

**NSF ERC  
for  
EUV  
Science  
and  
Technology**



# news from the EUV ERC

Volume 2 Issue 2

April, 2011 0

## IAB Meeting 2010

IAB meeting, San Jose, February 23, 2010

Presentations:

***Progress in the development of EUV lasers and applications***  
Jorge Rocca

***Coherent Ultrafast EUV and Soft X-Ray Beams from Femtosecond Lasers***  
Margaret Murnane

***EUVL research activities at LBNL***  
Patrick Naulleau

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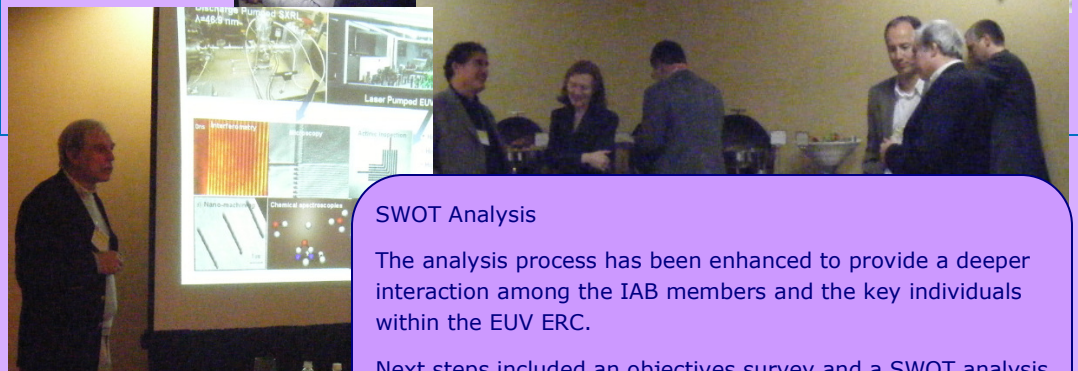
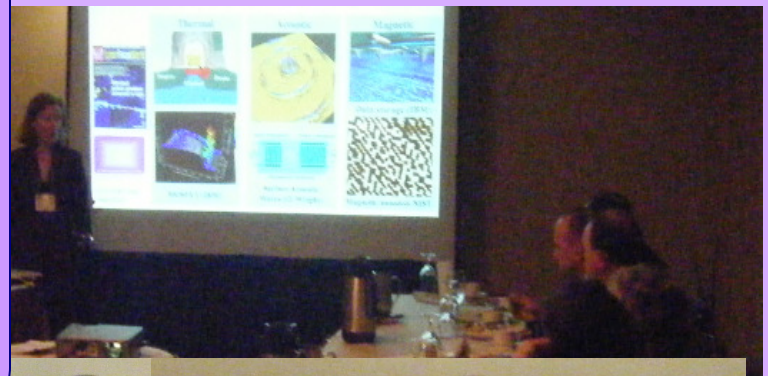
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### Industrial Advisory Board Meeting

of the  
NSF ERC for Extreme Ultraviolet  
Science and Technology



Tuesday, February 23, 2010 AGENDA



### SWOT Analysis

The analysis process has been enhanced to provide a deeper interaction among the IAB members and the key individuals within the EUV ERC.

Next steps included an objectives survey and a SWOT analysis conference call held on April 6, 2010.



**CLEO 2010: Laser Science to Photonic Applications**

**May 16-21, 2010**

**San Jose McEnergy Convention Center in San Jose, California**

**EUV ERC Presentations:**

Tuesday May 18, 12:00 - 12:15: Dale H. Martz, Hoang T. Nguyen, Dinesh Patel, Jerry A. Britten, Dave Alessi, Erik Krous, Yong Wang, Miguel Larotonda, Jason George Brian Knollenberg, Brad M. Luther, Jorge J. Rocca, Carmen S. Menoni, "Large Area High Efficiency Broad Bandwidth 800 nm Dielectric Gratings for High Energy Laser Pulse Compression".

Tuesday May 18, 2:30 - 3:00: Brendan A. Reagan, Federico J. Furch, Bradley M. Luther, Alden H. Curtis, Shaun P. Meehan, Jorge J. Rocca, "Soft X-Ray Laser Pumped by a Joule-Class, All-Diode-Pumped Laser System".

