ICAND 2016 Abstracts

Finding and Forming Synchronized Clusters in Complex Networks of Oscillators Using Symmetries

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Many networks are observed to produce patterns of synchronized clusters, but it has been difficult to predict these clusters in general or understand the conditions for their formation. We show the intimate connection between network symmetry and cluster synchronization. We apply computational group theory to reveal the clusters and determine their stability. In complex networks the symmetries can number in the millions, billions, and more. The connection between symmetry and cluster synchronization is experimentally explored using an electro-optic network. Moreover, in networks with Laplacian coupling clusters are possible which do not directly result from symmetries; however, it is possible to construct all possible synchronized clusters starting from the symmetry clusters. We show how to do this using the computational group theory as an aid and how to derive the variational equations for all the clusters.

Synchronization and Anti-Synchronization of Coupled Stochastic Oscillators

Katja Lindenberg
UCSD

For a number of years we have worked on designing and analyzing the simplest possible arrays of coupled stochastic oscillators that exhibit synchronization. This work has provided a wealth of information and understanding of a variety of such phenomena in these and in more complex arrays.

I will present portions of this work, in particular, of nonlinearly phase-coupled arrays of stochastic three-state units with unidirectional transitions governed by Markovian rate processes. I will discuss phase transitions to oscillatory synchronization and will argue that a mean field theory of this relatively simple setting exhibits qualitative behaviors characteristic of a variety of considerably more complex models. I will also present some results on coupling that disfavors the synchronized behavior of interacting units. The resultant spatiotemporal configurations can perhaps be said to be unanticipated.

Synchronization in Networks of Spin Torque Nano Oscillators for Microwave Signal Generation

James Turtle
SDSU

The 2007 Nobel prize in Physics was awarded jointly to Albert Fert and Peter Grunberg for their discovery of the Giant Magnetoresistance Effect (GMR). This effect is observed as a significant change in the electrical resistance of some materials depending on whether the magnetization of adjacent ferromagnetic layers are in antiparallel or in parallel. The most common application of this effect is the spin nano-valve device, which consists of at least two layers of ferromagnetic materials separated by a nonmagnetic metal layer. In one layer the magnetization vectors are fixed while on the other they are free. As predicted by Slonczewski and Berger, a spin-polarized current can exert a torque on the magnetization of a ferromagnetic layer leading to precession. Then the GMR effect can convert the magnetic precession into microwave voltage signals and turn the valve into a Spin Torque Nano-Oscillator (STNO) whose power output, about 1nW, is small. To generate a more powerful signal, several groups have proposed to harness the power of several STNOs connected together but their collective behavior, which belongs to the field of nonlinear dynamics, has been very challenging to understand. In particular, finding regions of complete and stable synchronization has proven to be a daunting task. In this work, we exploit the symmetry of the network to find analytical expressions for the loci of symmetry-preserving Hopf bifurcations that yield complete synchronization in networks of STNOs of arbitrary size.

Random Perturbations of Periodically Driven Nonlinear Oscillators: Homogenization and Large Deviations

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This paper develops an asymptotic method based on averaging and large deviations to study the dynamics of nonlinear oscillators excited by both periodic and random perturbations. We study these equations as random perturbations of two-dimensional period Hamiltonian systems. The phase space for a periodically driven nonlinear oscillator consists of many resonance zones. It is well known that, as the strengths of periodic excitation and damping go to zero, the measure of the set of initial conditions which lead to capture in a resonance zone goes to zero. In this paper we study the effect of weak noise on the escape from a resonance zone and obtain the large-deviation rate function for the escape. The primary goal is to show that the behavior of oscillators in the resonance zone can be adequately described by the (slow) evolution of the Hamiltonian, for which simple analytical results can be obtained, and then apply these results to study the transient stability margin of power system with stochastic loads. The classical swing equations of a power system of three interconnected generators with non-zero damping and small noise is considered as a nontrivial example to derive the “critical clearing time? analytically. Asymptotic techniques based on averaging and large deviations developed for dissipative noisy systems is used to determine the most probable transition pathways and the stability margin of power system with stochastic loads.

