Dr Braiman's Works

Title: Long-range synchronization of nonlinear dynamics in a large 1D-array of blue semiconductor lasers with filtered optical feedback

Date: 01/29/2025

Type: Conference Proceeding

Authors: Olivier Spitz, Parashu Nyaupane, Yehuda Braiman

Publisher/Details: Photonics West 2025

Abstract: Synchronization of nonlinear dynamics is a concept that is widely encountered in nature and it has been thoroughly explored in domains as varied as biology or mechanical clocks. In the context of lasers subject to optical feedback, most of the studies focus on systems with a limited number of emitters. Our experimental work demonstrates extended synchronization in a large array of blue semiconductor lasers subject to filtered optical feedback. The long-range synchronization among the 12 chaotic emitters in the array is confirmed by temporal correlations in the time series and by frequency locking in the optical spectra of individual lasers.

Title: Coherence and Phase-Locking in High-Power, Broad-Area, Highly Heterogeneous Blue Diode Laser Arrays

Date: 01/08/2025

Type: Journal Article

Authors: Parashu Nyaupane, Olivier Spitz, Greggory Scranton, Suyesh Koyu, Mark A. Berrill, Patrick L. LiKamWa, Yehuda Braiman

Publisher/Details: ACS Photonics 12 (2), 597-609 (2025)

DOI: 10.1021/acsphotonics.4c01062

Abstract: We have studied the dynamical routes toward phase-locking of coupled, high-power, highly heterogeneous, low fill factor arrays of blue diodes. We have demonstrated coherent beam combining and phase locking of large groups of lasers in linear 1D array of high-power, broad-area laser diodes emitting around 443 nm. The phase locking was confirmed by measuring clear and stable far-field interference fringes and comparing with a numerically calculated far-field intensity profile. The laser array can be tuned between in-phase and out-of-phase super modes by slightly changing the tip-tilt angle of the diffraction grating. Theoretical simulations of the far-field confirm the experimental observations while numerical simulations based on the Lang-Kobayashi model together with experimental observations indicate that the road to coherence in large arrays of lasers involve chimera and clustering states in the nonlinear dynamics triggered by external optical feedback. Overall, the experimental and numerical efforts presented in this work pave the way toward high-power emission at blue wavelength while maintaining superior beam quality and narrow line width.

Title: Optimization of Combined Coherent Gain-Switch Pulsing in a Large Array of Semiconductor Lasers

Date: 09/13/2024

Type: Journal Article

Authors: Olivier Spitz, Luis E Maldonado-Castillo, Mark A Berrill, Yehuda Braiman

Publisher/Details: IEEE Journal of Selected Topics in Quantum Electronics 31 (2), 1501614 (2025)

DOI: 10.1109/JSTQE.2024.3460738

Abstract: We combine gain switching and external optical feedback to achieve high-power coherent pulsing in a large array of semiconductor lasers. The simulations are performed in the framework of the Lang-Kobayashi model with modulation of the electrical bias. Long-range coupling in the network of emitters and precise tuning of the modulation frequency are key parameters to obtain both phase-locking between the emitters, and reproducible, periodic, high intensity bursts, i.e. robust, coherent pulsing. The configuration we present here relies on non-filtered conventional optical feedback and allows achieving phase-locked pulsing across the array, including at modulation frequencies that are resonant and not resonant with the external cavity frequency and its harmonics. This work impacts on the realization of phase-synchronized pulsed sources from semiconductor laser arrays and provides insight for the generation of complex nonlinear dynamics in large networks of oscillators.

Title: Sub-nanosecond periodic pulsing via gain switching in a large array of semiconductor blue lasers

Date: 08/15/2024

Type: Conference Paper

Authors: Olivier Spitz, Parashu Nyaupane, Yehuda Braiman

Publisher/Details: IEEE Research and Applications of Photonics In Defense (RAPID) 202

DOI: 10.1109/RAPID60772.2024.10647052

Abstract: We report on direct electrical modulation of a 23-laser array emitting at blue wavelength, resulting in gain-switched pulses. Physical properties of the blue lasers can be extracted from the typical sub-nanosecond pulse width.

Title: Synchronization of forced pulses in an array of semiconductor lasers subject to optical feedback

Date: 12/2023

Type: Conference Proceeding

Authors: Olivier Spitz, Suyesh Koyu, Mark Berrill, Yehuda Braiman

Publisher/Details: 2023 IEEE Photonics Conference (IPC)

DOI: 10.1109/IPC57732.2023.10360523

Abstract: Controllable spikes in lasers are sought after for various applications. In this work, we show numerically that a laser array under external optical feedback and electrical forcing generates controllable pulses. We investigate phase synchronization through the lens of the coupling between lasers in the array.

Title: Complex spatio-temporal non-linear dynamics in a 1D-array of 23 broad-area semiconductor laser diodes under external optical feedback

Date: 06/15/2023

Type: Conference Proceeding and Paper

Authors: Olivier Spitz, Suyesh Koyu, Parashu Nyaupane, Mark Berrill, Yehuda Braiman

Publisher/Details: Laser Technology for Defense and Security XVIII, SPIE Defense + Commercial Sensing

DOI: https://doi.org/10.1117/12.2663837

Abstract: Complex spatio-temporal dynamics can be observed in single broad-area semiconductor lasers under external optical feedback. Yet, non-linear dynamics is mostly unexplored in large 1D-arrays of lasers. In our recent investigations, we demonstrated both numerically and experimentally that single-mode and broad-area laser arrays in a V-shape external cavity can generate complex spatio-temporal dynamics with typical frequencies in the GHz range as well as periodic and chaotic phase-locking. Feedback misalignment and feedback strength are key parameters to warrant that diode lasers in the array display a variety of dynamics. Potential applications may include directed energy, LIDAR, and random number generators.

Title: Strong optical linewidth narrowing through surface grating feedback in two different blue laser diodes configurations

Date: 06/15/2023

Type: Conference Proceeding and Paper

Authors: Olivier Spitz, Parashu Nyaupane, Gregg Scranton, Patrick LiKamWa, Yehuda Braiman

Publisher/Details: Proc. SPIE 12515, Laser Technology for Defense and Security XVIII, SPIE Defense + Commercial Sensing

DOI: https://doi.org/10.1117/12.2663797

Abstract: High-power, narrow-linewidth blue laser sources with excellent beam quality are important for wide variety of applications including directed energy and underwater communication and sensing. Achieving narrow spectral linewidth from high-power blue semiconductor diode arrays is still a challenge. Our experimental efforts focused on two external cavity schemes involving single broad-area blue diodes and arrays of high-power blue diodes. We demonstrated narrowing the linewidth down to a few dozens of pm. The center wavelength of this narrow optical mode was tunable in the range of several nm and tunability was controlled by the angle of the surface grating providing optical feedback.

Title: Disorder-Promoted Cooperative Dynamics

Date: 05/14/2023

Type: Conference Proceeding

Authors: Y.Braiman, N. Nair, S. Koyu, O. Spitz, P. Nyaupane, and M. A. Berrill

Publisher/Details: SIAM Conference on Applications of Dynamical Systems 2023

Title: Beam combining and spectral linewidth narrowing of high-power, broad-area blue laser diode, and linear 1D array of diodes (447nm) via external cavity

Date: 03/15/2023

Type: Conference Proceeding and Paper

Authors: P. R. Nyaupane, O. Spitz, G. Scranton, P. L. LiKamWa, Y. Braiman

Publisher/Details: Proceedings Volume 12440, Novel In-Plane Semiconductor Lasers XXII, SPIE OPTO

DOI: 10.1117/12.2649237

Abstract: Blue diode and diode arrays became recently available commercially and offer a promise for high-power, excellent beam quality, compact and efficient light source for wide variety of applications including phototherapy, sanitization, underwater sensing and communication devices, and directed energy. Due to relatively recent availability on commercial market, these type of diodes and arrays have not yet been extensively studied, for example compared to their near-infrared counterparts. We experimentally investigated two external-cavity schemes involving single broad-area blue lasers and arrays of blue lasers. The feedback provided by a surface grating in Littrow configuration allowed demonstrations of spectral linewidth narrowing, wavelength tuning and paves the way towards locking of multiple diodes in a common external cavity for high-power applications.

Title: Dynamics and phase-locking in large heterogeneous arrays of semiconductor diode lasers

Date: 03/14/2025

Type: Conference Proceeding

Authors: Suyesh Koyu, Olivier Spitz, Mark A. Berrill, Yehuda Braiman

Publisher/Details: Proceedings Volume 12403, High-Power Diode Laser Technology XXI, SPIE LASE.

DOI: https://doi.org/10.1117/12.2649622

Abstract: We present theoretical and computational investigations of the nonlinear dynamics and heterogeneity-promoted synchronization of diode laser arrays with decayed non-local coupling topology. The diode laser array exhibits a wide variety of dynamical behaviors as laser and coupling parameters vary. Here, we explore the dynamics for the intermediate and large coupling feedback strengths and further analyze the phase diagram and power spectrum as a function of the feedback strength, coupling topology, and misalignment introduced in the array. The dynamics induced by intermediate feedback are complex for small values of external cavity misalignment but display a clustering phenomenon consisting of several separate groups showing incoherent and coherent dynamics for the appropriate value of the cavity misalignment parameter. Furthermore, the dynamics and the power spectrum in the stronger feedback regime show frequency and phase-locking as the amount of misalignment disorder increases.

Title: Spectral linewidth narrowing of broad-area blue diode bar in V-shape external Talbot cavity

Date: 5/24/2022

Type: Journal Article

Authors: Parashu R Nyuaupane, Patrick L Likamwa, Yehuda Braiman

Publisher/Details: Optics Letters Vol. 47, Issue 11, pp. 2802-2805

DOI: https://doi.org/10.1364/OL.456782

Abstract: A 1-D linear array of 23 high-power broad-area laser diode (BALD) beams in the blue spectral region (447 nm) is combined employing a V-shape external Talbot cavity in Littrow configuration. A surface grating provides optical feedback via self-imaged diffractive coupling to the diode bar and induces all the emitters to lase at a common central wavelength. The external cavity reduces the spectral linewidth of the free-running laser diode bar from several nm to 20–50 pm (FWHM) with the power level of 11.8 W. The narrow spectrum of the external cavity stabilized laser can be tuned in the range of 3–4 nm by adjusting the tilt angle of the grating while the laser diode bar is operated in constant current mode at a temperature of 20°C.

Title: High-T_c Superconducting Memory Cell

Date: 11/08/2021

Type: Journal Paper

Authors: Alexander Miloshevsky, Niketh Nair, Neena Imam, Yehuda Braiman

Publisher/Details: Supercond Nov Magn 35, 373–382

DOI: https://doi.org/10.1007/s10948-021-06069-5

Abstract: In this paper, operational principles of a cryogenic memory cell that utilizes high-temperature superconductors (high-T_c) are presented. Such a cell consists of three inductively coupled Josephson junctions coupled via inductors. Design and operational logic of this type of cell were recently introduced and demonstrated for low temperature 4 K environment. The basic memory cell operations (read, write, reset) can be implemented on the same simple circuit and both destructive and non-destructive memory cell operations can be realized. Here, we present the design principles and computational validation of basic memory cell operations (write, read, and reset) for the high-T_c memory cell. Our results for the high-T_c memory cell operations show very good resemblance with the previously presented low-temperature 4 K memory cell operations.

Title: Using Disorder to Overcome Disorder: A Mechanism for Frequency and Phase Synchronization of Diode Laser Arrays

Date: 10/22/2021

Type: Journal Article

Authors: Niketh Nair, Kai Hu, Mark Berrill, Kurt Wiesenfeld, Yehuda Braiman

Publisher/Details: Phys. Rev. Lett. 127, 173901

DOI: https://doi.org/10.1103/PhysRevLett.127.173901

ISSN: 1079-7114 (online), 0031-9007 (print)

Abstract: Noise and disorder are known, in certain circumstances and for certain systems, to improve the level of coherence over that of the noise-free system. Examples include cases in which disorder enhances response to periodic signals, and those where it suppresses chaotic behavior. We report a new type of disorder-enhancing mechanism, observed in a model that describes the dynamics of external cavity-coupled semiconductor laser arrays, where disorder of one type mitigates (and overcomes) the desynchronization effects due to a different disorder source. Here, we demonstrate stabilization of dynamical states due to frequency locking and subsequently frequency locking-induced phase locking. We have reduced the equations to a potential model that illustrates the mechanism behind the misalignment-induced frequency and phase synchronization.

Title: Spectral linewidth narrowing of two broad-area blue laser diodes (445 nm) with a common external cavity

Date: 05/24/2021

Type: Journal Article

Authors: Parashu R. Nyaupane, Patrick L. Likamwa, and Yehuda Braiman

Publisher/Details: Optics Letters, Vol. 46, Issue 11, pp. 2718-2721

DOI: https://doi.org/10.1364/OL.425409

Abstract: Two watt-level broad-area laser diodes were simultaneously locked into a common external cavity made using a surface grating in a Littrow configuration. The spectral linewidth of the combined laser beam was narrowed down from over a nanometer to 10–15 pm (FWHM), and the output power was the sum of the power of the individually locked laser diodes. The spectrum of the combined laser beam can be tuned over a range of 2–3 nm by changing the tilt angle of the grating and varying the injection currents of each laser diode.

