Physics in Intense Fields (PIF2013)

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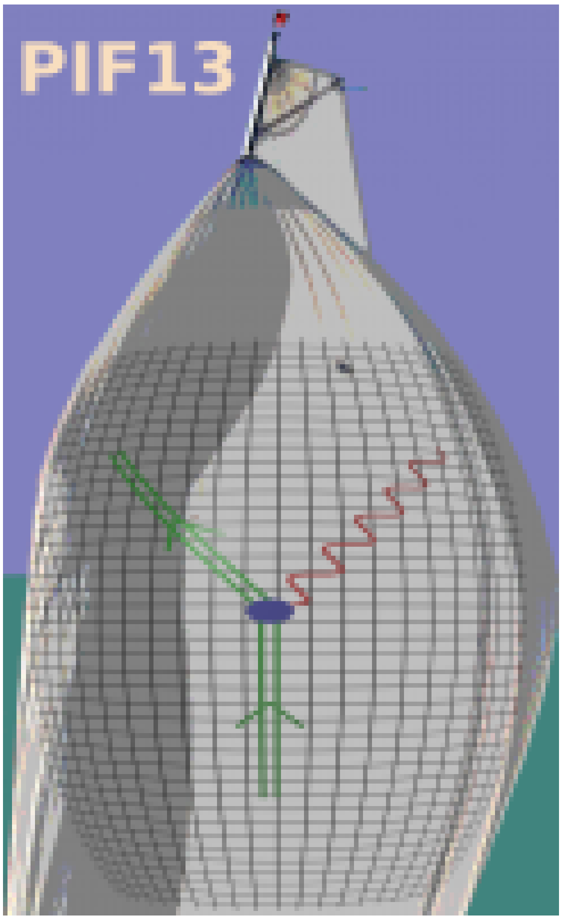

Book of Abstracts

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Workshop Welcome

Processes and Solutions / **3**

Resonances in the 2-vertex Furry picture processes and their potential experimental verification

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Furry picture particle processes exactly include the contribution from the external field. For a circularly polarised external field the contribution is discrete being a multiple of the external field momentum. The 2-vertex Furry picture processes display interesting behaviour due to their propagators reaching the mass shell for particular kinematic combinations. I discuss this behaviour in the 2-vertex Compton scattering. The nature of the apparent divergences is analysed and their correction by inclusion of the electron self energy and the Furry picture vertex correction is discussed. Cross-sections obtained show large variation from the Klein-Nishina process and provide a new arena within which to test Furry Picture predictions. The Furry picture Compton scattering is amenable to experimentation since initial photons can be tuned to scan resonances, and event rates are easily sufficient for detection using the present laser intensities available.

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[2] Hartin A, PhD Thesis, University of London (2006)

Ultra-Intense LASERs / **4**

Electron-seeded pair-creation in external fields

Author: Ben King[1]

Co-authors: Hartmut Ruhl [1]; Nina Elkina [1]

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Motivated by the ever-increasing interest in simulating the intense irradiation of plasmas by combining the scales of classical plasma physics and strong-field QED processes, we present the results of two studies into common approximations. First, we derived polarised non-linear Compton scattering and pair-creation rates in a constant crossed field and studied their inclusion in simulations, finding good agreement in the spectra and number of photons generated when photons are treated as scalars but also a large asymmetry in the polarisation distribution [1]. Second, we derived electron-seeded pair creation (the trident process) in a constant crossed field to investigate the approximation of using chains of integrated tree-level processes to approximate higher-order ones [2]. The only disparity we recorded here was inclusion of photon polarisation which corresponded to less than 10% difference in the total rate. Furthermore, the results hint that short-pulse lasers and electron beams could be used to measure the one-step process mediated by a virtual photon.

[1] B. King, N. Elkina and H. Ruhl, Photon polarisation in electron-seeded pair-creation cascades, Phys. Rev. A (accepted) http://arxiv.org/abs/1301.7001, (2013)
[2] B. King and H. Ruhl, Trident pair creation in a constant crossed field, http://arxiv.org/abs/1303.1356, (2013)

Plasmas and Radiation Reaction / **5**

Relativistic plasmas and beams, and the radiative self-force

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Contemporary advances in ultra-intense laser facilities have driven the recent surge of interest in the collective behaviour of charged matter in extreme conditions, and a particularly vexing topic in that context concerns the coupling of an electron to its own radiation field. In most practical cases, the Lorentz force on an electron, due to an applied electromagnetic field, is considerably larger than the force due to the electron's emission and the effect of the recoil due to the emitted radiation is negligible or can be adequately represented using simple physical reasoning. Although such arguments avoid the difficulties that plague more comprehensive analyses, the parameter regimes promised by forthcoming ultra-intense laser facilities, such as ELI, ensure that more fundamental considerations are now of practical necessity.
We will discuss recent developments in relativistic kinetic and fluid theory in the above context.