A Solvable Chaotic Oscillator with Multiple Set Points

Marko Milosavljevic
Charles M. Bowden Laboratory, U.S. Army

Recently, a class of chaotic hybrid dynamical systems has been shown to have analytic solutions. Here we present a new example in this class and its electronic circuit implementation. This example builds on a previous study of a first order system in which a set point is switched between two values at times dictated by an external clock. We explore increasing the number of set points. An analytic solution to the system is presented and an electronic circuit is described. The circuit consists of an unstable resistor-capacitor filter with switching feedback. The feedback switches the set point to any number of values at times determined by an externally generated clock signal. The waveform of this oscillator is optimum for communications in noise when a resistor-capacitor integrate-and-dump filter is used as a received.

A 4 MHz Chaotic Oscillator Based on a Jerk System

Robert Dean
Auburn University

Chaotic oscillators have a wide range of possible applications including random number generation (RNG), stimulation source for characterization of MEMS devices, and audio range and RF noise sources. Some distinct characteristics of chaotic systems include topological mixing, determinism, long term aperiodic behavior, sensitivity to initial conditions, as well as a spread spectrum response. In particular, the aperiodic behavior and sensitivity to initial conditions make chaotic oscillators an ideal candidate for RNG. In practice, one of the more important aspects of a RNG is the speed at which data/bits can be generated. In electronics, as the frequency of operation increases, so do the design restrictions and challenges. In addition, many of these chaotic systems are based on nonlinearities or complex math functions that are difficult to implement in electronics. Through careful selection of the system's structure, complex behavior can be implemented in electronics using minimal components, reducing footprint and power consumption. This reduces the design complexity and can aid in increasing the frequency by minimizing the feedback paths of the oscillator. Presented in this work is a printed circuit board electronic implementation of a 4 MHz chaotic jerk system that exhibits complex, rich dynamics using very simple electronic circuits.

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Nonlinear dynamics induced anomalous Hall effect in topological insulators

Ying-Cheng Lai

Arizona State University

We investigate the magnetization dynamics of an insulating ferromagnet (FM) deposited on the surface of a three-dimensional topological insulator (TI), subject to an external voltage. The spin-polarized current on the TI surface induces a spin-transfer torque on the magnetization of the top FM while its dynamics can change the transmission probability of the surface electrons through the exchange coupling and hence the current. We find a host of nonlinear dynamical behaviors including multistability, chaos, and phase synchronization. Strikingly, a dynamics mediated Hall-like current can arise, which exhibits a nontrivial dependence on the channel conductance. We develop a physical understanding of the mechanism that leads to the anomalous Hall effect. The nonlinear dynamical origin of the effect stipulates that a rich variety of final states exist, implying that the associated Hall current can be controlled to yield desirable behaviors. The phenomenon can find applications in Dirac-material based spintronics.

This is a joint work with ASU Ph.D. students Mr. Guanglei Wang and Mr. Hongya Xu.

Nonlinear analysis of variable stars in Kepler field of view

Vivek Kohar

North Carolina State University

The quest for habitable planets has dramatically improved our understanding of variable stars. Recent high resolution photometry of variable stars using Kepler space telescope has shown that their dynamics is quite complex exhibiting typical nonlinear dynamical features like period doubling and quasiperiodicity leading to strange nonchaotic dynamics. Despite these advances, a concrete understanding of their dynamics and Blazhko effect still eludes us. We present the nonlinear time series analysis and phenomenological modeling of variable stars, including the search for strange (fractal) or chaotic dynamics.

Chimera and Chimera-Like States in Populations of Nonlocally Coupled Homogeneous and Heterogeneous Chemical Oscillators

Kenneth Showalter

West Virginia University

We have studied chimera and chimera-like states in populations of photochemically coupled Belousov-Zhabotinsky (BZ) oscillators. Simple chimeras and chimera states with multiple and traveling phase clusters, phase-slip behavior, and chimera-like states with phase waves are described. Simulations with a realistic model of the discrete BZ system of populations of homogeneous and heterogeneous oscillators are compared with each other and with experimental behavior.