Title: Misalignment-induced frequency locking in lasers

Date: 03/06/2020

Type: Abstract

Authors: Niketh Nair, Yehuda Braiman

Publisher/Details: APS March Meeting 2020, Volume 65, Number 1

Link: https://meetings.aps.org/Meeting/MAR20/Session/X25.8

Abstract: We study arrays of heterogeneous single-mode semiconductor lasers coupled through an external cavity with facet misalignments. This system can be modeled mathematically as a set of coupled nonlinear delay-differential equations. The heterogeneity, in the form of frequency detuning, is represented as parametric disorder between the oscillators, and the facet misalignments is represented by a small disordering of the time-delays in the coupling terms. In this system, we show that the introduction of time-delay disorder induces perfect frequency locking in a system that otherwise is unable to frequency-lock due to heterogeneous natural frequencies, as well as chaotic behavior.

Title: On the controllability of transitions between equilibrium states in small inductively coupled arrays of Josephson junctions: A computational approach

Date: 02/15/2020

Type: Journal Article

Authors: Roland Glowinski, Jorge López, Héctor Juárez, Yehuda Braiman

Publisher/Details: Journal of Computational Physics, Volume 403, 109023

DOI: https://doi.org/10.1016/j.jcp.2019.109023

ISSN: 0021-9991

Abstract: In this article, we investigate computationally some controllability properties of a physical system consisting of three inductively coupled Josephson junctions. This system is modeled by nonlinear ordinary differential equations. A particular attention is given to the optimal control of the transition between equilibrium states, possibly unstable. After defining the control problem cost function, we use a perturbation analysis to compute its differential and formulate an optimality system. After appropriate time discretization of the control problem, we use a conjugate gradient algorithm to solve the discrete analogue of the above optimality system. The methodology we briefly described above has been applied successfully to the current pulse driven transition between two stable equilibrium states. This type of transitions was used in [1], [2], [3], [4], [5], to study *Read/Write* cryogenic memory cell operations based on the dynamics of small Josephson junction arrays. In order to show the robustness of our control-based approach we apply it also to the transitions from a stable equilibrium state to an unstable one.

Title: Memory cell comprising coupled Josephson junctions

Date: 12/24/2019

Type: Patent

Authors: Yehuda Braiman, Neena Imam, Brendan Neschke

Publisher/Details: US10516089B2, application number 15726173

Abstract: Methods and apparatus are disclosed for operating a memory cell formed from the plurality of coupled Josephson junctions. The memory cell is configured such that applying an electrical signal to the junctions can cause at least one, but not all, of the junctions to change their respective phase states. Subsequent writes to the memory cell using substantially the same electrical pulse do not change the phase state of the plurality of junctions. The memory cell can be ready by providing another electrical pulse to one of the junctions and receiving an output electrical pulse generated in response by a different Josephson junction of the memory cell. A set of phase states are selected to represent the logic values that are stable across anticipated operating conditions for the memory cell. Methods of selecting electrical parameters and manufacturing memory cells are further disclosed.

Title: Experimental demonstration of a Josephson cryogenic memory cell based on coupled Josephson junction arrays

Date: 10/10/2019

Type: Journal Article

Authors: Niketh Nair, Amir Jafari-Salim, Anthony D'Addario, Neena Imam, Yehuda Braiman

Publisher/Details: IOP Publishing, Superconductor Science and Technology, Volume 32, Number 11

DOI: 10.1088/1361-6668/ab416a

Abstract: In this paper, experimental verification for a cryogenic memory cell consisting of three inductively coupled Josephson junctions is presented. Design and operational logic of this type of cell was recently introduced. The basic memory cell operations (read, write, reset) can be implemented on the same simple circuit and this type of memory cell is fundamentally different from the existing single flux quantum-based memory cells. Here, we present design principles and experimental validation for write operations and readout operation for four versions of the design, each with different parameters. Our experimental results show excellent resemblance with the previously presented memory cell operational logic and also show an excellent fit with simulations of the entire memory cell circuit that includes the memory cell and all the peripheral circuitry.

Title: Ternary and higher order classical cryogenic memory cells

Date: 03/2019

Type: Abstract

Authors: Niketh Nair, Yehuda Braiman

Publisher/Details: APS March Meeting 2019, abstract id.Y08.006

Abstract: For many classical cryogenic computing applications, a key issue in designing powerful and practical systems is the scaling of memory. In particular, the amount of circuitry required to build and access memory units has limited the amount of information that it is possible to store. A possible solution to this problem is to consider designs that store more information in a single memory unit. Therefore, it may be beneficial considering ternary and higher order multivalued memory systems that use the same number of Josephson junctions as binary units. In this talk we will present a ternary cryogenic memory cell paradigm based on an array of inductively coupled Josephson junctions. We show how reading, writing and resetting are implemented using single flux quantum (SFQ) current pulse inputs and outputs from the circuit. We further show how both destructive readout (DRO) and nondestructive readout (NDRO) can be implemented**.**

Title: Almost Perfect In-Phase and Anti-Phase Chaotic and Periodic Phase Synchronization in Large Arrays of Diode Lasers

Date: 03/2019

Type: Abstract

Authors: Yehuda Braiman, Niketh Nair, Erik Bochove

Publisher/Details: APS March Meeting 2019, abstract id.C56.005

Abstract: We studied phase synchronization in large arrays of weakly coupled single mode semiconductor laser diodes. We show that if the coupling topology is chosen appropriately, the laser array exhibits robust and almost perfect phase synchrony (including chaotic and non-chaotic phase synchrony). Furthermore, one can define coupling topologies that lead to chaotic anti-phase synchronization. When diodes are coupled via a decayed non-local coupling scheme, the leading spatial mode can be stable. This

leads to an almost-perfect phase synchronous state where the phases are synchronized, even though the system is not being exactly on the synchronization manifold. This almost-perfect phase synchronous state is robust to noise and frequency and phase disorder and can be realized under periodic (fixed-intensity limit cycle) continuous-wave and chaotic behavior.

Title: Almost perfect in-phase and anti-phase chaotic and periodic phase synchronization in large arrays of diode lasers

Date: 01/01/2019

Type: Journal Article

Authors: Niketh Nair, Erik Bochove, Yehuda Braiman

Publisher/Details: Optics Communications, Volume 430, Pages 104-111

DOI: https://doi.org/10.1016/j.optcom.2018.08.020

ISSN: 0030-4018

Abstract: In this paper we study phase synchronization in large arrays of weakly coupled single mode semiconductor laser diodes. We show that if the coupling topology is chosen appropriately, the laser array exhibits robust phase synchrony (including chaotic and non-chaotic phase synchrony). Furthermore, one can define coupling topologies that lead to chaotic anti-phase synchronization. To the best of our knowledge, chaotic anti-phase synchronization has not been observed in large arrays of coupled nonlinear oscillators. When diodes are coupled via a decayed non-local coupling scheme, the leading spatial mode can be stable. This leads to an almost-perfect phase synchronous state where the phases are synchronized, but the system is not set exactly on the synchronization manifold. This almost-perfect phase synchronous state is robust to noise and frequency disorder and can be realized under periodic (fixed-intensity limit cycle) continuous-wave and chaotic behavior. The presented result is an example of the broader phenomenon of linear transverse mode selection taking place in a coupled oscillator system with nonlinear dynamics.

Title: A ternary memory cell using small Josephson junction arrays

Date: 10/16/2018

Type: Journal Article

Authors: N Nair and Y Braiman

Publisher/Details: IOP Publishing, Superconductor Science and Technology, Volume 31, Number 11

DOI: 10.1088/1361-6668/aae2a9

Abstract: In this paper we present a ternary cryogenic memory cell paradigm that is based on an array of inductively coupled Josephson junctions. We show how reading, writing and resetting are implemented using single flux quantum current pulse inputs to the circuit and reading voltage pulse outputs from the circuit. We further show how both destructive readout and non-destructive readout can be implemented.

Title: Phase-locking of arrays of weakly coupled semiconductor lasers

Date: 07/25/2018

Type: Journal Article

Authors: Niketh Nair, Erik Bochove, and Yehuda Braiman

Publisher/Details: Optics Letters, Vol. 26, Issue 16, pp. 20040-20050

DOI: https://doi.org/10.1364/OE.26.020040

Abstract: In this paper we study the conditions for achieving almost perfect phase locking in large arrays of semiconductor diodes. We show that decayed non-local coupling of diode lasers can provide the necessary conditions for robust phase synchronization of an entire diode laser array. Perfect global coupling is known to allow for robust synchronization, however it is often physically impossible or impractical to achieve. We show that when diodes are coupled via the decayed non-local coupling layout, the dominant transverse mode of the laser array has a uniform phase across the lasers and can be stable. This state is robust to noise and frequency disorder and can be realized under periodic (fixed-intensity limit cycle) continuous-wave and chaotic behavior of lasers.

Title: Coherent addition of high power broad-area laser diodes with a compact VBG V-shaped external Talbot cavity

Date: 05/01/2018

Type: Journal Article

Authors: Bo Liu, Yehuda Braiman

Publisher/Details: Optics Communications, Volume 414, Pages 202-206

DOI: https://doi.org/10.1016/j.optcom.2018.01.021

ISSN: 0030-4018

Abstract: We introduced a compact V-shaped external Talbot cavity for phase locking of high power broad-area laser diodes. The length of compact cavity is ~25 mm. Near diffraction-limit coherent addition of 10 broad-area laser diodes indicated that high quality phase locking was achieved. We measured the near-field emission mode of each individual broad-area laser diode with different feedback, such as a volume Bragg grating and a high reflection mirror. We found out that the best result of phase locking broad-area laser diodes was achieved by the compact V-shaped external Talbot cavity with volume Bragg grating feedback.

Title: Principles of a cryogenic memory cell design using small arrays of coupled Josephson junctions

Date: 03/2018

Type: Abstract

Authors: Yehuda Braiman, Niketh Nair, Neena Imam

Publisher/Details: APS March Meeting 2018, abstract id.K31.012

Abstract: We present a cryogenic memory cell design paradigm that is based on the dynamics of small coupled array of Josephson junctions. All the basic memory operations (e.g., Write, Read, and Reset) are implemented on the same circuit and different junctions in the array can in principle be utilized for these operations. The presented memory operation paradigm is fundamentally different from conventional single quantum flux operation logics (SFQ). We have calculated memory cell access times and access energies that are in the ranges of tens of ps for access times and 10^{-18}-10^{-19} J for access energies. As an example, we will discuss memory cell operation driven by a SFQ pulse employing an inductively coupled array of three Josephson junctions.

Title: Phase Synchronization and Mode Selection in Arrays of Delay-Coupled Semiconductor Lasers

Date: 03/2018

Type: Abstract

Authors: Niketh Nair, Erik Bochove, Yehuda Braiman

Publisher/Details: APS March Meeting 2018, abstract id.V47.007

Abstract: We consider existence and stability of spatial modes of the external cavity of the delay-coupled semiconductor laser diode array and show that such arrays can be almost perfectly phase synchronized when the cavity is designed appropriately. Using an extension of Master Stability Function theory, we show that by using a decayed nonlocal coupling scheme, it is possible to induce robust and close-to-perfect CW and chaotic phase synchronous states. These synchronous states are robust to noise and moderate amounts of frequency disorder between elements. We also find that the critical coupling strength for which the synchronous state destabilizes increases approximately linearly with array size.

Title: Parameter optimization for transitions between memory states in small arrays of Josephson junctions

Date: 05/15/2017

Type: Journal Article

Authors: Jacob D Rezac, Neena Imam, Yehuda Braiman

Publisher/Details: Physica A: Statistical Mechanics and its Applications, Volume 474, Pages 267-281

DOI: https://doi.org/10.1016/j.physa.2017.01.044

ISSN: 0378-4371

Abstract: Coupled arrays of Josephson junctions possess multiple stable zero voltage states. Such states can store information and consequently can be utilized for cryogenic memory applications. Basic memory operations can be implemented by sending a pulse to one of the junctions and studying transitions between the states. In order to be suitable for memory operations, such transitions between the states have to be fast and energy efficient. In this paper we employed simulated annealing, a stochastic optimization algorithm, to study parameter optimization of array parameters which minimizes times and energies of transitions between specifically chosen states that can be utilized for memory operations (Read, Write, and Reset). Simulation results show that such transitions occur with access times on the order of 10–100 ps and access energies on the order of 10^{-19}–5×10^{-18} J. Numerical simulations are validated with approximate analytical results.

