

Contents

Introduction to Simple Atoms

Savely G. Karshenboim, Francesco S. Pavone 1

Part I Hydrogen and Helium

Precision Spectroscopy of Atomic Hydrogen

F. Biraben, T.W. Hänsch, M. Fischer, M. Niering, R. Holzwarth, J. Reichert, Th. Udem, M. Weitz, B. de Beauvoir, C. Schwob, L. Jozefowski, L. Hilico, F. Nez, L. Julien, O. Acef, J.-J. Zondy, A. Clairon 17

Ultracold Hydrogen

Lorenz Willmann, Daniel Kleppner 42

Review of High Precision Theory and Experiment for Helium

Gordon W. F. Drake 57

Part II Positronium and Muonium

Spectroscopy of the Muonium Atom

Klaus-Peter Jungmann 81

Experimental Tests of QED in Positronium: Recent Advances

Ralph S. Conti, Richard S. Vallery, David W. Gidley, Jason J. Engbrecht, Mark Skalsey, Paul W. Zitzewitz 103

Part III Fundamental Constants and Frequency Metrology

A New Type of Frequency Chain and Its Application to Fundamental Frequency Metrology

Thomas Udem, Jörg Reichert, Ronald Holzwarth, Scott Diddams, David Jones, Jun Ye, Steven Cundiff, Theodor Hänsch, John Hall 125

Fundamental Constants and the Hydrogen Atom

Peter J. Mohr, Barry N. Taylor 145

Present Status of $g - 2$ of Electron and Muon

Toichiro Kinoshita 157

Part IV Few-Electron Highly-Charged Ions

Laser Spectroscopy of Hydrogen-Like and Helium-Like Ions

Edmund G. Myers 179

The g Factor of Hydrogenic Ions: A Test of Bound State QED

G. Werth, H. Häffner, N. Hermanspahn, H.-J. Kluge, W. Quint, J. Verdú 204

Part V Exotic Atoms

Elementary Relativistic Atoms

Leonid Nemenov 223

Antiprotonic Helium – An Exotic Hydrogenic Atom

Toshimitsu Yamazaki 246

Appendix: Abstracts of Contributed Papers

Edited by S. G. Karshenboim and F. S. Pavone 266

Subject Index 285

Author Index 290

Contributed Papers (on CD only)

Part VI Hydrogen and Helium

Towards a Precise Measurement of the He^+ 2S Lamb Shift

S. A. Burrows, S. Guérandel, E. A. Hinds, F. Lison, M. G. Boshier 303

High Precision Measurements on Helium at 1083 nm

Pablo Cancio Pastor, Paolo De Natale, Giovanni Giusfredi, Francesco S. Pavone, Massimo Inguscio 314

Absolute Frequency Measurement of the 1S-3S Transition in Hydrogen

Gaëtan Hagel, Rémy Battesti, Catherine Schwob, Francois Nez, Lucile Julien, Francois Biraben, Ouali Acef, Jean-Jacques Zondy, André Clairon . 328

2s Hyperfine Structure in Hydrogen Atom and Helium-3 Ion

Savely G. Karshenboim 335

Three-Loop Slope of the Dirac Form Factor and the 1S Lamb Shift in Hydrogen	
<i>Kirill Melnikov, Timo van Ritbergen</i>	344
Radiative Decay of Coupled States in an External dc Field	
<i>Vitaly Pal'chikov, Yuri Sokolov, Valery Yakovlev</i>	352
Atomic Interferometer and Coherent Mixing of 2S and 2P States in the Hydrogen Atom	
<i>Yuri Sokolov</i>	356
Ground State Energy of the Helium Atom	
<i>Alexander Yelkhovsky</i>	363

Part VII Muonium and Positronium

Two-Loop Corrections to the Decay Rate of Orthopositronium	
<i>G.S. Adkins, R.N. Fell, J. Sapirstein</i>	375
Recent Results in Positronium Theory	
<i>Andrzej Czarnecki, Kirill Melnikov, Alexander Yelkhovsky</i>	387
Test of CPT and Lorentz Invariance from Muonium Spectroscopy	
<i>Vernon W. Hughes, David Kawall, Weiwen Liu, Matthias Grosse Perdekamp, Klaus Jungmann, Gisbert zu Putlitz</i>	397
Positronium: Theory Versus Experiment	
<i>Richard Ley, Günter Werth</i>	407
Highly Accurate Theoretical Simulation of the Resonant Multi-photon Ionization Processes With Simplest Atoms	
<i>Victor Yakhontov, Klaus Jungmann</i>	419

