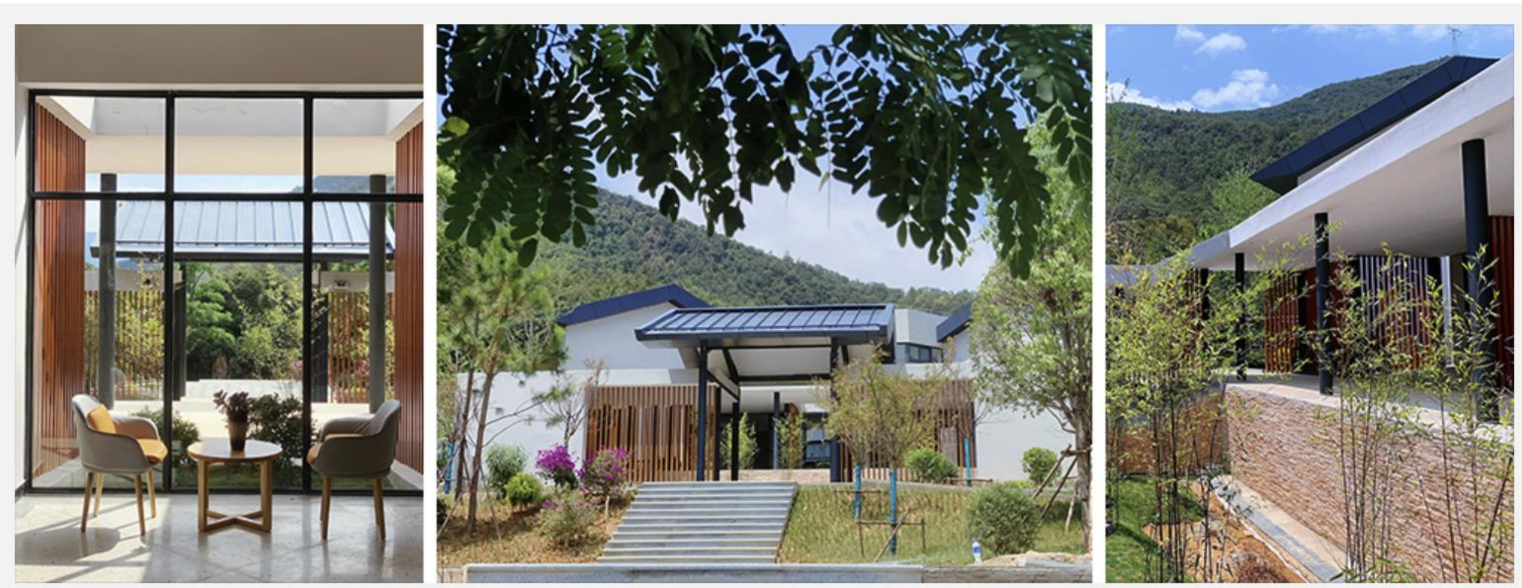
天元數學國際交流中心
Tianyuan Mathematics Research Center

Efficient Algorithms for Highly Oscillatory Systems: Construction, Theory, and Applications

23 August - 29 August, 2026

Tianyuan Mathematics Research Center
Kunming, China



About the Workshop

This workshop is dedicated to advancing research on efficient algorithms for highly oscillatory systems, covering their construction, theoretical foundations, and practical applications. It gathers leading international experts to explore key challenges, share latest findings, and foster interdisciplinary collaborations, aiming to push forward the development of related fields in modern mathematics and computational science.

Organizers

Xu Qian, National University of Defense Technology

Bin Wang, Xi’an Jiaotong University

Wansheng Wang, Shanghai Normal University

Venue

Tianyuan Mathematics Research Center, Kunming, China

Dates

23 August - 29 August, 2026

Programme Overview

All talks take place in the lecture hall. Each talk is **40 minutes** including discussion.