Title: Transverse Modes of Coupled Nonlinear Oscillator Arrays

Date: 03/23/2017

Type: Book Chapter

Authors: Niketh Nair, Erik Bochove, Yehuda Braiman

Publisher/Details: Transverse Modes of Coupled Nonlinear Oscillator Arrays. In: In, V., Longhini, P., Palacios, A. (eds) Proceedings of the 4th International Conference on Applications in Nonlinear Dynamics (ICAND 2016). ICAND 2016. Lecture Notes in Networks and Systems, vol 6. Springer, Cham.

DOI: https://doi.org/10.1007/978-3-319-52621-8_24

Print ISBN: 978-3-319-52620-1

Online ISBN: 978-3-319-52621-8

Abstract: We derive and apply an extension of Master Stability Function (MSF) theory to learn how transverse modes arise in arrays of coupled nonlinear oscillators. The MSF theory shows how network topology affects the stability of perfect synchrony between the oscillators. In particular it shows how the dynamics of the single oscillator and the eigenvalue spectrum of the coupling matrix determine the degree of synchronization of a coupled nonlinear system. In our description, the synchronous state actually corresponds to the first transverse mode of the system. We show that the MSF theory can also describe whether a non-synchronous transverse mode is stable. We apply this analysis to arrays of semiconductor lasers in order to demonstrate how mode selection occurs.

Title: Memory states in small arrays of Josephson junctions

Date: 10/30/2016

Type: Journal Article

Authors: Yehuda Braiman, Brendan Neschke, N Nair, Neena Imam, Ronald Glowinski

Publisher/Details: APS, Phys. Rev. E 94, Issue 5, 052223

DOI: https://doi.org/10.1103/PhysRevE.94.052223

ISSN: 2470-0053 (online), 2470-0045 (print).

Abstract: We study memory states of a circuit consisting of a small inductively coupled Josephson junction array and introduce basic (write, read, and reset) memory operations logics of the circuit. The presented memory operation paradigm is fundamentally different from conventional single quantum flux operation logics. We calculate stability diagrams of the zero-voltage states and outline memory states of the circuit. We also calculate access times and access energies for basic memory operations.

Title: Memory cell operation based on small Josephson junctions arrays

Date: 10/14/2016

Type: Journal Article

Authors: Yehuda Braiman, N Nair, J Rezac, Neena Imam

Publisher/Details: IOP Publishing, Superconductor Science and Technology, Volume 29, Number 12

DOI: 10.1088/0953-2048/29/12/124003

Abstract: In this paper we analyze a cryogenic memory cell circuit based on a small coupled array of Josephson junctions. All the basic memory operations (e.g., write, read, and reset) are implemented on the same circuit and different junctions in the array can in principle be utilized for these operations. The presented memory operation paradigm is fundamentally different from conventional single quantum flux operation logics (SFQ). As an example, we demonstrate memory operation driven by a SFQ pulse employing an inductively coupled array of three Josephson junctions. We have chosen realistic Josephson junction parameters based on state-of-the-art fabrication capabilities and have calculated access times and access energies for basic memory cell operations. We also implemented an optimization procedure based on the simulated annealing algorithm to calculate the optimized and typical values of access times and access energies.

Title: Resonator modes and mode dynamics for an external cavity-coupled laser array

Date: 03/03/2015

Type: Conference Proceeding

Authors: Niketh Nair, Erik J Bochove, Alejandro B Aceves, Mohammad R Zunoubi, Yehuda Braiman

Publisher/Details: SPIE LASE, Proc. SPIE 9343, Laser Resonators, Microresonators, and Beam Control XVII, 93431D

DOI: https://doi.org/10.1117/12.2080569

Abstract: Employing a Fox-Li approach, we derived the cold-cavity mode structure and a coupled mode theory for a phased array of N single-transverse-mode active waveguides with feedback from an external cavity. We applied the analysis to a system with arbitrary laser lengths, external cavity design and coupling strengths to the external cavity. The entire system was treated as a single resonator. The effect of the external cavity was modeled by a set of boundary conditions expressed by an N-by-N frequency-dependent matrix relation between incident and reflected fields at the interface with the external cavity. The coupled mode theory can be adapted to various types of gain media and internal and external cavity designs.

Title: Phase dynamics of high radiance fiber laser arrays with active phase control

Date: 03/03/2015

Type: Conference Proceeding

Authors: Erik Bochove, Brendan Neschke, Niketh Nair, Paul Delgado, Yehuda Braiman

Publisher/Details: SPIE LASE, Proc. SPIE 9343, Laser Resonators, Microresonators, and Beam Control XVII, 93431C, pp. 207-221

DOI: https://doi.org/10.1117/12.2080538

Abstract: The existing model of the LOCSET technique for the active phase synchronization of fiber laser arrays (T. Shay, Opt. Express, 2006) is extended to include relevant physical properties of the system, such as inherent optical path differences (OPD), line-width and group velocity dispersion (GVD), and we also include phase "jitter" of the master oscillator's output in the model, which in experiments is implemented to induce spectral broadening for suppression of nonlinear frequency conversion. Linearization of the phase error signal, which incorrectly predicts convergence to a synchronous equilibrium state, is not performed. Instead, the closed-loop control dynamics are shown to be described by differential equations of Kuramoto type when phase corrector response dynamics are negligible. Linear stability analysis indicates that there is always one and no more than one dynamically stable state. The latter is shown to be normally synchronous, except when strong "jitter" is applied. A Liapounov function is found as subject to the validity of certain symmetry conditions.

Title: Nonlinear dynamics and synchronization of an array of single mode laser diodes in external cavity subject to current modulation

Date: 08/15/2014

Type: Journal Article

Authors: B. Liu, Y. Braiman, N. Nair, Y. Lu, Y. Guo, P. Colet, M. Wardlaw

Publisher/Details: Optics Communications, Volume 324, Pages 301-310

DOI: https://doi.org/10.1016/j.optcom.2014.03.001

ISSN: 0030-4018

Abstract: We study the dynamics of an array of single mode laser diodes subject to filtered feedback provided by an external reflection grating. Our numerical simulations show that by modulating the injection current the array can be phase synchronized leading to high power coherent emission. The output peak power density can be varied by tuning the modulation frequency and can be resonantly enhanced once the frequency matches the inverse of external cavity round trip time and mode-locking behavior is realized. Both non-resonant and resonant injection current modulation results in an excellent degree of phase synchronization and coherence at certain modulation amplitudes and frequencies that is manifested by coherent enhancement of far-field optical intensity.

Title: Associative memory in phasing neuron networks

Date: 05/06/2014

Type: Conference Proceeding

Authors: Niketh Nair, Erik Bochove, Yehuda Braiman

Publisher/Details: IEEE, Proceedings of the 2014 Biomedical Sciences and Engineering Conference

DOI: 10.1109/BSEC.2014.6867743

Electronic ISBN: 978-1-4799-4159-9

Abstract: We studied pattern formation in a network of coupled Hindmarsh-Rose model neurons and introduced a new model for associative memory retrieval using networks of Kuramoto oscillators. Hindmarsh-Rose Neural Networks can exhibit a rich set of collective dynamics that can be controlled by

their connectivity. Specifically, we showed an instance of Hebb's rule where spiking was correlated with network topology. Based on this, we presented a simple model of associative memory in coupled phase oscillators.

Title: Nonlinear Dynamics and Synchronization of Laser Diode Array in External Cavity Subject to Current Modulation

Date: 01/01/2014

Type: Journal Article

Authors: Bo Liu, Yehuda Braiman, Yao Lu, Yi Guo, Pere R Colet, Michael Wardlaw

Publisher/Details: Optics Communications, Vol. 324

DOI: https://doi.org/10.1016/j.optcom.2014.03.001

ISSN: 0030-4018

Title: Coherent beam combining of high power broad-area laser diode array with near diffraction limited beam quality and high power conversion efficiency

Date: 12/11/2013

Type: Journal Article

Authors: B Liu, Y Braiman

Publisher/Details: Optical Society of America, Optics Express, Vol. 21, Issue 25, pp. 31218-31228

DOI: https://doi.org/10.1364/OE.21.031218

Abstract: We explored a path of achieving high quality phase-locking of broad-area laser diode (BALD) array that operates at high electrical to optical power conversion efficiency (PCE). 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. Subsequently, we redesigned and improved a V-shaped external Talbot cavity and employed low reflectivity anti-reflection (AR) coated, low-“smile” BALD array to meet these three important requirements. We demonstrated near-diffraction limit far-field coherent pattern with 19% PCE and 95% visibility. 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 5A injection current and 1.6 diffraction angular limited with visibility of 95% for 14A injection current. Power scaling of diode array is discussed.

Title: Increasing power conversion efficiency of coherent beam combining high power broad-area laser diode array with an optimized V-shaped external Talbot cavity

Date: 12/01/2013

Type: Journal Article

Authors: Bo Liu, Yehuda Braiman

Publisher/Details: Optics Express, Volume 21, Issue 25

DOI: https://doi.org/10.1364/OE.21.031218

ISSN: 1094-4087

Title: Synchronizing coupled semiconductor lasers under general coupling topologies

Date: 06/17/2013

Type: Conference Proceeding

Authors: Shuai Li, Yi Guo, Yehuda Braiman

Publisher/Details: IEEE, 2013 American Control Conference

DOI: 10.1109/ACC.2013.6580004

Electronic ISBN: 978-1-4799-0178-4

Print ISBN: 978-1-4799-0177-7

Abstract: We consider synchronization of coupled semiconductor lasers modeled by coupled Lang and Kobayashi equations. We first analyze decoupled laser stability, and then characterize synchronization conditions of coupled laser dynamics. We rigorously prove that the coupled system locally synchronizes to a limit cycle under the coupling topology of an undirected connected graph with equal in-degrees. Graph and systems theory is used in synchronization analysis. The results not only contribute to analytic understanding of semiconductor lasers, but also advance cooperative control by providing a realworld system of coupled limit-cycle oscillators.

Title: Near Diffraction Limit Coherent Addition of Broad-Area Laser Diode Array

Date: 01/01/2013

Type: Conference Proceeding

Authors: Bo Liu, Yehuda Braiman

Publisher/Details: Solid State and Diode Laser Technology Review, Santa Fe, NM, USA, 20130624, 20130627

OSTI ID: 1086658

Title: Semiconductor laser beam combining

Date: 01/01/2013

Type: Book Chapter

Authors: Bo Liu, Pere Colet, Yehuda Braiman

Publisher/Details: Woodhead Publishing Series in Electronic and Optical Materials, Semiconductor Lasers, Woodhead Publishing, Pages 121-148

DOI: https://doi.org/10.1533/9780857096401.1.121

ISBN: 9780857091215

Abstract: In this chapter, we will review recent advances and trends in phase locking of broad-area laser diode arrays. In particular, we will concentrate on coherent phase locking of high-power, broad-area diode arrays in a passive external cavity. We will present a newly designed external cavity called the V-shape external Talbot cavity. The V-shape external cavity is capable of selecting single transverse mode operation of individual laser diodes on an array and providing optical coupling among laser diodes. The high visibility far-field interference pattern confirms that phase locking is achieved among laser diodes on an array. Two experimental schematic designs of the V-shape external Talbot cavity are explored. One is the V-shape external Talbot cavity, and the other is the closed V-shape external Talbot cavity. The differences in external cavity design and performance will be discussed.

Title: V-shaped resonators for addition of broad-area laser diode arrays

Date: 12/25/2012

Type: Patent

Authors: Bo Liu, Yun Liu, Yehuda Y Braiman

Publisher/Details: US8340151B2, Patent number 8340151

Abstract: A system and method for addition of broad-area semiconductor laser diode arrays are described. The system can include an array of laser diodes, a V-shaped external cavity, and grating systems to provide feedback for phase-locking of the laser diode array. A V-shaped mirror used to couple the laser diode emissions along two optical paths can be a V-shaped prism mirror, a V-shaped stepped mirror or include multiple V-shaped micro-mirrors. The V-shaped external cavity can be a ring cavity. The system can include an external injection laser to further improve coherence and phase-locking.

Title: Spectral linewidth narrowing and tunable two-color laser operation of two diode laser arrays

Date: 04/10/2012

Type: Journal Article

Authors: Bo Liu, Yehuda Braiman

Publisher/Details: Applied Optics, Vol. 51, Issue 11, pp. 1816-1821

DOI: https://doi.org/10.1364/AO.51.001816

Abstract: We propose and implement a common external cavity to narrow spectral linewidth of two broad-area laser diode arrays (LDAs) and align their center wavelengths. The locked center wavelength of two LDAs can be tuned in the range of ~10 nm by tuning the tilted angle of the diffraction grating. The output beams of two LDAs are spatially overlapped through the polarization beam splitter of the common external cavity, and the total output power equals the power of two LDAs. The center wavelength of each LDA can be independently tuned by shifting the corresponding fast-axis collimation lens. As a result, the high-power two-color LDA operation is demonstrated with the tunable wavelength difference of up to 2 nm (~1 THz).

