Dr. Vlado A. Lubarda Elected to European Academy of Sciences and Arts

Dr. Vlado A. Lubarda, a Research Affiliate of CMRR and an Adjunct Professor of MAE, was elected to the European Academy of Sciences and Arts for his research contribution to the field of applied mechanics and written technical books that are used widely in engineering educations in the U.S. and in Europe. The European Academy of Sciences and Arts is composed of numerous scholars from varying fields who focus on ethical, cultural, social and scientific issues facing the world. (For more information visit: http://nanoengineering.ucsd.edu/).

SELECTED PAPERS AND TALKS

Professor Eric E. Fullerton

Edward Dechaumphai, Dylan Lu, Jimmy J. Kan, Jaeyun Moon, Eric Fullerton, Zhaowei Liu, Renkun Chen, "Ultralow Thermal Conductivity of Multilayers with Highly Dissimilar Debye Temperatures", *Nano Letters*, April 14, 2014.

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Sabine Alebrand, Ute Bierbrauer, Michel Hehn, Matthias Gottwald, Oliver Schmitt, Daniel Steil, Eric E. Fullerton, Stephane Mangin, Mirko Cinchetti, Martin Aeschlimann, "Subpicosecond magnetization dynamics in TbCo alloys", *Physical Review B*, Vol. 89, 144404, April 3, 2014.

Sabine Alebrand, Ute Bierbrauer, Michel Hehn, Matthias Gottwald, Oliver Schmitt, Daniel Steil, Eric E. Fullerton, Stephane Mangin, Mirko Cinchetti, Martin Aeschlimann, "Subpicosecond magnetization dynamics in TbCo alloys", *Physical Review B*, Vol. 89, 144404, April 3, 2014.

D.B. Gopman, D. Bedau, S. Mangin, E.E. Fullerton, J. A. Katine, A.D. Kent, "Temperature dependent nucleation, propagation, and annihilation of domain walls in all-perpendicular spin-valve nanopillars", *Journal of Applied Physics*, Vol 115, 113910, March 20,2014.

Professor Paul H. Siegel

Aman Bhatia, Minghai Qin, Aravind R. Iyengar, Brian M. Kurkoski and Paul H. Siegel, "Lattice-Based WOM Codes for Multilevel Flash Memories," *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 5, pp. 933-945, May 2014.

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Xiaojie Zhang, Paul H. Siegel, "Quantized Iterative Message Passing Decoders with Low Error Floor for LDPC Codes," *IEEE Transactions on Communications*, vol. 62, no. 1, pp. 1-14, January 2014.

Professor Frank Talke

Liane M. Matthes, Bernhard Knigge, and Frank E. Talke, "Head-Disk Proximity Sensing using Contact Sensors in Hard Disk Drives", submitted to *IEEE Magnetics*, April 17, 2014.

Y. Fu, R. Brunner, J.P Peng, J. Apte, J. McFadyen, and F. E. Talke, Fellow, IEEE, "The Effects of Parking Time, Temperature and Slider Position on Lubricant Migration in Hard Disk Drives", submitted to IEEE, April 17, 2014.

Chuanwei Zhang, Andrey Ovcharenko, Min Yang, Neil Knutson, and Frank E. Talke, "Investigations of Thermal Asperity Sensors in Thermal Flying-height Control Sliders", submitted to IEEE, April 10, 2014.

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Professor Ami Berkowitz

S.-W. Chen, X. Lu, E. Blackburn, V. Lauter, H. Ambaye, K. T. Chan, E. E. Fullerton, A. E. Berkowitz, and S. K. Sinha, "Nonswitchable magnetic moments in polycrystalline and (111)-epitaxial permalloy/CoO exchange-biased bilayers" *Physical Review B* 89, 094419 (2014).

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Professor Sungho Jin

Phi-Khanh Nguyen, Sungho Jin, and Ami E. Berkowitz, "MnBi particles with high energy density made by spark erosion", *Journal of Applied Physics* 115, 17A756 (2014).

Professor Vitaliy Lomakin

Qing Gu, Joseph S. T. Smalley, Maziar P. Nezhad, Aleksandar Simic, Jin Hyoung Lee, Michael Katz, Olesya Bondarenko, Boris Slutsky, Amit Mizrahi, Vitaliy Lomakin, Yeshaiahu Fainman, "Subwavelength semiconductor lasers for dense chip-scale integration", *Advances in Optics and Photonics*, Vol. 6, p. 1-56, Submitted 2014.

