C. Vijayan

Prof. C. Vijayan
Professor
Indian Institute of Technology, Madras

Department of Physics

Chennai 600036
India

tel: 91-44-22574877
fax: 505 272 7801
E-mail: cvijayan@iitm.ac.in
Web: http://www.physics.iitm.ac.in/~cvijayan

Area of Expertise

Nonlinear Optics and Nanophotonics; Novel optical materials and processes, Photonic Crystals, Optical properties of nanomaterials

Biography

Prof. C. Vijayan obtained his M. Sc. and Ph. D degrees from Indian Institute of Technology, Madras, Chennai, INDIA. He served as a senior project officer in the laser laboratory of IIT Madras during 1986-87 and joined the central University as a lecturer in 1988. Later he joined the faculty of the Department of Physics, IIT Madras in 1993 and is a senior professor there presently.

He has guided nine research students so far for their Ph. D degree and is presently guiding three more in the areas of nanomaterials, nonlinear optics and nanophotonics. He has coauthored over 70 research papers in prestigious international journals such as Physical Review, Applied Physics Letters, Journal of Applied Physics, Langmuir, JOSA and Nanotechnology and contributed chapters to three books so far. He has also been a reviewer for many of these and several other leading journals. He has been involved in several national and international research projects and interacts with research groups in USA, UK, Germany, Australia and Singapore.

Prof. Vijayan has given several invited talks in seminars and conferences in India and abroad. He has served as thesis examiner, resource person for refresher courses and as member in various academic committees of other IITs, National Institutions, National laboratories and Universities. He has also been invited to deliver lectures in Physics to UG and PG students of several colleges and universities.

Lecture Title(s)

Foundations of Nanophotonics:
This talk introduces the basic concepts of Nanophotonics, an emerging frontier of intense research activity. This field of research has evolved from the realization that a wide variety of novel phenomena that occur when light interacts with new kinds of specially designed nanostructures. These new modes of interaction are of fundamental interest in view of the fascinating physical processes involved. They also hold excellent promise for the next generation device applications in photonics.

The advent of lasers and the ensuing progress in understanding nonlinear optical response of matter were perhaps the very first milestones of the long journey from optics to nanophotonics. The next was the realization that the interaction of light with metamaterials based on periodic structures with submicron features ushers in involves a rich variety of new and interesting Physics.

One topic of intense activity has been the search for techniques to obtain efficient low threshold laser action and a seemingly unrelated topic of interest has been effects of Anderson-like localization of light within extremely small volumes. It appears that the most efficient approach so far for the realization of both these dreams is the design media made up of specially designed nanostructures where periodic variations of refractive index can be obtained.

The physics of the problem is very similar to that of interaction of electrons with a periodic potential as in the case of crystalline media. It is well known that this leads to the concept of the band gap in semiconductors and insulators. In a similar manner, the interaction of light with dielectric media with a periodic variation of high and low values of refractive indices leads to the idea of stop bands where light of certain frequency range is not allowed to propagate within the structure.

Light-matter interaction in such periodic media can lead to a host of interesting possibilities, which are being realized. Under suitable conditions of design, these media can exhibit negative refraction, slow down the speed of light considerably, localize intense optical fields and lead to extremely low threshold laser action

The Fascinating Frontier of Slow Light

Recent research has established the possibility of bringing down the speed of light to a considerably low value in specially designed materials/structures. Specific techniques to slow down and even store light in appropriate media at room temperature have been developed and its effective utilization in device applications is being investigated actively. This talk introduces the basic physical concept of light propagation at values of group velocities much lower than that of the speed of light in vacuum, outlines different approaches to achieving slow light and discusses the scope for practical applications.

The speed of light in any material medium is lower than that in vacuum and the extent of this reduction is characterized by the value of the refractive index of the medium. However, slow light refers to groups of light waves traveling at group velocities which are lower than the speed in vacuum by several orders of magnitude. Several experimental techniques have been used for the practical and convenient realization of slow light. One of these is using the phenomenon of electromagnetically induced transparency which arises due to certain subtle quantum effects in specific energy level systems. This leads to interesting spectral profiles of optical absorption which in turn manifests as the kind of dispersion of the group refractive index required for slowing of light.