Title: Atomic-scale friction control by vibration using friction force microscope

Date: 11/2011

Type: Journal Article

Authors: Yi Guo, Zheng Wang, Zhihua Qu, Yehuda Braiman

Publisher/Details: Control Engineering Practice, Volume 19, Issue 11, Pages 1387-1397

DOI: https://doi.org/10.1016/j.conengprac.2011.07.014

ISSN: 0967-0661

Abstract: Manipulation of friction at the nanoscale has been traditionally approached by chemical means (lubrication). Recent friction force microscopy (FFM) experiments demonstrated that it can be done mechanically by applying vibration to accessible elements of the system. This paper provides analytic understanding on why vibration can reduce friction based on a 1D model imitating the FFM tip moving on a substrate. Open-loop stability is first studied, and a feedback vibration control is then designed using the accessible variable. Comparing to the open-loop system, friction force is significantly reduced in the closed-loop system. Numerical simulations show satisfactory performances.

Title: Simple model to explain instabilities in passively-phased high-power fiber laser arrays

Date: 06/09/2011

Type: Conference Proceeding

Authors: Erik J Bochove, Sami A Shakir, Yuji Starcher, Adrián Jacobo, Pere Colet, Alejandro B Aceves, Yehuda Braiman, Ralf Deiterding, Casey Miller, Charles Rhodes

Publisher/Details: Proc. SPIE 8080, Diode-Pumped High Energy and High Power Lasers; ELI: Ultrarelativistic Laser-Matter Interactions and Petawatt Photonics; and HiPER: the European Pathway to Laser Energy, 808009

DOI: https://doi.org/10.1117/12.886659

Abstract: We propose a simple physical mechanism to explain observed instabilities in the dynamics of passively phased fiber amplifier arrays that arises from two properties: First that a weak phase disturbance of the output field of the array is converted into a strong intensity disturbance through the mode-selective feedback mechanism. Second, that this intensity fluctuation regenerates a phase fluctuation due to the nonlinear properties of the amplifying media. At sufficiently high operating power levels this cyclic disturbance continues to grow upon each cavity round trip, creating instability. This simple picture is supported by the results of a linear stability analysis of the set of propagation and population rate equations, which are in good agreement with observed critical power levels. A third level of quantitative confirmation was obtained by comparison to the results of numerical integration of the original set of nonlinear equations. This predicted instability is entirely a property of passively phased arrays of more than one element.

Title: Dynamics of passively phased fiber laser arrays

Date: 05/22/2011

Type: Conference Proceeding

Authors: A Jacobo, P Colet, EJ Bochove, Y Braiman, AB Aceves, R Deiterding, CA Miller, C Rhodes, SA Shakir

Publisher/Details: The European Conference on Lasers and Electro-Optics

ISBN: 978-1-4577-0532-8

Abstract: The goal of scaling fiber lasers to high power levels for applications has created an interest in coherently combine the beams of a number of fibers. However, success in accurately controlling the frequencies and phases of the fields by either passive, active or hybrid means has until now been limited. Studies of the dynamics of passively phased fiber arrays have been published, but the understanding of their instabilities is limited.

Title: Model of the Self-Q-Switching Instability of Passively Phased Fiber Laser Arrays

Date: 04/25/2011

Type: Journal Article

Authors: Erik J Bochove, Alejandro B Aceves, Yehuda Braiman, Pere Colet, Ralf Deiterding, Adrián Jacobo, Casey A Miller, Charley Rhodes, Sami A Shakir

Publisher/Details: IEEE Journal of Quantum Electronics, Volume 47, Issue 6, pp. 777-785

DOI: 10.1109/JQE.2011.2112637

Abstract: We present a simple model for self-pulsation instability in passively phased high power optical fiber amplifier arrays with external feedback. Its key features are, first, the feedback level's sensitivity, and thus that of the cavity Q-value, to small phase changes of the array fields, and, second, the effect of refractive index nonlinearity in the amplifiers. The model's prediction of an instability threshold for arrays of at least two amplifiers is confirmed by a linearized stability analysis of a system in ring-cavity geometry, and the magnitudes of predicted power levels are well within the domain of recent experiments.

Title: Dynamic stability analysis of passively-phased ring-geometry fiber laser array

Date: 06/21/2010

Type: Conference Proceeding

Authors: EJ Bochove, AB Aceves, R Deiterding, L Crabtree, Y Braiman, A Jacobo, P Colet

Publisher/Details: Optica Publishing Group, Nonlinear Photonics, NME56

DOI: https://doi.org/10.1364/NP.2010.NME56

ISBN: 978-1-55752-896-4

Abstract: We perform a linearized stability analysis and preliminary simulations of passive phasing in a CW operating ring-geometry fiber laser array coupled in an external cavity that uses a single-mode feedback fiber functioning as spatial filter, which predicts that a two-element array with path length error will have a dynamically stable stationary operating state at the wavelengths of relative maxima in output power.

Title: Control of friction at the nanoscale

Date: 04/06/2010

Type: Patent

Authors: Jacob Barhen, Yehuda Y Braiman, Vladimir Protopopescu

Publisher/Details: US7693587B2, Application number 10770857

Abstract: Methods and apparatus are described for control of friction at the nanoscale. A method of controlling frictional dynamics of a plurality of particles using non-Lipschitzian control includes determining an attribute of the plurality of particles; calculating an attribute deviation by subtracting the attribute of the plurality of particles from a target attribute; calculating a non-Lipschitzian feedback control term by raising the attribute deviation to a fractionary power $\xi=(2m+1)/(2n+1)$ where n=1, 2, 3 . . . and m=0, 1, 2, 3 . . . , with m strictly less than n and then multiplying by a control amplitude; and imposing the non-Lipschitzian feedback control term globally on each of the plurality of particles; imposing causes a subsequent magnitude of the attribute deviation to be reduced.

Title: Coherent beam combining of high power broad-area laser diode array with a closed-V-shape external Talbot cavity

Date: 03/24/2010

Type: Journal Article

Authors: Bo Liu, Yun Liu, Yehuda Braiman

Publisher/Details: Optics Express, Vol. 18, Issue 7, pp. 7361-7368

DOI: https://doi.org/10.1364/OE.18.007361

Abstract: We have coherently combined a high-power broad-area laser diode array by using a feedback loop closed off-axis external Talbot cavity. The off-axis feedback from two gratings provides transverse-mode control of broad-area lasers. The Talbot configuration of the external cavity implements diffractive coupling among laser diodes. Feedback from two gratings increases external cavity quality factor and spectrum selection capability. As a result, spatial coherence was improved and spectral linewidth was narrowed down. The high visibility of the far-field profile indicates that high spatial coherence was achieved. We also observed symmetric far-field profiles indicating that laser array was phase locked to in-phase and out-of-phase super-modes, respectively. Transition between these super-modes was observed by tuning one grating's tilted angle.

Title: Coherent beam combining of high-power broad-area laser diode array in CW and pulsed modes

Date: 02/17/2010

Type: Conference Proceeding

Authors: Bo Liu, Yun Liu, Yehuda Braiman

Publisher/Details: Proc. SPIE 7583, High-Power Diode Laser Technology and Applications VIII, 75830Z, pp. 319-326

DOI: https://doi.org/10.1117/12.842259

Abstract: We present experimental results on coherent beam combining from large arrays of high power broad-area semiconductor lasers. Our laser array consists of 47 high-power anti-reflection coated broad-area semiconductor lasers and each laser emitter is capable of emitting 1.8 W when uncoated with a maximum array output power of 80W. The total available power from the AR coated array is approximately 40W. By using an external V-shape cavity design, we experimentally demonstrated a coherently combined beam at the output power of ~13 W with the 0.07 nm FWHM spectrum linewidth that is limited by the sensitivity of the optical spectrum analyzer. We also discuss coherent beam combining of highpower broad area laser diode array in current driver pulse mode operation.

Title: Space-time-dynamic model of passively phased ring-geometry fiber laser array

Date: 02/17/2010

Type: Conference Proceeding

Authors: E Bochove, A Aceves, Ralf Deiterding, Lily Crabtree, Yehuda Braiman, Adrián Jacobo, Pere Colet

Publisher/Details: Proc. SPIE 7580, Fiber Lasers VII: Technology, Systems, and Applications, 758026

DOI: https://doi.org/10.1117/12.840998

Abstract: We performed a linearized stability analysis and preliminary simulations of passive phasing in a CW operating ring-geometry fiber laser array coupled in an external cavity with a single-mode feedback fiber that functions as spatial filter. A two-element array with path length error is predicted to have a dynamically stable stationary operating state at the computer operating wavelength.

Title: Nanoscale oscillatory fracture propagation in metallic glasses

Date: 05/15/2009

Type: Journal Article

Authors: Yehuda Braiman, T Egami

Publisher/Details: Physica A: Statistical Mechanics and its Applications, Volume 388, Issue 10, Pages 1978-1984,

DOI: https://doi.org/10.1016/j.physa.2008.12.072

ISSN: 0378-4371

Abstract: We describe the oscillatory crack propagation for small propagation velocities at the atomistic scale that was recently observed for brittle metallic glasses [G. Wang, Y.T. Wang, Y.H. Liu, M.X. Pan, D.Q. Zhao, W.H. Wang, Appl. Lett. 89 (2006) 121909; G. Wang, D.Q. Zhao, H.Y. Bai, M.X. Pan, A.L. Xia, B.S. Han, X.K. Xi, Y. Wu, W.H. Wang, Phys. Rev. Lett. 98 (2007) 235501]. Based on a simple model of crack propagation [Y. Braiman, T. Egami, Phys. Rev. E, 77 (2008) 065101(R)], we derived and analyzed expressions for the feature size, oscillation period, and maximum strain accumulated in the material.

Title: Linewidth reduction of a broad-area laser diode array in a compound external cavity

Date: 01/08/2009

Type: Journal Article

Authors: Bo Liu, Yun Liu, Yehuda Braiman

Publisher/Details: **Applied Optics** Vol. 48, Issue 2, pp. 365-370

DOI: https://doi.org/10.1364/AO.48.000365

Abstract: A compound external cavity is designed and implemented to achieve a homogeneous spectrum distribution of broad area laser diodes in an array and to narrow the spectral linewidth of the entire array. The compound external cavity is composed of an optical coupler and a Littrow external cavity with a telescope along the fast axis. The inhomogeneous distribution of individual laser diodes spectrum generated by the “smile” effect was reduced by the telescope. The effective transverse coupling among individual laser diodes in an array was enhanced by the optical coupler, which further reduced the spectrum inhomogeneous distribution of the entire array. The spectral linewidth of a 49-emitter laser array is reduced to 0.1 nm at the output power of 12.5 W.

Title: Nanotribology and nanoscale friction

Date: 12/31/2008

Type: Journal Article

Authors: Yi Guo, Zhihua Qu, Yehuda Braiman, Zhenyu Zhang, Jacob Barhen

Publisher/Details: IEEE Control Systems Magazine, Volume: 28, Issue: 6, pp. 92-100

DOI: 10.1109/MCS.2008.929420

Abstract: Tribology is the science and technology of contacting solid surfaces in relative motion, including the study of lubricants, lubrication, friction, wear, and bearings. It is estimated that friction and wear cost the U.S. economy 6% of the gross national product [1]. For example, 5% of the total energy generated in an automobile engine is lost to frictional resistance. The study of nanoscale friction has a technological impact in reducing energy loss in machines, in microelectromechanical systems (MEMS), and in the development of durable, low-friction surfaces and ultra-thin lubrication films.

Title: Coherent addition of high power laser diode array with a V-shape external Talbot cavity

Date: 12/03/2008

Type: Journal Article

Authors: Bo Liu, Yun Liu, Yehuda Braiman

Publisher/Details: Optics Express Vol. 16, Issue 25, pp. 20935-20942

DOI: https://doi.org/10.1364/OE.16.020935

Abstract: We designed a V-shape external Talbot cavity for a broad-area laser diode array and demonstrated coherent laser beam combining at high power with narrow spectral linewidth. The V-shape external Talbot cavity provides good mode-discrimination and does not require a spatial filter. A multi-

lobe far-field profile generated by a low filling-factor phase-locked array is confirmed by our numerical simulation.

Title: Cascaded injection resonator for coherent beam combining of laser arrays

Date: 10/21/2008

Type: Patent

Authors: Vassili Kireev, Yun Liu, Vladimir Protopopescu, Yehuda Braiman

Publisher/Details: US7440483B2, Application Number 11652238

Abstract: The invention provides a cascaded injection resonator for coherent beam combining of laser arrays. The resonator comprises a plurality of laser emitters arranged along at least one plane and a beam sampler for reflecting at least a portion of each laser beam that impinges on the beam sampler, the portion of each laser beam from one of the laser emitters being reflected back to another one of the laser emitters to cause a beam to be generated from the other one of the laser emitters to the beam reflector. The beam sampler also transmits a portion of each laser beam to produce a laser output beam such that a plurality of laser output beams of the same frequency are produced. An injection laser beam is directed to a first laser emitter to begin a process of generating and reflecting a laser beam from one laser emitter to another laser emitter in the plurality. A method of practicing the invention is also disclosed.