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ISSUE 41
SPRING 2014

CMRR REPORT

CENTER FOR MAGNETIC RECORDING RESEARCH
University of California, San Diego ISSN: 0888-7381

this issue

RESEARCH HIGHLIGHT

Enhancing Spontaneous Emission Rates Using Nanopatterned Multi-layer Hyperbolic Metamaterials

Plasmonic nanostructures have been extensively used to manipulate the spontaneous light emission rate of light emitters and their radiative efficiency. Because light emitters near a metallic surface experience a different environment than in free-space, their spontaneous radiative emission rate is generally enhanced . Such enhancement, measured by means of the Purcell factor, arises as a consequence of the overlap between the surface plasmon mode frequency and the light emission spectrum. However, such overlap is available only for a few narrow bands of frequency due to the limited plasmonic materials existing in nature . Although this limitation can be overcome by using hyperbolic metamaterials -- a type of nanoscale artificial material with hyperbolic dispersion relations -- the Purcell factor and the radiative power have remained relatively low . Here we show that by nanopatterning a hyperbolic metamaterial made of Ag and Si multilayers, the spontaneous emission rate of rhodamine dye molecules is enhanced by 76-fold at tunable frequencies and the emission intensity of the dye increases by ~80 fold compared to the same hyperbolic metamaterial without nanostructuring.

(continues on p. 3)

Fifth Annual Non-Volatile Memories Workshop

On March 9–11, 2014, researchers from UC San Diego hosted the 5th Annual Non-Volatile Memories Workshop (NVMW 2014) on the UCSD campus in La Jolla, California (and at a reception and banquet (pictured above) in the San Diego Museum of Art).

As with the preceding workshops in the NVMW series, the primary objective was to encourage the development of a "vertical" vision for research on the role of NVM technologies in an ever-increasing number of application scenarios, ranging from data-intensive computing systems to super high-resolution video games. As the capabilities of NVM-based storage rapidly evolve, it is more critical than ever that researchers at each level of the system "stack" be aware of the needs, challenges, and opportunities associated with the other levels. The workshop provides researchers and practitioners the opportunity to gain a broader understanding of what is needed to accelerate the development and adoption of NVM-based storage technologies, and to establish relationships that will provide the basis for further advances.

The workshop began with a tutorial entitled "System-level Reliability in Storage Stacks," presented by Dr. Cheng Huang of Microsoft Research and Dr. Hao Zhong of Fusion-io. Approximately 175 people were in attendance. The Program Committee assembled a technical program consisting of 32 contributed papers organized into 8 sessions on Devices, Coding for Enhanced Endurance, Coding for Reliability, Data Encoding and Mapping Techniques, System Architectures for Flash, System Architectures for Next-Generation Memories (I and II), and Applications. A poster session featured another 30 papers that broadened the scope and depth of the workshop's technical content.

The keynote addresses that opened each day of technical sessions were another highlight of the meeting. John Scaramuzzo, Senior VP of Enterprise Storage Solutions at SanDisk presented his vision of the future in a talk titled, "The Flash Transformed Data Center." Dr. Kaladhar Voruganti, Senior Technical Director of the Advanced Technology Group at NetApp spoke about "NVM and New Storage Design Centers," exploring the dramatic effect that non-volatile memory technologies are having on storage system design. The social program included a welcome reception at the Sheraton La Jolla Hotel and a banquet at the San Diego Museum of Art.

The workshop attracted a record 235 registered participants from industry, academia, and national labs. Overall, about 60% of the participants came from industry, with the remaining 40% hailing from academic and government institutions. About one-quarter of the attendees were graduate students and post-doctoral researchers, whose participation was funded in large part by a generous grant from the National Science Foundation.

The NVMW series is co-organized by Prof. Paul Siegel of the Center for Magnetic Recording Research (CMRR) and Prof. Steven Swanson of the Non-volatile Systems Laboratory (NVSL) at UCSD. This year's workshop was sponsored by the IEEE Magnetics Society and also enjoyed generous corporate support from HGST, Micron, and NetApp, as well as from LSI, Marvell, Microsoft Research, PMC, Rambus, SK Hynix Memory Solutions, Toshiba, and Western Digital. An archival website at http://nvmw.ucsd.edu provides a lasting record of all of the NVMW workshop proceedings and a resource for the scientific community and general public. For more about NVMW 2014, see article and photos on p.6.

CMRR Graduate Student Wins Poster Award at MMM 2014

Nasim Eibagi (below) earned her undergraduate degree from UC Davis. She is currently a graduate student in the Electrical and Computer Engineering Department at UC San Diego and is working under the supervision of Professor Eric Fullerton at CMRR. Recently she was honored for her outstanding poster at the 58th Annual Magnetism and Magnetic Materials (MMM) Conference in Denver in November 2013. Congratulations, Nasim!

