participants	Total	OSA MBR	N-MBR	INTL	US	CORP	GOV	ACAD	STUD	Local	NonLocal
Cavity Optomechanics	2	43	45	12	33	17	28	1	4	40	3	2	43

The below ratings are on a 0-5 scale, feedback gathered from participants and averaged

Quality of Speakers		Interaction/Networking Opportunities		DC Location		Expected/Quality Attendees		International Participation	
Data	Rating	Data	Rating	Data	Rating	Data	Rating	Data	Rating
Excellent	5	Excellent	5	Excellent	5	Agree	4	Strongly Agree	5

Background

The Optical Society of America is a scientific society of over 18,500 members with an executive office in Washington, D.C. The Society is dedicated to increasing and diffusing the knowledge of optics in all its branches, pure and applied. The membership consists primarily of physicists, engineers, and other physical and biological scientists.

The Society sponsors topical meetings on subjects in which many rapid advances are taking place so that contributors to the field may interchange ideas to their mutual benefit. The format of such meetings usually consists of invited and contributed papers. Contributed papers are reviewed. Summaries of papers as submitted by authors are collected and published. Publications are provided to participants and are also available to others interested in the meeting subject. These topical meetings have provided much stimulus in research areas such as: integrated optics, optical fiber communication, optical storage of digital data, atmospheric transmission, reconstruction from projections, image processing, and picosecond phenomena.

Technical Scope

In recent years with the advent of high Q optical and mechanical micro-cavities, it has been possible to observe coupling between optical radiation and the mechanical modes in moveable structures in fine detail. Light when confined within a resonator exerts radiation pressure on the mechanical structure which gives rise to the effect of dynamic back-action. This leads to, among other things, parametric instability and opto-mechanical back-action cooling. Recently the dynamic manifestations of radiation pressure forces on micro- and Nano-mechanical objects have become an experimental reality. These observations have created a great deal of interest in exploiting these effects to study fundamental properties of light and mechanical systems and research in this topic has grown quickly over the past few years to include areas such as optical micro and nano-mechanical resonators, entanglement, generation of squeezed states of light, measurements at or beyond the standard quantum limit, single photon non-linearities, and fundamental sources leading to decoherence. In this incubator meeting, we will examine the emerging areas referred to as cavity opto-mechanics and cavity quantum opto-mechanics with the goal of discussing the latest advances which define the state of the art, and exploring the opportunities afforded by this new technology to better understand coupled systems and the quantum phenomena encompassing both optical and mechanical systems.

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7. **Mechanical Sensing/Metrology in the Quantum Regime:** what are the prospects?
Overview: Dr. Keith Schwab, Caltech

Meeting Organization

This incubator meeting is sponsored by the Optical Society of America.

The organization of the technical and scientific program led by meeting hosts:

Markus Aspelmeyer, *University of Vienna, Austria*

Pierre Meystre, *University of Arizona, USA*

Final Registration

First Name	Last Name	Org Name	Country
Jamil	Abo-Shaeer	Defense Advanced Res Projects Agency	UNITED STATES
Girish	Agarwal	Oklahoma State University	UNITED STATES
Markus	Aspelmeyer	University of Vienna	AUSTRIA
Gaurav	Bahl	University of Illinois at Urbana Champaign	UNITED STATES
Paul	Baker	Army Research Office	UNITED STATES
Paul	Barclay	University of Calgary	CANADA
Sunil	Bhave	Cornell University	UNITED STATES
Miles	Blencowe	Dartmouth College	UNITED STATES
Ania	Bleszynski Jayich	University of California Santa Barbara	UNITED STATES
Tal	Carmon	University of Michigan	UNITED STATES
Hengky	Chandrahalim	University of Michigan	UNITED STATES
Yanbei	Chen	California Institute of Technology	UNITED STATES
Aashish	Clerk	McGill University	CANADA
Pierre-Francois	Cohadon	Ecole Normale Superieure	FRANCE
Thomas	Corbitt	Louisiana State University	UNITED STATES
Tatjana	Curcic	AFOSR	UNITED STATES
Mark Klemens	Dong	University of Michigan	UNITED STATES
	Hammerer	Leibniz University Hannover	GERMANY
Kurt	Jacobs	University of Massachusetts Boston	UNITED STATES

Rina	Kanamoto	Meiji University	JAPAN
Mo	Li	University of Minnesota	UNITED STATES
Florian	Marquardt	University of Erlangen	GERMANY
Leopoldo	Martin	La Laguna University	UNITED STATES
Nergis	Mavalvala	Massachusetts Institute of Technology	UNITED STATES
David	McAuslan	University of Queensland	AUSTRALIA
David	McClelland	Australian National University	AUSTRALIA
Michael	Metcalfe	Booz Allen Hamilton, Inc.	UNITED STATES
Pierre	Meystre	University of Arizona	UNITED STATES
Haixing	Miao	Caltech	UNITED STATES
Gerard	Milburn	University of Queensland	AUSTRALIA
Preeti	Ovartchaiyapong	University of California Santa Barbara	UNITED STATES
Thomas	Purdy	JILA	UNITED STATES
Oriol	Romero-Isart	Max Planck Institute of Quantum Optics	GERMANY
Keith	Schwab	California Institute of Technology	UNITED STATES
Signe	Seidelin	Université Joseph Fourier (Grenoble I)	FRANCE
Kartik	Srinivasan	National Inst of Standards & Technology	UNITED STATES
Dan	Stamper-Kurn	University of California Berkeley	UNITED STATES
Charles	Tahan	LPS	UNITED STATES
Michael	Tobar	The University of Western Australia	AUSTRALIA
Paolo	Tombesi	Universita di Camerino	ITALY
Herre	van der Zant	Delft University of Technology	NETHERLANDS
Mukund	Vengalattore	Cornell University	UNITED STATES
Ewold	Verhagen	Ecole Polytechnique Federale de Lausanne	SWITZERLAND
David	Vitali	Universita di Camerino	ITALY
Ignacio	Wilson-Rae	TU Munich	GERMANY
huan	yang	Caltech	UNITED STATES