Title: Transitions from oscillatory to smooth fracture propagation in brittle metallic glasses

Date: 06/11/2008

Type: Journal Article

Authors: Yehuda Braiman, T Egami

Publisher/Details: Phys. Rev. E **77**, 065101(R)

DOI: https://doi.org/10.1103/PhysRevE.77.065101

Abstract: We present a simple model to explain the transition from oscillatory to smooth crack propagation in brittle metallic glasses. We demonstrate that the smooth fracture propagation that is characteristic for higher temperature or higher crack opening velocities (for type 1 crack propagation) becomes unstable and oscillatory behavior is being observed. The characteristic feature size of the crack propagation may be at the nanometer scale and grows as the opening velocity decreases.

Title: Proof-of-principle demonstration of high efficiency laser-assisted H− beam conversion to protons

Date: 05/02/2007

Type: Journal Article

Authors: V Danilov, A Aleksandrov, S Assadi, J Barhen, W Blokland, Y Braiman, D Brown, C Deibele, W Grice, S Henderson, J Holmes, Y Liu, A Shishlo, A Webster, IN Nesterenko

Publisher/Details: Phys. Rev. ST Accel. Beams 10, 053501

DOI: https://doi.org/10.1103/PhysRevSTAB.10.053501

Abstract: Thin carbon foils are used as strippers for charge exchange injection into high intensity proton rings. However, the stripping foils become radioactive and produce uncontrolled beam loss, which is one of the main factors limiting beam power in high intensity proton rings. Recently, we presented a scheme for laser stripping an H− beam for the Spallation Neutron Source (SNS) ring. First, H− atoms are converted to H0 by a magnetic field, then H0 atoms are excited from the ground state to the upper levels by a laser, and the excited states are converted to protons by a magnetic field. In this paper we report on the proof-of-principle demonstration of this scheme to give high efficiency (around 90%) conversion of H− beam into protons at SNS in Oak Ridge. The experimental setup is described, and comparison of the experimental data with simulations is presented.

Title: Frictional Dynamics at the Atomic Scale in Presence of Small Oscillations of the Sliding Surfaces

Date: 01/01/2007

Type: Book Chapter

Authors: Sangmin Jeon, Thomas Thundat, Yehuda Braiman

Publisher/Details: Frictional Dynamics at the Atomic Scale in Presence of Small Oscillations of the Sliding Surfaces, Superlubricity, Elsevier Science B.V., Pages 119-130. Editor(s): Ali Erdemir, Jean-Michel Martin

DOI: https://doi.org/10.1016/B978-044452772-1/50038-X

ISBN: 9780444527721

Introduction: This chapter examines the effect of surface oscillations on frictional properties of surfaces by using an atomic force microscope (AFM). A diode laser was focused on the end of the cantilever and aligned to reflect the laser beam to the center of the detector. Proportional and integral gains of a feedback loop were set to low values because high values could exert a large influence on the lateral force measurement. The upper and lower curves represented trace and retrace in standard AFM measurements, respectively. Although the accurate amplitude of the vertical vibration was not measured at the high frequency, its amplitude-to-voltage parameter was about 1 nm/V at the low frequency, and the amplitude was linearly dependent on the applied voltage in the given frequency. The difference started to decrease even at a low driving voltage of 0.1 V and reached to an almost negligible value at 1 V. Different trends of frictional behavior might be observed for oscillation frequencies that are too close or much higher than the characteristic oscillation frequency defined by the AFM scanning velocity.

Title: Effect of normal vibration on friction in the atomic force microscopy experiment

Date: 05/23/2006

Type: Research Article

Authors: Sangmin Jeon, Thomas Thundat, Yehuda Braiman

Publisher/Details: Appl. Phys. Lett. 88, 214102

DOI: https://doi.org/10.1063/1.2203741

Abstract: We studied the effect of periodic normal (out-of-plane) surface vibrations on friction in an atomic force microscope experiment. Vibration frequency was varied in the range of 1–100kHz, and vibration amplitude was varied in the range of a few nanometers. We observed a reduction of a few orders

of magnitude in friction coefficient due to the periodic vibrations. Friction reduction is over a wide range of vibration frequencies and amplitudes. Very low values (of the order of 0.01) of friction coefficient were measured. Our numerical simulation based on a minimalist modeling qualitatively agrees with the experimental results. Based on numerical simulations, a mechanism of friction reduction and/or increase with normal vibrations is proposed.

Title: Thin-film adhesion measurement using laser-generated high-power surface acoustic wave

Date: 05/10/2008

Type: Research Article

Authors: V Kireev, Y Liu, Y Braiman, B Radhakrishnan, CH Hsueh, PF Becher

Publisher/Details: Appl. Phys. Lett. 88, 191911

DOI: https://doi.org/10.1063/1.2203205

Abstract: A method of the interfacial adhesion measurements utilizing the generation and monitoring of high-power surface acoustic wave has been reported. High-power surface acoustic wave was generated by surface optical breakdown in a transparent dielectric substrate. Modification of the tension-to-shear stresses ratio with film thickness was demonstrated. The normal stress generated at the interface is about one order of magnitude higher compared to those reported in laser spallation experiments; therefore stronger interfaces can be tested with less damage to the substrate.

Title: First Results of SNS Laser Stripping Experiment

Date: 01/2006

Type: Conference Proceeding

Authors: Viatcheslav Danilov, A Aleksandrov, Saeed Assadi, Jacob Barhen, Yehuda Braiman, D Brown, W Grice, Stuart Henderson, J Holmes, Yun Liu, A Shishlo

Publisher/Details: 10th European Particle Accelerator Conference

Abstract: Thin carbon foils are used as strippers for charge exchange injection into high intensity proton rings. However, the stripping foils become radioactive and produce uncontrolled beam loss, which is one of the main factors limiting beam power in high intensity proton rings. Recently, we presented a scheme for laser stripping of an H- beam for the Spallation Neutron Source ring. First, H - atoms are converted to H0 by a magnetic field, then H0 atoms are excited from the ground state to the upper levels by a laser, and the excited states are converted to protons by a magnetic field. This paper presents first results of the SNS laser stripping proof-of-principle experiment. The experimental setup is described, and possible explanations of the data are discussed.

Title: H^- Laser Stripping Proof-of-Principle Experiments Overview

Date: 06/08/2005

Type: Journal Article

Authors: V Danilov, A Aleksandrov, S Assadi, J Barhen, Y Braiman, W Grice, A Shishlo, S Henderson, B Lang, Y Liu, G Murdoch, K Potter, D Berkaev, V Kobets, I Koop, V Kuz'Minykh, Yu Shatunov, D Shwartz

Publisher/Details: High Intensity and High Brightness Hadron Beams, Vol. 773, pp. 286-290

Abstract: H- ion laser stripping was proposed long ago, but it is only now becoming feasible due to technical and theoretical advances. This paper presents a description and a comparison of proof-of-principle experiments under development in Oak Ridge and Brookhaven National Laboratories.

Title: Determination of Contact Area During Small-Scale Friction Experiments by Means of Continuous Stiffness Measurements

Date: 01/2005

Type: Conference Proceeding

Authors: Andrei Rar, Yehuda Y Braiman, Warren C Oliver, David L Goldsby, Terry E Tullis, George M Pharr

Publisher/Details: WTC2005-63373, pp. 261-262; 2 pages

DOI: https://doi.org/10.1115/WTC2005-63373

Abstract: Despite the hallmark observation of the almost linear relationship between friction force and contact area in the case of “dry” friction, the direct measurement of this dependency is an area of active research [1, 2]. In this study, a new approach to the measurement of contact area during friction experiments is proposed. The method is based on the well known proportionality between the contact area and the contact stiffness raised to the second power [3]. The main benefit of the proposed method is its broad applicability. Preliminary measurements of the dependence between friction and contact area are discussed.

Title: Dynamics and Synchronization in a Broad-Area Semiconductor Laser Array with External Optical Feedback

Date: 12/09/2004

Type: Research Article

Authors: Yun Liu, Yehuda Braiman

Publisher/Details: AIP Conf. Proc. 742, 267–275

DOI: https://doi.org/10.1063/1.1846486

Abstract: We report experimental results on the dynamics and synchronization of a 19-broad-area semiconductor laser array in an external cavity containing a lens array, projection optics, and a diffractive grating. All lasers are locked to single longitudinal mode. Significant improvement of the spatial profile of the entire laser array output beam has been observed. Laser coupling is investigated through the radio-frequency (RF) spectrum and temporal correlation of coupled laser emitters. Such coupling is found to exert certain effects on the frequency locking of the laser array.

Title: Cross talk between bending, twisting, and buckling modes of three types of microcantilever sensors

Date: 11/01/2004

Type: Research Article

Authors: Sangmin Jeon, Yehuda Braiman, Thomas Thundat

Publisher/Details: Rev. Sci. Instrum. 75, 4841–4844

DOI: https://doi.org/10.1063/1.1809259

Abstract: Microcantilevers generally deflect in three ways: bending, twisting, and buckling. Among these, the accurate measurement of bending is essential for atomic force microscopy imaging and sensing applications. However, it was found that the bending of certain cantilevers can be coupled with twisting and buckling of the cantilever. In this article, cross talk between bending and twisting modes of microcantilevers of three different designs such as rectangular, triangular, and piezoresistive cantilevers is described. For the experiments, a thermal stress was applied to the rectangular and triangular cantilevers, and a Lorentz force was exerted on the triangular and the piezoresistive cantilevers. While the bending of the rectangular cantilever induced a negligible amount of twisting when heated, the triangular cantilevers showed nonlinear twisting responses during bending. This nonlinear response of the triangular cantilever was attributed to the variations in the spring constants between the two legs. When a Lorentz force was exerted on the triangular cantilevers, coupling of the bending and twisting modes depended on the direction of a magnetic field. For the piezoresistive cantilevers, a Lorentz force induced the in-phase buckling which accompanied both the bending and twisting modes.

Title: Synchronization of high-power broad-area semiconductor lasers

Date: 10/31/2004

Type: Journal Article

Authors: Yun Liu, Yehuda Braiman

Publisher/Details: IEEE Journal of Selected Topics in Quantum Electronics, Volume: 10

DOI: 10.1109/JSTQE.2004.835310

Electronic ISSN: 1558-4542

Abstract: Semiconductor lasers offer significant operational advantages due to their compactness and high electrical-optical conversion efficiency. The major drawback in considering semiconductor lasers for many applications is the relatively small emission power that can be obtained from a single semiconductor laser. Synchronization of laser arrays provides a unique solution to this limitation. In this paper, we describe our recent research on the synchronization of high-power broad-area semiconductor lasers and laser arrays. We demonstrate experimental results on 1) simultaneous injection locking of multiple broad-area lasers to achieve single longitudinal/transverse mode beams and 2) synchronization and coherent beam combination of an integrated 19 broad-area laser array based on a scalable external cavity. A number of issues in the synchronization of broad-area lasers have been addressed in this paper. These include the effects of laser coupling on the array synchronization performance and the gigahertz complementary intensity oscillations occurring at different transverse modes of broad-area lasers subject to the optical injection

Title: Master laser injection of broad area lasers

Date: 08/24/2004

Type: Patent

Authors: Yehuda Y Braiman, Yun Liu

Publisher/Details: US6782016B2, Application Number 09999187

Abstract: Systems and methods are described for laser array synchronization using master laser injection of broad area lasers. A method, includes: master laser injecting a plurality of broad area lasers; and externally cavity coupling the plurality of broad area lasers. A method, includes: master laser injecting a plurality of broad area lasers; and externally Q switch coupling the plurality of broad area lasers. A method, includes: injection synchronizing a plurality of pulsed broad area lasers using a signal source; modulating the plurality of pulsed broad area lasers using the signal source; and externally coupling the plurality of pulsed broad area lasers.

Title: Dynamics and Friction in Submicrometer Confining Systems

Date: 07/17/2004

Type: Book

Authors: Yehuda Braiman, JM Drake, Fereydoon Family, Joseph Klafter

Publisher/Details: ACS Symposium Series 882, Oxford University Press

DOI: 10.1021/bk-2004-0882

ISBN13: 9780841238299

eISBN: 9780841219885

Title: Broad-area laser array synchronization using external cavity

Date: 06/01/2004

Type: Conference Proceeding

Authors: Yun Liu, Vassili A. Kireev, Yoshiro Takiguchi, Yehuda Braiman

Publisher/Details: Proceedings Volume 5336, High-Power Diode Laser Technology and Applications II

DOI: https://doi.org/10.1117/12.528077

Description: We present experimental results on the locking of a 19-broad-area semiconductor laser array using a novel design of external cavity containing a lens array, projection optics, and a diffractive grating. All lasers are locked to single longitudinal mode. Significant improvement of the spatial profile of the entire laser array output beam has been observed. The center lobe of the far-field pattern of the laser array shows a single wavelength which can be tuned over a range more than 10 nm. The proposed technology can be applied to larger arrays including the stacked arrays.

