Symposium Kernphysik mit starken Laserfeldern (SYKL)

gemeinsam veranstaltet
vom Arbeitskreis AMOP und
dem Fachverband Physik der Hadronen und Kerne (HK)

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Moderne Lasersysteme haben Pulsleistungen bis in den Petawattbereich und erlauben bei Fokussierung dadurch Intensitäten, die das Feld der laserinduzierten Kernphysik erschließen. Die Wechselwirkung zwischen Photonen und Atomkernen erfolgt entweder indirekt z.B. über ein Plasma oder auch direkt ohne sekundäre Teilchen. Charakteristisch sind hierbei einerseits die hohe Energiedichte, die etwa Teilchenbeschleunigung auf kleinsten Raum ermöglicht. Andererseits können durch die Kohärenz des Lichtes bei für die Kernphysik relevanten Photonenenergien z.B. die in der Atomphysik typischen Kohärenz- und Interferenzeffekte auf die Kernphysik übertragen werden. In diesem Symposium soll ein Überblick über das vielfältige Anwendungsspektrum im Überlappbereich zwischen Laser- und Kernphysik gegeben werden.

Übersicht der Hauptvorträge und Fachsitzungen

(Hörsaal 1A)

Hauptvorträge

SYKL 1.1	Di	8:30– 9:00	1A	**Status of research into isomer depletion reactions** — •James J. Carroll
SYKL 1.2	Di	9:00– 9:30	1A	**Optical access to the lowest nuclear transition in ^{229}Th*** — •Peter G. Thirolf, Michael Bussmann, Dietrich Habs, Hans-Jörg Maier, Jürgen Neumayr, Jörg Schreiber, Michael Sewtz, Jerzy Szerypo
SYKL 1.3	Di	9:30–10:00	1A	**Direct interaction of nuclei with superintense laser fields** — •Thomas Bürvenich
SYKL 1.4	Di	10:00–10:30	1A	**Aspects of Electromagnetically induced transparency using nuclear radiation** — •Jos Odeurs
SYKL 2.1	Di	11:00–11:30	1A	**Acceleration of particles by short ultra-intense laser pulses** — •Oswald Willi
SYKL 2.2	Di	11:30–12:00	1A	**Prospects for the application of laser-accelerated particle beams** — •Ulrich Schramm
SYKL 2.3	Di	12:00–12:30	1A	**A Vision for Laser Induced Particle Acceleration and Applications** — •Kenneth Ledingham
SYKL 2.4	Di	12:30–13:00	1A	**Laser-Driven Recollisions: From Atomic to Nuclear Physics and Beyond** — •Carsten Müller, Atif Shahbaz, Guido R. Mocken, Karen Z. Hatsagortsyan, Christoph H. Keitel

Fachsitzungen

SYKL 1.1–1.4	Di	8:30–10:30	1A	**Resonant laser-nucleus interactions**
SYKL 2.1–2.4	Di	11:00–13:00	1A	**Photo-nuclear reactions and MeV particle acceleration**

SYKL 1: Resonant laser-nucleus interactions

Zeit: Dienstag 8:30–10:30 Raum: 1A

Hauptvortrag SYKL 1.1 Di 8:30 1A

Status of research into isomer depletion reactions — •James J. Carroll — Department of Physics and Astronomy, Youngstown State University, One University Plaza, Youngstown, Ohio 44555 USA

Nuclear isomers are attractive targets for study since their very existence reflects specific structural barriers to transitions between them and other nuclear levels. An inhibition of isomer decay corresponds to an intriguing ability to store energy at high densities, particularly for long-lived isomers with half-lives longer than a day. Apart from a basic physical interest in isomerism, the potential for practical applications of this form of energy storage has provided an additional impetus for research. To this point, experimental studies have primarily focused on resonant interactions between nuclei and external stimulae, like photons, by which to induce a depletion of isomeric populations through intermediate states. Currently induced depletion has been demonstrated for three isomers, ^{180m}Ta, ^{177m}Lu and ^{68m}Cu, and additional tests are underway or anticipated for other isomers. The cross sections for resonant depletion reactions appear to be relatively small. However, non-resonant processes like NEET and NEEC have been suggested as means of enhancing the efficiency of isomer depletion through a coupling between atomic and nuclear transitions. This talk will survey the status of research into resonant depletion of isomers and look ahead to new directions related to non-resonant processes.