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Network of Coupled Oscillators for Precision Timing

Patrick Longhini

SSC Pacific SPAWAR

Precise time dissemination and synchronization have been some of the most important technological tasks for several centuries. It was realized that precise time-keeping devices having the same stable frequency and precisely synchronized can have important applications in navigation. Satellite-based global positioning and navigation systems such as the GPS use the same principle. However, even the most sophisticated satellite navigation equipment cannot operate in every environment. In response to this need, we present a computational and analytical study of a network-based model of a high-precision, inexpensive, Coupled Oscillator System and Timing device. Preliminary results from computer simulations seem to indicate that timing errors decrease as $1/N$ when N crystals are coupled as oppose to $1/\sqrt{N}$ for an uncoupled assemble. This manuscript is aimed, however, at providing a complete classification of the various patterns of collective behavior that are created, mainly, through symmetry-breaking bifurcations. The results should provide guidelines for follow-up simulations, design and fabrication tasks.

Ultrafast nonlinear dynamics in mesoscopic oscillators

Chee Wei Wong
University of California Los Angeles

Chaos has revolutionized the field of nonlinear science and stimulated foundational studies from neural networks, extreme event statistics, to cryptography. Recently our team has examined two types of mesoscopic nonlinear oscillators in optomechanics and frequency combs that provide new platforms to uncover quintessential architectures of chaos generation and the underlying physics. In the first instance, we will describe the deterministic chaos formation at 60 fJ intracavity energies, through coupled Drude electron-hole plasma and radiation pressure. Statistical and entropic characterization quantifies the complexity of the chaos, including a correlation dimension D_2 approximately 1.67 for the chaotic attractor, reminiscent of Lorenz chaos, along with the Lyapunov exponents. The dynamical maps demonstrate the plethora of subharmonics and bifurcations, with distinct transitional routes into chaotic states. In the second instance, the transition from ultrastable frequency comb states to chaos and soliton states are described in detail.

Optoelectronic Nonlinear Dynamics: Application to Random Number Generation

Rajarshi Roy
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Random number generation is essential for encryption of information and Monte Carlo simulations. We examine sources and signatures of randomness and determinism in optoelectronic nonlinear dynamical systems. Measures of entropy production and dependence on observational precision and time resolution are described. Applications of optoelectronic systems to physical random number generation and assessment are explored and state-of-the-art techniques will be discussed.

Chaos computing

Behnam Kia
North Carolina State University

Moore's Law - which states that the number of transistors on a chip doubles every two years - is beginning to fail because conventional semiconductor technology is reaching the limits of physics. As a result, alternative approaches need to be introduced in order to increase the performance of computers. One common idea behind such approaches is getting more amount of computation from less number of transistors. Chaos computing is one such alternative approach, where the focus is on utilizing the rich, complex dynamics of nonlinear transistor circuits. A very simple nonlinear circuit composed of a few transistors can have very complex dynamics, and we have shown that this complex dynamics is capable of performing many different types of functions, thereby realizing the goal of getting more out of less. We have recently introduced the computing exponent, which characterizes the amount of computation that a nonlinear circuit or system can dynamically perform. Here we review this new exponent and compare it with other measures of complexity. We present some of our latest results on integrated circuits fabricated for chaos computing, and describe the software/hardware systems that we have designed and developed for this new technology.

Computing below the expected energy limits

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Universita' di Perugia, ITALY

In modern computers, computation is performed by assembling together sets of logic gates. Popular gates like AND, OR, XOR, processing two logic inputs and yielding one logic output, are often addressed as irreversible logic gates where the sole knowledge of the output logic value, is not sufficient to infer the logic value of the two inputs. Such gates are usually believed to be bounded to dissipate a finite minimum amount of energy determined by the input-output information difference. Here we show that this is not necessarily the case, by presenting an experiment where a OR logic gate, realized with a micro electromechanical cantilever, is operated with energy well below the expected limit, provided the operation is slow enough and frictional phenomena are properly addressed.