Nasim Eibagi

Letter from the Director

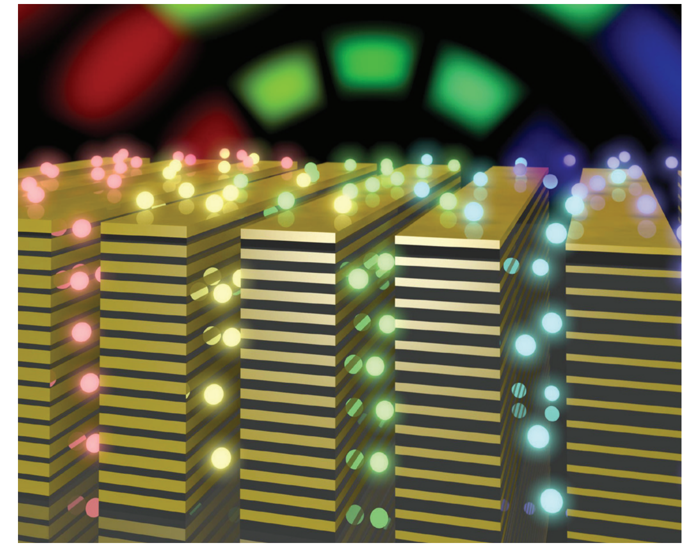
Eric Fullerton
Director, CMRR

This newsletter comes at a time of continued growth at CMRR as reflected in increased corporate memberships and federal grants as well as the presentations at the Spring 2014 research review. I'm pleased to announce that Qualcomm, Inc. joined our roster of corporate members earlier this year. We are also pleased with the strong interactions of our students with industry partners – given CMRR's mission to train students for jobs in the information technologies industries. Last summer, we had 14 students participate in summer internships and I hope to see similar interactions this summer. I would encourage companies interested in CMRR students for summer internships to contact me or other CMRR faculty sooner rather than later. I hope we can reinforce the importance of these internships for the students and our corporate sponsors alike so that the program can grow in the years ahead.

We continue to expand our educational and outreach efforts by organizing various conferences and workshops as highlighted in this newsletter. Paul Siegel and Steve Swanson have organized the Non-Volatile Memories Workshop (NVMW) each of the last five years, and NVMW 2014 was a great success. The workshop provides a unique showcase for outstanding research on solid-state, non-volatile memories. We look forward to NVMW 2015 and are planning additional workshops in the coming year. We are also planning on bidding for the IEEE Magnetics Society Summer School.

Finally I would like to announce that we will be changing the name of CMRR's auditorium to the Jack K. Wolf Auditorium at CMRR in honor of the late Jack Wolf, one of the Center's founding faculty members. This will be in recognition of Jack's extensive contributions to research and education at CMRR, UC San Diego and the broader engineering community. The naming ceremony takes place on October 28, 2014, with a reception and lecture to be delivered by Peggy Johnson, Executive Vice President, Qualcomm Technologies, Inc. and President, Global Market Development. I hope to see you there!

On April 25, 2014, some CMRR members got to experience a wonderful team-building activity at the UCSD challenge course. The group consisted of CMRR administrative staff and students, including (pictured l-r): grad students Phi Nguyen, Nasim Eibagi, and Alex Phan; fund manager Julie Matsuda; grad student Bing Fan; administrative assistant Agapi (Gabby) Tshamjyan; as well as grad students Youngwoo Seo, Benjamin Suen, Aman Bhatia and Rajasekhar Medapalli. Everyone who participated in the challenge course adventure was able to face their fears and learn something new, making it a challenging but rewarding experience.



RESEARCH HIGHLIGHT

Enhancing Spontaneous Emission Rates Using Nanopatterned Multi-layer Hyperbolic Metamaterials

Underwater Communications at the Speed of Light

(continued from page 1)

Metamaterials offer new methods for the design of materials with attractive optical properties for potential applications in super-resolution imaging and multifunctional devices [10].

Metamaterials comprised of a stack of multilayers are particularly promising because of their unique, hyperbolic dispersion relation [11]. When brought into the near field of multilayer metamaterials, light emitters release their energy predominantly through three channels: radiative emission, plasmonic modes and other non-radiative decay modes [5, 6]. Plasmonic modes usually dominate over other decay channels [11]. Because of their tunable dispersion relations, hyperbolic metamaterials (HMMs) offer a larger plasmonic density of states (DOS) at any desired wavelength, which lead to an enhancement in spontaneous emission rates. However, the difficulties in fabricating metal-dielectric multilayer HMMs at deep subwavelength scales, as well as the non-radiative nature of the dominating plasmonic modes in uniform HMMs, limit Purcell enhancement and the external quantum efficiency in the far field. Accordingly, an outcoupling mechanism is necessary to extract energy from the non-radiative plasmonic modes.