Refs: J. Math. Phys. 54, 043101 (2013); arXiv:1303.7385

Radiation reaction / **6**

Radiation reaction directly from QED

Author: Greger Torgrimsson[1]

Co-author: Anton Ilderton [1]

[1] *Chalmers*

There remains great interest in radiation reaction, both theoretically and experimentally, especially in the context of strong laser fields.

In this talk I will derive classical radiation reaction directly from QED. The treatment is fully quantum and and we make no approximation except the usual coupling expansion of QED.

We calculate the expectation value of the momentum and the position of an electron in QED. Taking the classical limit, hbar goes to zero, of these expectation values allows us to identify which of the many different classical equations proposed to describe radiation reaction are consistent with QED.

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Pre-acceleration from Landau-Lifshitz Series

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The Landau-Lifshitz equation is considered as an approximation of the Abraham-Lorentz-Dirac equation. The former is derived from the latter by treating radiation reaction terms as a perturbation. However, while the Abraham-Lorentz-Dirac equation has pathological solutions of pre-acceleration and runaway, the Landau-Lifshitz equation and its finite higher order extensions are free of these problems. So it seems mysterious that the property of solutions of these two equations is so different. We show that the problems of pre-acceleration
and runaway appear when one consider a series of all-order perturbation which we call it the Landau-Lifshitz series. The Landau-Lifshitz series diverges in general. Hence a resummation is necessary to obtain a well-defined solution from the Landau-Lifshitz series. This resummation leads the pre-accelerating and the runaway solutions.

LASERs and Simulations / 8

Understanding the Dynamics of Particles in Intense Laser Fields

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During the next few years a number of new laser facilities are expected to come online (such as ELI and XCELS). These will provide fields of unprecedented powers and intensities, allowing us to explore a range of physics under extreme conditions. In this talk I intend to discuss both classical and quantum aspects of laser-particle interactions and the boundary between the two regimes. I will begin by considering electron motion in an intense field, explaining what happens as we make the transition from continuous (classical) emissions of radiation to discrete (quantum) emissions. I will next describe how a laser pulse can be optimally focussed in order to lower the intensity threshold for pair production. Finally, I will discuss the dynamics of the created pairs and the impact of radiation damping on their dynamics.

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QCD with external magnetic fields

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I review the recent progress concerning QCD with external fields, especially the catalysis resp. inverse catalysis of the quark condensate, the critical temperature, the magnetic susceptibility etc. from lattice simulations in comparison to other approaches.

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Any Light Particle Search (ALPS) - II

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The ALPS-II experiment at DESY combines expertise from cw-laser
precision setups with low-flux photon detectors
and high-field superconducting magnets to search for low-mass,
weakly-interacting particles (WISPs) such as axion-like particles. After a brief introduction to the scientific goals of the three ALPS-II
stages, I will review the crucial components of the setup,
and comment on alternative search mechanisms for WISPs.

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QCD in Strong Magnetic Fields

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We study electromagnetic and topological properties of the QCD vacuum and quark-gluon plasma in the background of strong (hadronic scale) magnetic fields comparable to the ones taking place in heavy-ion collisions. Among the properties are the following ones: electric conductivity, magnetization and magnetic susceptibility, local CP-violation and induced anomalous currents, distribution of the topological charge density, chiral symmetry breaking and the chiral condensate. I will mainly present the results obtained within the lattice QCD simulations and, if there is time left, with the use of original analytic methods.

Strong Field QFT / 13

Aspects of QED in an Intense Magnetic Field

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In this talk we will discuss interesting aspects of QED in an intense magnetic field in the context of nonperturbative QED. We show that thanks to the magnetic catalysis of chiral symmetry breaking (i) there is a few percent increase in the electron mass around 10^{15} Gauss, the typical magnetic fields on the surface of young neutron stars, and (ii) the magnetized QED vacuum is stable for all values of the magnetic field.

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Nonlinear double Compton scattering in the ultrarelativistic quantum regime

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A detailed analysis of the process of two-photon emission by an electron scattered from a high-intensity laser pulse is presented. The calculations are performed in the framework of strong-field QED and include exactly the presence of the laser field described as a plane wave [1]. We investigate the full nonlinear quantum regime of interaction with a few-cycle pulse, where nonlinear effects in the laser field amplitude, photon recoil, and the short pulse duration substantially alter the emitted photon spectra as compared to those in previously studied regimes. We provide a semiclassical explanation for such differences, based on the possibility of assigning a trajectory to the electron in the laser field before and after each quantum photon emission [2]. Our numerical results indicate the feasibility of investigating experimentally the full ultrarelativistic quantum regime of nonlinear double Compton
scattering with available electron accelerator and laser technology.

