Raman Centre for Atomic, Molecular & Optical Sciences

Indian Association for the Cultivation of Science

Jadavpur, Kolkata 700032

Two-day workshop on selected topics in modern optics

Optomechanics, Orbital Angular Momentum & Spin-Orbit Interactions of Light

12 & 13 January 2017

Abstracts

Subhasish Dutta Gupta, University of Hyderabad

Coherent perfect absorption mediated enhancement in nonlinear and spin optics

Abstract

We start with a brief overview of coherent perfect absorption (CPA) or anti-lasing which enables the total absoption of all the incident coherent light in a given structure. We show how the phenomenon is intimately related to the perfect destructive interference of light. We highlight the field enhancement associated with CPA and utilize it to enhance the Bellinfante's elusive transverse spin. We present a brief description of the transverse spin and show how it emerges in structured light. We pick two examples, namely, a planar and a spherical metal-dielectric structure and work near the avoided crossing. Note that avoided crossings are almost always associated with a dramatic change in the physical properties of a system due to modal exchange. We try to keep the presentation simple, leaving out all the details of, for example, Mie theory and other complications related to solving the dispersion relations, which are transcendental in character. However, we do mention the critical steps for the benefit of interested students.

Mishkat Bhattacharya, Rochester Institute of Technology

Talk-1

Cavity optomechanics of linearly vibrating systems

Abstract

This talk will introduce the interaction of linearly vibrating systems with a confined mode of the electromagnetic field. The talk will be conducted at a tutorial level. It will begin with second quantization and first examine the unitary dynamics of the system, and then proceed to include the effects of dissipation and noise. Fundamental phenomena including bistability, displacement sensing, cooling, regenerative motion, entanglement, information storage and readout, and strong coupling will be addressed. A brief survey of various experimental platforms will also be presented.

Talk-2

Optomechanics based on the exchange of orbital angular momentum between light and matter

Abstract

This talk will introduce optomechanical interactions which rely on orbital angular momentum (OAM) exchange. The talk will be conducted at the tutorial level. It will begin with a review of OAM-carrying optical beams, with emphasis on methods by which such beams are generated. A number of theoretical proposals as well as experiments, with and without resonators, addressing torsional and rotational mechanical motion will then be presented, including spiral phase plates, levitated nanorods, nanospheres,graphene flakes, surface acoustic waves, and Bose-Einstein condensates.

Bimalendu Deb, IACS

An introduction to orbital angular momentum of light & its potential applications

Abstract

The concept of “angular momentum of light” or “optical angular momentum” will be introduced from the point of of view of the fundamental principles of electromagnetism. It would be shown that using paraaxial approximation, the optical angular momentum (OAM) may be decomposed into spin and orbital parts. The spin part can be identified with the polarization of light while the orbital part is related to the azimuthal phase of light beam. A brief review of the seminal works in the field of OAM of light since early 1990s will be presented. Potential applications of optical OAM in spectroscopy will be briefly discussed.

Nirmalya Ghosh, IISER, Kolkata

Weak measurements on spin optical effects

Abstract

Spin orbit interaction (SOI) dealing with the coupling of spin and orbital degrees of freedom of massive (e.g., electron) and mass-less (e.g., photon) particles has led to several fundamental consequences in diverse fields of physics. Since light can carry both spin (SAM, circular / elliptical polarization) and orbital angular momentum (OAM), on conceptual grounds, coupling and inter-conversion between the spin and orbital AM degrees of freedom of light is expected under certain circumstances [1-4]. This leads to the SOI of light, which is typically manifested as two interdependent effects. (i) evolution of azimuthal geometric phase due to the effect of the trajectory on the state of polarization of light, leading to intrinsic SAM to intrinsic OAM inter-conversion and its various intriguing manifestations (such as formation of polarization controlled vortices); and (ii) the reverse effect of polarization on the trajectory of light, leading to intrinsic SAM to extrinsic OAM inter-conversion and manifesting as the so-called Spin Hall effect (SHE) of light [1 -4]. These spin optical effects are under recent intensive investigations because of their fundamental nature and potential applications towards development of novel spin-controlled photonic devices. However, these effects are rather tiny and accurate measurement / unique interpretation of these are extremely challenging. Weak measurement which was originally discovered in the context of quantum mechanics [5], being an interference dependent phenomenon, is perfectly applicable in the classical optical settings [6-8]. In fact, weak measurements have been employed recently to amplify various weak effects in the classical optics domain. In this talk, I shall introduce the concept of weak measurements and discuss its applications for the amplification of the spin optical effects of classical light beam [6-10].

