Development of GPU-based Visual Environment for Metamaterials Design

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Graphics Processing Units (GPUs) have become increasingly popular nowadays, giving exciting computational resources for the low-cost gaming gadgets. GPUs are also well suited for scientific applications, allowing researchers to accelerate computations and to improve the precision of mathematical methods. Paper describes a new version of Visual Environment for Metamaterials Modelling (VEM2), which implements algorithms of computation of physical properties of metamaterials using GPUs of a desktop computer. This allows VEM2’ users to make intensive calculations with cheap hardware equipment instead of expensive supercomputers and significantly increase the effectiveness of metamaterials design.

Keywords: Domain Specific Language; Geometrical Metamodel; Visual Environment; Metamaterial; GPUs, Computational Intelligence.

1. INTRODUCTION

Visual Environment for Metamaterials Modelling (VEM)1 allows users to design geometrical structure of a metamaterial and apply mathematical methods for the computation of physical properties. VEM was successfully applied in several scientific projects2,3 for the design of metamaterials, having required physical properties:

1) Design of photonic metamaterials. Calculation of effective tensors (permittivity, permeability and crossed magnetoelectric ones) for the bianisotropic response of photonic crystals of arbitrary Bravais lattice and form of the inclusions in the unit cell.

2) Design of phononic metamaterials. Computing an effective dynamic mass and an elastic module for phononic crystals of arbitrary Bravais lattice and form of the components in the unit cell.

3) Calculation of optical spectra (reflectivity, absorption, and transmissivity) of periodic (metal-dielectric, metal-semiconductor metal-magnetic) nanostructures.

4) Computing optical absorption of nanoparticles of arbitrary shape.

VEM implements the methodology of Domain Specific Mathematical Modelling (DSMM)4. Application of DSMM significantly increases the efficiency of physical modelling due to application of the metamodelling technology for physical models development5.

VEM makes the design of metamaterials a simple task, achievable for the different end-users (first of all, physicist-experimenters). At the same time, while the geometrical design of a metamaterial takes with VEM only several minutes, computation of metamaterial’ properties may take several hours. This is caused by the linear implementation of computational algorithms, which do not use the power of the parallel architectures of modern desktop computers. As result, the existing method may fail to make accurate results due to limitations in the computational resources.

Use of the last generation of massively parallel hardware architectures provides a solution to overcome this problem. This paper, together with expanding VEM functionality and graphical user interface, discusses the