References

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[2] F. Mackenroth and A. Di Piazza, Phys. Rev. Lett. 110, 070402 (2013).

Ultra-Intense LASERs / 15

Gamma-ray generation in strong laser field: QED cascading and laser-solid interaction in QED regime

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We discuss generation of energetic photons in strong laser field at intensities above 10^23 W/cm^2. First we discuss production of electron-positron-gamma-quanta plasma at QED cascading. QED or electromagnetic cascades are one of the basic phenomena of high-field physics. QED cascades can efficiently convert laser radiation into gamma-quanta. The various methods and schemes to control of the efficiency, brightness and directivity of the gamma-ray source based on QED cascade are proposed. The proposed schemes are verified by numerical simulations with 3D QED PIC-MC code. We also discuss laser-solid interaction in QED regime when QED effects become significant. The conversion efficiency of the laser energy to the gamma-ray energy is calculated by 3D PIC-MC simulation for a wide range of laser-solid parameters. It is shown that in the low intensity regime the main part of the laser energy is converted into the ion motion while in the high intensity regime the gamma-ray generation becomes the key channel of the laser energy conversion.

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J/Ψ photo-production in Pb-Pb and p-Pb ultra-peripheral collisions with ALICE at LHC

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The photoproduction of vector mesons in Ultra-Peripheral Collisions (UPC) is a powerfull tool to probe the nuclear gluon-distribution, for which there is considerable uncertainty in the low-x region. We present the first measurements in Pb-Pb collisions at √s_NN = 2.76 TeV, performed with the ALICE detector. The J/ψ is identified via its dimuon decay in the forward rapidity region and via dimuon and dielectron decay at mid-rapidity. The results are compared to theoretical models for coherent J/ψ production and found to be in good agreement with models which include nuclear gluon shadowing. The cross section measurement for incoherent J/ψ and γγ->e+e- at mid-rapidity will be shown. Finally we present the first results on p-Pb UPC at
√s_NN = 5.02 TeV.

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Fermion production in inhomogeneous electric fields

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We investigate fermion production in space- and time-dependent electric fields in 1+1 dimensional QED using real-time lattice techniques. We compute the non-equilibrium time evolution of gauge invariant observables and investigate the decay of the field due to the backreaction mechanism. The latter allows us to discuss the striking phenomenon of a linear rising potential building up between produced fermion bunches after the initial electric pulse has ceased.

Strong field effects / 18

The Kapitza-Dirac effect in the relativistic regime

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The Kapitza-Dirac effect is the diffraction of electrons at a standing wave of light [1]. We solve the relativistic quantum dynamics of this electron diffraction by integrating the Dirac equation numerically and perturbatively in momentum space and demonstrate that spin-flips can be observed in the Kapitza-Dirac effect with three interacting photons [2]. Our recent work shows that significant spin effects may also appear in the well known Kapitza-Dirac effect with two interacting photons [3,4] and we describe the spin dynamics as a rotation of the spin of the diffracted electron [5]. Furthermore, our numerical solution allows us to analyze the in-field quantum dynamics of the diffraction process and to verify a generalized Rabi theory for the description of the Bragg condition of the Kapitza-Dirac effect.

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Overview / 19

Probing of QED vacuum with superstrong laser field

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The development of laser technologies promises very rapid growth of laser intensities in close future already. Two exawatt class facilities (ELI and XCELS, Russia) in Europe are already in the planning stage. Realization of these projects will make available a laser of intensity ~10^26 W/cm^2 or even higher. Therefore discussion of nonlinear optical effects in vacuum are becoming urgent for experimentalists and are currently gaining much attention. We show that, in spite of the fact that the respective field strength is still essentially less than E_S=m^2c^3/eħ=1.32•10^16V/cm, the nonlinear vacuum effects will be accessible for observation at ELI and XCELS facilities. The most promissory for observation is the effect of pair creation by laser pulse in vacuum. It is shown that at intensities \gtrsim 5•10^25 W/cm^2 creation even of a single pair is accompanied by development of an avalanchelike QED cascade. There exists an important distinctive feature of the laser-induced cascades, as compared with the air showers arising due to primary cosmic ray entering the atmosphere. In our case the laser field plays not only the role of a target (similar to a nucleus in the case of air showers). It is responsible also for acceleration of slow particles. It is shown that the effect of pair creation imposes a natural limit for attainable laser intensity. Apparently, the field strength ~ E_S is not accessible for pair creating electromagnetic field at all.

