SYTL 2: Symposium on interactions between twisted light and particles II (SYTL)

Time: Friday 14:30–16:30 Location: C/gHS

Invited Talk SYTL 2.1 Fri 14:30 C/gHS

Electron vortex beams: Twisted matter waves — •Peter Schattschneider — Vienna University of Technology, 1040 Vienna, Austria

After the discovery of vortex electrons in 2010, free electrons with topological charge can now be routinely created in the electron microscope. Such vortices are characterized by a spiralling wavefront and a phase singularity at the center, similar to optical vortices that were described by Nye & Berry in 1974. Owing to their short wavelength, these matter waves can be focused to atomic size. Another novel aspect is their magnetic moment, quantized in multiples of the Bohr magneton, independent of the electron spin. These features make electron vortices extremely attractive as a nanoscale probe for solid state physics.

Although the theory of electron vortices in free space is well understood, interaction with fields or matter is more involved. Experimentally, a non-classical rotation mechanism in magnetic fields was found. It is caused by the Landau-Zeeman phase, analogous to the Berry phase causing rotation of optical beams. Nanocluster manipulation, breaking of rotational symmetry to distinguish enantiomeres, and detection of spin polarisation of single atomic columns was demonstrated. Electron vortices could serve as tweezers to move or rotate single atoms or molecules, or to detect sub-meV energy differences in the electron microscope.

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Invited Talk SYTL 2.2 Fri 15:00 C/gHS

Inelastic effects on the lateral wave function of electron beams — •Javier García de Abajo — ICFO-The Institute of Photonic Sciences, Mediterranean Technology Park, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain

Electron beams carry spatial information encoded in their lateral wave function, which evolves as the beam interacts with different parts of a microscope, as well as with a sample. In this talk, we will formulate a rigorous theoretical analysis for the evolution of an electron beam due to inelastic interaction with some of those elements. In particular, we will study the transfer of orbital angular momentum between vortex electron beams and chiral samples, such as staircase plasmonic nanostructures and biomolecules, which are predicted to produce large dichroism in the momentum-resolved electron energy-loss spectra. Additionally, we will discuss the effect of thermal noise during the electron interaction with distant materials, for example when the electron is moving along the center of a hollow metallic tube, or when it is divided by a biprism, passed above a surface, and later recorded in the far field. Recently observed stochastic thermal deflections and lost of visibility in the interference fringes are shown to be explained by this formalism in semi-analytical form.

SYTL 2.3 Fri 15:30 C/gHS

Electron-spin dynamics in elliptically polarized light — •Heiko Bauke[1], Sven Ahrens[1], Rainer Grobe[2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Intense Laser Physics Theory Unit and Department of Physics, Illinois State University, Normal, Illinois 61790–4560 USA

Electrons as well as elliptically polarized light carry spin angular momentum. Although it is well-known that different angular momentum degrees of freedom may couple to each other, the coupling of electronic and photonic spin degrees of freedom has been considered rarely. We demonstrate that the photonic spin density can induce electron-spin precession [1, 2]. This effect is of similar origin as the well-known spin-orbit coupling. The spin-precession frequency is proportional to the product of the laser field's intensity and its spin density. The electron-spin dynamics is analyzed by employing exact numerical methods as well as time-dependent perturbation theory based on the fully relativistic Dirac equation and on the nonrelativistic Pauli equation that is amended by a relativistic correction that accounts for the light's spin density. Although, the predicted spin precession is an intrinsic relativistic effect it may be observed also at nonrelativistic laser intensities.

[1] H. Bauke, S. Ahrens, C. H. Keitel, R. Grobe, *New Journal of Physics*, **16**, 103028 (2014)
[2] H. Bauke, S. Ahrens, R. Grobe, *Phys. Rev. A*, **90**, 052101 (2014)

SYTL 2.4 Fri 15:50 C/gHS

Design and realisation of variable C shaped structured illumination — •Michael Mousley, Jun Yuan, Mohamed Babiker, and Gnanavel Thirunavukkarasu — University of York, UK

Computer generated holograms (CGHs) have been designed to create structured illumination with a C shape. The structured illumination is based on a vortex state, however the inclusion of radial phase gradients leads to non integer topological charge and a redistribution of intensity in the far field diffraction pattern. By analysing the phase gradients present in the wavefunction the structured illumination pattern can be predicted and independent control of the radius and opening angle is possible. C shaped illumination is experimentally produced in an electron microscope showing two different opening angles , using two different CGH mask types. C-shaped structured illumination offers interesting particle interactions and trapping possibilities with the ability to control the size of the gap between trapped particles at the ends of the intensity curve. C shaped illumination promises potential applications both in the optical and electron beam lithography of metamaterials which utilise split ring structures and dimensions as small as nanometres can be achieved in the electron beam case.

SYTL 2.5 Fri 16:10 C/gHS

Neutron vortex beams and their interaction with laser pulses — •Armen Hayrapetyan and Jörg Götte — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden

Vortex beams are known to carry quantized orbital angular momentum along their axes of propagation, they possess phase singularities occurring at the center where the beam intensity is zero. While recent advances in technology have lead to creation of both optical and electron vortex beams, called also twisted light and electrons, there have been striking yet largely unexplored studies on other types of material vortex beams. To deepen this analogy between the light and matter waves, we report on the first study of neutron vortex beams (NVBs) and their interaction with plane-wave laser pulses within the framework of relativistic Dirac theory. The interaction with the field is determined via the anomalous magnetic moment of neutron that manifests itself in the exact, Skobelev solutions of the Dirac equation, analogous to the Volkov states of relativistic electrons. To characterize a twisted state of laser-driven neutrons, we construct analytically exact solutions of the Dirac equation that demonstrate the spin-to-orbit conversion for the NVB and the influence of light upon it. Our new solutions generalize, on the one hand, the recently obtained vortex-beam solutions of the field-free Dirac particles, on the other hand, the Dirac-Skobelev solutions for the laser-driven plane-wave neutrons. We pay a particular attention to the evolution of twisted neutrons in the presence of high-power laser fields that have become accessible during the last decade.