Nanopatterned multilayer hyperbolic metamaterials

Figure 1 presents the schematic configuration of the studied HMM structure, which consists of nanopatterned Ag-Si multilayers. The multilayers were prepared by alternatively sputtering Si and Ag layers onto glass substrates at room temperature using the ultrahigh vacuum sputtering machine at CMRR. Dark-field scanning transmission electron microscope (STEM) images of the cross-sectional view at different magnifications indicate a well-formed periodic lattice structure in the Ag-Si multilayers with a highly conformal coating across the substrate (Fig. 2a). There is no accumulation of film roughness along the growth direction, and 10 nm layer thicknesses are consistently achieved.

Nanoscale trenches were inscribed into the multilayers by focused ion beam (FIB) milling with different periods to form grating nanostructures. The fluorescence R6G dye molecules mixed in polymethyl methacrylate (PMMA) were spin-coated onto the uniform and nanopatterned surface of the multilayers. A scanning electron microscope (SEM) image of one of the fabricated samples is shown in Fig. 2b (inset image is at a titled angle).

by Dylan Lu, Jimmy J. Kan, Eric E. Fullerton and Zhaowei Liu

Tunable broadband Purcell effect in multilayer metamaterials

We first calculated the Purcell factor [4] based on a modified theory of dipole interaction with metal films to quantify the spontaneous emission-rate enhancement in the multilayer system at different emission wavelengths. Figure 3a shows the calculated Purcell factors for isotropic dipoles at a distance of d =10 nm above the Ag film and the Ag-Si multilayer HMM, respectively, at various emission wavelengths. The Purcell factor for a bulk Ag layer peaks at λ = 360 nm with a narrow bandwidth of ~10 nm, corresponding to surface plasmon resonance of the Ag film. In contrast, for the Ag-Si multilayer HMM the Purcell factor peaks around λ = 600 nm with a much broader bandwidth of over 60 nm, which aligns better with the emission spectrum of Rhodamine 6G (R6G). The Purcell enhancement at 600 nm is ~60-fold on the Ag-Si multilayer HMMs but less than ten-fold on the Ag film.

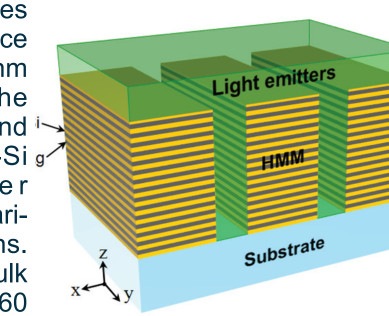
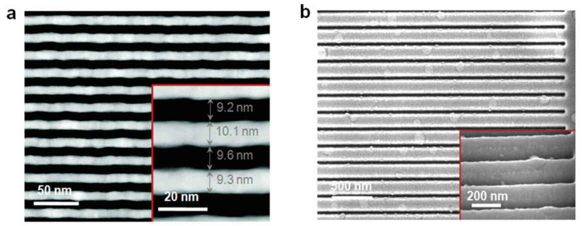


Fig. 1: (above) Schematic configuration of nanopatterned multilayer HMMs on a glass substrate. The multilayers consist of Ag-Si stacks forming grating patterns with different periods. Light emitters mixed in polymer matrix are coated onto the surface.

Fig. 2: (right) Fabrication of nanopatterned multilayer HMMs. a) Dark-field STEM images of the cross-sections of Ag-Si multilayers under different magnifications, showing well-formed periodic lattice structures (each layer thickness, ~10 nm). The white color corresponds to Ag and the black to Si. b) SEM image of one of the fabricated nanopatterned HMMs (period 200 nm; trench width 40 nm). Inset: perspective-view SEM image of the grating nanostructure.



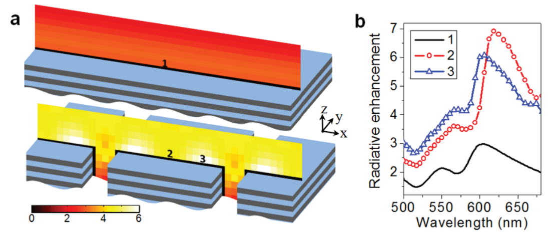


Fig. 4: (above right) Comparison of radiative emission enhancement for uniform and nanopatterned multilayer HMMs. a) Cross-sectional mapping of radiative enhancement for isotropic dipoles on the uniform and nanopatterned multilayer HMMs at an emission wavelength of 600 nm. The nanopatterned HMM has a grating period 200 nm and trench width 40 nm. Color bar represents the magnitude of radiative enhancement. b) Radiative enhancement as a function of emission wavelength for isotropic dipoles at locations 1, 2 and 3.

