Titles and Abstracts

1. Vrushali A. Bokil, Department of Mathematics, Oregon State University, Corvallis, OR, USA.

Title: Dispersion Minimized Mimetic Finite Difference Methods for Maxwells Equations in Complex Dispersive Materials

Abstract: One of the major challenges to numerical modeling of wave phenomena in time domain formulations is controlling numerical dispersion, an artificial dependence of wave propagation speed on the wave-frequency. Numerical dispersion is present in all discrete models of wave phenomena and produces the major contribution to long-time integration error. Therefore, reduction of numerical dispersion is essential for accuracy of numerical simulations. In this talk, we will focus on numerical modeling of electromagnetic waves in linear dispersive media. Important examples of such media include biological tissue, wet soils, and various metamaterials. In dispersive media planar electromagnetic waves travel with phase velocities that depend on their frequency. Therefore, unlike the case of a vacuum, planar waves spread and change shape even away from boundaries and interfaces. This physical dependence of wave speed on wave frequency in a dispersive material makes it necessary to differentiate between physical and nonphysical effects in corresponding numerical methods.

We construct a high order numerical method for electromagnetic wave propagation in linear dispersive media based on an optimization procedure, called M-adaptation. We initially applied this technique to 2D electromagnetic wave propagation in a vacuum, in which optimization of numerical dispersion is performed on parameterized families of Mimetic Finite Difference (MFD) schemes on rectangular meshes that are at least second order accurate in space and time. These families all utilized the lowest order Nédélec edge elements in space and a Leapfrog discretization in time. Within this family we found an optimal member with the least (in the sense of order) numerical dispersion. In this prior work we produced such an optimal M-adapted numerical scheme with the numerical dispersion and anisotropy reduced from second to fourth order. In this talk, we present the M-adaptation procedure for Maxwells equations in linear dispersive media. The dispersive effects in the models are primarily due to various lower order time derivative terms in the constitutive laws for the electric displacement, and magnetic induction. These terms model material responses to the incident electric and magnetic fields, such as relaxation or resonance processes. In the classical Yee scheme with Leapfrog time staggering these terms are typically approximated using time-averaging. Following this approach M-adaptation cannot reduce the numerical dispersion error from second to fourth order. We show that with exponential differencing in time coupled with MFD discretization in space it is possible to obtain an optimal M-adapted numerical scheme with fourth order numerical dispersion error.

This is joint work with Nathan Gibson in the department of Mathematics at Oregon State University, Vitaliy Gyrya in the Applied Mathematics and Plasma Physics group at Los Alamos National Laboratory, and Duncan McGregor in the Computational Multiphysics group at Sandia National Laboratory.

2. Guy Bouchitté, Université de Toulon, France

Title: Resonance-induced Transmission of Acoustic Waves through Subwavelength Hole Arrays

Abstract: We study a device that consists of a bidimensional array of holes inside a matrix with a very high permittivity. This kind of structure gave rise to a very large amount of theoretical and experimental publications after the discovery that they could transmit waves at certain wavelengths larger than the diameter of holes. This phenomena can also be observed for acoustic waves. In the present work, we study the low frequency behavior, i.e. the homogenization, of scalar waves. More precisely, the structure is periodic with a period η much smaller than the wavelength. It is illuminated by an incident scalar field u^i satisfying Helmholtz equation. It gives rise to a total field u_η satisfying a Helmholtz equation of type $\nabla \cdot (a_\eta \nabla u_\eta) + k^2 u_\eta = 0$. The coefficient a_η is equal to 1 inside the holes and to η^2 inside, i.e. the permittivity of the matrix in which the holes are made is very high. We study the limit of u_η when η tends to 0. A homogenized model is derived where the array is described by a strongly anisotropic and dispersive homogenized permittivity: the field can only propagate in the direction of the holes. Resonances are shown to exist as poles of the homogenized permeability, leading to sharp peaks in the transmission. These resonances correspond to frequency that are the eigenvalues of a spectral problem taking place on the basic cell of the device.
Joint work with Christophe Bourel (Calais University, France) and Didier Felbacq (L2C, Montpellier university, France).