Wednesday May 19, 2:45 - 3:00pm: Chan La-o-vorakiat, Stefan Mathias, Patrik Grychtol, Roman Adam, Mark Siemens, Justin M. Shaw, Hans Nembach, Martin Aeschlimann, Claus M. Schneider, Thomas J. Silva, Margaret M. Murnane, Henry C. Kapteyn, "Ultrafast, Element-Specific, Demagnetization Dynamics Probed Using Coherent High Harmonic Beams".

Thursday May 20, 3:15 - 3:45pm: Paul C. Arpin, Ming-Chang Chen, Tenio Popmintchev, Michael Gerrity, Matt Seaberg, Bosheng Zhang, Eric Gullikson, Farhad Salmassi, Yanwei Liu, Alon Bahabad, Henry C. Kapteyn, Margaret M. Murnane, "Demonstration of Fully Spatially Coherent Soft X-Ray High Harmonic Beams in the Water Window".

Thursday May 20, 3:45 - 4:00pm: Qing Li, Mark E. Siemens, Ronggui Yang, Margaret M. Murnane, Henry C. Kapteyn, Erik H. Anderson, Keith A. Nelson, "Observation of Quasi-Ballistic Heat Transport at Nano-Interfaces Using Coherent Soft X-Ray Beams".

Thursday May 20, 10:30 - 10:45am: David A. Alessi, Dale H. Martz, Brad M. Luther, Yong Wang, Mark A. Berrill, David J. Kemp, Dinesh Patel, Carmen S. Menoni, Jorge J. Rocca, "High Energy 13.9 nm Table-Top Soft X-Ray Laser Operating at 2.5 Hz Repetition Rate".

Thursday May 20, 5:15 - 5:45pm: Ming-Chang Chen, Paul Arpin, Tenio Popmintchev, Michael Ryan Gerrity, Matt Seaberg, Bosheng Zhang, Margaret Murnane, Henry Kapteyn, "Full Phase Matching of Ultrafast Coherent High Harmonic X-Rays at 0.5 keV".

Friday May 21, 9:30 - 9:45am: Fernando Brizuela, Sergio Carbajo, Anne Sakdinawat, Yong Wang, David Alessi, Dale Martz, Bradley Luther, Kenneth A. Goldberg, David T. Attwood, Bruno La Fontaine, Jorge Rocca, Carmen Menoni, "Table-top Extreme Ultraviolet Laser Aerial Imaging of Lithographic Masks".

Friday May 21, 9:30 - 9:45am: Alon Bahabad, Margaret Murnane, Henry Kapteyn, "Generalized Spatiotemporal Quasi Phase Matching".

Friday May 21, 9:30 - 9:45am: Yong Wang, David Alessi, Dale Martz, Mark Berrill, Brad Luther, Jorge Rocca, "1 Hz Operation of a Gain-Saturated 10.9 nm Table-Top Laser".

# Spotlight on the Undergraduate Research Program

Since the fall of 2003, 140 undergraduates have contributed to the EUV Center's research thrusts by collaborating with Center faculty and graduate students on current research projects.

A successful research experience instills confidence in undergraduates who may be uncertain about their suitability for graduate school. It also enhances their competitiveness for admission to strong graduate programs and for national fellowships. The undergraduate education program offers both summer and year round research experiences. The goals of the EUV ERC Undergraduate Research program are to,

1. Improve participants' understanding of EUV science by involving them in cutting-edge research projects with state-of-the-art equipment with top EUV researchers,
2. Generate interest among participants in pursuing a graduate education and provide them with the information and skills needed to make a successful graduate school application
3. Motivate women and URM students to enter careers in science and engineering

## Research and networking

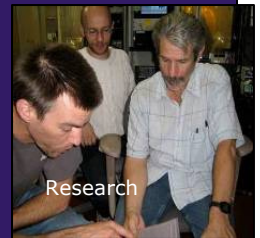
- Weekly video meetings with the REUs and faculty from all 3 Sites
- Daily meetings with Mentor
- Directed research as part of a team to develop interpersonal skills



Site meetings



Mentors



Research

## Learning and career information

- Four safety training courses: lasers, chemicals, high voltage & machine shop
- Regular practice for presentation
- Weekly seminars on photonics, graduate school preparation, industry & ethics