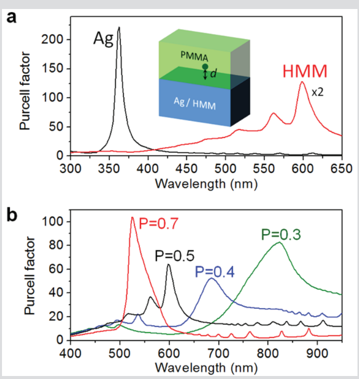


Fig. 3: (above) Comparison of Purcell factors for Ag-Si multilayer HMMs and a pure Ag single layer. a) Purcell factor for a dipole located d = 10 nm above the uniform Ag single layer (black curve) and the Ag-Si multilayer HMM (red curve, multiplied by 2 for comparison), each with the same total thickness of 305 nm. The multilayer has 15 pairs of Ag and Si layers (each layer thickness, 10 nm). b) Tunable Purcell enhancement across the visible spectra for isotropic dipoles located d = 10 nm above the uniform Ag-Si HMMs by adjusting the volumetric filling ratio of the metal, P.

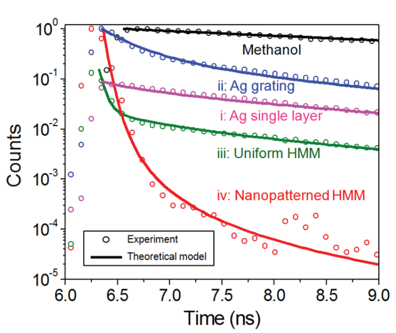


Fig. 5: (above) Experimental measurements and theoretical fit of time-resolved fluorescence for dye molecules on different samples. Time-resolved fluorescence measurements for R6G on the nanopatterned Ag-Si HMM (iv, red open circles), Ag grating (ii, blue open circles) and in methanol solutions (black open circles) after being normalized to the maximum of individual curves observed at an emission wavelength of 560 nm. Grating period, 200 nm. Data for a uniform Ag-Si HMM (iii, green open circles) and a Ag single layer (i, purple open circles) are included for comparison. Corresponding theoretical fit curves in solid lines explain well the spontaneous emission behaviour in the time domain.

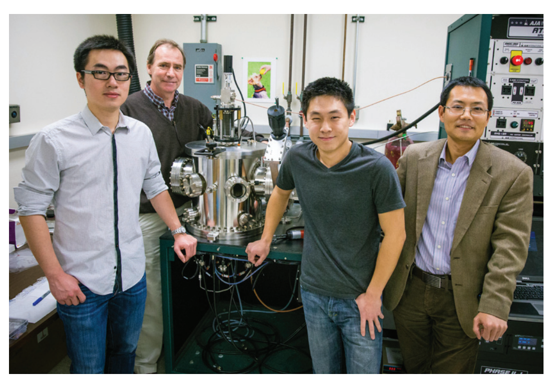
By adjusting the filling ratio of Ag in HMMs, the Purcell enhancement can be tuned, as shown in Fig. 3b, demonstrating the versatility of plasmonic DOS engineering in multilayer HMMs to achieve better control of emission processes at desired wavelengths.

Outcoupling effect in nanopatterned hyperbolic metamaterials

We use the full-wave simulation method to study the interaction of dipole emitters with the nanopatterned multilayer HMM. Figure 4a presents the calculated cross-sectional mapping of the enhancement of radiative emission for isotropic dipole emitters placed at different locations on uniform and nanopatterned Ag-Si HMMs at λ = 600 nm. Thanks to the outcoupling effect of the grating, radiative emission is significantly enhanced on nanopatterned multilayer HMMs as compared with uniform ones. The radiative emission on the uniform HMM is almost invariant with emitter-metamaterial distance, whereas on the nanopatterned multilayer HMM it has strong enhancement close to the surface of the HMMs where higher plasmonic DOS is available for outcoupling. The corresponding spectra of radiative enhancement for dipole locations 1, 2, and 3 are also shown in Figure 4b. In comparison with the uniform HMM, radiative emission on the nanopatterned HMM is improved by over 100% at the peak wavelength, which will lead to the same improvement in the external quantum efficiency of dipole emitters. It is worth noting that the radiative enhancement factor relies on the geometry of the nanopatterns.