Special Lecture/DESY Seminar / 20

The Search for the Schwinger Effect: Non-perturbative Pair Production from Vacuum

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The prospect of next-generation ultra-high-intensity laser sources has prompted recent renewed study of the Schwinger effect, in which the instability of the QED vacuum is probed by external fields. Experimental observation of this long-sought effect would provide controlled access to non-perturbative processes in quantum field theory under extreme conditions, which is of direct interest in particle physics and astrophysical applications. I review why this is also such an interesting and challenging theoretical problem.

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Asymmetries of Azimuthal Photon Distributions in Non-Linear Compton Scattering in Ultra-Short Intense Laser Pulses

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Non-linear Compton scattering in ultra-short intense laser pulses is discussed. The focus is on angular and azimuthal distributions of the emitted photon in intense single-cycle and few-cycle laser pulses. Asymmetries of the azimuthal distributions are predicted for both
linear and circular polarization. For linear polarization, the dominant direction of the emission changes from a perpendicular pattern with respect to the laser polarization at low-intensity to a dominantly parallel emission for high-intensity laser pulses.

Quantum Dynamics / 22

Ionic and nuclear quantum dynamics in intense low and high-frequency light fields

Author: Christoph H. Keitel[1]

Co-authors: Adriana Pálffy [1]; Enderalp Yakaboylu [1]; Heiko Bauke [1]; Karen Z. Hatsagortsyan [1]; Michael Klaiber [1]; Wen-Te Liao [1]; Zoltán Harman [1]

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The interaction of highly charged ions and nuclei with intense light sources is introduced [1]. We begin discussing the quantum relativistic bound electron dynamics in highly charged ions and super intense laser fields [2,3]. Then, special attention is devoted to laser-induced tunneling in the relativistic regime. Here, we show that an intuitive picture can be developed for relativistic tunneling employing spatially dependent energy levels. Also the issue of time under the barrier is discussed at length and how the various times may leave detectable signatures [3]. In what follows, we investigate how populations may be transferred among nuclear states employing accelerators and XFEL light [4]. Then, various applications employing high frequency light are introduced such as high-precision determinations of nuclear lines and phase-sensitive storage schemes of x-ray photons [5]. Finally, resonance fluorescence of highly charged ions is discussed and how this may be favorably employed in laboratory astrophysics [6].

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Strong field effects / 23

Photon emission process from a charged particle under the strong laser field

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Co-authors: Alexander. I. Titov [2]; Atsushi Hosaka [1]

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We propose a uniform formulation to calculate photon emission processes from a charged scalar field or spinor field under the strong laser field. One photon emission from a charged particle, which is forbidden in the vacuum, can be observed in the strong EM field, for example, SLAC E-144 experiment (1997). The process is expressed as non-linear Compton scattering, which means the number of incident photons is 2, 3 or more. But in the short pulse strong laser field, the expression must be changed because the laser field includes various frequency photons.
In this presentation, we show that not integer but real number photons interact with a charged particle under short pulse laser field, how to calculate these processes with non-linear QED and some numerical results.

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Electron-Positron Pair Production from Multi-Photon Absorption

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The process of electron-positron pair production in rapidly time-dependent and linearly polarized electric fields is investigated within the quantum kinetic formalism. Similarities between atomic ionization and pair production are pointed out for field parameters where the Schwinger effect (tunneling) is contributing but subdominant against multi-photon absorption (above-threshold ionization).
The non-monotonic dependence of the particle yield on the carrier
frequency will be discussed as well.

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Dynamically assisted Sauter-Schwinger effect

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Recently it has been found that the superposition of a strong
and slow electric field with a weaker and faster electromagnetic
pulse can significantly enhance the probability for

non-perturbative electron-positron pair creation out of the
vacuum —the dynamically assisted Sauter-Schwinger effect.
After a brief introduction into the basics of this effect,
this talk will be devoted to the dependence of this enhancement
mechanism on momentum and the pulse shape as well as further
developments.