3. Min Chen, Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

Title: Manipulating Smith-Purcell Emission with Babinet Metasurfaces Dispersive Materials

Abstract: Swift electrons moving closely parallel to a periodic grating produce far-field radiation of light, which is known as the Smith-Purcell effect. In this letter, we demonstrate that designer Babinet metasurfaces composed of C-aperture resonators offer a powerful control over the polarization state of the Smith-Purcell emission, which can hardly be achieved via traditional gratings. By coupling the intrinsically non-radiative energy bound at the source current sheet to the out-of-plane electric dipole and in-plane magnetic dipole of the C-aperture resonator, we are able to excite cross-polarized light thanks to the bianisotropic nature of the metasurface. The polarization direction of the emitted light is aligned with the orientation of the C-aperture resonator. Furthermore, the efficiency of the Smith-Purcell emission from Babinet metasurfaces is efficiently increased by 84%, in comparison with the case of conventional gratings. These findings not only open up a new way to manipulate the electron-beam-induced emission in the near-field region, but also promise compact, tunable and efficient light sources and particle detectors.

4. Eric Chung, Department of Mathematics, The Chinese University of Hong Kong, Hong Kong SAR

Title: SDG Method for the Maxwell's Equations

Abstract: In this talk, a new type of staggered discontinuous Galerkin (SDG) methods for the three dimensional Maxwell's equations is presented The spatial discretization is based on staggered Cartesian grids so that many good properties are obtained. First of all, our method has the advantages that the numerical solution preserves the electromagnetic energy and automatically fulfills a discrete version of the Gauss law. Moreover, the mass matrices are diagonal, thus time marching is explicit and is very efficient. Our method is high order accurate and the optimal order of convergence is rigorously proved. It is also very easy to implement due to its Cartesian structure and can be regarded as a generalization of the classical Yee's scheme as well as the quadrilateral edge finite elements. Furthermore, a superconvergence result, that is the convergence rate is one order higher at interpolation nodes, is proved. Numerical results are shown to confirm our theoretical statements, and applications to problems in unbounded domains with the use of PML are presented. A comparison of our staggered method and non-staggered method is carried out and shows that our method has better accuracy and efficiency. This work is partially supported by the Hong Kong RGC General Research Fund (Project: 14301314).

5. Jintao Cui, Department of Applied Mathematics, The Hong Kong Polytechnic University

Title: Multigrid Methods for Two-dimensional Maxwell's Equations Based on Hodge Decomposition

Abstract: In this work, we investigate the numerical solution for two-dimensional Maxwell's equations on graded meshes. The approach is based on the Hodge decomposition. The solution u of Maxwell's equations is approximated by solving standard second order elliptic problems. The quasi-optimal error estimates for both u and curl of u in the L_2 norm are obtained on graded meshes. We then prove the uniform convergence of the W-cycle and full multigrid algorithms for the resulting discrete problems. The performance of these methods is illustrated by numerical results. Similar numerical approach can also be applied to solve the fourth order curl problems. We will report some preliminary results for the multigrid algorithms.

6. Zhaoyun Duan, School of Physical Electronics, University of Electronic Science and Technology of China, China

Title: Reversed Cherenkov radiation in the metamaterials

Abstract: A metamaterial is a material engineered to have some exotic properties that is not found in nature, including the negative refractive index, the reversed Doppler effect, and the Reversed Cherenkov radiation(RCR). The so-called RCR is the exotic elecrtomagnetic radiation which is emitted in the opposite direction of fast moving charged particles in a left-handed material.

7. Xiaobing Feng, Department of Mathematics, The University of Tennessee, USA

Title: An Efficient Monte Carlo Discontinuous Galerkin Method for Wave Scattering in Random Media

Abstract: In this talk I shall present a newly developed multi-modes Monte Carlo approach for wave scattering in random media and for random PDEs in general. The approach is based on a multi-modes representation of the solution of the random PDE, as a result, the original random wave equation can be reduced to a finite number of deterministic wave equations with random source terms. Efficient numerical methods and solvers can be formulated for solving the reduced problems. The random Helmholtz equation and the random elastic Helmholtz equations, which govern respectively acoustic and elastic wave scattering in random media, will be discussed in details to explain the main ideas of the proposed approach. Convergence analysis and numerical experiments will be presented to demonstrate the potential advantages of the proposed approach. If time permits, extension to random diffusion equations will also be discussed. This is a joint work with Junshan Lin of Auburn University and Cody Lorton of University of West Florida, U.S.A.