Time-resolved photoluminescence on the hyperbolic metamaterials

To identify the Purcell enhancement of the multilayer HMMs, the lifetime of R6G dye molecules on various samples was measured by time-resolved photoluminescence in a two-photon microscope system.



(Above l-r) ECE grad student Dylan Lu, CMRR Director Eric Fullerton, Qualcomm's Jimmy Kan, and ECE Prof. Zhaowei Liu

Figure 5 shows the measured time-resolved fluorescence decay for R6G on both nanopatterned Ag-Si HMM and Ag grating substrates. Unlike the case of R6G in methanol with a fixed lifetime of 3.8 ns, the decay rate for the nanopatterned Ag-Si HMM and the Ag grating cannot be fit by a single-exponential function, because the detected fluorescence signals arise from the collective responses of the randomly distributed molecules. For the nanopatterned Ag-Si HMM sample with a period of 200 nm, the fluorescence intensity initially decays at ~1/(0.07 ± 0.003) ns-1 attributed to the molecules strongly coupled to the HMM structure before slowing down to 1/(2.2 ± 0.3) ns-1, which is determined mainly by those molecules away from the HMM. By the same token, for the Ag grating sample, the decay rates at the maximum and minimum are 1/(0.4 ± 0.03) ns-1 and 1/(2 ± 0.1) ns-1, respectively. The HMMs with plasmonic DOS aligned with the molecular emission spectra further enhance the decay rate by about one order of magnitude compared with the pure Ag gratings.

Figure 5 also presents the measurement results for the uniform Ag-Si HMM and the Ag single layer. Compared with uniform films, a stronger Purcell enhancement was detected in both the nanopatterned HMM and Ag grating. The grating nanostructures outcouple the dominating plasmonic modes in the HMM for better far-field detection of fast-decaying signals from molecules strongly coupled to the metamaterials. Not only does the strong Purcell effect become accessible in the far field - the fluorescence intensity is also enhanced significantly. The theoretical fit based on a dynamic Lorentzian model given as solid lines in Fig. 5 agrees well with experimental measurements.

A systematic study of the geometrical dependence of decay rate and intensity enhancement was carried out for nanopatterned HMMs with different grating periods. Figure 6a shows that the measured lifetime of R6G further decreases as the period of the grating reduces. A corresponding larger Purcell factor results in a total 76-fold decay-rate enhancement for R6G on the nanopatterned HMM with a period of 80 nm. As shown in Figure 6b, an intensity enhancement factor close to 80-fold was achieved for the nanopatterned HMM with a period of 80 nm, compared with an eightfold intensity enhancement for larger periods. Smaller grating periods better match and outcouple high-wavevector plasmonic modes, resulting in stronger Purcell and fluorescence intensity enhancement, simultaneously.

Conclusion

In conclusion, we have shown that the spontaneous emission rate of dye molecule emitters can be greatly enhanced by nanostructuring HMMs composed of alternating multilayers of Ag and Si. In nanopatterned HMMs, non-radiative plasmonic modes are out-coupled, resulting in a 76-fold enhancement in Purcell factor and an 80-fold enhancement in emission intensity compared to HMMs without nanostructuring. Engineering plasmonic DOS using outcoupling nanostructures in multilayer HMMs can provide the desired tunability of Purcell factor enhancement for light emission for various applications, with both high speed and high radiative intensity at broadband operational frequencies. This concept will be extended to the light-emitting devices for improving the modulation speed and emission efficiency in our future work.

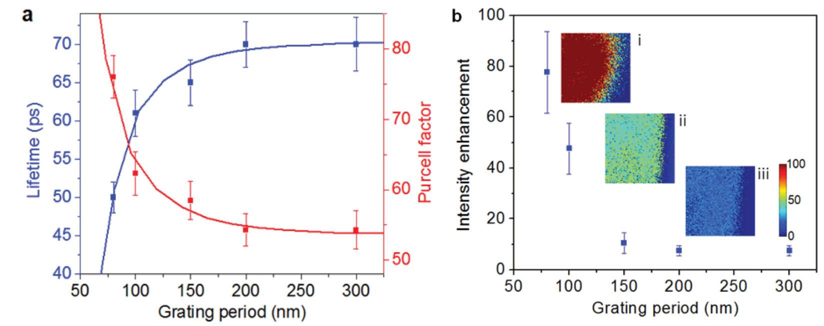


Fig. 6: (left) Experimental demonstration of the geometrical dependence of Purcell and fluorescence intensity enhancement on nanopatterned multilayer HMMs. a) Lifetime (blue) measured at the maximum decay rate of time-resolved fluorescence and the corresponding Purcell factor (red) for R6G on the nanopatterned Ag-Si HMM with different grating periods. Solid lines are a guide to the eye. b) Fluorescence intensity enhancement for R6G on the nanopatterned Ag-Si HMM with different grating periods. Inset: optical images of the fluorescence intensity accumulated over 100 frames (grating periods: a = 80 nm (i); a = 100 nm (ii); a = 200 nm (iii)).