Title: Frequency locking and synchronization of nanosecond-pulsed broad-area lasers

Date: 06/01/2004

Type: Conference Proceeding

Authors: Yun Liu, Vassili A. Kireev, Yehuda Braiman

Publisher/Details: Proceedings Volume 5336, High-Power Diode Laser Technology and Applications II

DOI: https://doi.org/10.1117/12.528072

Abstract: Pulsed lasers with pulse durations of nanosecond to millisecond are very important tools for free-space optical communication, LADAR, laser material processing, and optical sensing. Although Q-switched solid-state lasers or gas lasers are currently the most popular light sources for these purposes, pulsed semiconductor lasers have the potential for the above applications because of their compactness, accessibility of direct modulation, and inherently large electrical to optical conversion efficiency. The drawbacks with high-power semiconductor lasers are their poor beam quality and low coherence factors. This work addresses the above issues through experimental demonstration of frequency locking, wavelength tuning, and synchronization of nanosecond pulsed broad-area semiconductor lasers. Nanosecond optical pulses with the peak power of 25 W and the repetition rates of 4 KHz to 240 KHz are generated from a broad-area laser. An external cavity with a diffractive grating is used to reduce the linewidth of the laser from over 5 nm to less than 0.1 nm. The wavelength of the pulsed laser is tunable over more than 10 nm. We have conducted injection locking of a nanosecond pulsed broad-area laser with optical injection from a frequency-locked master laser. Successful injection locking strongly support the feasibility of synchronization and beam combination of pulsed broad-area lasers.

Title: Frequency locking and wavelength tuning of nanosecond pulsed broad-area semiconductor laser

Date: 05/24/2004

Type: Research Article

Authors: Y Liu, V Kireev, Y Braiman

Publisher/Details: Appl. Phys. Lett. 84, 4265–4267

DOI: https://doi.org/10.1063/1.1758782

Abstract: We discuss experimental results of frequency locking and wavelength tuning of a nanosecond pulsed broad-area semiconductor laser. Nanosecond optical pulses with peak power of 25 W and repetition rates of 4–240 kHz are generated from a broad-area laser. An external cavity with a diffractive grating is used to reduce the linewidth of the laser from over 5 nm to less than 0.1 nm. The wavelength of the pulsed laser is tunable over more than 10 nm. The dependence of the laser linewidth on pulse parameters has been investigated.

Title: Torsional spring constant obtained for an atomic force microscope cantileve

Date: 03/08/2004

Type: Research Article

Authors: Sangmin Jeon, Yehuda Braiman, Thomas Thundat

Publisher/Details: Appl. Phys. Lett. 84, 1795–1797

DOI: https://doi.org/10.1063/1.1667000

Abstract: In this letter, a method to measure the torsional spring constant of a microcantilever is described. The cantilever was twisted laterally without any normal load by inducing the Lorentz force. An electrical current was applied to the cantilever in a magnetic field, and the torsional resonance frequency of the cantilever was obtained. Based on the observation that the torsional resonance frequency is the same as the second resonance peak of the thermally vibrating cantilever, the ratio of deflection spring constant to torsional spring constant is easily obtained from a simple relationship. For the cantilever used here, the torsional spring constant is 11.24 N/m, 28 times greater than the deflection spring constant.

Title: Non-Lipschitzian Control Algorithm for Nanoscale

Date: 2004

Type: Research Article

Authors: V Protopopescu, J Barhen, Y Braiman

Publisher/Details: MRS Online Proceedings Library (OPL) , Volume 790: Symposium P – Dynamics in Small Confining Systems–2003 , 2003 , P1.7

DOI: https://doi.org/10.1557/PROC-790-P1.7

Extract: We present a robust feedback control algorithm and apply it to the nonlinear oscillator array (Frenkel-Kontorova) model of nanoscale friction. The new control approach is based on the concepts of non-Lipschitzian dynamics and global targeting. We show that average quantities of the controlled system can be driven - exactly or approximately - towards desired targets which become additional, linearly stable attractors for the system's dynamics. Extensive numerical simulations show that the basins of attraction of these targets are reached in very short times and the control exhibits very strong robustness. We investigate the efficiency of the control in terms of various parameters (e.g., system size, non-Lipschitzian exponent).

Title: Non-lipshitzian control of friction

Date: 01/2004

Type: Conference Proceeding

Authors: Y. Braiman, J. Barhen, and V. Protopopescu

Publisher/Details: ACS Symposium Series

Abstract: Recently, we proposed a new algorithm to control frictional dynamics of an array of particles towards pre-assigned values of the average sliding velocity [1]. The algorithm is based on the concepts of terminal attractor and global targeting, which endow the control with robust efficiency. In this paper, we focus on the transient times needed to reach the prescribed behavior and their dependence on the control parameters.

Title: Non-Lipschitzian Control Algorithm for Nanoscale

Date: 12/01/2003

Type: Conference Proceeding

Authors: Friction V Protopopescu, J Barhen, Y Braiman

Publisher/Details: Springer International Publishing, MRS Online Proceedings Library 790, 17

DOI: https://doi.org/10.1557/PROC-790-P1.7

Abstract: We present a robust feedback control algorithm and apply it to the nonlinear oscillator array (Frenkel-Kontorova) model of nanoscale friction. The new control approach is based on the concepts of non-Lipschitzian dynamics and global targeting. We show that average quantities of the controlled system can be driven - exactly or approximately - towards desired targets which become additional, linearly stable attractors for the system's dynamics. Extensive numerical simulations show that the basins of attraction of these targets are reached in very short times and the control exhibits very strong robustness. We investigate the efficiency of the control in terms of various parameters (e.g., system size, non-Lipschitzian exponent)

Title: Three-step H− charge exchange injection with a narrow-band laser

Date: 05/06/2003

Type: Journal Article

Authors: V Danilov, A Aleksandrov, S Assadi, S Henderson, N Holtkamp, T Shea, A Shishlo, Y Braiman, Y Liu, J Barhen, T Zacharia

Publisher/Details: Phys. Rev. ST Accel. Beams 6, 053501

DOI: https://doi.org/10.1103/PhysRevSTAB.6.053501

Abstract: This paper presents a scheme for three-step laser-based stripping of an H− beam for charge exchange injection into a high-intensity proton ring. First, H− atoms are converted to H0 by Lorentz stripping in a strong magnetic field, then neutral hydrogen atoms are excited from the ground state to upper levels by a laser, and the remaining electron, now more weakly bound, is stripped in a strong magnetic field. The energy spread of the beam particles gives rise to a Doppler broadened absorption linewidth, which makes for an inefficient population of the upper state by a narrow-band laser. We propose to overcome this limitation with a “frequency sweeping” arrangement, which populates the upper state with almost 100% efficiency. We present estimates of peak laser power and describe a method to reduce the power by tailoring the dispersion function at the laser-particle beam interaction point. We present a scheme for reducing the average power requirements by using an optical ring resonator. Finally, we discuss an experimental setup to demonstrate this approach in a proof-of-principle experiment.

Title: Optimal control of the transient behavior of coupled solid-state lasers

Date: 04/09/2003

Type: Journal Article

Authors: E Jung, S Lenhart, V Protopopescu, Y Braiman

Publisher/Details: Phys. Rev. E 67, 046222

DOI: https://doi.org/10.1103/PhysRevE.67.046222

Abstract: We apply optimal control theory to substantially reduce transient times for transitions between in-phase and out-of-phase states in coupled solid-state lasers. The control is a time-varying optical field that is injected into the cavities of each laser. We have analytically derived the optimal control and numerically solved the optimality system. Numerical simulations indicate that transient times can be significantly reduced upon increasing the injection strength very briefly.

Title: Control of Friction at the Nanoscale

Date: 03/05/2003

Type: Journal Article

Authors: Yehuda Braiman, Jacob Barhen, Vladimir Protopopescu

Publisher/Details: Phys. Rev. Lett. 90, 094301

DOI: https://doi.org/10.1103/PhysRevLett.90.094301

Abstract: We propose a new algorithm to control frictional dynamics of a small array of particles towards preassigned values of the average sliding velocity. The control is based on the concepts of non-Lipschitzian dynamics and terminal attractor. Extensive numerical simulations illustrate the robustness, efficiency, and convenience of the algorithm.

Title: Injection locking of broad-area semiconductor lasers for free-space laser communication

Date: 12/09/2002

Type: Conference Proceeding

Authors: Yun Liu, Hua-Kuang Liu, Yehuda Y Braiman

Publisher/Details: Proc. SPIE 4821, Free-Space Laser Communication and Laser Imaging II

DOI: https://doi.org/10.1117/12.450938

Abstract: This paper describes experimental results on the injection locking of high-power broad-area semiconductor lasers in a commercially available 19-laser array driven by a common current source. Single-frequency optical spectrum and single lobe far-field pattern are observed as a result of injection locking. We discuss the temporal dynamics, the amplification of the injection light, and the phase coherence between the injection-locked lasers, which are key issues in their applications to free-space laser communication.

Title: Enhancement of coherence and intensity in a broad-area semiconductor laser array with injection locking

Date: 06/04/2002

Type: Conference Proceeding

Authors: Yun Liu, Gabriel Bitton, Patrick Cheinet, WR Garrett, HK Liu, Yehuda Y Braiman

Publisher/Details: Proceedings Volume 4632, Laser and Beam Control Technologies

DOI: https://doi.org/10.1117/12.469753

Abstract: This paper describes a method of enhancing coherence and intensity of a broad-area laser array. An experimental scheme has been proposed to injection lock a single or multiple broad-area high-power lasers in a commercially available 19-laser array driven by a common current source. We experimentally demonstrate both the injection locking of each individual broad-area laser and the simultaneous injection of two broad-area lasers in a 19-laser array using a single-mode laser as the source of injection. The method and required conditions for the simultaneous locking of all 19 lasers have been discovered from the experimental results.

Title: Size Evolution and Control of Nanostructures in Laser-Directed Atomic Deposition

Date: 03/2002

Type: Abstract

Authors: Jianxin Zhong, Yehuda Braiman, Jack C Wells

Publisher/Details: APS March Meeting Abstracts. abstract id. Q23.008

Abstract: A widely observed phenomenon in laser-directed growth of ordered arrays of nanostructures is that the feature size of fabricated nanostructures is much larger than the theoretically predicted value from calculating the atom accumulation due to laser focusing. We examine the diffusion effect on the size broadening by considering two major diffusion processes for deposited atoms, namely terrace diffusion and step-edge descending. A criterion is derived to predict the size evolution of nanostructures, which is a function of terrace diffusion barrier, Ehrlich-Schwoebel step-edge barrier, substrate temperature, deposition flux, and laser properties. Our predicted value of the feature width of aluminum quantum wires is in excellent agreement with the experimental findings. Research to predict the feature size for chromium and other materials is in progress.

Title: Lasers and Laser Optics-Simultaneous injection locking of couples of high-power broad-area lasers driven by a common current source

Date: 2002

Type: Journal Article

Authors: Yun Liu, Hua-Kuang Liu, Yehuda Braiman

Publisher/Details: Applied Optics, Vol. 41, Issue 24, pp. 5036-5039

Title: Use of a Synchronized Laser Array as a Source for Quantum Communication

Date: 2002

Type: Conference Proceeding

Authors: Y Braiman, Y Liu, HK Liu, J Barhen, RE Meyers, KS Deacon

Publisher/Details: SPIE Free-Space Laser Communication Conference

Title: Amplitude dropout in coupled lasers

Date: 11/15/2000

Type: Journal Article

Authors: AI Khibnik, Y Braiman, V Protopopescu, TAB Kennedy, K Wiesenfeld

Publisher/Details: Phys. Rev. A 62, 063815

DOI: https://doi.org/10.1103/PhysRevA.62.063815

Abstract: We study the entrainment of coupled solid-state lasers by an external injected field. We show that the total output intensity exhibits unexpected nonmonotonic behavior as a function of the injected field and find the critical amplitude marking the transition to the low-intensity branch. In addition, we also show that substantial partial entrainment can be achieved for injected fields much weaker than that required for full entrainment.

Title: Neuromorphic pattern recognition using arrays of quantum dots

Date: 07/23/2000

Type: Conference Proceeding

Authors: J Barhen, J Wells, V Protopopescu, Y Braiman

Publisher/Details: Proceedings of Fourth World Multiconference on Systemics, Cybernetics and Informatics

Abstract: Revolutionary advances in computing, communication, detection, and sensing using nanoscale devices subsume a profound understanding of the complex dynamics of small arrays of quantum structures. Such arrays produce bi-stable and multi-stable robust behavior, which can be harnessed for unconventional, yet powerful computational concepts. In this paper, we propose a novel approach to signal pattern analysis using an array of quantum dots (QD). Our methodology combines an ultrafast neuromorphic learning algorithm with photon-assisted tunneling in the QD array. The latter enables emulation of the plasticity of neural synapses.