8. Liping Gao, School of Science, China University of Petroleum, China

Title: Energy identities of Maxwell equations and applications in some FDTD methods

Abstract: Apart from the L^2 forms of energy identities in Poynting Theorem, there are more energy identities for Maxwell equations. In this talk, we present some new energy identities of Maxwell equations with the perfectly electric conducting and periodic boundary conditions and their derivation. It is shown that the new identities are related or represented by the H^1 and H^2 norms and that the curl and the curl of curl of electromagnetic fields are preserved in terms of their magnitude. Application of these new identities in some finite difference methods of Maxwell equations are studied. Numerical energy identities of the schemes: Yee Scheme, ADI-FDTD and EC-S-FDTD are derived. Stability and second order convergence of these three schemes in H^1 and H^2 are proved. Numerical experiments to confirm energy identities and convergence are provided. The talk is mainly based on the joint work with professors B. Zhang, D. Liang and W., Chen, Dr R. Shi and other collaborators.

9. Joscha Gedicke, Faculty of Mathematics, University of Vienna, Austria

Title: An Adaptive Finite Element Method for Two-dimensional Maxwell's Equations

Abstract: We extend the Hodge decomposition approach for the cavity problem of two-dimensional time harmonic Maxwell's equations to include the impedance boundary condition, with anisotropic electric permittivity and sign changing magnetic permeability. We derive error estimates for a P_1 finite element method based on the Hodge decomposition approach and develop a residual type *a posteriori* error estimator. We show that adaptive mesh refinement leads empirically to smaller errors than uniform mesh refinement for numerical experiments that involve metamaterials and electromagnetic cloaking. The well-posedness of the cavity problem when both electric permittivity and magnetic permeability can change sign is also discussed and verified for the numerical approximation of a flat lens experiment. This talk is joint work with S.C. Brenner and L.-Y. Sung.

10. Tom Hagstrom, Southern Methodist University, USA

Title: Numerical Methods for Dispersive Wave Equations

Abstract: We describe some issues in the development and analysis of numerical methods in the time domain for dispersive wave equations. These include:

i: High order Hermite, discontinuous Galerkin, and Galerkin difference schemes;
ii: Numerical homogenization via the heterogeneous multiscale method;
iii: Stable and convergent treatment of radiation boundary conditions.

11. Maryna Kachanovska, POEMS, ENSTA ParisTech, Palaiseau, France

Title: Stable Perfectly Matched Layers for a Class of Anisotropic Dispersive Models

Abstract: We consider the problem of electromagnetic wave propagation in dispersive anisotropic media in an infinite or semi-infinite domain. This phenomenon is modelled by the Maxwell equations with a diagonal anisotropic tensor of dielectric permittivity and scalar magnetic permeability, which depend on the frequency. One of the ways to bound the computational domain is offered by the use of the perfectly matched layer (PML) techniques. However, when applied to problems with anisotropy and dispersion, classical PMLs often exhibit instabilities in the time domain, connected to the presence of backward propagating waves.

We will discuss how the PML can be stabilized for the model in question with the help of the frequency-dependent PML change of variables. Moreover, we will provide the energy estimates for the resulting PML system. The novelty of our approach lies in the use of the Laplace domain based techniques, which allows to simplify the PML analysis, as well as provides some intuition on obtaining the energy estimates.

This presentation is based on a joint work with Éliane Bécache.

12. Hyeonbae Kang, Inha University, Korea

Title: The Spectral Theory of the Neumann-Poincare Operator, Plasmon Resonance, and Anomalous Localized Resonance

Abstract: On the surface of dielectric materials with the negative dielectric constant a resonance occurs. This resonance is called the surface plasmon resonance and is underlying physical phenomenon of important imaging modalities such as SERS (surface enhanced Raman spectroscopy). It turns out that the Plasmon resonance is closely related to the spectrum of the Neumann-Poincare (NP) operator defined on the surface. In this talk I will explain the connection of the plasmon resonance and the spectrum of the NP operator and review recent development in the spectral theory of the NP operator. The NP spectrum is also closely related to the anomalous localized resonance which attracts much attention in connection with the invisibility cloaking. I will explain this as well.

