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RTO MEETING PROCEEDINGS **MP-SET-139**

Photonic Metamaterials for Defence and Security Applications

(Les méta-matériaux photoniques pour les applications de défense et de sécurité)

Papers presented at the Sensors and Electronics Panel (SET) Workshop held in Strasbourg, France on 10 and 11 April 2008.

Published April 2008

The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Photonic Metamaterials for Defence and Security Applications

(RTO-MP-SET-139)

Executive Summary

Metamaterials are a new class of manmade ordered composites that exhibit exceptional properties not readily observed in naturally-formed materials. Most research in metamaterials has dealt with their exceptional electromagnetic properties, and thus have led to the unveiling of many promising applications in optics (the science of describing the behavior and properties of light, and the interaction of light with matter) and photonics (the science of generating, controlling, and detecting photons). One of the main reasons researchers have studied metamaterials so extensively recently is the possibility of creating a structure having a negative index of refraction (not found in naturally occurring materials). With a negative index, superlenses or hyperlenses (forming images that have resolutions that beat the diffraction limit) and cloaking devices (surrounding an object with a shell that affects the passage of light) become possible.

The main focus of most recent research in metamaterials has been in the Radio Frequency (RF) regime, but because of the implications of negative indices of refraction in the visible or Infrared (IR), it was clear that the military community should try to gage the state-of-the-art of this new research field at those shorter wavelengths. To that end, in April 2008 a Workshop on Photonic Metamaterials for Defence and Security Applications was held. Nine of the top researchers in the world in the area of metamaterials were invited to speak to over 50 attendees from government, industry, and academia.

During the talks and Panel Discussion at the end of the workshop, numerous applications related to defence and security were discussed:

- Optical, thermal, and acoustic cloaks for counter-detection and electromagnetic shielding applications;
- The concentration of light for increased signal-to-noise ratios, increased speed, decreased size, and increased range in optical sensor systems;
- Smaller and more efficient antennas and transmission lines in RF communications systems;
- Superlenses or hyperlenses (for improved resolution in optical lithography and optical microscopy) and flat lenses (for reduced weight and cost of large optical sensor systems);
- Reduced reflection in optical systems; and
- Sub-wavelength focusing.

It became clear that the topic of metamaterials for defence, especially for optical or photonic applications, should be further pursued in an Exploratory Team.

Les méta-matériaux photoniques pour les applications de défense et de sécurité

(RTO-MP-SET-139)

Synthèse

Les méta-matériaux sont une nouvelle catégorie de composites ordonnés artificiels présentant des propriétés exceptionnelles qui ne sont pas facilement observables dans les matériaux naturels. La plupart des recherches sur les méta-matériaux ont été consacrées à leurs exceptionnelles propriétés électromagnétiques, et ont ainsi conduit au lancement de nombreuses applications prometteuses en optique (la science descriptive du comportement et des propriétés de la lumière, et l'interaction entre la lumière et la matière) et en photonique (la science de la génération, du contrôle et de la détection des photons). La possibilité de créer une structure ayant un index négatif de réfraction (introuvable dans les matériaux naturels) est une des principales raisons qui a poussé les chercheurs à approfondir leurs études sur les méta-matériaux. Avec un index négatif, les superlentilles ou les hyperlentilles (formant des images dont la résolution va au-delà de la limite de diffraction) et les dispositifs de dissimulation (entourant un objet avec une coquille qui modifie le passage de la lumière) deviennent possibles.

De nombreuses recherches récentes sur les méta-matériaux ont été tout particulièrement consacrées au régime des radiofréquences (RF). Cependant, du fait des implications des indices négatifs de réfraction dans le visible ou l'infrarouge (IR), il est certain que la communauté militaire doit essayer d'évaluer l'état de l'art dans ce nouveau domaine de recherche pour ces longueurs d'onde inférieures. A cette fin, un atelier sur les méta-matériaux photoniques pour la défense et la sécurité s'est tenu en avril 2008. Neuf des meilleurs chercheurs au monde dans le domaine des méta-matériaux ont été invités pour en parler à plus de 50 participants venant de l'administration, de l'industrie ou du milieu universitaire.

De nombreuses applications relatives à la défense et à la sécurité ont été abordées au cours des présentations et lors de la discussion de la commission à la fin de l'atelier :

- Des revêtements optiques, thermiques, et acoustiques pour la contre-détection et des applications de blindage électromagnétique ;
- La concentration de la lumière pour des rapports signal/bruit plus importants, une vitesse plus élevée, une taille réduite, et une gamme plus large pour les systèmes de capteurs optiques ;
- Des antennes et des lignes de transmission plus petites et plus efficaces pour les systèmes de communication RF ;
- Des superlentilles ou des hyperlentilles (pour une résolution améliorée en lithographie optique et microscopie optique) et des lentilles plates (pour une réduction du poids et du coût des gros systèmes de capteurs optiques) ;
- Une réduction de la réflexion dans les systèmes optiques ; et
- Une mise au point des sous-longueurs d'onde.

Il est apparu évident que les études sur les méta-matériaux pour la défense, en particulier les applications optiques ou photoniques, devraient être poursuivies plus tard par une équipe exploratoire.

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The main focus of most recent research in metamaterials has been in the Radio Frequency (RF) regime, but because of the implications of negative indices of refraction in the visible or Infrared (IR), it was clear that the military community should try to gage the state-of-the-art of this new research field at those

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