References

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Ayan Banerjee, IISER, Kolkata

'Light-bandi?!' Trapping and manipulating mesoscopic matter using optical tweezers

Abstract

Optical tweezers confine mesoscopic particles by generating a gradient force of dipolar origin that is restoring in nature and is produced by tight focusing of light. Particles are trapped in three dimensions, typically in a viscous fluid which damps out the inertial response of the trapped particle. In the first part of the talk, we shall describe the basic theory behind optical tweezers and basic experimental configurations and calibration methods. Now, particles can be trivially moved by moving the light beam itself, or by using angular-momentum carrying beams that lead to rotational motion of trapped particles. In the second part, we shall describe a method where complex motion can be generated in trapped particles <u>without</u> moving the beam or using tailored beams, and thus demonstrate the absolute ‘control’ that light can exercise over mesoscopic matter. Here, we utilise effects of the spin-orbit interaction of light that are generated by the act of tight focusing itself. Thus, there appears a spin-redirection topological phase in the beam, as well as a longitudinal component in the electric field that produces

transverse energy flows which manifest as a spin-Hall shift in the beam or the transverse separation of the two constituent opposite circular polarization modes of the input linearly polarized state. We accentuate these effects by using a stratified medium in the path of the trapping beam so that polarization dependent side lobes are created in the intensity distribution near the trapping plane. Particles are preferentially trapped in these high-intensity side lobes and can be moved along the beam perimeter by changing the polarization state of the input beam [1]. Also, regions of opposite circular polarization are produced in the vicinity of the focus, where particles spin in a controllable manner [2].

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Prasanta K. Panigrahi, IISER, Kolkata

TBA

Sonjoy Majumder, IIT-Kgp

Transfer of orbital angular momentum from light to trapped atoms

Abstract

Interaction of spin degree of freedom or polarisation of light with trapped single atom or ensemble of atoms are well known. This is the source of electronic transitions in atoms abide by well established selection rules. There have been studies in recent years on the transfer mechanism of the other degree of freedom of light, orbital angular momentum (OAM), to atoms. Many endeavours tried to establish their school of thoughts: whether the angular momentum will transfer only to the centre of mass (CM) of the trapped atoms, to have their physical rotation and/or it also generates transition in their electron sector like polarisation does. In this presentation, I will briefly discuss, from the first principle, that the OAM of paraxial light generates electron transitions minimum at the quadrupole level of approximation. Whereas, I will show that the interaction with non-paraxial beam generates vortex in atoms at multiple hyperfine levels. I will also discuss few applications, like circular dichroism-like effect leads to direct estimation of the vortex charge of the condensate without destroying total condensate.

Tarak Nath Dey, IIT Guwahati

Coherent generation, control and manipulation of structured beam in atomic vapor

Abstract

A novel scheme for coherent generation, control and manipulation of structured beams in a system of homogeneously broadened atomic vapor with atoms in a closed three-level Λ-configuration has been used to explain the recent experimental results of Radwell *et al.* Phys. Rev. Lett. **114**, 123603(2015). The key feature underlying structured beam generation is transverse magnetic field induced phase dependent absorption between two Laguerre-Gaussian beams which connects two optical transitions of opposite polarities. We show how the coherent control field can be used to manipulate an azimuthal modulation of the absorption profile that is dictated by the phase and polarization structure of the probe beam. The mechanism of efficient generation and manipulation of an optical beam may have important applications in information science and optical communications.

Students' presentations

Sriram S., IISER-Kolkata

On the origin of the coherence of sunlight on earth

Abstract

It is shown that the observed far-field behaviour of sunlight on the earth's surface, located in the near-field region, is due to the small angular width it subtends at the center of the sun. The investigation of the angular behaviour of the cross spectral density function explicitly leads to Bessel-like far zone behaviour for a small angle without any restriction on the value of l.

