AFRL-AFOSR-CL-TR-2019-0004

Novel Nanophotonics Approach to Up-Conversion Lasing in Nanostructured, Plasmonically Coupled Metamaterials

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03/14/2019
Final Report

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
14-03-2019	Final	01 Sep 2012 to 30 Sep 2015

4. TITLE AND SUBTITLE
Novel Nanophotonics Approach to Up-Conversion Lasing in Nanostructured, Plasmonically Coupled Metamaterials

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-12-1-0450

5c. PROGRAM ELEMENT NUMBER
61102F

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Recife, 50740-530 BR

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/SOARD
U.S. Embassy Santiago
Av. Andres Bello 2800
Santiago, Chile

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/AFOSR IOS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-AFOSR-CL-TR-2019-0004

12. DISTRIBUTION/AVAILABILITY STATEMENT
A DISTRIBUTION UNLIMITED: PB Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Objective: The objective of our proposal is to produce and characterize highly efficient low loss metallo-dielectric metamaterials, which will be the basis for advanced nanophotonics concepts including: (i) random lasing utilizing enhanced feedback from plasmonically coupled nanosize scatterers; (ii) SPASERs for local nanolasing utilizing coupling between a plasmonic band and the quantum states of a gain medium; (iii) distributed feedback from the band gap in a hollow core photonic crystal fiber and (iv) nonlinear optics and stimulated Mie scattering in plasmonically coupled nanosize scatterers. During the course of the project we achieved a number of significant results in all of aforementioned areas, resulting in 2 publications which acknowledge support from SOARD. These papers are referenced below.

15. SUBJECT TERMS
metamaterials, upconversion, nanoparticles

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			POKINES, BRETT
Unclassified	Unclassified	Unclassified	SAR		19b. TELEPHONE NUMBER *(Include area code)* 703-588-1772

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Final Report

Project Title: **Advanced Nanophotonics Approach to Random Lasing and Nonlinear Optics in Plasmonic Dicroic Nanocomposite**

Reporting Period: 01 Dec 2015 to 30 Nov 2017

Anderson S. L. Gomes – Physics Department, UFPE, Brazil

Objective: The objective of our proposal is to produce and characterize highly efficient low loss metallo-dielectric metamaterials, which will be the basis for advanced nanophotonics concepts including: (i) random lasing utilizing enhanced feedback from plasmonically coupled nanosize scatterers; (ii) SPASERs for local nanolasing utilizing coupling between a plasmonic band and the quantum states of a gain medium; (iii) distributed feedback from the band gap in a hollow core photonic crystal fiber and (iv) nonlinear optics and stimulated Mie scattering in plasmonically coupled nanosize scatterers. During the course of the project we achieved a number of significant results in all of aforementioned areas, resulting in 2 publications which acknowledge support from SOARD. These papers are referenced below.

1) Random Lasing :

Scattering of light by disordered structures is a common phenomenon in our daily life. For many scientific applications, scattering is often treated as a detrimental effect. However, recent development in the field of nanophotonics shows that scattering in disordered nanostructures can enable new functionalities, including the unexpected property of random lasing. A random laser is different from a traditional laser in that the feedback amplification is not provided by a cavity formed by reflection components, but by disorder-induced scattering. Our work focused primarily on multiphoton lasing in organic random materials, where we demonstrated 3 photon lasing. We published our collective work on random lasing and its applications in Nano Today.

2) Nonlinear Optics in Plasmonic Dichroic nanocomposites:

During the course of this project we prepared gold nanorods with well controlled aspect ratio and incorporated these nanorods into a polymer matrix (PVA). The resulting composite materials were then characterized regarding their linear and nonlinear absorption and dichroism properties. Polarization resolved femtosecond Z-scan measurements were employed to characterize the nonlinear optical properties of nanocomposites. We observed 57-fold enhancement of nonlinear absorption because of giant plasmon field induced by resonant excitation of the aligned gold nanorod clusters, when mechanically stretching the PVA films. Numerical simulations of the local electric field enhancement showed a remarkable agreement with the experiment when clustering of the gold nanorods in PVA matrix was taken into account. The results of this work are quantitatively consistent with models of local field enhancement within the clusters, therefore providing a rational for the morphological design of optical nanocomposites with ultra-high plasmonic nonlinearities.

Publications:

1. M. Maldonado, H.T.M.C.M. Baltar, A.S.L. Gomes, R. Vaia, K. Park, J. Che, M. Hsiao, C.B. de Araújo, A. Baev, and P.N. Prasad, "Coupled-Plasmon induced optical nonlinearities in anisotropic arrays of gold nanorod clusters supported in a polymeric film," *J. Appl. Phys.* **121**, 143103 (2017).

2. F. Luan, B. Gu, A.S.L. Gomes, K-T. Yong, S. Wen, P.N. Prasad, “Lasing in nanocomposite random media,” *Nano Today* **10**, 168-192 (2015).

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Changes in research objectives, if any: None

Change in AFOSR program manager, if any: Yes, from Brett Pokines to Michael Martinez

Extensions granted or milestones slipped, if any: None

No new discoveries, inventions or patent disclosures during this period.

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