References:

Momentum dependence in the dynamically assisted Sauter-Schwinger effect
Christian Fey and Ralf Schützhold
Phys. Rev. D 85, 025004 (2012)

Catalysis of Schwinger vacuum pair production
Gerald V. Dunne, Holger Gies, and Ralf Schützhold
Phys. Rev. D 80, 111301 (2009)

Dynamically Assisted Schwinger Mechanism
Ralf Schützhold, Holger Gies, and Gerald Dunne
Phys. Rev. Lett. 101, 130404 (2008)

Processes and Solutions / 26

Analytical Solutions of the Dirac and the Klein-Gordon Equations in Plasma Induced by High Intensity Laser

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Co-author: Shalom Eliezer [2]

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We obtain analytical solutions of the Dirac and the Klein-Gordon equations coupled to a strong electromagnetic wave in the presence of plasma environment. These are a generalization of the familiar Volkov solutions. The contribution of the non-zero photon effective mass to the scalar and fermion wavefunctions, conserved quantities and effective mass is demonstrated for the first time. The new wavefunctions exhibit differences from Volkov solutions for nowadays available laser intensity

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On the properties of the boost modes and existence of the Unruh effect

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Recently, a significant amount of attention is payed in the literature to the proposals for experimental observation of the so-called "Unruh effect" and "Unruh radiation", in particular via application of the state-of-the-art laser facilities. In the papers [1-4] we have reconsidered the original derivation [5] of the Unruh effect. This "effect" originates essentially due to splitting of the field degrees

of freedom into the "left" and "right" Unruh modes, the former considered invisible by a uniformly accelerating observer. However, we have demonstrated that existence of the "zero" mode, which is entirely responsible for singular contribution at the horizons, was ignored in [5] and by the successors. As a result, this zero mode is irretrievably lost in the course of such a naive separation, so that application of the Unruh quantization (giving rise to the Unruh effect in the sense of a universal QFT phenomenon) to the problem of the field in Minkowski spacetime is mathematically incorrect (though may be attributed to some different physical contexts). Neither transition to the smeared fields formalism, nor appeal to the Bisognano-Wichman theorem is capable for consistent correction of the derivation. In the talk, the arguments in favour of non-existence of the Unruh effect will be reviewed.

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LASERs and Simulations / 28

Straggling in laser-electron beam collisions

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Current high intensity laser facilities can be used to reach the
regime in which electron trajectories are strongly modified by
the quantum equivalent of the radiation reaction force. We describe a
Monte-Carlo simulation of a set-up in this regime and present results in which GeV electrons counter-propagate into a 10^{22} W/sq cm laser pulse. These show that the stochastic nature of quantum synchrotron
emission results in many more high energy photons than expected
from a purely classical calculation, and that electron-positron
pair production by an analog of the nonlinear Breit-Wheeler process should be observable.

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Inhomogeneous chiral phase in high magnetic field

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One of the interesting subjects may be a possible appearance of inhomogeneous chiral phases on the QCD phase diagram and their implications on high-energy heavy-ion collisions or compact stars

[1,2]. Here we discuss their properties in a strong magnetic field. Theoretically the effect of the magnetic field causes interesting phenomena such as an enhancement of spontaneously symmetry braking (SSB) [3,4]. So it should be interesting to consider how the magnetic effect works for inhomogeneous chiral phases.
Here we consider the dual-chiral-density-wave (DCDW) within the NJL model [1].
We shall see that lowest Landau level (LLL) of the quark energy spectrum plays a peculiar role in this context: (1) the energy spectrum of LLL exhibits a spectral asymmetry, so that the Atiyah-Patodi-Singer eta invariant becomes finite [5]. This is a manifestation of the chiral anomaly in 1+1 dimensional theory
in the presence of the magnetic field. Physically the anomalous baryon density is associated with the condensates and the inhomogeneous chiral phase is remarkably extended in the QCD phase diagram. (2) effective dimensional reduction proceeds as magnetic field increases, and DCDW becomes to be realized as the lowest-energy state in sufficiently large magnetic field, as in the case of 1+1 dimensional case [6].
Some implications on magnetars are briefly discussed.

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Present status of the conceptual design for the GEKKO-EXA laser system

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The GEKKO-EXA project[1] was revised depending on the domestic user's demand. Here presented is a revised proposal for the GEKKO-EXA project. The project is aiming at the investigation of the physics under the intense laser field up to 10^24 W/cm^2.
As for the future application of the intensity laser, the intensity of 10^23W/cm^2 is one of the mile stone to be overcome since, in the region of radiation-dominated plasma, effective high energy gamma ray flush and its abundant applications are expected. From the physical interest, the process itself is to be demonstrated. The remedy for the radiation reaction in the analysis is still controversial and to be examined by experiment. Technologically, the repetitive high intensity laser system with the output power of several PW is desired to be developed. In the new design of the GEKKO-EXA, the split disk laser system[2] was picked up to deliver the k-J sub-nanosecond pulse with 0.01 Hz which will potentially provide a several PW pulse at the same repetition.
At the intensity of 10^24 W/cm^2, QED avalanche is expected[3] and electron-positron plasma might be created effectively. As a final amp, the existing amplifier chain of the LFEX are to be utilized and the final output of 500 J in 20 fs, which makes 25 PW in the revised design of the GEKKO-EXA.
The preliminary computational simulation for the experiments such as the QED avalanche will be also reported with the revised design of the laser system.