13. Linghua Kong, School of Mathematics and Information Science, Jiangxi Normal University, China

Title: Efficient and accurate numerical methods for the multidimensional convection-diffusion equations Dispersions

Abstract: A class of high order compact methods combined with local one-dimensional method have been studied to numerically solve multidimensional convection-diffusion equations. The methods are widely accepted due to their compactness, high accuracy. In this kind of methods the spatial derivatives are approximated implicitly rather than explicitly with smaller stencil but with higher accuracy. The local one-dimensional strategy is adopted in time to reduce the scale of algebraic equations resulting from numerical methods. This makes the multidimensional problems can be easily coded. Based on analyzing the splitting error of the local one-dimensional method, a more accurate scheme is obtained through minor modification on the original scheme. By Von Neumann approach, we can find that the proposed schemes are unconditionally stable. Some numerical results are reported to illustrate that the schemes are robust, efficient and accurate.

14. Yun Lai, School of Physical Science and Technology, Soochow University, China

Title: Ultra-Transparent Media and Transformation Optics with Shifted Spatial Dispersions

Abstract: Transformation optics has been established based on local medium framework, in which the parameters of materials are not dependent on the wave vector or incident angles. The local medium can only be produced by metamaterials at deep subwavelength scale. We show that photonic crystals can sometimes effectively behave as nonlocal medium with its parameters dependent on the wave vector or incident angle. In particular, when the spatial dispersion of the photonic crystals exhibits a shift in k-space, we find that the principle of transformation optics can still be applied. One especially important advantage is the realization of ultra-transparent media by such photonic crystals, which could be the most transparent media on earth.

15. Dong Liang, Department of Mathematics and Statistics, York University, Canada

Title: The Energy-Conserved Identities and Numerical Methods for Metamaterial Electromagnetics

Abstract: Due to their unusual physical properties that could not be found in natural materials, metamaterials have many important applications such as in aerospace applications, aircraft radar, radio-frequency, microwave, antennas, medical imaging device, cloaking device, etc. In this talk, we will present our results on energy-conserved identities of electromagnetic energy in metamaterials and the developed energy conserved numerical methods for metamaterial electromagnetic problems. We will talk theoretical results on energy conservation, stability and convergence and will give numerical examples to show their performances.

16. Qinhuo Liu, Duke University, USA

Title: Multiscale Computational Electromagnetics for Sensing, Imaging, and Metamaterials

Abstract: TBA

17. Jun Mei, Department of Physics, South China University of Technology, China

Title: Dirac Cones and Topological Edge States in Two-dimensional Acoustic Crystals

Abstract: Many of graphenes interesting properties originate from its unique linear dispersion relations around the K point, the so-called Dirac point. Around this high symmetry point on the Brillouin zone (BZ) boundary, two bands cross over each other linearly, and the relevant band structures can be described by the Dirac Hamiltonian. Similarly, linear dispersion relations have been found around the K point for classical periodic systems such as photonic and acoustic crystals, where interesting wave transport properties like pseudo-diffusion have been studied and explored. In this work, we show that a double Dirac cone can be realized at the BZ center of a two-dimensional acoustic crystal (AC) composed of a triangular array of core-shell cylinders embedded in a water host. For each cylinder, the inner core is iron rod and the shell is made of silicone rubber. We show that the double Dirac cone is induced by utilizing the *accidental degeneracy* of two double-degenerate Bloch states, i.e., the dipolar states and quadrupolar states. In an AC consisting of a triangular lattice of circular cylinders, the point group at the BZ center is C_{6v}, which has two 2D irreducible representations: E_1 and E_2. In this case, the dipolar states correspond to E1 representation and the quadrupolar states correspond to E_2 representation. If we alter the inner and outer radii of the core-shell structure, the four-fold degeneracy will be lifted and the dipolar states will be separated from the quadrupolar states, and this is what the *accidental degeneracy* means here. By using a k.p perturbation method, we demonstrate that the double Dirac cone is composed of *two identical and overlapping* Dirac cones from first principles, whose linear slopes can also be accurately predicted from the method. Because the double Dirac cone occurs at a relatively low frequency, we reveal that in the vicinity of the double Dirac point frequency, a slab of our acoustic system can be mapped onto an acoustic zero-index medium by using a standard retrieval method. Here, we demonstrate with two examples the interesting wave transport behaviors in our systems. These examples unambiguously show that zero phase change and total transmission of plane waves can be simultaneously achieved, both in a straight waveguide and in a U-shaped narrow neck waveguide channel. Potential applications can be expected in diverse fields such as acoustic wave manipulations and energy flow control. Furthermore, we find that topologically protected edge states for acoustic waves can be realized in such a simple system. By utilizing the point group symmetry of two doubly degenerate eigenstates at the Γ point, we can construct *pseudo-time-reversal symmetry* as well as pseudo-spin states in this classical system. We develop an effective Hamiltonian for the associated dispersion bands around the BZ center, and find the inherent link between the band inversion and the topological phase transition. With numerical simulations, we clearly demonstrate the unidirectional propagation of acoustic edge states along the interface between a topologically nontrivial acoustic crystal and a trivial one, and the robustness of the edge states against defects with sharp bends. Our work provides a new design paradigm for manipulating and transporting acoustic waves in a topologically protected manner. Technological applications and devices based on our design are expected in various frequency ranges of interest, spanning from infrasound to ultrasound. In the last part of this talk, I will report our recent work of constructing of an AC with topologically nontrivial band gaps by breaking