Hauptvortrag SYKL 1.2 Di 9:00 1A

Optical access to the lowest nuclear transition in ^{229}Th* — •Peter G. Thirolf, Michael Bussmann, Dietrich Habs, Hans-Jörg Maier, Jürgen Neumayr, Jörg Schreiber, Michael Sewtz, and Jerzy Szerypo — Ludwig-Maximilians-Universität München and Maier-Leibnitz Laboratory, Garching, Germany

The isomeric first excited state of ^{229}Th is known to be the lowest excitation in the whole chart of nuclei. For a long time its nuclear level energy was reported as 3.5±0.5eV. In a recent experiment this transition energy was remeasured, resulting in an important change of the energy to E_γ=(7.6±0.5) eV, corresponding to a transition wavelength of λ=(163 ± 11)nm [1]. The estimated lifetime of the level is τ= 3-5 hours, which corresponds to a relative line width of about 10^{-20}, 5 to 6 orders of magnitude smaller than typical relative atomic line widths measured in experiments with single laser-cooled ions. The ^{229m}Th transition appears to be the most sensitive probe for studying the time dependence of the fine structure constant α and quark masses. We are presently working on a stepwise approach to confirm the excitation energy and the long lifetime of ^{229m}Th, aiming at a measurement of the transition energy with increasing accuracy. Since possible lasers for λ=(163 ± 11)nm depend very much on the exact transition wave length, the question of directly exciting the nucleus can only be addressed after the transition energy has been determined more accurately in nuclear excitation.

[1]: B.R. Beck et al., PRL **98** (2007) 142501.

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Hauptvortrag SYKL 1.3 Di 9:30 1A

Direct interaction of nuclei with superintense laser fields — •Thomas Bürvenich — Frankfurt Institute for Advanced Studies, Frankfurt, Germany

The direct interaction of nuclei with superintense laser fields is studied. While direct laser-nucleus interactions have often been dismissed, we demonstrate that present and upcoming high-frequency laser facilities do allow for resonant laser-nucleus interaction. These direct interactions may be utilized for the model-independent optical measurement of nuclear properties or the preparation and control of nuclear states [1]. We further study non-resonant direct laser-nucleus interactions such as the dynamic nuclear Stark shift [2]. While electric dipole-allowed transitions in nuclei correspond most closely to atomic quantum optics, it is shown that in nuclei non-electric-dipole transitions are promising candidates [3]. Perspectives for the field of nuclear quantum optics are given.

[1] T. J. Bürvenich, J. Evers, and C. H. Keitel, Phys. Rev. Lett. 96, 142501 (2006)
[2] T. J. Bürvenich, J. Evers, C. H. Keitel, Phys. Rev. C 74, 044601 (2006)
[3] A. Pálffy, J. Evers, and C. H. Keitel, arXiv:0711.0015

Hauptvortrag SYKL 1.4 Di 10:00 1A

Aspects of Electromagnetically induced transparency using nuclear radiation — •Jos Odeurs — Katholieke Universiteit Leuven, Instituut voor Kern- en Stralingsfysica, Celestijnenlaan 200D, B-3001 Leuven, Belgium

Coherence and interference using gamma radiation has led to the relatively new field of nuclear quantum optics. It deals with the resonant interaction of single gamma photons with an ensemble of nuclei incorporated in a solid-state lattice. Gamma ray sources having an extremely narrow energy spectrum (of the order of 10-9 eV) can be produced because of recoilless emission, i.e., the Mössbauer effect, which eliminates the phonon line broadening. Electromagnetically induced transparency (EIT) is the phenomenon, known in atomic quantum optics, where a resonant medium can become transparent for radiation by applying another coherent radiation field. An important deficit in absorption under well-defined conditions has been observed for gamma radiation emitted by the 14.4 keV excited state of 57Fe passing through a single crystal of FeCO3. The experiment will be described and the theory, based on a variation of EIT in the nuclear realm, called level-mixing induced transparency, will be outlined.

Slow group velocity for gamma radiation will be discussed. For the experiments on FeCO3, the group velocity of the single gamma photons can be estimated at 1 km/s.