Title: Biophysical Directed Assembly of Nanotructures for Neurocomputing

Date: 05/15/2000

Type: Conference Proceeding and Paper

Authors: JC Wells, L Mayaz, K Stevenson, TG Thundat, J Barhenl, Y Braiman, V Protopopescu

Publisher/Details: Eighteenth Symposium of Energy Engineering Sciences

Abstract: This paper reports progress in the development of a quantum-dot array that can be operated at room temperature for carrying out nontrivial and innovative computations. We discuss the actual fabrication of 2-rim metal clusters to serve as the quantum dots, device architecture, device simulation,

and the development of a computational model. Innovative and unconventional paradigms underlie the different stages of this work. For example, regular array geometry is achieved by directing appropriately derivatized metal clusters to preselected locations along a stretched strand of an engineered DNA sequence. The proposed applications include the implementation of neuromorphic algorithms for pattern recognition.

Title: Friction and Phase Synchronization

Date: 03/2000

Type: Abstract

Authors: Y Braiman, V Protopopescu, F Family, H.G.E Hentschel

Publisher/Details: American Physical Society, Annual March Meeting, March 20-24, 2000 Minneapolis, MN, abstract id. E9.003

Abstract: **S**patiotemporal fluctuations in small discrete nonlinear arrays affect the dynamics of the center of mass. We derive the equations describing the dynamics of the center of mass and the spatial fluctuations for each coherent mode of the array. Analysis of these equations indicates that depending on array stiffness, size, and the external forcing - quantized jumps occur in the minimum friction (maximum velocity) of the array. We propose an analytical formalism to determine the occurrences of these jumps. We present numerical evidence indicating that phase synchronization is related to the frictional properties of sliding objects at the atomic scale and discuss mechanisms of tuning and controlling nanoscale friction.

Title: Friction at the Nanoscale

Date: 03/14/2000

Type: Journal Article

Authors: Fereydoon Family, HGE Hentschel, Y Braiman

Publisher/Details: J. Phys. Chem. B 2000, 104, 16, 3984–3987

DOI: https://doi.org/10.1021/jp994260i

Abstract: Dissipation mechanisms at the nanoscale are influenced by finite size effects that may significantly affect the frictional response of sliding objects. In particular, locking of temporal and spatial dynamics may introduce several distinct modes of motion leading to friction selection. Here, we discuss such nonlinear mechanisms leading to stick−slip dynamics at the atomic scale.

Title: Friction Selection in Nonlinear Particle Arrays

Date: 07/05/1999

Type: Journal Article

Authors: HGE Hentschel, F Family, Y Braiman

Publisher/Details: Phys. Rev. Lett. **83**, 104

DOI: https://doi.org/10.1103/PhysRevLett.83.104

Abstract: When a discrete nonlinear array is driven across a periodic surface spatially coherent modes of motion can coexist associated with different average velocities due to resonant parametric forcing of the particle fluctuations by the center of mass motion. Depending on the coupling strength κ and size of the array N, jumps in the minimum friction (maximum velocity) exhibited by the array occur at κm[fo](N)~(N/m)2 as new modes stabilize and are selected by the dynamics. The existence of such coherent modes allows both an effective low dimensional description of the dynamics to exist and the possibility for control of friction close to these instabilities.

Title: Tuning friction with noise and disorder

Date: 05/1/1999

Type: Journal Article

Authors: Y Braiman, HGE Hentschel, F Family, C Mak, J Krim

Publisher/Details: American Physical Society, Phys. Rev. E 59, R4737(R)

DOI: https://doi.org/10.1103/PhysRevE.59.R4737

Abstract: We present numerical and experimental evidence which demonstrates that under certain conditions friction can be reduced by spatial disorder and/or thermal noise. We discuss possible mechanisms for this behavior.

Title: Nanoscale Science, Engineering and Technology Research Directions

Date: 01/01/1999

Type: Report

Authors: Lowndes, D H; Alivisatos, A P; Alper, M; Averback, R S; Jacob Barhen, J; Eastman, J A; Imre, D; Lowndes, D H; McNulty, I; Michalske, T A; Ho, K-M; Nozik, A J; Russell, T P; Valentin, R A; Welch, D O; Barhen, J; Agnew, S R; Bellon, P; Blair, J; Boatner, L A ; Braiman, Y; Budai, J D; Crabtree, G W; Feldman, L C; Flynn, C P; Geohegan, D B; George, E P; Greenbaum, E; Grigoropoulos, C; Haynes, T E; Heberlein, J; Hichman, J; Holland, O W; Honda, S; Horton, J A; Hu, M Z -C; Jesson, D E; Joy, D C; Krauss, A; Kwok, W -K; Larson, B C; Larson, D J; Likharev, K; Liu, C T; Majumdar, A; Maziasz, P J; Meldrum, A; Miller, J C; Modine, F A; Pennycook, S J; Pharr, G M; Phillpot, S; Price, D L; Protopopescu, V; Poker, D B; Pui, D; Ramsey, J M; Rao, N; Reichl, L; Roberto, J; Saboungi, M-L; Simpson, M; Strieffer, S; Thundat, T; Wambsganss, M; Wendleken, J; White, C W; Wilemski, G; Withrow, S P; Wolf, D; Zhu, J H; Zuhr, R A; Zunger, A; Lowe, S

Publisher/Details: DOESC (USDOE Office of Science (SC))

DOI: https://doi.org/10.2172/899254

Abstract: This report describes important future research directions in nanoscale science, engineering and technology. It was prepared in connection with an anticipated national research initiative on nanotechnology for the twenty-first century. The research directions described are not expected to be inclusive but illustrate the wide range of research opportunities and challenges that could be undertaken through the national laboratories and their major national scientific user facilities with the support of universities and industry.

Title: Quenched disorder enhances chaotic diffusion

Date: 10/01/1998

Type: Journal Article

Authors: M. N. Popescu, Y. Braiman, F. Family, and H. G. E. Hentschel

Publisher/Details: Phys. Rev. E 58, R4057(R)

DOI: https://doi.org/10.1103/PhysRevE.58.R4057

Abstract: We show that chaotic diffusion of a single particle moving on a one-dimensional rough surface is enhanced by a small amount of spatial quenched disorder. In addition to enhanced diffusion we also find that there is a crossover from expanding to bounded motion. The crossover time to bounded motion decreases with increasing disorder, and there exists a threshold value of disorder above which chaotic motion is completely suppressed.

Title: Spatial Coherence and Size Effects in Nanoscale Friction

Date: 03/1998

Type: Abstract

Authors: H.G.E Hentschel, Y. Braiman, F. Family

Publisher/Details: American Physical Society, Annual March Meeting, March 16-20, 1998 Los Angeles, CA, abstract id. Y22.10

Abstract: We investigate the frictional behaviour in nanoscale particle arrays due to the appearance of coherent spatial modes in their driven dissipative dynamics. Numerical simulations suggest that as a function of array size and coupling different spatially coherent modes are selected by the dynamics. Associated quantized jumps are observed in the friction of the array. Theoretically such mode selection can be understood as occuring via resonant parametric forcing of the particle fluctuations by the centre of mass dynamics. We discuss the dependence of mode selection on system size, and the magnitude of associated spatiotemporal fluctuations in the driven array.

Title: Reducing Friction by Quenched Disorder

Date: 03/1998

Type: Abstract

Authors: Y. Braiman, F. Family, H.G.E Hentschel

Publisher/Details: American Physical Society, Annual March Meeting, March 16-20, 1998 Los Angeles, CA, abstract id. Y22.09

Abstract: We present numerical and theoretical evidence that quenched disorder can reduce dry friction in array of coupled particles moving on periodic and rough surfaces. We discuss possible mechanisms of such behavior in three different dynamical regimes : (a) in a limit when the nonlinear substrate potential dominates the dynamics, and therefore attractor hopping and the interplay between the basins of attraction

leads to decrease in friction by disorder; (b) in a limit when thermal noise and dissipation is large, and stick-slip motion controls the dynamics; (c) in the limit where dissipation is small, and friction is reduced by disorder at short times, leading to a transition from the pinned state to sliding, though friction will be increased by disorder for long times. We will discuss possible experimental setups to observe this behavior.

Title: Phase model analysis of two lasers with injected field

Date: 01/1998

Type: Journal Article

Authors: A.I Khibnik, Y. Braiman, T.A.B Kennedy, K. Wiesenfeld

Publisher/Details: Physica D: Nonlinear Phenomena, Volume 111, Issues 1–4, Pages 295-310

DOI: https://doi.org/10.1016/S0167-2789(97)80017-6

ISSN: 0167-2789

Abstract: We study the dynamics of two coupled solid state lasers subject to an injected field. A singular perturbation technique is used to reduce the full set of rate equations; we present a comprehensive bifurcation analysis of the resulting phase model. We find four distinct routes to full entrainment as the injected field amplitude increases; bifurcation diagram predicts that the entrainment (reflected in the total intensity) does not monotonically improve with the injected field strength. Our numerical simulations suggest that the reduced phase model captures the relevant dynamics well beyond the asymptotic regime in which it is derived.

Title: Nonlinearity and attractor hopping in stick-slip motion

Date: 07/04/1997

Type: Conference Proceeding

Authors: F. Family, Y. Braiman, H.G.E Hentschel

Publisher/Details: World Scientific; Friction, Arching, Contact Dynamics-Proceedings Of The Workshop, pp. 93-100

Title: Effects of Noise and Disorder on the Dynamics of Nonlinear Oscillator Chains

Date: 03/1997

Type: Abstract

Authors: H.G.E Hentschel, F. Family, Y. Braiman

Publisher/Details: APS March Meeting Abstracts. American Physical Society, Annual March Meeting, March 17-21, 1997, abstract id. A28.01

Abstract: We present the results of our studies of thermal noise and quenched disorder on stick-slip motion and friction in a 1D array of nearest-neighbor coupled nonlinear oscillators, all subject to the same

external force. Sufficient thermal noise destroys periodic stick-slip motion and results in irregular but increased stick-slip motion due to thermally induced attractor hopping resulting in a friction coefficient which decreases with noise by an Arrhenius factor. Spatial disorder can induce phase synchronization, improve signal transmission and eliminate chaos from nonlinear chains. Introducing quenched disorder, in addition to thermal noise, leads to "disorder-induced lubrication" above a critical disorder level due to such increased synchronization in the chain dynamics.

Title: Nonlinear friction in the periodic stick-slip motion of coupled oscillators

Date: 02/15/1997

Type: Journal Article

Authors: Y. Braiman, F. Family, and H. G. E. Hentschel

Publisher/Details: Phys. Rev. B 55, 5491

DOI: https://doi.org/10.1103/PhysRevB.55.5491

Abstract: We suggest that coupling-induced orbit hopping is one possible mechanism for stick-slip dynamics. This mechanism is dominant in the highly nonlinear regime. Our example is a one-dimensional array of nonlinearly coupled oscillators subject to a strong periodic potential. The nonlinear dynamics leads to a fundamentally different friction law, in particular when the driving force is barely larger than the minimal force needed to start motion. We find a dramatic increase in the friction coefficient of the array compared to that of a single uncoupled oscillator, even though the same constant force f is applied to each oscillator in the array. The sliding friction coefficient η is found to diverge as $\eta \propto (\kappa\text{-}\kappa c)^{-1/2}$, where κc is the critical value of the coupling constant κ. The coefficient η also grows linearly with the number of elements in the array N and shows dynamical transitions as the external force f applied to each of the oscillators is increased.

Title: Discrete voltage states in one-dimensional parallel array of Josephson junctions

Date: 05/27/1996

Type: Research Article

Authors: Y. Braiman; F. Family; H. G. E. Hentschel

Publisher/Details: Appl. Phys. Lett. 68, 3180–3182

DOI: https://doi.org/10.1063/1.115817

Abstract: We study low-voltage dynamics in highly discrete one-dimensional arrays of Josephson junctions. In particular, we focus on the resonant solutions emerging from the locking between the time period of the oscillations of the single junction with the spatial period of the wave propagating across the array. We find that the average voltage across the array scales as $V \propto (\kappa - \kappa c)^{1/2}$, where κ*c* is the critical value of the coupling. The connections to high voltage solutions are discussed.

Title: Array-enhanced friction in the periodic stick-slip motion of nonlinear oscillators

Date: 04/01/1996

Type: Journal Article

Authors: Y. Braiman, F. Family, and H. G. E. Hentschel

Publisher/Details: Phys. Rev. E 53, R3005(R)

DOI: https://doi.org/10.1103/PhysRevE.53.R3005

Abstract: We study the nonlinear contribution to stick-slip motion in a weakly coupled discrete one-dimensional array of oscillators subject to a periodic potential. We find a dramatic increase in the friction coefficient of the array compared to that of a single uncoupled oscillator, even though the same constant force f is applied to each oscillator in the array. The sliding friction coefficient is found to diverge as $\eta \propto (\kappa - \kappa c) - 12$, where κc is the critical value of the coupling constant κ, and shows two dynamical transitions as we increase the external force f applied to each of the oscillators.

