

Orientalional Optical Nonlinearity of Nematic Liquid Crystals Induced by High-Molecular-Mass Azo-Containing Compounds¹

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Abstract—Processes of light-induced reorientation of nematic liquid-crystalline molecules induced by the addition of low concentrations (0.1–2.0 wt %) of comb-shaped polymers and carbosilane dendrimers containing azobenzene fragments are studied. When the molecular structure of the above compounds becomes more complicated, the induced orientational nonlinearity increases. The introduction of 2G and 3G dendrimers into a nematic has for the first time made it possible to visualize and study a purely optical first-order Fredericksz transition in the field of a linearly polarized wave.

DOI: 10.1134/S0965545X11080025

INTRODUCTION

The light-induced reorientation of molecules entails changes in the refractive index of a medium and various nonlinear optical phenomena, such as self-focusing and self-defocusing, wavefront conjugation, optical bistability, and formation of solitons etc. This phenomenon can be used for data recording, control over propagation of light beams, optical modulation, and other applications. The phenomena of optical reorientation are most pronounced for a “soft matter,” whose simplest representatives are nematic liquid crystals (NLCs).

In liquid crystals, the nematic phase is produced by rodlike molecules. Owing to the action of intermolecular forces, they align primarily in one direction that is locally characterized by a unit vector, director \mathbf{n} [1, 2]. The NLC director can be easily rotated by an external low-frequency electrical field. This phenomenon serves as a basis for diverse applications of NLCs. A similar effect is observed for light fields [3–6]. A light beam passing through a layer of a transparent NLC rotates director \mathbf{n} and aligns it along the direction parallel to the direction of light field \mathbf{E} , thus increasing the refractive index of an extraordinary wave. The corresponding (“positive”) orientational optical nonlinearity of the NLC is nine orders of magnitude higher than the Kerr nonlinearity of conven-

tional liquids [4]. The mechanism of optical orientation in nonabsorbing NLCs is related to the action of light field \mathbf{E} on dipoles induced in the NLC molecules by the same field. The torque acting on molecules of a nematic matrix and normalized to the unit volume of the NLC has the form

$$\Gamma = \frac{\Delta\epsilon |A|^2}{8\pi} (\mathbf{n}\mathbf{e})[\mathbf{n}\mathbf{e}], \quad (1)$$

where $\Delta\epsilon$ is the dielectric anisotropy at the light frequency, A is the light-field amplitude, and \mathbf{e} is the light-polarization unit vector.

When a nematic matrix is doped with dye molecules, orientational optical nonlinearity can increase by three orders of magnitude (when the concentration of the additive is ~1 wt %) [7]. In the doped NLCs, the director can rotate both parallel and perpendicularly to the light-field direction. In the second case, the refractive index of the extraordinary wave decreases. (“Negative” nonlinearity is observed [8].)

The mechanisms leading to the light-induced rotation of the director in the absorbing NLCs cannot be considered indisputable, and several models of this phenomenon are known [9–14]. However, it is common knowledge that the rotation of the director requires the development of an ensemble of excited dye molecules whose orientational distribution is asymmetric with respect to the director [7]. The torque acting on the director of the absorbing NLC can be described by a relationship that is similar to Eq. (1):

¹ This work was supported by the Russian Foundation for Basic Research (project nos. 11-02-01313 and 11-03-01046) and the Federal target program Scientific and Educational Specialists of Innovation Russia (State Contract no. 0.2.7-00.1.0-047).

Orientational Optical Nonlinearity Of Liquid Crystals

Iam-Choon Khoo

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Nonlinear Optics of Organic Molecules and Polymers Hari Singh Nalwa, Seizo Miyata, 2020-07-09 The field of nonlinear optics emerged three decades ago with the development of the first operating laser and the demonstration of frequency doubling phenomena These milestone discoveries not only generated much interest in laser science but also set the stage for future work on nonlinear optics This book presents an excellent overview of the exciting new advances in nonlinear optical NLO materials and their applications in emerging photonics technologies It is the first reference source available to cover every NLO material published through 1995 All theoretical approaches measurement techniques materials technologies and applications are covered With more than 1 800 bibliographic citations 324 figures 218 tables and 812 equations this book is an invaluable reference source for graduate and undergraduate students researchers scientists and engineers working in academia and industries in chemistry solid state physics materials science optical and polymer engineering and computational science

Physics of Liquid Crystalline Materials Chor-San Heng Khoo, 1991-12-16 This work is based on lectures delivered at the summer school held in October 1988 Papers deal with microscopic properties collective phenomena elastic properties hydrodynamics linear and nonlinear optics and such diverse topics as NMR studies of liquid crystals orientational disorder and dynamics rheology of layered liquid crystals light scattering Minimal index Annotation copyrighted by Book News Inc Portland OR

