

Generation and Propagation of Flexoelectricity-Induced Solitons in Nematic Liquid Crystals

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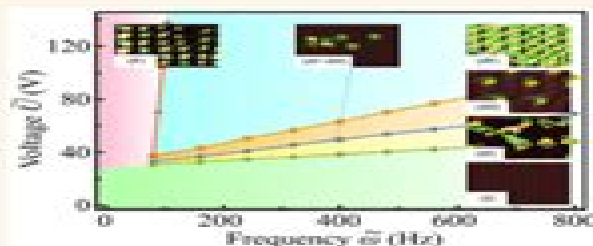
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ABSTRACT: Solitons in nematic liquid crystals facilitate the rapid transport and sensing in microfluidic systems. Little is known about the elementary conditions needed to create solitons in nematic materials. In this study, we apply a combination of theory, computational simulations, and experiments to examine the formation and propagation of solitary waves, or “solitons”, in nematic liquid crystals under the influence of an alternating current (AC) electric field. We find that these solitary waves exhibit “butterfly”-like or “bullet”-like structures that travel in the direction perpendicular to the applied electric field. Such structures propagate over long distances without losing their initial shape. The theoretical framework adopted here helps identify several key factors leading to the formation of solitons in the absence of electrostatic interactions. These factors include surface irregularities, flexoelectric polarization, unequal elastic constants, and negative anisotropic dielectric permittivity. The results of simulations are shown to be in good agreement with our own experimental observations, serving to establish the validity of the theoretical concepts and ideas advanced in this work.

KEYWORDS: soliton, nematic achiral liquid crystal, flexoelectricity, mechanism of generation, dynamic process



Solitons are wave packets that maintain their shape while propagating at a constant speed over long distances.

This preservation of shape is attributed to a nonlinear feedback mechanism that counteracts dispersion during their journey.^{1–3} Solitons have a widespread presence in nature, with manifestations observed in narrow water channels, proteins and DNA, optical fibers, magnets, and even in nuclear physics.^{4–6} Several recent reports have documented the emergence of solitons in liquid crystals (LCs) under an applied AC electric field.⁷ Potential applications of solitons include long-distance information carriers for optical signals or for particles and chemical species within nematic LCs.

In liquid crystals, three-dimensional solitons are typically observed near surface imperfections, dust particles, or electrode edges, traveling long distances perpendicular to the director field.^{8,9} Initial observations of such solitons were made by P. Cladis and colleagues¹⁰ decades ago. More recently, several research groups^{11–16} have explored solitons from an experimental perspective, while others have considered various underlying theoretical aspects.^{17–23}

Recent reports have discussed the motion of topological three-dimensional structures in AC fields, such as twist walls and skyrmions, by invoking the nonreciprocal evolution of the

director field.^{23–27} These findings illustrate how the “squirming” nonreciprocal evolution of the director, due to the intrinsic properties of nonpolar LCs, can generate the movement of localized solitonic structures. Chirality is believed to play a key role in the formation of these topological structures. Specifically, recent reports indicate that the presence of chirality allows for a broader range of folding modes, and topological solitons with Möbius structures can be manipulated by adjusting the induced AC field.²⁸ In our own work, in the process of generating solitons, we find that flexoelectricity plays a central role in the stabilization of solitons, which is reminiscent of the effects of chirality.

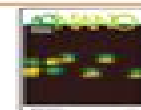
Experimental evidence suggests that solitons initially display quadrupolar symmetry at low frequencies, transforming into bullet-like structures with a curved director field at higher

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Solitons In Liquid Crystals

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Solitons In Liquid Crystals:

Solitons in Liquid Crystals Lui Lam, Jacques Prost, 2012-12-06 Solitons are a well known and intriguing aspect of nonlinear behavior in a continuous system such as a fluid a wave propagates through the medium without distortion Liquid crystals are highly ordered systems without a rigid long range structure Solitons in liquid crystals sometimes referred to as walls have a wide variety of remarkable properties that are becoming important for practical applications such as electroluminescent display This book the first review of the subject to be published contains not only surveys of the existing literature but presents new results as well

Nematicons Gaetano Assanto, 2012-10-16 The first book of its kind to introduce the fundamentals basic features and models potential applications and novel phenomena and its important applications in liquid crystal technology Recognized leader in the field Gaetano Assanto outlines the peculiar characteristics of nematicons and the promise they have for the future growth of this captivating new field