Part VIII Muonic Atoms

Time-of-Flight Spectroscopy of Muonic Hydrogen Atoms and Molecules	
<i>M. C. Fujiwara, A. Adamczak, J. M. Bailey, G. A. Beer, J. L. Beveridge, M. P. Faifman, T. M. Huber, P. Kammel, S. K. Kim, P. E. Knowles, A. R. Kunselman, V. E. Markushin, G. M. Marshall, G. R. Mason, F. Mulhauser, A. Olin, C. Petitjean, T. A. Porcelli, J. Zmeskal (TRIUMF Muonic Hydrogen Collaboration)</i>	435
Hyperfine Structure in Muonic Hydrogen	
<i>Klaus Jungmann, Vladimir G. Ivanov, Savely G. Karshenboim</i>	446

Towards a Measurement of the Lamb Shift in Muonic Hydrogen

R. Pohl, F. Biraben, C.A.N. Conde, C. Donche-Gay, T.W. Hänsch, F.J. Hartmann, P. Hauser, V.W. Hughes, O. Huot, P. Indelicato, P. Knowles, F. Kottmann, Y.-W. Liu, V.E. Markushin, F. Mulhauser, F. Nez, C. Petitjean, P. Rabinowitz, J.M.F. dos Santos, L.A. Schaller, H. Schnewly, W. Schott, D. Taqqu, J.F.C.A. Veloso 454

Part IX Exotic Atoms**Antihydrogen Production and Precision Spectroscopy with ATHENA/AD-1**

C. Amsler, G. Bendiscioli, G. Bonomi, P. Bowe, C. Carraro, C. L. Cesar, M. Charlton, M.J.T. Collier, M. Doser, K. Fine, A. Fontana, M.C. Fujiwara, R. Funakoshi, J. Hangst, R.S. Hayano, H. Higaki, M. H. Holzscheiter, W. Joffrain, L.V. Jørgensen, D. Kleppner, V. Lagomarsino, R. Landua, D. Lindelof, E. Lodi-Rizzini, M. Macri, D. Manuzio, G. Manuzio, M. Marchesotti, P. Montagna, H. Pruys, C. Regenfus, P. Riedler, A. Rotondi, G. Rouleau, G. Testera, T.L. Watson, D.P. van der Werf, T. Yamazaki, Y. Yamazaki 469

Precision Spectroscopy of X-rays from Antiprotonic Hydrogen

D. F. Anagnostopoulos, M. Augsburg, G. Borchert, C. Castelli, D. Chatellard, P. El-Khoury, J.-P. Egger, H. Gorke, D. Gotta, P. Hauser, P. Indelicato, K. Kirch, S. Lenz, N. Nelms, K. Rashid, Th. Siems, L. M. Simons 489

Charged Pion Mass Determination and Energy – Calibration Standards based on Pionic X-ray Transitions

D. F. Anagnostopoulos, M. Augsburg, G. Borchert, D. Chatellard, P. El-Khoury, J.-P. Egger, H. Gorke, D. Gotta, P. Hauser, M. Hennebach, P. Indelicato, K. Kirch, S. Lenz, Y.-W. Liu, B. Manil, N. Nelms, Th. Siems, L. M. Simons 500

Pionic Hydrogen: Status and Outlook

D. F. Anagnostopoulos, S. Biri, G. Borchert, W. H. Breunlich, M. Cargnelli, J.-P. Egger, B. Gartner, D. Gotta, P. Hauser, M. Hennebach, P. Indelicato, T. Jensen, R. King, F. Kottmann, B. Lauss, Y. W. Liu, V. E. Markushin, J. Marton, N. Nelms, G. C. Oades, G. Rasche, P. A. Schmelzbach, L. M. Simons, J. Zmeskal 508

Antiprotonic Helium “Atomcule”: Relativistic and QED Effects

V.I. Korobov 517

Towards Laser Spectroscopy of Antihydrogen

Jochen Walz, Anette Pahl, Kjeld S.E. Eikema, Theodor W. Hänsch 521

Hyperfine Structure Measurements of Antiprotonic Helium and Antihydrogen

Eberhard Widmann, John Eades, Ryugo S. Hayano, Masaki Hori, Dezso Horvath, Takashi Ishikawa, Bertalan Juhász, Jun Sakaguchi, Hiroyuki A. Torii, Hidetoshi Yamaguchi, Toshimitsu Yamazaki 528

Part X Precision Spectroscopy, Fundamental Constants and Fundamental Symmetry

Indium Single-Ion Optical Frequency Standard

Thomas Becker, Mario Eichenseer, Alexander Yu. Nevsky, Ekkehard Peik, Christian Schwedes, Mikhail N. Skvortsov, Joachim von Zanthier, Herbert Walther 545

Matter Neutrality Test Using a Mach-Zehnder Interferometer

Caroline Champenois, Matthias Büchner, Rémi Delhuille, Renaud Mathevet, Cécile Robilliard, Carlo Rizzo, Jacques Vigué 554