Safety



Presentation



Seminars

## Outreach

- Support to communicate summer experience to home institute
- Frequent opportunities to teach high-school students
- Weekly Lab or Industry Tour



Outreach Home



Teaching



Tours



# NSF Site Visit And Annual Review

May 4, 5 and 6, 2010  
University of Colorado,  
Boulder

## May 4<sup>th</sup> and 5<sup>th</sup> Highlights

### Research Session I: Compact Sources -

**Margaret Murnane (30m), Jorge Rocca (30m)**  
(30m questions)

### Research Session II: Imaging, Metrology & Patterning -

**Overview: David Attwood (10m) ,  
Carmen Menoni and Anne Sakdinawat (30 m)  
Margaret Murnane and Yanwei Liu ( 30 m)  
Willie Rockward (15m) (30m questions)**

### Research Session III: EUV Materials and Molecular Science -

**Overview: Henry Kapteyn (15m), Stephan  
Mathias(15m), Chung Li or Rongui Yang  
(15m), Elliot Bernstein (15m), Steve Leone  
(15m) (30m questions)**

### EUV Technology & Science Highlights by students -

**Six Center Students (5 m ea)**

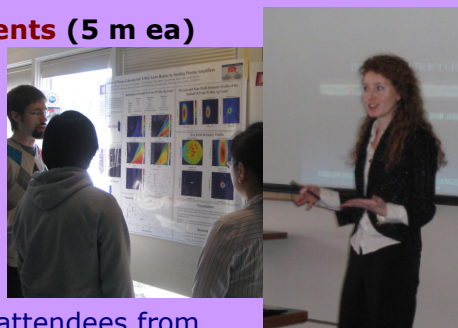
### Poster Session

### Industrial Collaboration

### Education and Outreach

### Infrastructure

A private meeting between attendees from industry and the Site Visit Team is scheduled for the morning of the 5<sup>th</sup>.


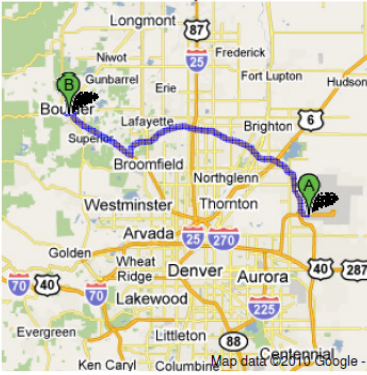


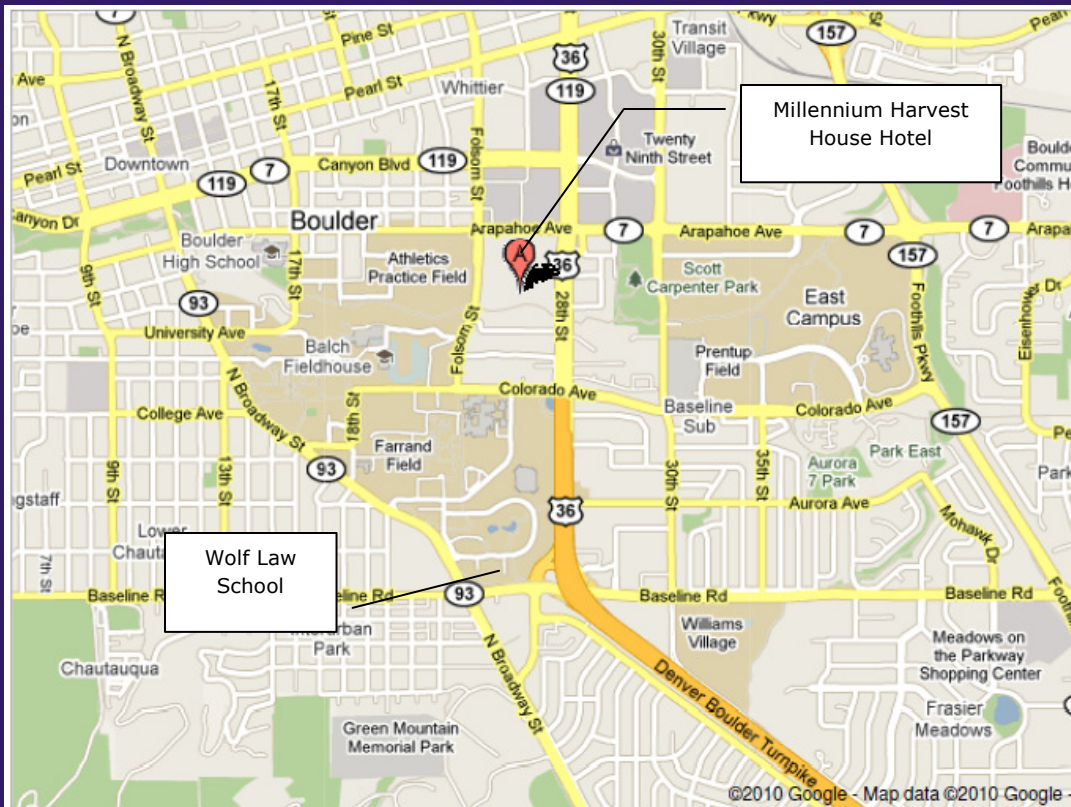
For further information please contact your Industrial Liaison Officer, Bob Bower, at [Robert.Bower@ColoState.EDU](mailto:Robert.Bower@ColoState.EDU)