Another way of obtaining slowlight is by utilizing certain specific features of the photonic band gap of suitably designed metamaterials. Photonic crystals can permit extremely low values of group velocity under certain conditions as a result of the propagation of light in a periodic arrangement of two different materials with alternating high and low values of refractive index.

Slow light can induce remarkable modifications in the manner in which matter interacts with light, paving way for novel forms of physical processes that can revolutionize the design of optoelectronic and photonic devices. Nonlinear optical response with extremely large efficiency is expected when intense slow light interacts with material media. This, along with a possible reduction in size of devices, can revolutionize the present design of optical switches, diodes and modulators, paving the way for the realization of the long cherished dreams of all optical computing technologies of communication and control. While the basic physics of slow light and its interaction with matter is quite intriguing at a fundamental level, recent results on the experimental front highlight the scope of photonic-crystal-based slow-light-structures in shaping up new, efficient and economic avenues of this emerging technology.

Design of Stable Nanocomposites for Applications in Photonics

An the emerging frontier area of research in Photonics is the design and development of efficient materials that exhibit interesting modes of linear as well as nonlinear optical response. One of the promising classes of candidate materials in this regard is that of nanomaterials, hybrids and composites, with enhanced and modified mechanisms of nonlinear optical response. This talk presents the basic physics of optical response of nanomaterials and outlines Stronglystrategies for their efficient utilization for applications in Photonics.

Strongly quantum confined semiconductor quantum dots are of particular interest in this regard, given the truly remarkable modification of the electronic and optical properties arising out of spatial confinement. Various mechanisms of nonlinear absorption such as multiphoton absorption, saturable absorption and reverse saturable absorption have been established in quantum confined systems.

Strategies are presented towards meeting the challenge of packaging size-tuned nanoclusters in transparent and stable host membranes in a cost-effective and eco-friendly manner. Simple and economic methods can be designed to develop novel nanocomposites with large nonlinear optical absorption, stability, versatility and convenience of use. New kinds of oxide nanoxlusters are synthesized in a variety of shapes such as micro and nanoflowers and nanobelts by simple chemical methods and these are found to have interesting optical as well as magnetic properties. Functionalization of carbon and porphyrin nanotubes has been shown to render them water-soluble and to alter their physical properties remarkably. An overview of the new vistas of design of stable photonic nanocomposites will be presented with specific examples.

The Charm and Challenge of Nonlinear Optics

The twentieth century has witnessed the fascinating metamorphosis of optics to photonics and then to nanophotonics. The idea of understanding light-matter interaction and harnessing light and other forms of electromagnetic radiation for a variety of applications has been evolving through different stages in an exciting manner. This talk starts with basic physics of light-matter interaction and outlines the physics of interaction of intense light with exotic forms of matter, in a step-by-step manner.

The major step that led to the emergence of nonlinear optics as a frontier area of science and technology is the practical realization of laser action. With these powerful sources of intense light, it became feasible to unravel novel physical processes such as wave mixing phenomena, sum-and-difference frequency generation, optical phase conjugation, photonic switching, self focusing and pulse shaping, to name a few. New physical mechanisms of nonlinear refraction and absorption are being encountered and understood. Many of which have a large scope in achieving smart optical limiting, spatial and temporal pulse shaping and soliton propagation, optical computing, switching and data processing, tunable solid state laser design and saturable absorption.

A major challenge of nonlinear optics continues to be the difficulty in the availability of ideal materials which exhibit sufficiently large and fast optical nonlinearity for efficient use in device applications. The approach here is to go beyond naturally available materials and to design of newer media through the avenues of molecular engineering and quantum engineering. For example, structure-modified organic polymers, low dimensional materials such as quantum dot structures and photonic crystals are being examined as new classes of nonlinear optical materials. Extreme nonlinearity is also expected to be useful in emerging applications such as convenient and efficient generation of X-rays, super continuum/white light laser sources, biomedical applications such as multi photon imaging.