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[2] H. Okada, H. Yoshida, H. Fujita and M. Nakatsuka
Opt. Commun.261, p342-348 (2006), ibid 266, pp274-279 (2006).
[3] A. R. Bell, Phys. Rev. Lett. 101, 200403(2008).

Radiation reaction / 31

Radiation reaction effects on the interaction of an electron with an intense laser pulse

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Rapid advances in laser technology have hastened the need for a consistent and physically reasonable model of how losses to radiation affect the motion of electrons. We report on a recent investigation of the Ford-O'Connell equation, exploring its relation to other commonly used descriptions of radiation reaction, in particular that of Landau and Lifshitz. By analysing the motion of an electron passing through a laser pulse, we find that radiation reaction effects prevent the particle from reaching a regime in which the Landau-Lifshitz approximation would break down.

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Spin effects in laser-induced electron-positron pair production

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Electron-positron pair production by an incident high-energy photon or a relativistic proton colliding with an intense laser field is considered. Our focus lies on the role played by the electron spin degree of freedom. A comparative study between production of Dirac versus Klein-Gordon pairs is performed [1,2] and a helicity analysis is carried out [3].

[1] S. Villalba-Chavez and C. Mueller, Phys. Lett. B 718, 992 (2013)
[2] T.-O. Mueller and C. Mueller, Phys. Lett. B 696, 201 (2011)
[3] T.-O. Mueller and C. Mueller, Phys. Rev. A 86, 022109 (2012)

LASERs and Simulations / 33

Development of the quasi-static Particle-In-Cell code HiPACE

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High intensity laser- or particle beams excite large amplitude plasma waves when propagating in appropriate gas targets. The fields, carried by these plasma waves, can exceed 100 GV/m and are capable of accelerating particles to high energies within short distances. To design, advance and understand experiments, numerical investigations of the dynamics in such plasma accelerators are vital. Full Particle-In-Cell (PIC) simulations, however, are often computationally too expensive for parameter scans or detailed analyses. This talk will present a Highly efficient Plasma ACcelerator Emulation (HiPACE), which can allow for order of magnitude speedup compared to full PIC codes

for a class of problems. The physical basis, numerical implementation, computational framework and parallel performance of this code will be discussed.

LASERs and Simulations / 34

Numerical challenges in laser driven electron-positron plasma

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The next generation of laser facilities will make possible to
study electron-positron laser plasma arising due to electromagnetic cascades.
The cascade consists of
quantum electrodynamic effects of hard photon
emission and electron-positron pair creation.
A central problem in description of
plasma with quantum electrodynamic effects is the need for a proper model for radiation, which would simultaneously account for both classical radiation responsible for collective emission and quantum recoil due to non-coherent hard photons.
The mathematical description of the cascades
boils down
to a system of transport equations for particles distribution function and
the Maxwell equations for electromagnetic fields.
Numerical simulation of these equation in ultra-high intensity regime
involves difficulties arising from broad spectrum of time and space scales simultaneously present in the problem.
The major part of applied computations concerning the kinetic equation is based
on the probabilistic Monte Carlo
methods. However, the stochastic method heavily relies on the use of random sampling of
transport integrals and may lead to noisy and possibly unstable solution of the transport equation.
Alternative highly accurate deterministic methods for the kinetic equations are computationally demanding.
In this context the adaptive grid refinement is advantageous because of electromagnetic cascades are localized at
laser focus.
In this talk, I will review recent advances in the
computational algorithms for QED plasma and discuss open problems.

Plasmas and Radiation Reaction / 35

Radiation reaction force induced nonlinear mixing of Raman sidebands of an ultra-intense laser pulse in a plasma

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Stimulated Raman scattering of an ultra-intense laser pulse in plasmas is studied by pertur- batively including the leading order term of the Landau-Lifshitz radiation reaction force in the equation of

motion for plasma electrons. In this approximation, radiation reaction force causes phase lag in nonlinear current densities that drive the two Raman sidebands (anti-Stokes and Stokes waves), manifesting itself into the nonlinear mixing of two sidebands. This mixing results in a strong enhancement in the growth of the forward Raman scattering instability.