SYKL 2: Photo-nuclear reactions and MeV particle acceleration

Zeit: Dienstag 11:00–13:00 Raum: 1A

Hauptvortrag SYKL 2.1 Di 11:00 1A

Acceleration of particles by short ultra-intense laser pulses — •Oswald Willi — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

The recent demonstration of the acceleration of energetic electrons, protons and ions by irradiation of matter by intense laser pulses has opened new perspectives for major applications in scientific, technological and medical areas. Quasi mono-energetic electrons with an energy up to one GeV and quasi mono-energetic protons in the several MeV range have been observed in recent experiments. These beams have interesting properties including small source size, high degree of collimation, short duration and large number densities allowing many potential novel applications. One of the applications is the diagnosis of high-density plasmas using protons allowing the transient electric and magnetic field generation mechanisms in laser-produced plasmas to be studied. For example, the electric fields responsible for the acceleration and expansion of multi-MeV protons from the rear surface of thin solid foils irradiated by an intense laser pulse or the electric fields inside a laser irradiated hollow metal cylinder which acts as an electrostatic micro-lens for proton focusing and energy selection can be measured. In addition, magnetic fields produced inside high density plasmas can be studied. In the presentation a summary of the latest experimental studies investigating electric and magnetic fields in laser produced plasmas will be discussed.

Hauptvortrag SYKL 2.2 Di 11:30 1A

Prospects for the application of laser-accelerated particle beams — •Ulrich Schramm — Forschungszentrum Dresden-Rossendorf (FZD), Germany

The field of laser-electron and laser-proton acceleration has matured over the last years to an extent that applications of laser-accelerated particle pulses can be envisaged in life science and material research. At the newly established 150TW laser lab of the FZ Dresden-Rossendorf we therefore prepare to exploit these technologies in close collaboration with the electron accelerator lab ELBE and the radiation biology departments of the center and of oncoray Dresden. Here, the status of the lab and first results will be reported.

Hauptvortrag SYKL 2.3 Di 12:00 1A

A Vision for Laser Induced Particle Acceleration and Applications — •Kenneth Ledingham — Department of Physics, University of Strathclyde, Glasgow G40NG, Scotland

Large particle accelerators like CERN and GSI have for more than half a century been at the vanguard of nuclear and particle physics revealing the fundamental building blocks and forces of nature. However the size and cost of these are fuelling serious efforts to develop new and more compact accelerator technologies. Recently it has been shown that ultra-intense lasers, via plasma conditions, can generate high intensity beams of electrons, photons, protons, neutrons and heavy ions. This talk will describe some of the experiments which have been carried out as proof of principle of this new field. The experiments which will be described were mostly carried out on large single pulse lasers which equally are large accelerators. One of the important applications of compact high power lasers is to PET isotope production and in the longer term to proton oncology.

New high intensity lasers sources with intensities $> 10^{23}$ Wcm^{-2} will be discussed and possible experiments they can perform.

However the future of this exciting field could be further developed by intense counter propogating laser beams which in principle could produce beams of positrons, muons and pions and even create particles from the vacuum. This of course could lead to γ-γ colliders. The possibility of creating Unruh radiation will also be discussed.

Hauptvortrag SYKL 2.4 Di 12:30 1A

Laser-Driven Recollisions: From Atomic to Nuclear Physics and Beyond — •Carsten Müller, Atif Shahbaz, Guido R. Mocken, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg

The interaction of atoms and molecules with intense laser fields can lead to electron recollisions with the parent ionic core due to the oscillating nature of laser fields. These collisions give rise to various nonlinear phenomena such as above-threshold ionization and high-harmonic generation. In the talk we report on recent theoretical studies on potential applications of the recollision mechanism in nuclear and high-energy physics [1,2]. To this end, the interaction of laser pulses with atoms, highly-charged ions, and exotic systems like positronium and muonic atoms is considered. It is shown that under suitable conditions, nuclear excitation can occur by the electronic charge cloud that is driven across the nucleus by the laser field. Moreover, the high-harmonic response from compact systems like muonic atoms exhibits signatures of the binding nucleus which might be useful for determination of unknown nuclear properties [1]. Finally, the recollision scheme can be extended to the highly relativistic regime by application of positronium atoms. This way, even particle reactions like muon production can be triggered in laser-driven electron-positron collisions [2].

[1] A. Shahbaz, C. Müller, A. Staudt, T. J. Bürvenich, and C. H. Keitel, Phys. Rev. Lett. 98, 263901 (2007)
[2] C. Müller, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Lett. B, accepted (arXiv:0705.0917)