Reducing microwave absorption with frequency modulation

Alfred Hubler
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Wireless energy transfer with microwaves is effective in microwave ovens. Outside the metallic cage of a microwave oven, intense microwave radiation can be harmful to living beings. Sinusoidal microwaves are most effective in transferring energy to matter or a microwave antenna, because the dynamics of both systems is linear. The equation of motion of molecules in matter is a linear Schroedinger equation and the dynamics of a conventional microwave antenna is a linear oscillator. We show that the absorption of frequency modulated microwaves by matter is much less, because frequency modulated microwaves do not resonate with most quantum systems. This suggests that most matter, including water, human tissue, and air is largely transparent to frequency modulated microwaves. In contrast, frequency modulated microwaves can resonate with nonlinear antennas. This means that frequency modulated microwaves can pass undiminished through matter, and then be absorbed by a nonlinear antenna, and thereby transport energy from an energy source to an energy sink, without depositing energy in any matter between the source and the sink. In addition we show that controlling the phase of the antenna can lead to a targeted energy flow from the source to the sink, due to destructive interference in the far-field. We discuss potential applications for safe and secure wireless energy transfer.

Design of high-frequency high-efficiency converters by applying bifurcation analysis techniques.

Hiroo Sekiya

Chiba University, JAPAN

Recently, small size and high power density are required to power electronics circuits. For circuit scale reductions, high frequency operation is effective but we suffer from the switching losses. From these background, fast and accurate design procedure for the high-frequency converter is required. This talk presents a numerical design algorithm of the power-electronics circuits. The problem similarity between the bifurcation analysis and the converter designs is explained. In addition, I will show one or two concrete examples of high frequency converters. I believe that many nonlinear analysis techniques may apply many engineering research fields. This is one of the good examples of the applications of the nonlinear-analysis techniques.

Attractor Comparisons based on Density

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How can we find one number that describes how similar two chaotic attractors are to each other? One attractor comparison method that we are developing uses concepts from density estimation to convert the chaotic attractor into a density in phase space, and then uses density comparison methods to compare densities. We do not retain time information when finding the density for the attractor, but other than that, no information is lost. We use a statistical method to find the smallest length scale on which we can tell that the points on the attractor are not uniformly distributed; this length scale can vary for different parts of the attractor. Density estimation is not a new concept in dynamics: dimension estimation is an example of characterizing the density of the attractor.

Density estimation can be useful for large data sets because it reduces the size of the data set by clustering the attractor into regions that give no further information. Depending on the system, the number of points in a data set may be reduced by a factor of over 100. This data reduction could be a useful preprocessing step for network characterization of an attractor, as many network comparisons require calculation of the distance between each point on the attractor and every other attractor point. Density estimation can be used to detect small variations in an attractor, as we show in a simple circuit experiment, but the attractors do not need to be close together. In a simulation, we show that we can distinguish the 19 Sprott attractors from each other.

Nonlinear Dynamics from Infinite Impulse Response Matched Filters

Ned J. Corron

Charles M. Bowden Laboratory, U.S. Army

Modern communication technology is built upon the foundation established in the 1940s by Nyquist, Shannon, Wiener and others, whose theories enabled the rigorous derivation of optimal solutions to practical communication problems. In this talk, we apply the methods of communication theory to derive optimal waveforms for transmitting information through noise using simple infinite impulse response filters as receivers. Specifically we presume passive, linear RLC filters and derive the communication waveforms that maximize the receiver signalto-noise performance. From routine application of standard methods, we surprisingly find that these optimal waveforms are provably chaotic. We extrapolate from simple examples to argue that the optimal communication waveform for any stable infinite impulse response filter is similarly chaotic. If true, this conjecture implies the phenomena of nonlinear dynamics and chaos are fundamental and essential to a full understanding of modern communication theory.

Chaotic Oscillators for Wideband Radar Signal Processing

Chandra Pappu

University of Texas at El Paso

Previously, authors investigated a technique to generate the nonlinear chaotic FM waveforms to achieve wide bandwidth and frequency agility. The technique relied on the output of the Lorenz chaotic circuit. In this paper, authors present the potentials of Rossler based chaotic FM waveforms for wideband radar imaging and assess its statistical properties such as ergodicity, stationarity and invariant probability density functions. The correlation properties and ambiguity functions are illustrated to assess its resolution and clectronic counter-counter measure capabilities. By using the theoretical and experimental studies, a comparison will be performed between the FM waveforms generated by using the Lorenz chaotic oscillator and the Rossler chaotic oscillator. Finally, a generalized approach on the utilization of chaotic systems for high range resolution and bistatic radar applications will be presented.