Relativistic Corrections in Atoms

and Space-Time Variation of the Fine Structure Constant

Vladimir A. Dzuba, Victor V. Flambaum, Michael T. Murphy, John K. Webb 564

Frequency Comparison and Absolute Frequency Measurement of I₂-stabilized Lasers at 532 nm

A. Yu. Nevsky, R. Holzwarth, J. Reichert, Th. Udem, T. W. Hänsch, J. von Zanthier, H. Walther, H. Schnatz, F. Riehle, P. V. Pokasov, M. N. Skvortsov, S. N. Bagayev 576

Part XI Few-Electron Ions

A QED Calculation of Electron Interaction for He-Like and Li-Like Highly Charged Ions

Oleg Andreev, Leonti Labzowsky 591

The g_J Factor of an Electron Bound in Hydrogen-Like Carbon: Status of the Theoretical Predictions

Thomas Beier, Ingvar Lindgren, Hans Persson, Sten O. Salomonson, Per Sunnergren 605

Second-Order Self-Energy Calculations for Tightly Bound Electrons in Hydrogen-Like Ions

Igor A. Goidenko, Leonti N. Labzowsky, Andrei V. Nefiodov, Günter Plunien, Sven Zschocke, Gerhard Soff 619

Lamb Shift in Light Hydrogen-Like Atoms

Vladimir G. Ivanov, Savely G. Karshenboim 637

The g Factor of a Bound Electron in a Hydrogen-Like Atom

Savely G. Karshenboim 651

Laser Spectroscopy of the 2S Lamb Shift in Hydrogenic Silicon

H. A. Klein, H. S. Margolis, J. L. Flowers, K. Gaarde-Widdowson, K. Hosaka, J. D. Silver, M. R. Tarbutt, S. Ohtani, D. J. E. Knight 664

Ground-State Hyperfine Structure of Heavy Hydrogen-Like Ions

T. Kühl, S. Borneis, A. Dax, T. Engel, S. Faber, M. Gerlach, C. Holbrow, G. Huber, D. Marx, P. Merz, W. Quint, F. Schmitt, P. Seelig, M. Tomasselli, H. Winter, M. Wuertz, K. Beckert, B. Franzke, F. Nolden, H. Reich, M. Steck 672

Measurement of the $1s2p\ ^3P_0 - ^3P_1$ Fine Structure Interval in Helium-Like Magnesium

E.G. Myers, M.R. Tarbutt 679

Towards a Precision Measurement of the Lamb Shift in Hydrogen-Like Nitrogen

E.G. Myers, M.R. Tarbutt 688

Absolute Test of Quantum Electrodynamics for Helium-Like Vanadium

David Paterson, Christopher T. Chantler, Larry T. Hudson, F. G. Serpa, John D. Gillaspy, Endre Takács 699

Relativistic Recoil Corrections to the Atomic Energy Levels

Vladimir M. Shabaev 714

X-Ray Spectroscopy of Hydrogen-Like Ions in an Electron Beam Ion Trap

M.R. Tarbutt, D. Crosby, E.G. Myers, N. Nakamura, S. Ohtani, J.D. Silver ... 727

Part XII Advanced Quantum Mechanics and QED

CPT-Invariant Eight-Component Two-Fermion Equation

Viktor Hund 739

The Two-Time Green's Function and Screened Self-Energy for Two-Electron Quasi-Degenerate States

Éric-Olivier Le Bigot, Paul Indelicato, Vladimir M. Shabaev 746

**Higher-Order Stark Effect on Magnetic Fine Structure
of the Helium Atom**

Aleksandr Magunov, Vitaly Ovsiannikov, Vitaly Pal'chikov, Victor Pivovarov, Gebhard von Oppen 753

**Radiation Properties of Diamagnetic Manifolds in Atomic
Hydrogen: Line Intensity Dependence on a Magnetic Field**

V.D. Ovsiannikov, V.V. Chernushkin 762

**Precise Evaluation of the Electron ($g - 2$)
at 4 loops: the Algebraic Way**

Pierpaolo Mastrolia, Ettore Remiddi 776

**Relativistic Dipole Dynamic Polarizability of Lowest $ns_{1/2}$ -States
in Hydrogen-Like Atoms**

Victor Yakhontov 784

**Loop-After-Loop Contribution
to the Second-Order Self-Energy in Hydrogen**

Vladimir A. Yerokhin 800

Contents of the 1989 Hydrogen Atom Book¹ (on CD only)

**Part I Precision Spectroscopy of Hydrogen:
Fundamental Physics and Universal Constants**

**The Hydrogen Atom (An Historical Account of Studies of Its
Spectrum)**

G.W. Series 2

Interference of the Hydrogen Atom States ($n = 2$)