Speaker	24 August Monday	25 August Tuesday	26 August Wednesday	27 August Thursday	28 August Friday
Morning (9:00 – 12:00)	Arieh Iserles	Siqing Gan	Hongjiong Tian	Free Discussions	Wansheng Wang
	Chun Li	Aiguo Xiao	Jiyong Li		Meng Li
	Tobias Jahnke	Chengming Huang	Gengen Zhang		Bin Wang
	Dongfang Li	Yongkui Zou	Free Discussions		Beibei Zhu
Afternoon (14:00 – 17:00)	Jingjun Zhao	Linghua Kong	Break	Free Discussions	Break
	Chunmei Su	Xiaojie Wang			
	Jing Gao	Wenjun Cai			
	Hong Zhang	Lu Li			

Chair	Monday	Tuesday	Wednesday	Thursday	Friday
Morning (9:00 – 12:00)	Tobias Jahnke	Chengming Huang	Yuhao Cong		Bin Wang
	Arieh Iserles	Minghui Song	Xu Qian		Wansheng Wang
Afternoon (14:00 – 17:00)	Dongfang Li	Chun Li			
	Chunmei Su	Yanming Zhang			

Programme

24 August (Monday)

Time	Speaker	Title	Chair
8:45–9:00	**Opening remarks**		
9:00–9:40	Arieh Iserles	On mathematical foundations of spectral methods	Tobias Jahnke
9:40–10:20	Chun Li	Geometric Fourier-Galerkin numerical methods for the derivative nonlinear Schr\"{o}dinger equation	
10:20–10:40	Break		
10:40–11:20	Tobias Jahnke	High-frequency wave propagation in nonlinear dispersive media: analysis and numerics	Arieh Iserles
11:20–12:00	Dongfang Li	Relaxation Runge-Kutta methods for their application	
12:00–14:00	Lunch		
14:00-14:40	Jingjun Zhao	Serendipity VEMs for semilinear parabolic integro-differential equations on curved domains	Dongfang Li
14:40–15:20	Chunmei Su	Temporal high-order parametric finite element methods for geometric flows	
15:20–15:40	Break		
15:40–16:20	Jing Gao	Geometric spectral methods in multivariate domains	Chunmei Su
16:20–17:00	Hong Zhang	High-order complex resolvent IMEX Runge--Kutta methods for semilinear parabolic equations	
17:00–	Dinner		

25 August (Tuesday)

Time	Speaker	Title	Chair
9:00–9:40	Siqing Gan	Strong convergence of Milstein-type schemes for McKean-Vlasov SDEs with super-linear coefficients	Chengming Huang
9:40–10:20	Aiguo Xiao	Two novel domain-preserving schemes for a class of stochastic differential equations	
10:20–10:40	Break		
10:40–11:20	Chengming Huang	Spectral Petrov-Galerkin methods for ordinary and partial VIDEs with weakly singular solutions	Minghui Song
11:20–12:00	Yongkui Zou	Locking-free finite element approximation to electroporoelasticity equation	
12:00–14:00	Lunch		
14:00-14:40	Linghua Kong	Efficient Energy- Preserving Algorithms for Deterministic and Stochastic Maxwell Equations	Chun Li
14:40–15:20	Xiaojie Wang	Splitting SAV methods for the kinetic Langevin dynamics	
15:20–15:40	Break		
15:40–16:20	Wenjun Cai	Efficient linearly implicit methods preserving quadratic invariants via skew-gradient embedding	Yanming Zhang
16:20–17:00	Lu Li	Structure-Preserving Methods for Linearly Perturbed Hamiltonian Systems	
17:00–	Dinner		

26 August (Wednesday)

Time	Speaker	Title	Chair
9:00–9:40	Hongjiong Tian	Neural network solution based on PDDO for PBEs	Yuhao Cong
9:40–10:20	Jiyong Li	Error analysis of the Gautschi-type exponential integrators for the nonlinear Klein-Gordon equation	
10:20–10:40	Break		
10:40–11:20	Gengen Zhang	Long-time error analysis of energy-preserving scheme for the weakly nonlinear ``good" Boussinesq equation	Xu Qian
11:20–12:00		Free Discussions	
12:00–14:00	Lunch		
14:00–17:00	Break		
17:00–	Dinner		

27 August (Thursday)

Time	Speaker	Title	Chair
9:00–12:00	Free Discussions		
12:00–14:00	Lunch		
14:00–17:00	Free Discussions		
17:00–	Dinner		