This work is a collaborative effort between CMRR and the ECE department with contributions from Dylan Lu, Jimmy J. Kan, Eric E. Fullerton, and Zhaowei Liu. It is financially supported by ONR Young Investigator Award (no. N00014-13-1-0535), NSF-ECCS (grant no. 0969405) and NSF-CMMI (grant no. 1120795). This job could not be finished without help from P. Zhang, M. Digman, E. Gratton, L. Feng, H. Chen and Y. Liu during various phases of simulations and experiments.

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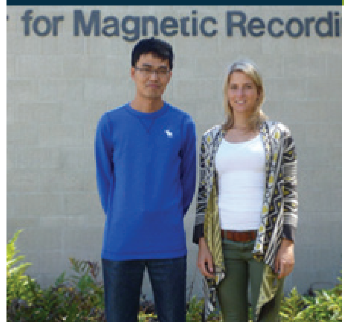
Shannon Memorial Lecture

Polar Codes vs. Spatially Coupled Codes

The reliable transmission of information over a noisy channel at rates close to capacity is a fundamental building block of any communication system. Once deemed to be a difficult problem, there are now several techniques available which allow researchers to accomplish this task efficiently. In the 12th annual Shannon Memorial Lecture organized by CMRR, École Polytechnique Fédérale de Lausanne (EPFL) Professor Rüdiger L. Urbanke surveyed two such techniques: polar codes and spatially-coupled codes. In designing a new system, asked Urbanke, “which is the right pick? Which is better with respect to scaling behavior, complexity, achievable throughput, universality, and robustness?” Urbanke concluded that, although much is known about both types of codes, several fundamental challenges remain.

Dr. Urbanke earned his Ph.D. in Electrical Engineering from Washington University in St. Louis, in 1995. He worked at Bell Labs before becoming a faculty member in EPFL's School of Computer & Communication Sciences, where he is a member of the Information Processing Group. Urbanke is primarily interested in the analysis and design of iterative coding schemes.



Jacobs School of Engineering Research Expo Best Poster in MAE Category

Two graduate students at CMRR were the poster winners for the 33rd annual Jacobs School Research Expo in the Mechanical and Aerospace Engineering category. Liane Matthes (pictured above right) and fellow Ph.D. student Chuanwei Zhang beat other MAE teams with their poster on "Head-Disk Proximity Sensing Using Contact Sensors in Hard Disk Drives." In their research, Matthes and Zhang developed a method to help improve the reliability of hard-disk drives. The method looks at the spacing between the magnetic disk (on which data is stored within the drive) and the magnetic head used to read and write data. They collected and analyzed data generated by a contact sensor located in the magnetic head and found a signal that predicts when the head makes contact with the disk. (For more information visit: http://www.jacobsschool.ucsd.edu/re/.)

COMMENTARY

Former CMRR Director Paul Siegel reflects on the 5th Annual Non-Volatile Memories Workshop (see page 1), which was hosted in March 2014 by CMRR, and where the technology is going:

Advances in data storage technology have been crucial to the evolution of the modern information age, enabling and accelerating the invention of new information-related applications in consumer entertainment, personal and business computing, enterprise data management, and scientific research. High-capacity, non-volatile, solid-state drives (SSDs) are in the process of revolutionizing this world of data storage.

SSDs have a number of features that complement those of conventional disk and tape drives, notably enhanced shock resistance, reduced power consumption, and faster data access. Although currently less competitive in some storage applications with respect to cost per bit, write latency, and product lifetime, continuing advances in SSDs based upon several non-volatile memory (NVM) technologies are setting the stage for a revolution in how computer systems and applications access and manipulate persistent data. Improved flash memories – along with emerging technologies such as magnetic RAM (MRAM), phase-change memories (PCM), spin-transfer torque memories (STTM), resistive RAM (RRAM), and the memristor – are driving designers to rethink how they integrate storage devices into computing systems, how operating systems manage data, and how applications create and process information. Realizing the full potential of NVM technologies is an exciting and important challenge with enormous societal consequences.