Solitons in Liquid Crystals Yuan Shen, 2022

Solitons in Liquid Crystals L Lam (ed), 1992

Introduction to Topological Defects and Solitons Jonathan V. Selinger, 2024-10-14 This textbook introduces topological defects and solitons at a level suitable for advanced undergraduates and beginning graduate students in physics and materials science It avoids the formal mathematics of topology and instead concentrates on the physical properties of these topological structures The first half of the book concentrates on fundamental principles of defects and solitons and illustrates these principles with a single example the xy model for 2D magnetic order It begins by defining the concept of a winding number and uses this concept to describe the topology of defects vortices or disclinations and solitons domain walls carefully identifying the similarities and differences between these two types of topological structures It then goes on to discuss physical properties of defects and solitons including free energy dynamics statistical mechanics and coupling with curvature It shows how these concepts emerge from a theory with variable magnitude of order and hence how topology can be viewed as an approximation to physics The second half goes on to explore a wider range of topological defects and solitons First it considers more complex types of order 2D nematic liquid crystals 3D magnetic or liquid crystal order 2D or 3D crystalline solids and shows how each type of order leads to specific topological structures Next it discusses defects and solitons that are characterized by 2D or 3D measuring surfaces not just 1D loops including hedgehogs skyrmions and hopfions These structures are more complex but they can still be understood using the same fundamental principles A final chapter describes the formation of phases with regular arrays of defects or solitons

Soliton-driven Photonics A.D. Boardman, A.P. Sukhorukov, 2012-12-06 It is ironic that the ideas of Newton which described a beam of light as a stream of particles made it difficult for him to explain things like thin film interference Yet these particles called photons have caused the adjective photonic to gain common usage when referring to optical phenomena The purist might argue that only when we are confronted by the particle nature of light should we use the word photonics Equally the argument goes on only when we are face to face with an integrable system i e one that possesses

an infinite number of conserved quantities should we say soliton rather than solitary wave Scientists and engineers are pragmatic however and they are happy to use the word soliton to describe what appears to be an excitation that is humped multi humped or localised long enough for some use to be made of it The fact that such solitons may stick to each other fuse upon collision is often something to celebrate for an application rather than just evidence that after all these are not really solitons in the classic sense Soliton therefore is a widely used term with the qualification that we are constantly looking out for deviant behaviour that draws our attention to its solitary wave character In the same spirit photonics is a useful generic cover all noun even when electromagnetic theory or optics would suffice

Nonlinear Physics For Beginners: Fractals, Chaos, Solitons, Pattern Formation, Cellular Automata And Complex Systems Lui Lam, 1998-03-31 Almost all real systems are nonlinear For a nonlinear system the superposition principle breaks down The system's response is not proportional to the stimulus it receives the whole is more than the sum of its parts The three parts of this book contains the basics of nonlinear science with applications in physics Part I contains an overview of fractals chaos solitons pattern formation cellular automata and complex systems In Part II 14 reviews and essays by pioneers as well as 10 research articles are reprinted Part III collects 17 students projects with computer algorithms for simulation models included The book can be used for self study as a textbook for a one semester course or as supplement to other courses in linear or nonlinear systems The reader should have some knowledge in introductory college physics No mathematics beyond calculus and no computer literacy are assumed

Liquid Crystals : Optics and Applications Tomasz R. Woliński, Marc Warenghem, Shin-Tson Wu, 2005 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in patent literature

Modern Topics In Liquid Crystals: From Neutron Scattering Ferroelectricity Agnes Buka, 1993-12-17 This volume contains 19 review articles written by leading experts in the field of neutron scattering NMR dielectric spectroscopy ferroelectricity liquid crystal polymers as well as related subjects The articles cover a broad range of topics which are currently the center of focus and interest in this field The book will be useful for experienced researchers as well as students and those who want to enter the field Apart from the fact that such a publication covers a gap in the literature there is also a personal actuality This volume will be devoted to Professor L Bata who started the liquid crystal research in Hungary some 25 years ago and who is still head of the department at KFKI today He initiated a lot of new subjects in the field and supported many young scientists during these years He is celebrating his 60th birthday this year

Voltage-Sensitive Ion Channels H. Richard Leuchtag, 2008-12-21 The goal of this book is to explore the complexity of a microscopic bit of matter that exists in a myriad of copies within our bodies the voltage sensitive ion channel We seek to investigate the way in which these macromolecules make it possible for the long fibers of our nerve and muscle cells to conduct impulses These integral

components of cell membranes are marvels of nature's evolutionary adaptation. To understand them we must probe the boundaries of physics and chemistry. Since function is intimately related to structure we examine the molecular structure of channels focusing on physical principles that govern all matter. With the application of genetic methods our knowledge of ion channels has broadened and deepened. In the hope that research can help ameliorate suffering we discuss the diseases that arise from channel malfunctions due to genetic mutations. This book is intended for students and scientists who are willing to travel into uncharted waters of an interdisciplinary science. We approach the subject of voltage sensitive ion channels from various points of view. This book seeks to give voice to the viewpoints of the physical and the biological scientist and to bridge gaps in terminology and background. Readers may find this book to have both elementary and advanced aspects. For the reader trained in the biological sciences it reviews background in physics and chemistry; for the reader trained in the physical sciences it reviews background in physiology and biochemistry.

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