the real time-reversal symmetry. We show that the degeneracy associated with a Dirac-like cone in the BZ center will be lifted in this system. We demonstrate that simultaneously breaking the *real time-reversal symmetry* and altering the geometric size of the unit cell result in a topological transition that we verify by the Chern number calculation and edge-mode analysis. We develop a complete model based on the tight binding to uncover the physical mechanisms of the topological transition. Both the model and numerical simulations show that the topology of the band gap is tunable by varying both the velocity field and the geometric size; such tunability may dramatically enrich the design and use of acoustic topological insulators.
The talk is mainly based on the joint works with Prof. Ying Wu, Dr. Yan Li, Mr. Ze-Guo Chen and other collaborators.

18. Peter Monk, University of Delaware, Newark DE, USA

Title: Stekloff Eigenvalues in Inverse Scattering

Abstract: We consider a proposed method for non-destructive testing in which small changes in the (possibly complex valued) refractive index of an inhomogeneous medium of compact support are to be determined from changes in measured far field data due to incident plane waves. Discussing first the Helmholtz equation, the problem is studied by considering a modified far field operator whose kernel is the difference of the measured far field pattern due to the scattering object and the far field pattern of an auxiliary scattering problem with the Stekloff boundary condition imposed on the boundary of a domain containing the scattering object. It is shown that scattering data can be used to determine the Stekloff eigenvalues corresponding to this domain. Extensions to Maxwell's equations will also be presented.

19. Weifeng Frederick Qiu, City University of Hong Kong

Title: A superconvergent HDG method for the Incompressible Navier-Stokes Equations on general polyhedral meshes

Abstract: We present a superconvergent hybridizable discontinuous Galerkin (HDG) method for the steady-state incompressible Navier-Stokes equations on general polyhedral meshes. For arbitrary conforming polyhedral mesh, we use polynomials of degree $k+1$, k, k to approximate the velocity, velocity gradient and pressure, respectively. In contrast, we only use polynomials of degree k to approximate the numerical trace of the velocity on the interfaces. Since the numerical trace of the velocity field is the only globally coupled unknown, this scheme allows a very efficient implementation of the method. The design of the stabilization function corresponding to diffusion operator comes from Lehrenfeld in Remark 1.2.4 in [1]. In [3, 2], this kind of stabilization functions is used for HDG methods for linear elasticity and diffusion problem with complete error analysis. However, the analysis used in [3, 2] can not be generalized for nonlinear problems like the Navier-Stokes equations because of lack of the corresponding discrete energy stability. In [4], we provide the discrete energy stability for HDG method for convection diffusion problem, which uses the same stabilization function for the diffusion operator. In this paper, by generalizing the discrete energy stability in [4], for the stationary case, and under the usual smallness condition for the source term, we prove that the method is well defined and that the

global L^2-norm of the error in each of the above-mentioned variables and the discrete H^1-norm of the error in the velocity converge with the order of $k+1$ for $k \geq 0$. We also show that for $k \geq 1$, the global L^2-norm of the error in velocity converges with the order of $k+2$. From the point of view of degrees of freedom of the globally coupled unknown: numerical trace, this method achieves optimal convergence for all the above-mentioned variables in L^2-norm for $k \geq 0$, superconvergence for the velocity in the discrete H^1-norm without postprocessing for $k \geq 0$, and superconvergence for the velocity in L^2-norm without postprocessing for $k \geq 1$.