Rik Chattopadhyay, RCAMOS, IACS

OAM of light at Dirac point in twisted Hollow core Photonic Crystal Fibre

Abstract

Orbital angular momentum (OAM) carrying guided optical mode find applications in particle trapping [1] and generation of spatio-temporal soliton besides application in optical communication [2]. It is shown that in twisted solid core photonic crystal fibre (PCF) this leads to transmission deeps at certain wavelengths as the core guided mode is topologically coupled with OAM carrying crystal modes [3]. In case of hollow core PCF (HC-PCF) one can trap crystal modes in the cladding carrying OAM at Dirac point by introducing twist. Propagating modes in the cladding of twisted PCF follow a helical path resulting azimuthal components that create discrete OAM modes. Now if we introduce a defect of specific diameter in the form of a hollow core in the PCF the OAM carrying crystal modes get coupled to the core and excites core guided OAM mode [4].

In this work we present a specially designed Germania glass (GeO_2) based hollow core photonic crystal fibre (HC-PCF) that can support modes carrying OAM. We considered a HC-PCF with pitch (Λ) 2.21μm and air filling fraction is 94%. The photonic band structure (PBS) shows (Fig. 1a) a full photonic bandgap (yellow region) between 1350-1420 nm. The edge states (purple box) appeared at 1503 nm and the Dirac point (orange box) appeared at 1300 nm in the untwisted PC where the out-of-plane propagation vector $k_z=3.4\pi/\Lambda$.

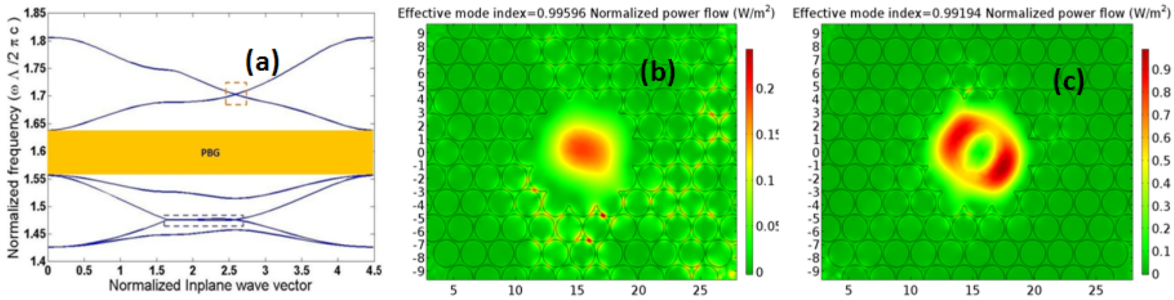

Figure 1. (a) PBS of the air-Ge doped glass PCF using PWEM of the untwisted PCF for $k_z\Lambda=3.4\pi$. The value of k_z is selected in such a manner that the Dirac point remains above the air line and maintaining its conical dispersion relation. Poynting vector along z-direction calculated by FEM at 1308 nm (b) LP_{01} mode (c) LP_{11} mode. Twist rate is set to 6.5 rad/mm.

This study shows that fiber modes carrying OAM can be excited in a twisted HC-PCF. It is also to be noted that since the Dirac point appeared in PBS has linear dispersion therefore we expect that the OAM carrying fiber mode should experience a linear dispersion and hence opens up new possibilities for future studies.

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Sudipta Saha, IISER kolkata

Reflection of waves from spatial Kramers-Kronig optical media

Abstract

Over the past few decades, the suppression of reflection has been one of the central topics of interest in optics because of its potential applications in constructing anti-reflection surfaces . In a recent work by Horsley *et. al* [Nat. Photonics 9, 436 (2015)], it was shown that a nonmagnetic media whose permittivity profile satisfies spatial Kramers-Kronig relations can support unidirectional anti-reflection. In this talk, I will discuss our recent work on the truncated spatial Kramers-Kronig media where we showed that such a media can only support one-sided null scattering under bidirectional illumination. This is shown to be a direct consequence of the non-reciprocity in reflection on scattering from such medium. We further showed at the possibility of surface modes in a highly

truncated spatial Kramers-Kronig medium for unidirectional illumination. For specific range of parameters, we showed the existence of TM polarized surface plasmons only for illumination from the 'metallic' side of the permittivity profile with negative real part of the permittivity in the Kramers-Kronig medium. The results of these studies will be presented.

Somnath Naskar, IACS

Photoassociative cooling and trapping of an atom-pair

Abstract

In this talk it would be shown that the process of photoassociation of a pair of interacting atoms can be utilized to cool the pair and trap their center-of-mass motion by a Sisyphus-like laser cooling mechanism.