

PLASMEN IN UNGEWÖHNLICHEN SITUATIONEN (SYPS)

gemeinsam veranstaltet von den Fachverbänden
 Atomphysik (A),
 Plasmaphysik (P) und
 Quantenoptik und Photonik (Q)

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EINLEITUNG

In der Vielteilchen-Atomphysik spielen Plasmen endlicher Ausdehnung eine zunehmende Rolle. Dies soll das Symposium an zwei aktuellen Forschungsthemen deutlich machen: Ultrakalte Plasmen, erzeugt durch das Kühlen von Gasen in Magneto-Optischen Fallen, und lasererzeugte nichtrelativistische Plasmen in Clustern und an Oberflächen, wie sie typischerweise unter Strahlung der zukünftigen Free-Electron-Laser (FEL's) in Hamburg (DESY) und Stanford auftreten werden.

ÜBERSICHT DER HAUPTVORTRÄGE UND FACHSITZUNGEN

(Hörsaal HU Audimax)

Hauptvorträge

SYPS 1.1	Mo	10:45	(HU Audimax)	Ultracold Neutral Plasmas , <u>Thomas Killian</u>
SYPS 1.2	Mo	11:15	(HU Audimax)	Strong coupling effects in expanding ultracold neutral plasmas , <u>Thomas Pohl</u>
SYPS 1.3	Mo	11:45	(HU Audimax)	Theory of strongly correlated charged particles in traps , <u>Michael Bonitz</u> , Alexei Filinov
SYPS 1.4	Mo	12:15	(HU Audimax)	Recent experiments with laser-cooled ion plasmas in a Penning trap , <u>M.J. Jensen</u> , J.J. Bollinger, T. Hasegawa, D.H.E. Dubin
SYPS 2.1	Mo	14:00	(HU Audimax)	Creation of cluster plasmas at short wavelengths: Results and perspectives , <u>Hubertus Wabnitz</u> , A. Rubens B. de Castro, Peter Guertler, Tim Laarmann, Wiebke Laasch, Patrick Montchicourt, Joachim Schulz, Christoph Bostedt, Thomas Moeller
SYPS 2.2	Mo	14:30	(HU Audimax)	Hot nanoplasmas: clusters in intense fields , <u>Christian Siedschlag</u>
SYPS 2.3	Mo	15:00	(HU Audimax)	Metal clusters under short and intense laser pulses , <u>K.H. Meiwes-Broer</u> , T. Döppner, Th. Fennel, P. Radcliffe, A. Przystawik, J. Tiggesbäumker
SYPS 2.4	Mo	15:30	(HU Audimax)	High-Density Plasmas Generated by DESY FEL-Beams , <u>Jürgen Meyer-ter-Vehn</u>

Fachsitzungen

SYPS 1	Symposium: Plasmas in unusual situations, Part I:	Mo 10:45–12:45	HU Audimax	SYPS 1.1–1.4
	Ultracold plasmas			
SYPS 2	Symposium: Plasmas in unusual situations, Part II:	Mo 14:00–16:00	HU Audimax	SYPS 2.1–2.4
	Laser generated plasmas			

Fachsitzungen

– Hauptvorträge –

SYPS 1 Symposium: Plasmas in unusual situations, Part I: Ultracold plasmas

Zeit: Montag 10:45–12:45

Raum: HU Audimax

Hauptvortrag SYPS 1.1 Mo 10:45 HU Audimax
Ultracold Neutral Plasmas — •THOMAS KILLIAN — Department of Physics and Astronomy, Rice University, Houston, Texas, USA

Ultracold neutral plasmas [1], formed by photoionizing laser-cooled atoms near the ionization threshold, stretch the boundaries of traditional neutral plasma physics. The electron temperature in these plasmas is from 1-1000K and the ion temperature is around 1 K. The density can be as high as 10^{10} cm⁻³. Fundamental interest stems from the possibility of creating strongly-coupled plasmas, but recombination, collective modes, and thermalization in these systems have also been studied.

The ultracold plasma group at Rice University recently demonstrated optical absorption imaging of a strontium plasma [2] using the Sr⁺ ²S_{1/2} → ²P_{1/2} transition at 422 nm. Images depict the density profile of the plasma and probe kinetics on a 50 ns time-scale. The Doppler-broadened ion absorption spectrum measures the ion velocity distribution, which gives an accurate measure of the ion dynamics in the first few hundred nanoseconds after photoionization.

Current work focuses on kinetic energy oscillations during plasma equilibration and developing the tools to laser cool and trap the plasma. This work is supported by the Department of Energy, National Science Foundation, Alfred P. Sloan Foundation, Research Corporation, and David and Lucille Packard Foundation.

[1] T. C. Killian, S. Kulin, S. D. Bergeson, L. A. Orozco, C. Orzel, and S. L. Rolston, Phys. Rev. Lett. **83**, 4776 (1999). [2] C. E. Simien, Y. C. Chen, P. Gupta, S. Laha, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, T. C. Killian, Phys. Rev. Lett. **92**, 143001 (2004).

