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TUNABLE AND MEMORY METAMATERIALS

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Final Report

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14. ABSTRACT
This program explored novel approaches to overcome common limitations of infrared metamaterials in order to achieve low electromagnetic losses and broad tunability of the electromagnetic response. One direction of the proposed work was to implement
graphene-based metamaterials. A complimentary direction of research was focused on the development and exploration of hybrid metamaterials with reconfigurable properties at the level of individual cells operating at infrared frequencies. The proposed hybrid metamaterial, combining split ring resonators with phase change materials, enabled convenient adjustments of the refraction index profile across the area of the metamaterial.

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Tunable and Memory Metamaterials

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The goal of this research program is to explore novel approaches towards overcoming common limitations of presently available infrared metamaterials including: low electromagnetic losses and broad tunability of the electromagnetic response. The PI has investigated various schemes for implementation of graphene-based metamaterials. One outcome of this work is that plasmonic-based approaches were established to be most beneficial for realization of graphene-based metamaterials [Nature 487 82 (2012)].. The PI has succeeded to visualize surface plasmons in graphene using infrared nanoscopy. These experiments revealed strong confinement of surface plasmons in graphene and also the ability of these plasmons to propagate over sub-micron distances. Critical assessment of plasmonic figures of merit carried out by the PI shows that graphene meets and surpasses some of the benchmark characteristics of all-metals plasmonics.

Another direction of research was focused on the development and exploration of hybrid metamaterials with reconfigurable properties at the level of individual cells operating in infrared frequencies. The PI has systematically investigated hybrid structures combining split ring resonators with phase change materials. The PI has been able to achieve gradients of the index across hybrid wafers with substantial variation of the properties on the length scales of the order of the wavelength. An experimental precondition for this latter finding was the design and fabrication of a versatile THz microscope. The PI has demonstrated the ability to produce controlled gradients of the refractive index suitable for steering microwave and THz beams [APL 102, 224103 (2013)].

In 2014 our group reported for the first time an observation of propagating phonon polaritons in a layered material: hexagonal boron nitride (hBN). Our measurements demonstrated that hBN is a natural hyperbolic material. This discovery [Science 343, 1125 (2014)] has triggered an enormous interest and numerous follow up studies.

Right panels: One reason behind a wide-spread interest in hyperbolic materials is the ability of these systems for "perfect lens"-type focusing of infrared radiation. We demonstrated this capability using a slab of hBN (schematics of the experiment is on the bottom right). We achieved lambda/33 focusing: the highest figure of merit ever reported for any hyperbolic medium. This work has appeared in Nature Communications 6, Article number: 6963 doi:10.1038/ncomms7963 (2015)

Finally, we have fabricated hybrid graphene/hBN structures and proposed a new concept of a van der Walls polaritonic metamaterial. In these structures plasmon polaritons of graphene hybridize with phonon polaritons of hBN. The hybrid polaritons

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possess combined virtues from plasmons in graphene and phonon polaritons in hBN. Therefore, G-hBN structures fulfill the definition of the electromagnetic metamaterial since the attained property of these devices is not revealed by its constituent elements. Our results uncover a practical approach for realization of agile nano-photonic metamaterials by exploiting the interaction of distinct types of polaritonic modes hosted by different constituent layers of van der Waals heterostructures [Nature Nanotechnology 10, 682 (2015)].

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1.

1. Report Type

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Professor Dimitri Bassov

Program Manager
The AFOSR Program Manager currently assigned to the award

Dr. Harold Weinstock

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Abstract

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Equipment/Facilities			
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Total			

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Appendix Documents

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