Membrane-dependent Neuromorphic Learning Rule for Unsupervised Temporal Spike Pattern Detection

Sadique Sheik

UCSD

Several learning rules for synaptic plasticity, that depend on either spike timing or internal state variables, have been proposed in the past imparting varying computational capabilities to acpSNN. Due to design complications these learning rules are typically not implemented on neuromorphic devices leaving the devices to be only capable of inference. We propose a unidirectional post-synaptic potential dependent learning rule that is only triggered by pre-synaptic spikes, and easy to implement on hardware. We demonstrated that such a learning rule is functionally capable of replicating computational capabilities of pairwise STDP. Further more, we demonstrate that this learning rule can be used to learn and classify spatio-temporal spike patterns in an unsupervised manner using individual neurons. We argue that this learning rule is computationally powerful and also ideal for hardware implementations due to its unidirectional memory access.

How Time-Dependent Complexity Measures Can Identify Sensor Dysfunction in Continuous Glucose Monitors

Eric Mauritzen

UCSD

The reliability of continuous, subcutaneous glucose current monitors are crucial in the development of mobile closed-loop technology for the treatment of Type I diabetic patients. Relatively sudden or transient (minutes to hours) corruption of the signal series resulting from sensor displacement or nocturnal signal attenuation can be evidenced using linearly predictive transformations or direct clinical observation. This contrasts with methods used to characterize and predict the more gradual (hours to days) decay in the accuracy of CGM time series which are mathematically turbulent. Having embedded the glucose current time series in suitably dimensioned phase space we use a moving window to assess the time-dependent complexity of the CGM series in regard to several measures. This time-dependent characterization of signal complexity allows us to assess sensor dysfunction and identify sensor failure.

Excitations and wave propagation in biomimetic networks

Harold M. Hastings
Hofstra University

I will explore the several key aspects of the dynamics of biomimetic networks, including the role of local dynamics in biomimetic networks, the role of fluctuations upon dynamics, and emergent behavior in these networks. Examples of biomimetic networks include FitzHugh-Nagumo and related neural and cardiac models, including Keener?s minimal electronic artificial neurons as well as the Belousov-Zhabotinsky chemical reaction, the prototype chemical oscillatory system. This talk is based upon joint work with Richard Field, Sabrina Sobel, Mark Spano and several students and includes experimental and simulation results. I will also describe applications to computer science, biology, and potentially to medicine.

Application of a Stabilizing Method Using Periodic Threshold to Current-Controlled DC/DC Converters

Hiroyuki Asahara
Oita University, JAPAN

We consider current-controlled DC/DC converters. The controller is composed of comparator and RS-type flip-flop. Previously, we showed that periodic threshold, which is applied into the comparator, has stabilizing effect for circuit behavior. However, the demonstration of the application of the stabilizing method is not reported at all. In this report, we show an example of the application for current-controlled DC/DC converters. Especially, we demonstrate maximum power point tracking (MPPT) control of photovoltaic (PV) module, which is power source of DC/DC converter. We propose an algorithm of MPPT control based on perturb and observation method, and confirm its validity through the numerical simulation.

Asynchronous Bifurcation Processor and its Applications to Neuromorphic Hardware Design

Hiroyuki Torikai
Kyoto Sangyo University, JAPAN

Neural systems are sophisticated nonlinear dynamical systems. There are mainly three ways to implement neuromorphic hardware, i.e., (1) analog nonlinear circuit having continuous-state and continuous-time, (2) DSP having discrete-state and discrete-time, (3) switched capacitor circuit having continuous-state and discrete-time. On the other hand, our group has been developing the fourth way, i.e, asynchronous sequential logic having discrete-state and continuous-time, and has been referring to such an implementation platform as an asynchronous bifurcation processor. In this talk, fundamental principles of the asynchronous bifurcation processor and its recent applications to neuromorphic hardware designs are presented.