Hauptvortrag SYPS 1.2 Mo 11:15 HU Audimax
Strong coupling effects in expanding ultracold neutral plasmas — •THOMAS POHL — Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, D-01187 Dresden

In a number of recent experiments ultracold neutral plasmas have been produced by photoionizing laser-cooled atomic ensembles. The very low initial temperatures suggest that these plasmas have been produced deep within the strongly coupled regime. Furthermore, the relaxation timescales realized in these plasmas indicate that Bogoliubov's functional hypothesis, frequently used in plasma kinetic theory, is violated in the present case, giving rise to an unusual relaxation behavior.

Based on a recently developed hybrid-molecular-dynamics approach [1], we discuss the expansion dynamics of ultracold plasmas with special emphasis on the strongly coupled ion dynamics. We demonstrate that the present method yields an accurate description of recent measurements [2,3] and allows to address important questions beyond present experimental capabilities.

Furthermore, we show that additional laser cooling during the plasma evolution drastically modifies the expansion dynamics, so that crystallization of the ion component can occur in this nonequilibrium system [4].

[1] T. Pohl, T. Pattard and J.M. Rost, Phys. Rev. A **70**, 033416 (2004)
 [2] C.E. Simien et al., Phys. Rev. Lett. **92**, 143001 (2004)

[3] J.L. Roberts et al., Phys. Rev. Lett. **92**, 253003 (2004)

[4] T. Pohl, T. Pattard and J.M. Rost, Phys. Rev. Lett. **92**, 155003 (2004)

Hauptvortrag SYPS 1.3 Mo 11:45 HU Audimax
Theory of strongly correlated charged particles in traps — •MICHAEL BONITZ and ALEXEI FILINOV — Institute for Theoretical Physics and Astrophysics, Christian-Albrechts-University Kiel, Leibnizstr. 15, 24098 Kiel

Charged particles which are spatially confined by trapping potentials constitute a peculiar type of plasmas which are *non-neutral*. Such plasmas can exist for very long times and may be manipulated in broad parameter ranges. Of special interest is the possibility to create and analyze in detail strong correlation phenomena, including the formation of bound states or of liquid-like and crystal-like collective behavior. Examples are ultracold ions in Paul traps, electron or positron plasmas in Penning traps, dusty plasmas, electrons and holes in quantum confined semiconductor structures or valence electrons of metal clusters.

In this talk we present theoretical results for classical two-dimensional and three-dimensional mesoscopic Coulomb crystals in parabolic spherical traps. After this, quantum Coulomb systems in traps are discussed. In particular, we present results for excitonic bound states in semiconductor quantum wells, including the influence of disorder (well width fluctuations), and for quantum Wigner crystals in quantum dots. Finally, a quantum kinetic theory for the short-time behavior of trapped correlated particles is outlined. Of particular interest is the dynamics of Coulomb correlations and the possibility of correlation induced cooling which was predicted a few years ago [1] and for which meanwhile a few interesting schemes have been proposed.

[1] D. Semkat, D. Kremp, and M. Bonitz, Phys. Rev. E **59**, 1557 (1999)

Hauptvortrag SYPS 1.4 Mo 12:15 HU Audimax
Recent experiments with laser-cooled ion plasmas in a Penning trap — •M.J. JENSEN¹, J.J. BOLLINGER¹, T. HASEGAWA², and D.H.E. DUBIN³ — ¹NIST, Boulder, CO 80305, USA — ²Univ. of Hyogo, Hyogo 678-1297, Japan — ³UCSD, La Jolla, CA 92093, USA

Up to $\sim 10^6$ ⁹Be⁺ ions are trapped in a 4.5 Tesla Penning trap and laser-cooled to ~ 1 mK where the ions form a crystal with an interparticle spacing of ~ 20 μ m. This system is a realization of a strongly coupled one-component plasma. Through Bragg scattering and direct imaging we have observed 3-dimensional periodic crystals in this plasma. Recently, we have measured the temperature of the plasma when not laser-cooled. A slow heating rate of < 100 mK/s, observed for the first 100-200 ms after turning off the laser-cooling, is followed by a sudden, rapid heating to 1-2 K in 100 ms as the plasma undergoes the solid-liquid phase transition at $T = 10$ mK ($\Gamma \sim 170$). We will present evidence that this rapid heating is due to a sudden release of energy from weakly cooled degrees of freedom involving the cyclotron motion of trapped impurity ions. A method to suppress this rapid heating will be presented, and the prospects for observing the latent heat associated with the phase transition will be discussed.