28 August (Friday)

Time	Speaker	Title	Chair
9:00–9:40	Wansheng Wang	Efficient stability-preserving algorithms for evolution equations in vector spaces	Bin Wang
9:40–10:20	Meng Li	Adaptive Moving Mesh Methods for Anisotropic Surface Diffusion	
10:20–10:40	Break		
10:40–11:20	Bin Wang	Structure-preserving low-regularity exponential-type integrators for the Gross--Pitaevskii equation	Wansheng Wang
11:20–12:00	Beibei Zhu	Stroboscopic averaging methods to study autoresonance	
12:00–14:00	Lunch		
14:00–17:00	Break		
17:00–	Dinner		

Abstracts

Efficient linearly implicit methods preserving quadratic invariants via skew-gradient embedding

Wenjun Cai (Nanjing Normal University)

This work proposes high-order linearly implicit methods for conservative PDEs with quadratic invariants, which linearize nonlinear terms via skew-gradient embedding and extrapolation to achieve high computational efficiency.

Strong convergence of Milstein-type schemes for McKean-Vlasov SDEs with super-linear coefficients

Siqing Gan (Central South University)

We present a unified class of Milstein-type discretizations for McKean-Vlasov SDEs with super-linear drift and diffusion coefficients. The proposed framework includes the tamed-, tanh-, and sine-Milstein methods as special cases and establishes order-one strong convergence for the associated interacting particle system under mild regularity assumptions, requiring only once differentiable coefficients. Numerical experiments are presented to support the theoretical findings.

Geometric spectral methods in multivariate domains

Jing Gao (Xi'an Jiaotong University)

Stable and efficient spectral methods for time-dependent partial differential equations depend crucially on the choice of basis functions. This talk presents geometric spectral methods for multidimensional unit balls and triangular domains. We construct orthonormal systems whose differentiation matrices are skew-Hermitian, providing stability and preserving important structures such as dissipativity and mass conservation. The resulting methods also offer rapid convergence, fast coefficient computation, and efficient matrix operations. Numerical examples illustrate their accuracy and computational advantages, demonstrating a practical framework for structure-preserving spectral approximation on non-tensor-product domains.

Spectral Petrov-Galerkin methods for ordinary and partial VIDEs with weakly singular solutions

Chengming Huang (Huazhong University of Science and Technology)

This talk presents high-order discretizations for two classes of weakly singular Volterra integro-differential equations. A spectral Petrov–Galerkin method with log orthogonal functions is first introduced for ordinary VIDEs, and then extended to a space-time spectral scheme for partial VIDEs. Under certain conditions, well-posedness and exponential convergence of the schemes are established for some problems with initial singularities. Numerical experiments confirm the effectiveness.

On mathematical foundations of spectral methods

Arieh Iserles (University of Cambridge)

In this talk I propose an alternative framework for the understanding of spectral methods for evolutionary PDEs: essentially, a spectral method is simply an orthonormal basis of a separable Hilbert space, plus Galerkin conditions – everything else is (a heaving mass of) detail. The talk will be devoted to understanding some of this detail, with an emphasis on methods that respect geometric features of the underlying PDE and to their analysis in a multitude of settings.

A good spectral method should tick four boxes: stability, preservation of geometric features, rapid convergence and fast numerical algebra. We will demonstrate that there exist methods, building upon ideas from harmonic analysis and the theory of orthogonal polynomials, that attain all these goals. In particular, perhaps surprisingly, there exist geometric spectral methods that are guaranteed to satisfy all geometric features (whether invariants or inequalities) of the exact solution.

We will highlight in this talk the significant recent advances in this area, while describing areas of ongoing research and sketching open problems.

High-frequency wave propagation in nonlinear dispersive media: analysis and numerics

Tobias Jahnke (Karlsruher Institut fuer Technologie)

High-frequency wave propagation in nonlinear dispersive media is typically modelled by semilinear Friedrichs systems where both the differential equation and the initial data contain the inverse of a small parameter ε. This causes oscillations in time and space with wavelengths proportional to ε, which makes the numerical approximation of the solution a challenging problem. Applying a standard scheme is prohibitively inefficient or even unfeasible, because then the oscillations have to be resolved by a very fine discretization in time and space, which requires unacceptable runtimes and memory footprints.

In this talk, we present several much more efficient ways to approximate the solution. Each of these approaches is based on a combination of analytical and numerical approximations.

This is a joint work with Julian Baumstark, Christian Lubich, Johanna Philipp, and Yanyan Shi.