Robustness of Injection-Locked Oscillators to CMOS Process Tolerances

Najme Ebrahimi

UCSD

For electronic systems, phased array and grid amplifiers are two areas that could benefit from synchronized nonlinear oscillators. Coupled oscillator phased arrays have the advantage of low-power and low-complexity, providing a phased-array architecture that easily scales the number of elements. However, the size of the array decreases and the power required to lock the array increases with larger variation between oscillator elements. Also, silicon process place manufacturing tolerances on the transistor and passive device variation. We present an injection-locked oscillator (ILO) phase shifter used for a phased array communication system to illustrate the robustness of nonlinear oscillators. The locking range, tuning range, phase noise variation, and amplitude errors on a Si- substrate as an IC will be presented. Different circuit topologies are considered to mitigate the coupling and parasitic effects and a new circuit scheme as a folded-cascode injection-locked oscillators, ILO, is discussed. The proposed idea is implemented in the fasted IBM SiGe technology, 90 nm, in a 4-elements array configuration. The phased array IC is the first implementation of coupled oscillator based phased array at E-band, 71-86 GHz, frequency range

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The Ringelmann Effect in an Array of Nonlinear Self-Tuning Sensors

Nigel Stocks

University of Warwick, UK

The Ringelmann Effect is widely used in the social sciences to account for performance losses in human and animal groups; we present the first mathematical description of this effect in an engineered system. Furthermore, in addition to the previously postulated mechanisms of ‘social loafing’ and ‘co-ordination losses’, we demonstrate that Ringelmann type effects can also be mediated by coupling-induced performance losses. Specifically, we show that coupling between optimized dynamic sensors can induce losses similar to that described by Ringelmann. Moreover, we propose a scheme that might be used to mitigate the performance degradation stemming from the Ringelmann Effect.

On the spectral dynamics of noise-seeded modulation instability in optical fibers

Pablo I. Fierens

Ingeniero Electrnico, Instituto Tecnolgico de Buenos Aires, Argentina

We revisit the problem of modulation instability in optical fibers, including all relevant effects, such as higher-order dispersion terms, self-steepening, and the Raman response. Our analysis allows us to calculate the spectral evolution of a small perturbation to a continuous pump, and thus obtain an analytical expression for the small-signal spectral dynamics, showing excellent agreement with numerical simulations. We apply the expression for the spectral evolution to the case of white Gaussian noise and calculate some relevant metrics of the resulting signal, such as its coherence, SNR, and higher-order moments. These calculations shed some light on the nonlinear phenomena of supercontinuum generation and rogue waves in optical fibers.

High-T_c nano-SQUIDs for magnetoencephalography

Dag Winkler

Chalmers University of Technology, SWEDEN

The Superconducting Quantum Interference Device (SQUID) is the most sensitive magnetometer down to very low frequency, making it ideal for e.g., biomagnetic measurements. Applications include geomagnetic surveys, non-destructive evaluations, immune- and bio-assays using magnetic nanoparticles, magneto-cardiography (MCG) and -encephalography (MEG). In recent years SQUIDs based on high-transition temperature (high-T_c) SQUIDs have become sensitive enough to compete with traditional low-T_c SQUIDs in certain application. One of these is MEG, where the proximity to the brain compensates for the lower sensitivity providing similar or better signal to noise ratio and higher spatial resolution. Successful MEG demonstrations using high-T_c bi-crystal grain boundary junctions and step-edge Josephson junctions have raised the hope for lower cost and higher resolution MEG systems. While such systems may need hundreds of SQUID units, scalability in production of high-T_c SQUIDs is an important issue. Bi-crystal devices can only be made piece by piece, while step-edge devices may be produced in larger numbers in each batch. However, the pick-up loop of a few millimeter in size still makes it hard to control the $YBa_2Cu_3O_7$ thin film uniformity if many devices are to be made on the same substrate. To increase the reproducibility, a possibility is to make a pick-up loop with a multilayer flux transformer and the SQUID device onto two different substrates and with separate fabrication runs. In this way, high-T_c SQUIDs could be made in larger quantities on a smaller substrate, diced, and then flip-chipped onto the flux-transformers with a large pick-up loop. For scalability we then need a different junction technology. Interestingly, recent work on high-T_c SQUIDs made on the nanoscale, where the Josephson effect is present across high-T_c nanostrips, has shown very low flux-noise down to $2\mu\Phi_o/\sqrt{Hz}$, and the implementation of these devices in MEG is presently under investigation in our research group. However, coupling of magnetic field into a nano-SQUID forms a substantial challenge. In this presentation, we will review the recent development of high-T_c MEG systems and how high-T_c nano-SQUIDs may impact the field.