SYPS 2 Symposium: Plasmas in unusual situations, Part II: Laser generated plasmas

Zeit: Montag 14:00–16:00

Raum: HU Audimax

Hauptvortrag SYPS 2.1 Mo 14:00 HU Audimax
Creation of cluster plasmas at short wavelengths: Results and perspectives — •HUBERTUS WABNITZ¹, A. RUBENS B. DE CASTRO², PETER GUERTLER², TIM LAARMANN³, WIEBKE LAASCH², PATRICK MONTCHICOURT¹, JOACHIM SCHULZ⁴, CHRISTOPH BOSTEDT⁵, and THOMAS MOELLER⁵ — ¹CEA, DRECAM/SPAM, France — ²HASYLAB/DESY, Hamburg — ³Max-Born Institut, Berlin — ⁴MAX-Lab, Sweden — ⁵TU Berlin

Until recently the investigation of the interaction of strong light fields with matter at short wavelengths beyond the ultraviolet spectral range was hindered by the lack of sufficiently intense light sources. The production of gigawatt radiation in the vacuum ultraviolet range with intensities up to 10^{13} W/cm² at the DESY free-electron laser opened the door to such studies. First experiments with clusters have shown that in principle a highly ionised medium is formed, which absorbs unexpectedly strong and finally disintegrates by Coulomb explosion. This contribution will

first review the results from the FEL experiment and then turn towards forthcoming experiments. Besides future work at the VUV-FEL, complementary time resolved cluster studies using high harmonic generation (HHG) as intense VUV light source will be presented.

Hauptvortrag

SYPS 2.2 Mo 14:30 HU Audimax

Hot nanoplasmas: clusters in intense fields — ●CHRISTIAN SIEDSCHLAG — AMOLF, Kruislaan 407, 1098SJ Amsterdam

Rare gas clusters respond extremely sensitive to irradiation with intense fields. Due to an absorption that can reach up to 100 %, hot, expanding nanoplasmas with 8 or more electrons per ion can be formed. We investigate the behavior of these hot clusters under a wide range of conditions, from single femtosecond IR pulses over FEL pulses in the VUV domain to various pump-probe schemes which turn out to be useful for the detailed understanding of the expansion process. The influence of different cluster sizes is investigated as well, and the evolution from molecular to plasma behavior is elucidated using an optimal control scheme.

Hauptvortrag

SYPS 2.3 Mo 15:00 HU Audimax

Metal clusters under short and intense laser pulses — ●K.H. MEIWES-BROER, T. DÖPPNER, TH. FENNEL, P. RADCLIFFE, A. PRZYSTAWIK, and J. TIGGESBÄUMKER — Fachbereich Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock

The interaction of metal clusters with intense laser light fields leads to a giant up-charging and subsequent Coulomb explosion. Most interestingly, it has been shown that for free metal clusters the highest charge states of the ionic fragments are not produced with the shortest laser pulses (and hence the highest intensity of $1.5 \times 10^{16} \text{ W/cm}^2$) but with stretched pulses having a width of 600 fs to 1000 fs [1]. This phenomenon we currently attribute to plasmon enhanced ionization. Studying the charging

dynamics using the femtosecond dual-pulse technique gives a much higher time resolution and simplifies the interpretation of the experimental findings. Applying this method to free clusters and those which are embedded in helium droplets, reveals a significant influence of charge transfer processes [2]. The experimental results will be discussed in view of Vlasov simulations [3].

[1] L. Köller, M. Schumacher, J. Köhn, S. Teuber, J. Tiggesbäumker, and K.H. Meiwes-Broer, Phys. Rev. Lett. **82**, 3783 (1999).

[2] T. Döppner, S. Teuber, Th. Diederich, Th. Fennel, P. Radcliffe, J. Tiggesbäumker, and K.H. Meiwes-Broer, Eur. Phys. J. D **24**, 157 (2003).

[3] Th. Fennel, G. Bertsch, and K.H. Meiwes-Broer, Eur. Phys. J. D **29**, 367 (2004).

Hauptvortrag

SYPS 2.4 Mo 15:30 HU Audimax

High-Density Plasmas Generated by DESY FEL-Beams — ●JÜRGEN MEYER-TER-VEHN — Max-Planck-Institute for Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

New options to study hot dense matter physics and plasma soft X-ray lasers with very intense XFEL beams at DESY in Hamburg will be discussed. Already the 100 fs XUV pulses, becoming available with photon energies of 20 - 200 eV in 2005, may reach intensities up to 10^{18} W/cm^2 when focussed to spots of 1 mm diameter. They will generate thin layers of uniform solid-density plasma with temperatures up to 1 keV and Gbar pressures and allow to investigate the phase diagram of hot dense matter in a wide density and temperature range, not accessible so far for high-precision measurements. In addition to target heating, scattered photons will provide detailed information on the structure of the generated plasma. During the 100 fs interaction time, the target material will be in an extreme state of non-equilibrium. Here we present theoretical investigations showing that the XUV pulses can be used as pumps to demonstrate He-a laser schemes for the first time.