Preface

The special issue is composed of eight original papers on general topics in diffractive optics, waveguides, electromagnetics, and quantum tunneling. The focus is on the mathematical modeling and the numerical computation of problems in optics and electromagnetics. The fields are fundamental, technology driven, and fit well with the mission of CiCP. The substantially growing applications of optical and electromagnetic technology have driven the need for modeling the relevant physical phenomena and developments of fast, efficient numerical algorithms. As the computational mathematics/physics community has begun to address a few of these challenging problems, there has been a rapid development of the theory, analysis, and computational techniques in these areas. Because of their strong interdisciplinary character, many of the problems are of significant interest to the computational physics community and demand cooperative efforts between the mathematics and physics communities. The special issue will serve as a vehicle to convey some of these recent advances. It is intended to provide researchers in applied and computational mathematics as well as computational physics with up-to-date results. It should also be highly relevant to researchers in related engineering disciplines.

The following is a brief survey of the topics.

There are two papers on the modeling and computation of diffractive optics. The paper by Rathsfeld, Schmidt, and Kleemann presents an efficient integral equation method for numerical solution of the optical diffraction grating problem if the grating profile may be determined by simple cross-section curves. This method is applicable to a broad class of grating profile curves, for example, corners, thin coated layers, or a large ratio of the period over the wavelength. Crucial issues include the efficient evaluation of the quasi-periodic Green kernels, the quadrature algorithm, and the iterative solution of the arising systems of linear equations. Arens, Chandler-Wilde and DeSanto consider the scattering of a plane wave by a one-dimensional, periodic rough surface. In the case of perfectly reflecting gratings in TE polarization in the EM case or sound soft in the acoustic case, a uniquely solvable first-kind integral equation formulation of the problem is derived. Various mathematical and computational issues are investigated on Galerkin's method of the ill-posed integral equation.

The paper by Meyer, Capistran and Chen treats the obstacle scattering for the Helmholtz equation. The authors introduce the equivalent sources for the Helmholtz equation and establish their connections to the naturally induced sources for the sound-soft, sound-hard, and impedance obstacles for the inverse scattering problems of the Helmholtz equation. As two applications, the naturally induced sources are employed to improve the boundary integral equation formulations for the obstacle scattering, and to develop a unified approach for establishing boundary conditions that govern the domain derivatives of scattered waves for the soft, hard, and impedance obstacles.

The next two papers, by Huang and Wood, and by Ammari, Kang and Kim, study the scattering by overfilled electromagnetic cavities and patch antennas, respectively. The former paper presents a hybrid finite element and Fourier transform method to analyze

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the time domain scattering of a plane wave incident on a two-dimensional overfilled cavity embedded in the infinite ground plane. An important step is to introduce an artificial boundary condition on a hemisphere enclosing the cavity that couples the fields from the infinite exterior domain to those inside. Ammari et al. consider a scattering problem inherent in curved microstrip structures mounted on thin dielectric structures. By developing an asymptotic technique, they derive approximate boundary conditions for such structures in the general framework of integral equations.

There are two papers on waveguide problems – a topic of lasting value. Joly, Li and Fliss examine exact boundary conditions for periodic waveguides containing a local perturbation. The exact boundary conditions and the key extension operators are computed by solving local problems on a single periodicity cell. Optical wave-guiding structures that are non-uniform in the propagation direction are fundamental building blocks of integrated optical circuits. Lu offers a review on recent developments in the most widely used simulation methods for frequency domain propagation problems.

The paper by Shi is concerned with the mathematical modeling of quantum tunneling. The high dimensionality of the potential energy surface poses a great challenge in both the theoretical and numerical description of tunneling. Numerical simulation based on Schrödinger equation is often prohibitively expensive. The author introduces an accurate, efficient, robust and easy-to-implement numerical method to calculate the ground state tunneling splitting based on an imaginary-time path integral. The method is multidimensional and free from any additional ad hoc assumptions on potential energy surface. It allows calculations of the effects of all coupling modes on the tunneling degree of freedom without loss. The paper may be viewed as a preliminary attempt to tackle the increasingly important research directions in nano modeling, particularly in the area of nano optics.

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