# NSF Site Visit And Annual Review

May 4, 5 and 6, 2010  
University of Colorado,  
Boulder

Meetings will be held at the Wolf Law building. More information is available at <http://www.colorado.edu/campusmap/map.html?bldg=WLaw> and <http://www.millenniumhotels.com/millenniumboulder/>

Directions		Map
 Denver International Airport		
	37.6 mi (about 38 mins)	
1. Head west on <b>Pena Blvd</b>	0.2 mi	
2. Take exit <b>6B</b> toward <b>Boulder/Ft. Collins</b> Toll road	0.9 mi	
3. Merge onto <b>E-470 N</b> Toll road	17.5 mi	
4. Continue onto <b>Northwest Pkwy</b> Partial toll road	9.4 mi	
5. Take the ramp onto <b>US-36 W</b>	8.9 mi	



For further information or assistance, please contact your Industrial Liaison Officer, Bob Bower, at [Robert.Bower@ColoState.EDU](mailto:Robert.Bower@ColoState.EDU)

## Awards

### Mark Siemens

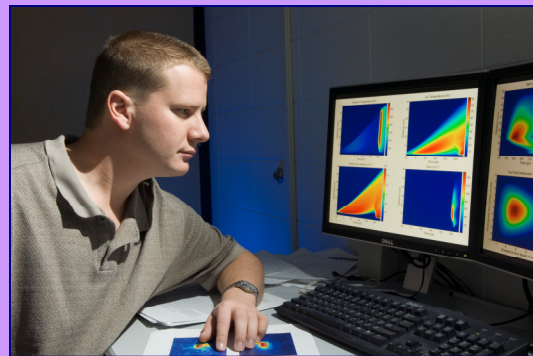
Dr. Mark Siemens, a former ERC graduate who worked on nanoscale heat transport and acoustic metrology, was awarded a National Research Council Postdoctoral Fellowship. As part of his work, he made the first experimental observation of quasi-ballistic heat flow from a nanoscale hot spot. Mark is now working in the area of energy research, and will combine his ERC research with energy research when he starts his faculty position at the University of Denver in the Fall of 2010. He will continue to collaborate with the EUV ERC and with industry.

The Fellowship Office of the National Academies awards fellowships on behalf of government and private/foundation sponsors. These fellowship awards play an important role in the career development of postdoctoral researchers and scholars for the academic, federal, industrial and international workforce.



### Mark Berrill

Mark has been selected as a Fellow in the prestigious Eugene P. Wigner Program at Oak Ridge National Laboratory. Mark's work at the EUV ERC has included the creation of computer models simulating laser created plasmas used to generate short wavelength lasers in the 10–50 nm range. His work is of interest in photo-physics, photo-chemistry, metrology and nanopatterning. He will complete his doctoral work at the Center this year and will, as Wigner Fellow, continue his research at Oak Ridge National Laboratory, the U.S. Department of Energy's largest science and energy laboratory and the world's foremost center for neutron science research. Included in ORNL's mission goals are high-performance computing, materials science at the nanoscale and neutron science.



