# NSF Center for Metamaterials Newsletter

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***In this issue:***



## CfM Partners with the Army Research Office

Researchers at the University of North Carolina at Charlotte (UNCC) have partnered with the Army Research Office to explore how methods developed to image strongly scattering structures can be applied to improve the design of materials with custom properties. They will be working on the project titled "Development of Inverse Scattering - Structure Synthesis Methods: subwavelength scale imaging - metamaterial design."

The collaboration, which was signed at the UNCC on Tuesday, June 3rd, will focus on research Michael Fiddy has carried out on the further development of nonlinear inverse scattering algorithms which can be used both for imaging, as well as the design of subwavelength featured structured materials, i.e. metamaterials.

The project builds on on-going ARO-funded work to develop time (and frequency) domain inverse scattering methods for the recovery of high resolution and quantitative information about scattering targets from limited backscatter data. Direct (i.e. non-iterative) methods that are computationally efficient have been pursued and developed through funds provided by DARPA and since then ARL, to apply the frequency domain method specifically for the synthesis of structures with permittivity profiles which would lead to very low scattering cross-sections. Applications for the time domain methods have been directed towards the detection of IEDs and the latter to the fabrication of low observable structures. During these programs, they have been able to incorporate constraints on the form-factor of the target(s) to be imaged and hence equivalently the size and shape of conformal low observable structures.

In this proposal, they address the question how to develop more accurate and efficient algorithms to image with higher resolution and, correspondingly, model the composite structure of complex materials that scatter in unusual ways, such as exhibiting low or negative refractive index. They plan this to be both a theoretical and experimental project and they have the facilities to conduct both microwave and optical experiments.

The Army Research Office hopes the work will lead to a new technological breakthrough. Dr. Joseph Myers, Program Director from ARO, signed the agreement alongside UNCC's Executive Grants and Contracts Director Marie Lou Harrell.

Michael Fiddy said: "This is a significant day for us. I am excited about the opportunities of working with ARO and I am delighted that we have been able to create a potentially long term relationship with them having budgeted for up to a five year commitment."

The U.S. Army Research Laboratory's Army Research Office (ARO) mission is to serve as the Army's premier extramural basic research agency in the engineering, physical, information and life sciences; developing and exploiting innovative advances to insure the Nation's technological superiority.

## Vasily Astratov Develops New Approach to Achieve Optical Super-resolution

Optical super-resolution is an extremely important and popular direction of research inthe areas of materials characterization and in life sciences. The resolution of conventional microscope systems has a fundamental limitation determined by the diffraction of light, typically half the wavelength of light. Increasing the resolution beyond the diffraction limit enables imaging the nanoscale world with visible light. The results may have dramatic consequences for industry, technology and research. It would allow visualization of the internal structure of metamaterials, biological cells, viruses and circuitry.

In this project CfM Professor Vasily Astratov developed a new approach to achieve optical super-resolution based on micron-scale dielectric microspheres placed in contact with investigated structures. His work shows that high-index microspheres immersed in a liquid are capable of picking up optical near-fields of nanoscale objects and projecting these fields into propagating far-fields. Thus, conventional microscopies can view the extraordinary fine features of nanoscale objects. The goals of his research are to understand the mechanisms of super-resolution imaging and to develop novel optical components that can boost the resolution of conventional microscopy systems.

The main result of this CfM study is that nanoplasmonic arrays can be visualized using high-index microspheres with ~*l*/7 resolution [1,2], where *l*is the wavelength of light. Microsphere-assisted imaging offers a series of advantages over conventional and solid immersion lens microscopies [3]. These advantages include improvements over diffraction-limited resolution, higher magnification, and smaller apertures.

Professor Astratov also performed fundamental studies of the optical and transport properties of an array of microspheres and observed novel polarization effects [4] and unusual waveguiding properties [5] which can be useful for developing various focusing, imaging, and waveguiding devices with polarization capability.

The key property for developing applications of super-resolution imaging by microspheres is an ability to controllably move the microspheres and align them with different surface nanostructures. CfM has developed a novel technology of embedding high-index microspheres in transparent thin-film matrices that can be easily translated along the surface of investigated structures. The thin film with embedded microspheres plays the part of a "magnifying glass" allowing one to see extraordinary small features with the resolution approaching ~*l*/7.

One more direction of our research is related to using tightly focused light beams produced by high-index microspheres, termed "photonic nanojets", for improving the pixel efficiency of mid-infrared imaging systems. We experimentally proved higher light sensitivity of the strained-layer superlattice infrared photodetectors integrated with microspheres on an order of magnitude. We developed techniques to align microspheres in device structures based on super-resolution imaging. The results are important for increasing detectivity, reducing dark currents and increasing the speed of mid-IR photodetector arrays.


[1] V. N. Astratov and A. Darafsheh, Methods and systems for super-resolution optical imaging using high-index of refraction microspheres and microcylinders, US patent application 14042834 filed on 10/01/2013 with priority from original application on 06/07/2012.

[2] A. Darafsheh, G. F. Walsh, L. Dal Negro, and V. N. Astratov, Optical super-resolution by high-index liquid-immersed microspheres, *Appl. Phys. Lett*. 101, 141128 (2012).

[3] A. Darafsheh, N. I. Limberopoulos, J. S. Derov, D. E. Walker Jr., and V. N. Astratov, Advantages of microsphere-assisted super-resolution imaging technique over solid immersion lens and confocal microscopies, *Appl. Phys. Lett*. **104**, 061117 (2013).

[4] A. Darafsheh, N. Mojaverian, N. I. Limberopoulos, K. W. Allen, A. Lupu, and V. N. Astratov, Formation of polarized beams in chains of dielectric spheres and cylinders, *Opt. Lett*. **38**, 4208-4211 (2013).

[5] K. W. Allen,A. Darafsheh,F. Abolmaali, N. Mojaverian, N. I. Limberopoulos, A. Lupu,and V. N. Astratov, Microsphere-chain waveguides: Focusing and transport properties, accepted to *Appl. Phys. Lett.* (2014).

## CfM Director serves as keynote speaker at Meta '14 in Singapore

CfM Director Dr. David Crouse served as a keynote speaker and chair of the Technologies and Applications session this May at the 5th International Conference of Metamaterials, Photonic Crystals and Plasmonics in Singapore.

His keynote talk entitled, "Light harvesting with metasurfaces: applications to sensors and energy generation" focused on metasurfaces that can provide light filtering according to wavelength, polarization, and other properties of an incident beam, and applied to a variety of sensors.

The conference attracted over 700 attendees and included sessions on the following topics: resonant dielectric nanostructures, metasurfaces at terahertz, infrared, and optical frequencies, photonic crystals, technologies and applications, numerical modeling techniques, hyperbolic metamaterials, hybrid quantum systems, negative index materials, and plasmonics and nanophotonics.

For more information, visit the conference website and view the event program here.

## Visit CfM Booth No. 26 at ASP-URSI Meeting

The 2014 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting will be held jointly, at the Memphis Cook Convention Center in Memphis, Tennessee, USA from July 7-11.


The symposium and meeting are cosponsored by the IEEE Antennas and Propagation Society (APS) and the U.S. Committee of the International Union of Radio Science (USNC-URSI) Commissions A, B, C, D, E, F, G, and K.

The joint meeting is intended to provide an international forum for the exchange of information on state-of-the-art research in antennas, propagation, electromagnetics, and radio science.

Center for Metamaterials will present its work on the development of next generation antennas enhanced by metamaterials. Please stop by Booth No. 26 to learn more.

*STAY CONNECTED*

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