Title: Low Voltage Dynamics in 1D Parallel Arrays of Josephson Junctions

Date: 03/1996

Type: Abstract

Authors: Y. Braiman, F. Family, G. Hentschel

Publisher/Details: American Physical Society, Annual March Meeting, March 17-22, 1996, abstract id. N10.08

Abstract: We study low-voltage dynamics in highly discrete slightly underdamped chains of Josephson junctions. In particular, we focus on the resonant solutions emerging from the locking between the temporal dynamics of the single junction with the spatial dynamics of the linear wave propagating across the array. We have developed a simple formalism to reduce the complexity of the equations and to calculate the average voltage in the array in highly nonlinear regime. The average voltage across the array scales as V ∝ (κ-κ_c)^1/2, where κ is the the coupling constant. The connections to high voltage solutions will be discussed.

Title: Array Enhanced Friction in Periodic Stick-Slip Motion of Nonlinear Oscillators

Date: 03/1996

Type: Abstract

Authors: G. Hentschel, F. Family, Y. Braiman

Publisher/Details: American Physical Society, Annual March Meeting, March 17-22, 1996, abstract id. N24.08

Abstract: We present the results of our study of stick-slip motion in a 1D array of nearest-neighbor coupled nonlinear oscillators, all subject to the same external force. Our motivation is to study friction and the underlying mechanism leading to stick-slip motion in the strongly nonlinear regime. We have developed simple formalism to reduce the complexity of the equations and to calculate the velocity and the friction coefficient of the elements in the array. We find a dramatic increase in the sliding friction coefficient $\eta \propto N(\kappa - \kappa_c)^{-1}/2$ as κ arrow κ_c, where N is the number of oscillators in the array, and κ is the coupling constant.

Title: Noise and Quenched Disorder in Nonlinear Friction in a Stick-Slip Motion of a 1D Chain Adsorbed on a Disordered Substrate

Date: 03/1996

Type: Abstract

Authors: Y. Braiman, F. Family, G. Hentschel

Publisher/Details: American Physical Society, Annual March Meeting, March 17-22, 1996, abstract id. N24.10

Abstract: We study friction and the underlying mechanism for stick-slip motion in a 1D array of nearest-neighbor coupled nonlinear chain placed on a disordered substrate potential. We concentrate on the strongly nonlinear regime (where the contribution of the substrate potential is high). The external forcing is applied either to each one of oscillators or to the right-end oscillator, and we introduce small coupling between the elements of an array and the substrate. We discuss the effect of thermal noise and disorder on the dynamics in an array. In particular, we concentrate on friction coefficient (both static and sliding) and the interrelation of noise and disorder to the parameters characterizing single oscillator and the coupling in array.

Title: Control of chaos in multimode solid state lasers by the use of small periodic perturbations

Date: 01/01/1996

Type: Journal Article

Authors: Pere Colet, Yehuda Braiman

Publisher/Details: Phys. Rev. E 53, 200

DOI: https://doi.org/10.1103/PhysRevE.53.200

Abstract: We present a numerical study of control of chaos in a model of a multimode neodymium-doped yttrium aluminum garnet laser using periodic perturbations of accessible control parameters. We show that a small modulation of either the losses or the pump can eliminate chaos or make the system even more chaotic. Depending on the parameters of the perturbation, two qualitatively different periodic outputs can be achieved.

Title: Effect of disorder on synchronization in prototype two-dimensional Josephson arrays

Date: 01/01/1995

Type: Journal Article

Authors: A. S. Landsberg, Y. Braiman, and K. Wiesenfeld

Publisher/Details: Phys. Rev. B 52, 15458

DOI: https://doi.org/10.1103/PhysRevB.52.15458

Abstract: We study the effects of quenched disorder on the dynamics of two-dimensional arrays of overdamped Josephson junctions. Disorder in both the junction critical currents and resistances is considered. Analytical results for small arrays are used to identify a physical mechanism which promotes frequency locking across each row of the array, and to show that no such locking mechanism exists between rows. The intrarow locking mechanism is surprisingly strong, so that a row can tolerate large amounts of disorder before frequency locking is destroyed.

Title: Taming spatiotemporal chaos with disorder

Date: 11/30/1995

Type: Journal Article

Authors: Y. Braiman, John F. Lindner, William L. Ditto

Publisher/Details: Nature, volume 378, pages 465–467

DOI: https://doi.org/10.1038/378465a0

Abstract: DISORDER and noise in physical systems usually tend to destroy spatial and temporal regularity, but recent research into nonlinear systems provides intriguing counterexamples. In the phenomenon of stochastic resonance[1], for example, the presence of noise improves the ability of some nonlinear systems to transfer information reliably. Noise can also remove chaos in a model oscillator[2], and facilitate synchronization in an extended array of bistable elements[3]. Here we explore the use of disorder as a means to control spatiotemporal chaos[4–8] in coupled arrays of forced, damped, nonlinear oscillators. Chaotic behaviour in spatially extended systems, especially in biology and physiology[9,10], might be amenable to control, as occurs in low dimensional temporally chaotic systems[11,12]. In our numerical experiments, one and twodimensional arrays of identical oscillators behave chaotically, but the introduction of slight, uncorrelated differences between the oscillators induces ordered motion characterized by complex but regular spatiotemporal patterns.

Title: Disorder-enhanced synchronization

Date: 10/02/1995

Type: Journal Article

Authors: Y. Braiman, W.L. Ditto, K. Wiesenfeld, M.L. Spano

Publisher/Details: Volume 206, Issues 1–2, 2 October 1995, Pages 54-60

DOI: https://doi.org/10.1016/0375-9601(95)00570-S

Abstract: We find that an increase in the disorder of an array of Josephson junctions can lead to significant improvement in the synchronization of the array. Both this effect and the opposite, more expected behavior are seen over a broad parameter range.

Title: Disorder and synchronization in a Josephson junction plaquette

Date: 09/25/1995

Type: Research Article

Authors: A. S. Landsberg; Y. Braiman; K. Wiesenfeld

Publisher/Details: Appl. Phys. Lett. 67, 1935–1937

DOI: https://doi.org/10.1063/1.114573

Abstract: We describe the effects of disorder on the coherence properties of a 2×2 array of Josephson junctions (a ‘‘plaquette’’). The disorder is introduced through variations in the junction characteristics. We show that the array will remain one-to-one frequency locked despite large amounts of the disorder, and determine analytically the maximum disorder that can be tolerated before a transition to a desynchronized state occurs. Connections with larger $N\times M$ arrays are also drawn.

Title: Entrainment of solid-state laser arrays

Date: 08/01/1995

Type: Journal Article

Authors: Y. Braiman, T. A. B. Kennedy, K. Wiesenfeld, and A. Khibnik

Publisher/Details: Phys. Rev. A 52, 1500

DOI: https://doi.org/10.1103/PhysRevA.52.1500

Abstract: We find that the natural antiphasing tendency in linear solid-state laser arrays can be overcome by an injected field, even if the N elements are not identical. We derive a condition for full entrainment that agrees well with numerical simulations using experimentally accessible parameters. The resulting output intensity saturates near the maximum coherent value of $N2$ times that of a single laser. We find that the entrained output can be modulated in a prescribed manner by a suitable choice of the injected field.

Title: Energy localization and delocalization in a nonlinear chain on a substrate

Date: 08/01/1994

Type: Journal Article

Authors: Y. Braiman, I. Goldhirsch, J. Klafter

Publisher/Details: Phys. Rev. E 50, 838

DOI: https://doi.org/10.1103/PhysRevE.50.838

Abstract: The dynamics of a linear chain of atoms with a central heavy atom is shown to be significantly affected by the presence of an external periodic potential representing a substrate. The system exhibits several dynamical phases, some of which are consequences of the existence of the substrate. The phases differ in the degree of energy localization and in other dynamical properties. It is shown that, unlike in a chain that is not subject to an external potential, energy localization is possible for heavy to light mass ratios that are of order one. Possible chemical applications are briefly mentioned.

Title: Global stabilization of a Josephson-junction array

Date: 06/01/1994

Type: Journal Article

Authors: Y. Braiman and K. Wiesenfeld

Publisher/Details: Phys. Rev. B 49, 15223

DOI: https://doi.org/10.1103/PhysRevB.49.15223

Abstract: We show that the addition of a weak periodic drive can stabilize the in-phase state of a current-biased series array of *N* Josephson junctions. The stabilization can be predicted by a local analysis of an effective one-junction problem regardless of *N*. In the parameter regime considered, the stabilization appears to be global.

Title: Symmetry properties of finite Frenkel-Kontorova chains

Date: 05/01/1993

Type: Journal Article

Authors: Y. Braiman, J. Baumgarten, J. Klafter

Publisher/Details: Phys. Rev. B 47, 11159

DOI: https://doi.org/10.1103/PhysRevB.47.11159

Abstract: We investigate the symmetry properties of finite Frenkel-Kontorova chains with free-end boundary conditions. A symmetry-breaking transition is found as one varies η, the relative strength of the harmonic and substrate interactions. This transition, from a symmetric configuration to a configuration with broken symmetry at η=η*c*, is characterized by a gap in the phonon spectrum and by disorder and reflection-symmetry parameters, all of which display the scaling behavior (η*c*-η)0.5. The chains are shown to be pinned both below and above the symmetry-breaking transition.

Title: Taming chaotic dynamics with weak periodic perturbations

Date: 05/20/1991

Type: Journal Article

Authors: Y. Braiman and I. Goldhirsch

Publisher/Details: Phys. Rev. Lett. 66, 2545

DOI: https://doi.org/10.1103/PhysRevLett.66.2545

Abstract: The possibility of eliminating chaos in a dynamical system or of decreasing the leading Liapunov exponent by applying a *weak* periodic external forcing to the system is demonstrated through the example of a periodically driven pendulum. The applications of the external forcing also results in other striking changes in the dynamics such as a stabilization of narrow subharmonic steps and the achievement of very low winding numbers.

Title: Symmetry-breaking transition in finite Frenkel-Kontorova chains

Date: 11/05/1990

Type: Journal Article

Authors: Y. Braiman, J. Baumgarten, Joshua Jortner, and J. Klafter

Publisher/Details: Phys. Rev. Lett. 65, 2398

DOI: https://doi.org/10.1103/PhysRevLett.65.2398

Abstract: In this Letter we investigate a symmetry-breaking transition in the Frenkel-Kontorova model for finite chains with free-end boundary conditions. We present a detailed study of the behavior in the vicinity of the transition. It is shown that the gap in the phonon spectrum, the disorder parameter, and the reflection-symmetry parameter display scaling properties close to the transition. Their associated critical exponents are discussed and related to the displacements of the particles in the chains.

Title: Microwave-induced ''Devil's Staircase'' structure and ''chaotic'' behavior in current-fed Josephson junctions

Date: 05/15/1981

Type: Research Article

Authors: E. Ben-Jacob; Y. Braiman; R. Shainsky; Y. Imry

Publisher/Details: Appl. Phys. Lett. 38, 822–824

DOI: https://doi.org/10.1063/1.92145

Abstract: We have obtained the various types of I-V characteristics measured experimentally and in analog simulations, by merely changing the junction and the microwave parameters within the same resistively shunted junction model with purely sinusoidal current-phase relation. It was found that the subharmonic steps do exist in the limit $\beta c \rightarrow 0$, though they can have finite rounding without thermal noise. The statistical properties of the ''chaotic'' solutions wer e discussed and their effective temperature was defined and calculated.

Title: Current noise effects on the microwave induced steps in current fed Josephson junctions

Date: 01/1981

Type: Journal Article

Authors: Y. Braiman, E. Ben-Jacob, Y. Imry

Publisher/Details: IEEE Transactions on Magnetics, Volume: 17, Issue: 1

DOI: 10.1109/TMAG.1981.1060952

Abstract: Harmonic and subharmonic microwave induced steps in the I-V characteristics of current fed Josephson junction were found and investigated by numerical and approximate analytical methods, for a purely sinusoidal Josephson current. The dependence of the steps on the various parameters is given and their local stability is discussed. Various types of I-V characteristics are shown. We have introduced thermal noise effects via a Langevin term in the equation of motion. The smaller steps are easily washed out by the thermal noise. The width of the fundamental step was found to be proportional to $T^{x}$for the range of parameters which we used, wherex \gsim 1/2.

Title: Microwave induced harmonic and subharmonic steps in the IV characteristics of current fed Josephson junctions

Date: 05/1980

Type: Book Chapter / Conference Proceeding

Authors: Y. Braiman, E. Ben-Jacob and Y. Imry

Publisher/Details: SQUID ’80. Superconducting Quantum Interference Devices and their Applications

Proceedings of the Second International Conference on Superconducting Quantum Devices (SQUID 80), Berlin (West), May 6–9, 1980

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