Handbook of Liquid Crystals, 8 Volume Set John W. Goodby, Peter J. Collings, Takashi Kato, Carsten Tschierske, Helen Gleeson, Peter Raynes, Volkmar Vill, 2014-04-14 Much more than a slight revision this second edition of the successful Handbook of Liquid Crystals is completely restructured and streamlined with updated as well as completely new topics 100% more content and a new team of editors and authors As such it fills the gap for a definitive single source reference for all those working in the field of organized fluids and will set the standard for the next decade The Handbook s new structure facilitates navigation and combines the presentation of the content by topic and by liquid crystal type A fundamentals volume sets the stage for an understanding of the liquid crystal state of matter while individual volumes

cover the main types and forms with a final volume bringing together the diverse liquid crystal phases through their applications This unrivaled all embracing coverage represents the undiluted knowledge on liquid crystals making the Handbook a must have wherever liquid crystals are investigated produced or used and in institutions where their science and technology is taught Also available electronically on Wiley Online Library www.wileyonlinelibrary.com/ref/holc Volume 1 Fundamentals of Liquid Crystals Volume 2 Physical Properties and Phase Behavior of Liquid Crystals Volume 3 Nematic and Chiral Nematic Liquid Crystals Volume 4 Smectic and Columnar Liquid Crystals Volume 5 Non Conventional Liquid Crystals Volume 6 Nanostructured and Amphiphilic Liquid Crystals Volume 7 Supramolecular and Polymeric Liquid Crystals Volume 8 Applications of Liquid Crystals CRC Handbook of Laser Science and Technology Supplement 2 Marvin J.

Weber,2020-09-23 In the CRC Handbook of Laser Science and Technology Supplement 2 experts summarize the discovery and properties of new optical materials that have appeared since the publication of Volumes III V Included are the latest advances in optical crystals glasses and plastics laser host materials phase conjugation materials linear electrooptic materials nonlinear optical materials magneto optic materials elastooptic materials photorefractive materials liquid crystals and thin film coatings The book also includes expanded coverage of optical waveguide materials and new sections on optical liquids glass fiber lasers diamond optics and gradient index materials Appendices include Designation of Russian Optical Glasses Abbreviations Acronyms and Mineralogical or Common Names for Optical Materials and Abbreviations for Methods of Preparing Optical Materials Extensive tabulations of materials properties with references to the primary literature are provided throughout the supplement The CRC Handbook of Laser Science and Technology Supplement 2 represents the latest volume in the most comprehensive up to date listing of the properties of optical materials for lasers and laser systems making it an essential reference work for all scientists and engineers working in laser research and development

Opticals Effects in Liquid Crystals I. Jánossy,2013-11-11 In 1988 physicists and chemists commemorated the centenary of the discovery of the first liquid crystals For a long period after this discovery although many significant results were found liquid crystal research remained a marginal topic of condensed matter physics The situation changed in the sixties At that time the remarkable electro optical properties of liquid crystals were recognized and found soon widespread application in numeric displays From a more fundamental point of view the interest in disordered systems increased in general at the same time Liquid crystals represented an important class of such systems Among others phase transitions hydrodynamics and topological defects occurring in them attracted considerable attention The connection between the liquid crystalline state and the structure of biological membranes stimulated a lot of works also In the present volume we discuss a relatively new and rapidly developing branch of the field namely nonlinear optical effects in liquid crystals Optical studies have always played a significant role in liquid crystal science Research of optical nonlinearities in liquid crystals began at the end of the sixties Since then it became a powerful tool in the investigation of symmetry properties interfacial phenomena

or dynamic behaviour Furthermore several new aspects of nonlinear processes were demonstrated and studied extensively in liquid crystals The subject covered in this book is therefore of importance both for liquid crystal research and for nonlinear optics itself The term nonlinear optics is used here in a broad sense

Frontiers of Polymers and Advanced Materials Paras N. Prasad, 2012-12-06 This book presents the proceedings of the Second International Conference on Frontiers of Polymers and Advanced Materials held in Jakarta Indonesia during January 10 15 1993 This conference was organized and sponsored by the Indonesian Institute of Sciences LIPI the State University of New York SUNY at Buffalo the Agency for Assessment and Application of Technology BPPT and the Indonesian Polymer Association The 244 participants represented a total of 24 countries and a wide variety of academic industrial and government groups The inauguration was held in the Royal Palace and was performed by President Soeharto of Indonesia High level media coverage ensured worldwide recognition The need for such a conference was emphasized by the fact that polymers have emerged as an important class of materials offering challenging opportunities for both fundamental research and new technological applications There has been a tremendous growth of interest in the field of polymers both in academia and in industry and polymer science offers tremendous opportunities for both fundamental and applied work This globally represented Second International Conference on Frontiers of Polymers and Advanced Materials was timely especially given the current heightened enthusiasm for polymers and emerging novel applications

Nonlinear Optics of Liquid and Photorefractive Crystals Gertruda V. Klimusheva, Andrey G. Iljin, 1996

Nonlinear Optical Materials and Devices for Applications in Information Technology A. Miller, K.R. Welford, B. Daino, 2013-04-17 Nonlinear Optical Materials and Devices for Applications in Information Technology takes the reader from fundamental interactions of laser light in materials to the latest developments of digital optical information processing The book emphasises nonlinear optical interactions in bulk and low dimensional semiconductors liquid crystals and optical fibres After establishing the basic laser material interactions in these materials it goes on to assess applications in soliton propagation integrated optics smart pixel arrays and digital optical computing