Efficient Energy- Preserving Algorithms for Deterministic and Stochastic Maxwell Equations

Linghua Kong (Jiangxi Normal University)

This talk constructs several efficient numerical schemes for the three- dimensional deterministic and stochastic Maxwell equations. Standard unconditionally stable schemes require solving algebraic systems of extremely large size at each time step. To address this issue, we adopt a splitting- step method to decompose the three- dimensional equations into a set of one- dimensional subproblems. This substantially reduces the size of the algebraic systems and improves computational efficiency. Throughout the equation splitting and scheme design, we consistently aim to preserve the intrinsic energy structure of the equations. Theoretical properties of the new schemes, such as convergence, are discussed. Finally, several numerical experiments are presented to validate the effectiveness of the proposed schemes.

Geometric Fourier-Galerkin numerical methods for the derivative nonlinear Schr\"{o}dinger equation

Chun Li (Nanjing University)

Based on its special Hamiltonian reformulation, Geometric Fourier-Galerkin numerical methods are proposed for the DNLS. Various error estimates are established for semi- and fully-discrete settings under low- regularity assumptions. The analysis relies on several novel technical ingredients: bootstrap arguments coupled with the stopping- time method and continuation strategies. Numerical experiments are presented for validation.

Relaxation Runge-Kutta methods for their application

Dongfang Li (Huazhong University of Science and Technology)

A novel family of high-order structure-preserving methods is proposed for the nonlinear Schrödinger equation. The methods are developed by applying the multiple relaxation idea to the different Runge-Kutta methods. It is shown that the multiple relaxation Runge-Kutta methods can achieve high-order accuracy in time and preserve multiple original invariants at the discrete level. Several numerical experiments are carried out to support the theoretical results.

Error analysis of the Gautschi-type exponential integrators for the nonlinear Klein-Gordon equation

Jiyong Li (Hebei Normal University)

In this talk, we investigate numerical methods for the long-time dynamics of the nonlinear Klein-Gordon equation (NKGE) with weak nonlinearity. We propose a Gautschi-type exponential wave integrator for the NKGE, which is time symmetric and energy-preserving. For the quadratic power nonlinearity, we establish improved error bounds for the proposed numerical scheme. For the first time, our analysis shows that the improved error bounds also hold for the Gautschi-type method.

Structure-Preserving Methods for Linearly Perturbed Hamiltonian Systems

Lu Li (Sun Yat- sen University)

Dissipative Hamiltonian systems arise in many physical models. This talk presents two energy-stable splitting exponential integrators for linearly perturbed Hamiltonian systems: SEISAV, which dissipates a modified energy using a scalar linear solve, and SEILM, which enforces original-energy dissipation through a scalar nonlinear constraint. We also briefly discuss CSympNet-ID for conformal-symplectic one-step map learning and interpretable damping identification from snapshot data.

Adaptive Moving Mesh Methods for Anisotropic Surface Diffusion

Meng Li (Huazhong University of Science and Technology)

In this report, we propose adaptive moving mesh methods for anisotropic surface diffusion and apply them to the numerical simulation of solid-state dewetting in thin films. The methods are formulated based on the mesh equidistribution principle, where a carefully crafted tangential velocity is used to dynamically redistribute the mesh points throughout the evolution.

Temporal high-order parametric finite element methods for geometric flows

Chunmei Su (Tsinghua University)

The quality of the mesh is crucial for simulating curvature flows, as standard approaches may fail due to mesh distortion. We will present a series of high-order parametric finite element methods based on the BGN formulation for solving various types of flows involving curves and surfaces. Extensive numerical experiments demonstrate the anticipated high-order accuracy while maintaining favorable mesh quality throughout the evolution process.

Neural network solution based on PDDO for PBEs

Hongjiong Tian (Shanghai Normal University)

The population balance equation (PBE), the primary governing equation for modeling dynamic crystallization behavior, is addressed in this paper through a proposed physics-informed neural network (PINN) framework based on the peridynamic differential operator (PDDO). By introducing the nonlocal integral form of PDDO into the loss function, the framework can inherently handle discontinuities and derivative singularities, thereby reducing its reliance on dense spatial and temporal discretization.