References

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20. Simon Shaw, Brunel University London, England

Title: Towards Space-Time Adaptivity for Metamaterial Models

Abstract: Although not a 'metamaterial' model, Debye polarization furnishes a simple model for a dispersive material - and has very strong mathematical similarities with the equations of linear solid viscoelasticity. This similarity will be outlined as will some useful observations and estimates from that area that provide the tools for deriving sharp stability and error bounds - bounds arrived at without recourse to Gronwall inequalities. Some examples of these type of results will be given and the potential for obtaining similarly sharp strong-data-stability estimates will be discussed. If such estimates can be derived there is a possibility of deriving a posteriori error bounds for space-time finite element discretizations which will allow for error control through spacetime adaptivity. The various ways in which this approach might be widened to include the Drude model will be covered with a summary of progress to date. The complete removal of the Gronwall-like exponential growth seems much more difficult than in the Debye case, but this may depend on how the problem is formulated. There is also a choice of timediscretization methods with continuous Galerkin allowing more flexibility in allowable boundary conditions that discontinuous Galerkin. The first part of the talk will be a summary of known results and the second more of a speculative outlook with the aim of stimulating discussion.

21. Jiguang Sun, Michigan Technology University, USA

Title: Numerical Methods for Transmission Eigenvalues

Abstract: Abstract: The interior transmission problem is a boundary value problem that arises in the scattering of time-harmonic waves by an inhomogeneous medium of compact support. The associated transmission eigenvalue problem has important applications in qualitative methods in inverse scattering theory. It is challenging

to compute transmission eigenvalues since it is neither elliptic nor self-adjoint. In this talk, we discuss some finite element methods for acoustic and electromagnetic transmission eigenvalue problems, discrete generalized matrix eigenvalue solver, and possible future research topics.

22. Bo Wang, Hunan Normal University, China

Title: An Efficient and Accurate Simulation of 3D Time Domain Electromagnetic Cloaking

Abstract: We present a new model for the simulation of time domain electromagnetic cloaking. The new model only involves the electric displacement D. Jump conditions across the interfaces between cloaking layer and other areas are derived from standard transmission conditions. The application of this new model in the simulation of spherical cloaking is studied. Due to the good features of the new model and the special geometry of the cloak, we introduce a highly efficient VSH-spectral-element discretization. The combination of the high order spectral element solver and NRBC in the discretization makes high accuracy. Various numerical examples are given to validate the model and the efficiency and accuracy of the VSH-spectral-element discretization.

23. Li-Lian Wang, Division of Mathematical Sciences, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore

Title: A Perfect Absorbing Layer from Inside-Out Invisibility Cloak for High-order Simulations of Scattering Problems

Abstract: In this talk, we introduce a perfect absorbing layer related to the design of the inside-out (or inverse) invisibility cloak, which is well-suited for high-order simulation of wave scattering problems with bounded scatterers. The notion of an inside-out cloak is to hide objects in an open space by rendering the observers inside a closed region unaware of the objects outside. In principle, this can be achieved by compressing the waves in the open space to a finite layer surrounding the closed region. If the cloak is perfect, it can be the best candidate of an absorbing non-reflective layer for wave scattering problems, especially, when one uses high-order methods. However, the ideal inverse cloak is far from perfect, so the purpose of this talk is to present ideas and techniques to make it perfect. We also report efficient high-order methods on accurate simulations of scattering problems arisen from transformation optics.

This talk is largely based on joint works with Zhiguo Yang.

24. Haijun Wu, Nanjing University, China

Title: Finite Element Method and its Analysis for a Nonlinear Helmholtz Equation with High Wave Number.