Plasmas and Radiation Reaction / **36**

Quantum radiation reaction in laser-electron beam collisions

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The intensity of short pulse lasers is now sufficiently high that the dynamics of energetic electrons in these fields is dominated by quantum radiation reaction. We present simulations of an experiment that uses a laser wakefield to drive GeV electrons into a counterpropagating laser pulse of intensity 10^{22} Wcm^{-2}. The stochastic nature of photon emission leads to broadening of the electron beam's energy spectrum and to a yield of high energy gamma rays much greater than that predicted by classical radiation theory. These signatures of strong-field QED processes should be detectable with current high intensity laser facilities.

Plasmas and Radiation Reaction / **37**

Simulations of beam-driven plasma acceleration at FLASHForward

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Plasma acceleration exploits extreme electric fields created in a plasma by high-current beams or high-intensity laser pulses, to accelerate charged particles. In current studies we explore prospects for beam-driven plasma acceleration within FLASHForward project at DESY, by means of 3D particle-in-cell simulations with the code OSIRIS. In particular, various techniques of injecting particles into a beam-driven wake are being considered. It is demonstrated that injecting particles by using transitions in plasma density allows for trapping and acceleration of electron beams, with final low emittance and low slice energy spread. The parameters of the driver beam and the plasma correspond to the current design for future experiments. Various parameter scans were performed, investigating sensitivity of the injected beam qualities, such its as length, charge, energy spread, and correlations in phase-spaces, to initial parameters of the driver and the plasma ramp.

Heavy ion collisions / **38**

Properties of photons and hadrons in strong magnetic fields

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Extremely strong magnetic fields appear in high-energy heavy-ion collisions and compact stars like magnetars. Under such strong magnetic fields, photons and even hadrons show unusual behaviors. In this talk, I will explain photon's vacuum birefringence and decay into an e+e- pair [1,2] and the conversion of neutral pions into (virtual) photons [3] both of which are possible in strong magnetic fields. I will also discuss how these phenomena can manifest in heavy-ion collisions.

[1] K. Hattori and K. Itakura,Vacuum birefringence in strong magnetic fields: (I) Photon polarization tensor with all the Landau levels,"
Annals Phys.330 (2013) 23 [arXiv:1209.2663 [hep-ph]].
[2] K. Hattori and K. Itakura,Vacuum birefringence in strong magnetic fields: (II) Complex refractive index from the lowest Landau level,"
Annals Phys.334 (2013) 58 [arXiv:1212.1897 [hep-ph]].
[3] K. Hattori, K. Itakura, S. Ozaki, "Neutral-pion reactions induced by chiral anomaly in strong magnetic fields," arXiv:1305.7224 [hep-ph]

Heavy ion collisions / **39**

Particle production from expanding flux tubes

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A high-energy nucleus can be viewed as a condensed state of high-density and weak-coupling gluons, which is called color glass condensate. After a collision of heavy nuclei, these gluons are emitted between the two nuclei and they can be interpreted as coherent classical chromo-electromagnetic fields polarized in the longitudinal beam direction. The strength of these fields is given by the scale Q_s, which characterize the gluon saturation phenomena in high-energy nuclei, and typically is the order of 1 GeV^2. As two nuclei recede from each other after the collision, these fields extend to the longitudinal direction with nearly the speed of light. In the transverse direction, these fields have a random distribution with a coherence length characterized by the scale Q_s.
To investigate quark production from such inhomogeneous classical fields, we employ a Monte Carlo technique, which enable us to simulate the real-time dynamics of quantum fields interacting with a background classical field with a cheaper numerical cost compared with another method. We will show the results of numerical calculations in which realistic configurations of the color gauge fields in heavy-ion collisions are taken into account.

Experiments and facilities / **40**

Future linear colliders: an opportunity to study strong field QED

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Future linear colliders will collide dense charge bunches generating
very intense electromagnetic fields at the IP, often approaching or even exceeding the Schwinger critical field in the rest frame of the
ultrarelativistic colliding particles. These strong fields affect all the processes happening at the IP, in particular, at 1st order, beamstrahlung and coherent pair production.
The dense beams at the LC offer another opportunity to test strong field/nonlinear QED and a whole range of further predicted phenomena.
We propose an experiment that will focus an intense laser on the LC electron beam post-IP.
High energy electrons then undergo vacuum polarization effects when the field strength approaches the Schwinger critical field.
Previously similar experiments at SLAC E144 have investigated nonlinear
Compton scattering, Breit-Wheeler pair production and electron mass shift using an electron beam of 46.6 GeV; the higher and intense beam energies at the next LC would allow more precise studies of these phenomena.
We also plan to test for the first time the radiative transitions between Zel'dovich electron quasi-levels in a laser.

Radiation reaction / 41

Radiation reaction in QED: perturbative and non-perturbative approaches.