Nonlinear Optics of Liquid and Photorefractive Crystals, 1996

Liquid Crystals Iam-Choon Khoo, 2022-01-26 The latest edition of the leading resource on the properties and applications of liquid crystals In the newly revised Third Edition of Liquid Crystals Professor Iam Choon Khoo delivers a comprehensive treatment of the fundamentals and applied aspects of optical physics light scattering electro optics and non linear optics of liquid crystals The book s opening chapters include coverage of the foundational physics and optical properties of liquid crystals and lead to more advanced content on the display photonics and nonlinear optics applications of liquid crystals New topics including photonic crystals metamaterials ultrafast nonlinear optics and fabrication methods for massive cholesteric and blue phase liquid crystals are discussed at length Analytical methods and experimental observations of nonlinear light propagation through liquid crystalline and anisotropic materials and devices are also discussed Liquid Crystals offers an insightful and unique treatment of the nonlinear optics of liquid

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Comprehensive Nanoscience and Technology , 2010-10-29 From the Introduction Nanotechnology and its underpinning sciences are progressing with unprecedented rapidity With technical advances in a variety of nanoscale fabrication and manipulation technologies the whole topical area is maturing into a vibrant field that is generating new scientific research and a burgeoning range of commercial applications with an annual market already at the trillion dollar threshold The means of fabricating and controlling matter on the nanoscale afford striking and unprecedented opportunities to exploit a variety of exotic phenomena such as quantum nanophotonic and nanoelectromechanical effects Moreover

researchers are elucidating new perspectives on the electronic and optical properties of matter because of the way that nanoscale materials bridge the disparate theories describing molecules and bulk matter. Surface phenomena also gain a greatly increased significance even the well known link between chemical reactivity and surface to volume ratio becomes a major determinant of physical properties when it operates over nanoscale dimensions. Against this background this comprehensive work is designed to address the need for a dynamic authoritative and readily accessible source of information capturing the full breadth of the subject. Its six volumes covering a broad spectrum of disciplines including material sciences, chemistry, physics and life sciences have been written and edited by an outstanding team of international experts. Addressing an extensive cross disciplinary audience each chapter aims to cover key developments in a scholarly readable and critical style providing an indispensable first point of entry to the literature for scientists and technologists from interdisciplinary fields. The work focuses on the major classes of nanomaterials in terms of their synthesis, structure and applications, reviewing nanomaterials and their respective technologies in well structured and comprehensive articles with extensive cross references. It has been a constant surprise and delight to have found amongst the rapidly escalating number who work in nanoscience and technology so many highly esteemed authors willing to contribute. Sharing our anticipation of a major addition to the literature they have also captured the excitement of the field itself in each carefully crafted chapter. Along with our painstaking and meticulous volume editors full credit for the success of this enterprise must go to these individuals together with our thanks for largely adhering to the given deadlines. Lastly we record our sincere thanks and appreciation for the skills and professionalism of the numerous Elsevier staff who have been involved in this project notably Fiona Geraghty, Megan Palmer and Greg Harris and especially Donna De Weerd Wilson who has steered it through from its inception. We have greatly enjoyed working with them all as we have with each other.

Physical Properties of Liquid Crystals George W. Gray, Volkmar Vill, Hans W. Spiess, Dietrich Demus, John W. Goodby, 2009-08-14. This handbook is a unique compendium of knowledge on all aspects of the physics of liquid crystals. In over 500 pages it provides detailed information on the physical properties of liquid crystals as well as the recent theories and results on phase transitions, defects and textures of different types of liquid crystals. An in depth understanding of the physical fundamentals is a prerequisite for everyone working in the field of liquid crystal research. With this book the experts as well as graduate students entering the field get all the information they need.

Nonlinear Optics Natalia Kamanina, 2012-02-29. Rapid development of optoelectronic devices and laser techniques poses an important task of creating and studying from one side the structures capable of effectively converting, modulating and recording optical data in a wide range of radiation energy densities and frequencies from another side the new schemes and approaches capable to activate and simulate the modern features. It is well known that nonlinear optical phenomena and nonlinear optical materials have the promising place to resolve these complicated technical tasks. The advanced idea approach and information described in this book will be fruitful for the readers to find a sustainable solution in

a fundamental study and in the industry approach The book can be useful for the students post graduate students engineers researchers and technical officers of optoelectronic universities and companies **Bibliography of Soviet Laser Developments** ,1984 **Nonlinear Optics And Optical Physics: Lecture Notes From Capri Spring School** Iam-choon Khoo,J F Lam,Francesco Simoni,1994-08-15 This book consists of contributions by leading authorities in nonlinear optics and optical physics The topics covered include fundamental theories and formalisms on nonlinear optics and current topics of interest in optical physics as well as more specialized subjects such as phase conjugation nonlinear guided waves parametric oscillations and some novel materials The coverage is comprehensive but pedagogical in nature *Organic Nonlinear Optical Materials* Manfred Eich,Mark G. Kuzyk,1999 This work brings together a selection of papers dealing with various aspects of organic nonlinear optical materials

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