Mark received the DOE Computational Science Graduate Fellowship in March of 2006, the SPIE Educational Scholarship in Optical Science and Engineering in August of 2005 and numerous other honors, awards and scholarships. Student memberships include American Physical Society, SPIE, Sigma Xi and Eta Kappa Nu.

See <http://www.today.colostate.edu/story.aspx?id=3614>

For further information please contact your Industrial Liaison Officer, Bob Bower, at [Robert.Bower@ColoState.EDU](mailto:Robert.Bower@ColoState.EDU)



# EUV ERC Students

## Graduating

### Fernando Brizuela

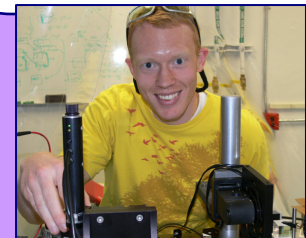
Fernando joined the NSF Center in 2003 after receiving a B.S. in Materials Engineering from the University of Mar del Plate in Argentina. Within the center he has worked in developing zone plate-based microscopes using table-top EUV lasers. One of these microscopes received an R&D100 award in 2008. Fernando participated in several other projects within the center gaining broad experience in the field of surface and material science. His most recent project was the development of full-field microscope for actinic inspection of extreme ultraviolet lithography masks.

Fernando will complete this Ph.D. from Colorado State University in May 2010 and is interested in pursuing a career in Research and Development in the areas of lithography, optics, and materials sciences.



### Erik Krous

Erik's work at the NSF EUV ERC includes large area multilayer dielectric diffraction gratings for chirped pulse amplification lasers and in-depth expertise on the growth and characterization of ion beam sputtered multilayer coatings for high power lasers. He gained expertise in thin film deposition and characterization of the interference coatings using a variety of chemical and optical probes. This work resulted in the demonstration of extremely low-loss, high-damage threshold optical coatings.



Erik Krous is graduating in May 2010 with a MS in Electrical and Computer Engineering and is looking to start an R&D career in materials and optical sciences. Erik is interested in a summer internship

### Jonathan Grava

Joining the NSF Center in 2003 after receiving a M.S. in Electrical Engineering from the University of Nice in France, Jonathan Grava is completing his Ph.D. in Electrical Engineering at Colorado State University. His group has conducted several dense plasma diagnostics experiments using a soft x-ray laser interferometry setup developed at CSU. He has gained broad knowledge in the fields of laser design and operation, optical systems and plasma physics.

Jonathan will complete his Ph.D. in May 2010 and is interested in pursuing a career in the industry using plasmas and involving laser systems, optics.



### Brook L. Messler

Brooke joined the NSF Center in 2004 after receiving a B. S. in Engineering Physics from the University of California at Berkeley. As part of the center Brooke has helped run the x-ray transmission microscope, XM-1, at the Advanced Light Source in Berkeley, CA. Brooke has conducted several experiments at XM-1 focusing on magnetic spin dynamics in patterned magnetic samples. In addition to an understanding of current magnetism issues, she fabricated all her samples. Brooke has experience with micro and nanofabrication, particularly e-beam lithography, e-beam evaporation, and both dry and wet etching.

Brooke will complete her Ph.D from the University of California at Berkeley in May 2010 and is interested in pursuing a career in fabrication either in the magnetic storage industry or in other computer technology industries.



The Extreme Ultraviolet (EUV) Engineering Research Center is one of 15 centers established in the United States through the National Science Foundation and supplemented by industry funding. Colorado State University (CSU) is the leading institution with partner sites at University of Colorado (CU), UC Berkeley and Lawrence Berkeley National Laboratory. The Center research mission is the development of compact coherent EUV sources and EUV-engineered systems that provide solutions to challenging scientific and industrial problems, including the development of new tools for nanotechnology and nanoscience. The Center has an important educational mission providing a unique environment for the training of students, young engineers and scientists. An Industry Advisory Board (IAB) with members, ranging from large- to small- capitalized companies, spanning instrumentation, semiconductor, laser and optics businesses, actively participate in early access of technologies, joint research projects, directed research projects and the hiring of the some of the best students in the world in these areas.

**Industry Members**



**Industry Affiliates**



**Work supported by the National Science Foundation  
Cooperative Agreement No. EEC-0310717 and  
Matching funds from participating institutions.**

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