Photos from festivities to mark the 5th Annual Non-Volatile Memories Workshop

Pictured counter-clockwise from top right: NVMW surfboard flash drive; reception at San Diego Museum of Art; dinner outdoors in Balboa Park; sunset reception at Birch Aquarium; Paul Siegel and Steven Swanson

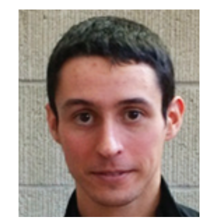
Photos by Alex Matthews

NEW SCIENTISTS + STUDENTS

Alexander Abdel Alim is a fourth-year undergraduate student studying Electrical Engineering at the University of California, San Diego. He is currently working in the lab of Professor Vitaliy Lomakin on developing part of the user interface for FastMag, a micromagnetic simulator. In the future, Alex plans to pursue graduate studies in Communication Systems.

Guido Hendriks is a first-year graduate student from Eindhoven University of Technology in the Netherlands, where he is working on a master's degree in Applied Physics with a specialization in nanoengineering. At CMRR, he is focusing on solid-state physics and more specifically (nano) magnetism. He will be working in the lab of Professor Eric Fullerton, where he will study magnetic Skyrmions.

Andreas Hegetschweiler is a visiting graduate student. He obtained his M.S. in Material Science at Saarland University, Saarbruecken, Germany in 2014. He graduated from the same department in 2012. Andreas is currently working under the supervision of Professor Frank Talke researching nano-wear of thermal flying height control sliders.

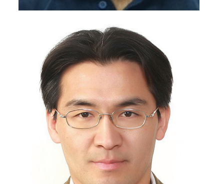


Vincent Joly is a visiting graduate student from France, currently partaking in an internship program at CMRR. He obtained his license in physics at the Faculté des Sciences et Technologies in Nancy, France. Vincent is conducting research on condensate matter and the reversal of magnetization of materials using only optical means.

Dokyun Kim has been a Postdoctoral Scholar-Employee at CMRR since February 1, 2014. He is working under the supervision of CMRR Director Eric Fullerton and his research activities include optimizing the magnetic properties of PMA MTJs for MRAM, and developing novel spintronic devices. He obtained his Ph.D in the Department of Materials Science and Engineering at Korea University in South Korea.

Dr. Longqiu Li is an associate professor at Harbin Institute of Technology (HIT) in Harbin, China. He got his PhD from HIT in 2010. During his Ph.D. studies, he spent two years at CMRR beginning in 2008. He was promoted to be an associate professor in 2012. His research interests involve mechanics and multiple modeling (MD, FEA) as well as experimental study of the mechanical, electrical and physical properties of surfaces and interfaces of micro/nano structures, thin films, photonic crystals and MEMS/NEMS. Dr. Li joined Prof. Talke's research group as a visiting research scientist in January 2014. His current research interest centers on in-situ investigation of the head/disk interface of Heat Assisted Magnetic Recording (HAMR).

Rajasekhar Medapalli is a postdoctoral employee at CMRR. He obtained his Ph.D. from Radboud University Nijmegen in the Netherlands. He is working under the supervision of Professors Eric Fullerton and Shaya Fainman. Dr. Medapalli's research involves the experimental investigation of ultrafast magnetization dynamics in various magnetic materials for data storage applications.



Justin Taekyoung Kim is a third-year Ph.D. student in the program of Materials Science and Engineering at UC San Diego. He obtained his M.S. in the department of Materials Science and Engineering at Yonsei University in South Korea. He is working under the supervision of MAE Professor Sungho Jin, and his research interest is in the development of materials for solar energy devices and batteries.

2014 Shannon Graduate Fellowship Awarded

CMRR awards an annual Shannon Graduate Fellowship to honor a graduate student who demonstrates outstanding achievement in information theory. For the 2014-15 academic year, the recipient is Ananda Theertha Suresh, a graduate student in Electrical and Computer Engineering who works in the lab of ECE Professor Alon Orlitsky on the intersection of information theory and machine learning. Ananda's work is focused on understanding the amount of data required for several machine-learning problems, including learning probability distributions and classification. Along with several co-authors, he has proposed efficient algorithms for Gaussian-mixtures, estimation over large domains, outlier detection, and competitive classification.

Young Scientist Awards

Marko Lubarda (above right), an Assistant Professor at the University of Donja Gorcia in Montenegro and former student of professors Vitaliy Lomakin and Eric Fullerton, was honored with two of the highest awards to young scientists in Montenegro: the 2013 Young Researcher Award from the Montenegrin Academy of Sciences and Arts; and the Montenegrin Ministry of Science Award for the Most Outstanding Scientist in that country under the age of 35. Lubarda's awarded research includes work on polycrystalline magnetic films and devices.