Abstract: The well-posedness of a nonlinear Helmholtz equation with an impedance boundary condition is established for high frequencies in two and three dimensions. Stability estimates are derived with explicit dependence on the wave number. Linear finite elements are considered for the discretization of the nonlinear Helmholtz equation, and the well-posedness of the finite element systems is analyzed. Stability

and preasymptotic error estimates of the finite element solutions are achieved with explicit dependence on the wave number.

25. Ying Wu, King Abdullah University of Science and Technology, Saudi Arabia

Title: Homogenization Schemes for Metamaterials

Abstract: In this talk, I will review our work on the homogenization schemes for metamaterials. I will focus on the coherent potential approximation and show how it can lead to a formula that can predict the effective medium parameters for metamaterials beyond the long wavelength limit, where resonance occurs. The applications of the effective medium theory on the design of emerging materials with intriguing properties, like negative refraction, zero-index and linear dispersion, will be demonstrated. Then I will talk about the limitations on the coherent potential approximation based homogenization and discuss how other schemes, such as multiple-scattering, field-averaging and Greens function methods, can overcome those limits and give proper effective medium parameters.

This talk will involve joint work with Ms. Xiujuan Zhang from KAUST, Prof. Zhaoqing Zhang, Prof. C. T. Chan and Prof. Ping Sheng from Hong Kong University of Technology, Prof. Yun Lai from Soochow University, Prof. Jensen Li from Birmingham University and Prof. Jun Mei from South China University of Technology.

26. Ziqing Xie, Hunan Normal University, China

Title: College of Mathematics and Computer Science , Hunan Normal University, China

Abstract: In this talk, a semi-discrete discontinuous Galerkin (DG) method is first intro- duced to solve the Maxwells equations in three dispersive media in a uniform framework, which is described by an integral-differential equation. Accuracy of $O(h^{k+\frac{1}{2}})$ is obtained. Then, a fully discrete scheme for Maxwells equation in metamaterial, which is based on DG method in spatial domain and Crank-Nicolson method in temporal domain, is proposed. Both the unconditionally stability and convergent rate of $O(\tau^2+h^{k+\frac{1}{2}})$ is obtained. Finally, it is also noted that the governing equations for three different meta-materials share a common feature. Based on this observation, a method combining the DG method in space with the CG method in time for Maxwells equation in meta-materials is discussed. We prove that this scheme is unconditionally stable and convergent at a rate of $O(\tau^{r+1} + h^{k+\frac{1}{2}})$.

27. Wei Yang, Xiangtan University, China

Title: Time-domain Metamaterial Models and Finite Element Simulations

Abstract: In this talk, we first introduce the development history of mematerials and give some time-domain mathematical model in metamaterials. ?Then, we focus on the time-domain cloaks model.??The explicit expressions of the cloak parameters without the contour curve expressions of the objects and ?2d arbitrary shape cloak model ?are established.?A new time-domain finite element scheme is developed to solve the governing equations, and it's stability is also provided.?Numerical results are presented to confirm the theoretical analysis and the effectiveness of our cloak model and FETD method.

28. Irwin Yousept, University Duisburg-Essen, Germany

Title: Optimal Control of Evolution Maxwell's Equations with Application in Type-II Superconductivity

Abstract: Electromagnetics plays an important role in many modern applications and key technologies, including applications in the energy science, nanotechnology, life science, magnetic confinement fusion, magnetic levitation technology, microwave heating, sensor technology, and many more. The optimal control of such complex electromagnetic processes is challenging and requires very careful mathematical and numerical investigations. In this talk, we present recent results on the optimal control of evolution Maxwell's equations with application in type-II superconductivity.

29. Weiying Zheng, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, China

Title: Exactly Divergence-free FEM for 3D MHD Equations

Abstract: Magnetohydrodynamic (MHD) equations describe the dynamic behavior of electrically conducting fluid and the coupling between the fluid and the magnetic field. It has broad applications in fluid dynamics and plasma physics. But numerical computations for 3D MHD equations are very challenging, particularly for large Hartmann number. For incompressible fluid, both the velocity of the fluid and the magnetic field are divergence-free. It is desirable in practical applications that the numerical solutions are also divergence-free exactly. In this talk, I will present a divergence-free finite element method for 3D MHD equations and propose an efficient preconditioner for the solution of discrete problems. We also validate the the method by extensive numerical experiments.