Structure-preserving low-regularity exponential-type integrators for the Gross--Pitaevskii equation

Bin Wang (Xi'an Jiaotong University)

We propose and analyze structure-preserving low-regularity integrators for the Gross--Pitaevskii (GP) equation by combining underlying low-regularity schemes with relaxation and projection corrections. We establish bounds and well-posedness of the correction parameters and analyze their effects on convergence and regularity requirements. Numerical experiments demonstrate the accuracy, exact preservation of the invariants, and high efficiency of the proposed methods under low regularity.

Efficient stability-preserving algorithms for evolution equations in vector spaces

Wansheng Wang (Shanghai Normal University)

This report discusses the generalized stability preservation of numerical methods for evolution equations in vector space under convex functionals. Here, the convex functional can be a norm, semi-norm, convex energy functional, positivity functional, convex entropy, etc., enabling the numerical method to preserve various physical properties. We also further discuss the unresolved issues therein.

Splitting SAV methods for the kinetic Langevin dynamics

Xiaojie Wang (Central South University)

The kinetic Langevin dynamics finds diverse applications in various disciplines such as molecular dynamics and high-dimensional sampling. In this talk, a novel splitting scalar auxiliary variable (SSAV) scheme is proposed for the dynamics, where the gradient of the potential is possibly non-globally Lipschitz continuous with superlinear growth. The strong and weak convergence rate of order one is obtained. Numerical experiments are presented to confirm the theoretical findings.

Two novel domain-preserving schemes for a class of stochastic differential equations

Aiguo Xiao (Xiangtan University)

In recent years, the positivity-preserving schemes for SDEs with positive solutions have received extensive attention. Most of these schemes are often ineffective for solving SDEs with solution valued in a domain. Research in this area is relatively scarce, even for the scalar case. We propose two novel domain-preserving schemes for solving a class of SDEs whose solution takes values in a given interval, whose strong convergence rates are showed to be 1/2 and 1, respectively.

Long-time error analysis of energy-preserving scheme for the weakly nonlinear ``good'' Boussinesq equation

Gengen Zhang (Yunnan University)

We establishes long-time error bounds for a linearly implicit energy-preserving scheme applied to the weakly nonlinear ``good'' Boussinesq (GB) equation. The finite difference method is first employed to discretize the GB equation, and a rigorous analysis is performed on its energy conservation and numerical stability. The results demonstrate that the scheme preserves the system's inherent invariant, making it particularly well-suited for long-time numerical simulations.

High-order complex resolvent IMEX Runge--Kutta methods for semilinear parabolic equations

Hong Zhang (National University of Defense Technology)

We construct high-order CIMEXRK methods by composing first-order IMEX Euler maps. Each stage combines an explicit forward-Euler evaluation of the nonlinearity with a backward-Euler resolvent and can be implemented with two solution-sized work vectors. A sequential composition with positive real increments cannot attain second order. We remove this obstruction by using complex increments with positive real parts and determine an operator sector in which every resolvent factor is contractive.

Serendipity VEMs for semilinear parabolic integro-differential equations on curved domains

Jingjun Zhao (Harbin Institute of Technology)

Under certain conditions of the mesh and the degree of approximation, the serendipity VEM eliminates all the internal-moment degrees of freedom. The strategy of approximating curved domains with polygonal domains is taken into consideration. To overcome the suboptimal convergence caused by enforcing Dirichlet boundary conditions strongly, Nitsche-based projection method is employed to impose the boundary conditions weakly. Moreover, error estimates are derived for the fully discrete scheme.

Stroboscopic averaging methods to study autoresonance

Beibei Zhu (University of Science and Technology Beijing)

Autoresonance is a phenomenon of physical interest that may take place when a nonlinear oscillator is forced at a frequency that varies slowly. The stroboscopic averaging method (SAM), which provides an efficient numerical technique for the integration of highly oscillatory systems, cannot be used directly to study autoresonance due to the slow changes of the forcing frequency. We study how to modify SAM to cater for such slow variations. Numerical experiments show the computational advantages.

Locking-free finite element approximation to electroporoelasticity equation

Yongkui Zou (Jilin University)

In this work, we establish the well-posedness and propose a locking-free finite element approximation to three-dimensional quasi-static electroporoelasticity equations. We prove that our numerical method inherits an asymptotic behavior from the original equations that the divergence of the approximate displacement tends to zero as the Lam\'{e} constant goes to infinity, ensuring the locking-free property of the algorithm.