Author: Anton Ilderton[1]

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I will discuss recent theoretical results in radiation reaction (RR). In the first part of the talk I will describe how and where RR appears in QED, and the possibilities for measuring RR in different regimes and in different experiments (with say lasers, or Coulomb fields).

RR effects are expected to become significant in the regimes reached by next generation laser facilities. Aside from a few exact solutions, there are though few nonperturbative treatments of RR available. In the second part of the talk I will describe a new non-perturbative approach to QED in strong background fields, called 'basis lightfront quantisation'.

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An analytical perturbative model for cascading in a nano-foil irradiated by intense circular laser radiation

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We consider circular ultra-intense laser radiation interacting with a
rigid nano-foil within the attractive potential of an immobile ion background in 1D. We show that the foil performs an-harmonic oscillations and
has always a finite recurrence time that depends on the foil density and
the irradiation parameters of the laser radiation. Under specific radiation and density conditions the foil can acquire large kinetic energy and
combining this with targeted irradiation conditions large quantum
efficiencies. We will solve the corresponding equations for cascading in a perturbative manner and

compare with the predictions of
our numerical simulation model.

Experiments and facilities / 43

Quantum Synchrotron Radiation Measurements using Crystals

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Co-author: Ulrik Uggerhoj [1]

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The classical description of synchrotron radiation fails at large Lorentz factors for relativistic electrons crossing strong transverse magnetic fields. When the Lorentz factor times the magnetic field is comparable to the so-called critical field of 4.4 GT, quantum corrections are essential for the description of synchrotron radiation. The radiation emission drastically changes character; not only in magnitude, but also in spectral shape and can only be described by quantum synchrotron radiation formulas. This has been experimentally tested with electrons of energies 10-150 GeV penetrating a germanium single crystal along the <110> axis. Apart from being a test of strong-field quantum electrodynamics, the results are also relevant for the design of future linear colliders where beamstrahlung - a closely related process - may limit the achievable luminosity.

Strong Field QFT / 44

Strongly interacting matter: equation of state and transport properties from a gravity dual

Author: Burkhard Kampfer[1]

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Employing the AdS/QCD correspondence the graviton potential is adjusted in a bottom-up approach. Lattice QCD data for the equation of state at non-zero temperature serve as input. Transport coefficients follow then without further assumptions or fine tuning.

Strong Field QFT / 45

Optical probes of the quantum vacuum

Author: Felix Karbstein[None]

The photon polarization tensor is the central object in an effective theory describing photon propagation in the quantum vacuum. It accounts for the vacuum fluctuations of the underlying theory, and in the presence of external electromagnetic fields, gives rise to such striking phenomena as vacuum birefringence and dichroism. For homogeneous magnetic fields it is explicitly known at one-loop accuracy in momentum space. Most of the studies currently available are manifestly carried out in momentum space, and are often limited to both constant fields and on-the-light-cone dynamics. We aim at insights into the photon polarization tensor beyond this restrictions: We emphasize that the full momentum dependence is essential in the treatment of problems explicitly posed in position space. Moreover, we argue that considerations of this type can provide access to new phenomena,

such as quantum reflection of probe photons off the polarized quantum vacuum.

Outlook / 46

Testing non-linear QED with Lasers - Experiments feasible now.

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The development of ultra-intense lasers has brought Physics in intense fields into sharp focus from a perspective of testing theoretical predictions - some quite longstanding - for the first time. Reaching a significant fraction of the critical QED field strength is still some way off for a real facility, however many possibilities exist with current technology or near-term achievable parameters and these will be the focus of the Presentation.

Radiation reaction / 51

Effect of radiation reaction on the motion of a high energy particle

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Radiation reaction effects, in particular the effects of stochasticity, in dynamics of a high energy particle are studied by using semiclassical approach to radiation reaction.

Workshop Greeting / 52

Workshop Greeting

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tribute to V. Baier

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Workshop Introduction

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Ultra-Intense LASERs / 55

Birefringence, dichroism and Raman spectroscopy of the vacuum: searching minicharged particles in a high-intensity laser field

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The quantum vacuum, polarized by a classical electromagnetic field, behaves as an active medium. Its absorptive and dispersive properties are studied in the presence of a high-intensity circularly polarized laser wave. The outcomes of this investigation reveal that, in the region relatively close to the threshold of the two-photon reaction, the birefringence and dichroism of the vacuum can be manifest with lasers of moderate intensities. We take advantage of such properties to impose upper bounds on the parameters associated with hypothetical minicharged particles. In addition, Raman-like electromagnetic waves resulting from a plausible inelastic interaction are suggested as an alternative form for finding exclusion limits on these charge carriers.

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Wrapup

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