Phase-Locking of High Power Broad Area Semiconductor Diode Laser Array

Yehuda (Yuri) Braiman

Oak Ridge National Laboratory & University of Tennessee

We studied a path of achieving high quality phase-locking of commercial quality broad-area laser diode (BALD) array. BALDs can operate at high electrical to optical power conversion efficiency, are compact and low cost. We found that (a) improving single transverse mode control for each individual BALD, (b) employing global Talbot optical coupling among diodes, and (c) enhancing strength of optical coupling among diodes are key factors in achieving high quality phase-locking of high power BALD array. We demonstrated near-diffraction limit far-field coherent pattern. The far-field angle (full width at half-maximum (FWHM)) of center lobe was measured as 1.5 diffraction angular limited with visibility of 99% for low-to-moderate power operation and 1.6 diffraction angular limited with visibility of 95% for moderate-to-high power operation of broad area diode array.

To better understand power scaling of diode array we considered existence and stability of spatial modes of the external cavity of the semiconductor laser diode array. We showed that by using a decayed nonlocal coupling scheme where the coupling strength of the lasers decreases as the distance between the elements increases, it is possible to induce a very robust close to perfect phase synchronous state of the array. We find that for such coupling scheme the leading spatial mode forges almost perfect and stable phase synchronization and phase synchronization is robust to noise and disorder.

Limits of detection Electric Fish and how SR might actually be implemented along successive stations of a sensory system

Andre Longtin

Centre for Neural Dynamics, University of Ottawa

Simplicial Characterisation of Time Series Networks: Theory and Applications

Neelima M. Gupte

Indian Institute Of Technology Madras, Chennai

We discuss the characterisation of time series networks using techniques of algebraic topology. We also discuss their application to the logistic map, and traffic time series.

Parametric system identification of resonant micro/nanosystems operating in a nonlinear response regime

Andrew B. Sabater

SSC Pacific SPAWAR

The parametric system identification of macroscale resonators operating in a nonlinear response regime can be a challenging research problem, but at the micro- and nanoscales, experimental constraints add additional complexities. For example, due to the small and noisy signals micro/nanoresonators produce, a lock-in amplifier is commonly used to characterize the amplitude and phase responses of the systems. While the lock-in enables detection, it also prohibits the use of established time-domain, multi-harmonic, and frequency-domain methods, which rely upon time-domain measurements. As such, the only methods that can be used for parametric system identification are those based on fitting experimental data to an approximate solution, typically derived via perturbation methods and/or Galerkin methods, of a reduced-order model. Thus, one could view the parametric system identification of micro/nanosystems operating in a nonlinear response regime as the amalgamation of four coupled sub-problems: nonparametric system identification, or proper experimental design and data acquisition; the generation of physically consistent reduced-order models; the calculation of accurate approximate responses; and the application of nonlinear least-squares parameter estimation. This work is focused on the theoretical foundations that underpin each of these sub-problems, as the methods used to address one sub-problem can strongly influence the results of another. To provide context, an electromagnetically transduced microresonator is used as an example. This example provides a concrete reference for the presented findings and conclusions.

Nonlinear Aeroelastic Responses of Highly Deformable Joined-Wing Configurations

Luciano Demasi

Department of Aerospace Engineering, San Diego State University

Diamond Wings, Strut- and Truss-Braced Wings, Box Wings, and PrandtlPlane, the so-called “Joined Wings”, represent a dramatic departure from traditional airplane configurations. Joined Wings are characterized by a structurally overconstrained layout which significantly increases the design space with multiple load paths and numerous solutions not available in classical wing systems. Researchers showed that the geometric structural nonlinearities may play a complex role in the static and dynamic aeroelastic stability properties and responses of these systems. Stiffnening/softening effects, flutter, and Limit Cycle Oscillations are observed, possibly followed by a loss of periodicity of the solution as speed is further increased. In some cases, it is also possible to ascertain the presence of period doubling (flip-) bifurcations. The fluid-structure energy exchange and its effects/interpretation on the dynamic stability will also be presented.

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