Yu.L. Sokolov 16

**Separated Oscillatory Field Measurement
of the Lamb Shift in H, $n = 2$**

F.M. Pipkin 30

Hydrogen Spectroscopy and Fundamental Physics

W. Lichten 39

**Doppler-Free Two-Photon Spectroscopy
of Hydrogen Rydberg States: Remeasurement of R_∞**

M. Allegrini, F. Biraben, B. Cagnac, J.C. Garreau, and L. Julien 49

¹ G.F. Bassani, M. Inguscio, T.W. Hänsch (eds.): *The Hydrogen Atom* (Springer, Berlin, Heidelberg 1989)

Two-Photon Transitions Between Discrete States	
<i>A. Quattropani and N. Binggeli</i>	61
Two-Photon Spectroscopy of Hydrogen 1S–2S	
<i>D.N. Stacey</i>	68
1S–2S Transition-Frequency Calibration	
<i>A.I. Ferguson, J.M. Tolchard, and M.A. Persaud</i>	81
High Resolution Spectroscopy of Hydrogen	
<i>T.W. Hänsch</i>	93
Trapped Atomic Hydrogen	
<i>D. Kleppner</i>	103
Atomic Hydrogen in a Magnetic Trapping Field	
<i>J.T.M. Walraven, R. van Roijen, T.W. Hijmans</i>	112
Frequency Standards in the Optical Spectrum	
<i>D.J. Wineland, J.C. Bergquist, W.M. Itano, F. Dietrich, and C.S. Weimer</i> .	123
Precision RF Spectroscopy of Circular Rydberg Atoms	
<i>M. Gross, J. Hare, P. Goy, and S. Haroche</i>	134

Part II Positronium, Muonium, and Other Hydrogen-Like Systems

Laser Spectroscopy of Positronium and Muonium	
<i>S. Chu</i>	144
Positronium Decay Rates	
<i>A. Rich, R.S. Conti, D.W. Gidley, and P.W. Zitzewitz</i>	153
New Schemes for the Production and Spectroscopy of Positronium	
<i>G. Werth</i>	161
Some Recent Advances in Muonium	
<i>V.W. Hughes</i>	171
Transitions in Muonic Helium Ions Induced by Laser Radiation	
<i>E. Zavattini</i>	182
Positrons for Low Energy Antihydrogen Production	
<i>G. Gabrielse and B.L. Brown</i>	196
Antihydrogen by Positronium-Antiproton Interaction	
<i>B.I. Deutch</i>	210
Antiprotonic Hydrogen	
<i>E. Klempt</i>	211

The Spectroscopy of Hydrogen-Like Highly Ionised Atoms	
<i>J.D. Silver</i>	221

Part III Quantum Electrodynamics and Beyond

The Bound State Problem in QED	
<i>A. Hill, F. Ortolani, and E. Remiddi</i>	240
Electron $g - 2$ and High Precision Determination of α	
<i>T. Kinoshita</i>	247
General QED/QCD Aspects of Simple Systems	
<i>V.L. Telegdi and S.J. Brodsky</i>	257
Search for Parity Nonconservation in Hydrogen	
<i>E.A. Hinds</i>	268

Part IV Hydrogen in Strong Fields and Chaos

Multiphoton Transition to the Continuum of Atomic Hydrogen	
<i>N.K. Rahman</i>	274
Hydrogen in Strong DC and Low Frequency Electric Fields – One Dimensional Atoms	
<i>M.H. Nayfeh, D. Humm, and M. Peercy</i>	280
Hydrogen Atoms in Strong Magnetic Fields – in the Laboratory and in the Cosmos	
<i>G. Wunner, W. Schweizer, and H. Ruder</i>	300
Theory of Chaos in Atomic Hydrogen	
<i>G. Casati</i>	311
Quantum Chaos and the Hydrogen Atom in Strong Magnetic Fields	
<i>D. Delande and J.-C. Gay</i>	323
Highly Excited Hydrogen in Strong Microwaves: Experimental Tests for Classically Chaotic Semiclassical Dynamics and for Quantum Localization	
<i>J.E. Bayfield and D.W. Sokol</i>	335
Quasi-Landau Spectrum of the Chaotic Diamagnetic Hydrogen Atom	
<i>A. Holle, J. Main, G. Wiebusch, H. Rottke, and K.H. Welge</i>	344

The Hydrogen Atom

Precision Physics of Simple Atomic Systems

Karshenboim, S.G.; Pavone, F.S.; Bassani, F.; Inguscio, M.; Hänsch, T.W. (Eds.)

2001, XXIII, 296 p. With CD-ROM., Hardcover

ISBN: 978-3-540-41935-8