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Plasma Polarization Spectroscopy: Past, Present, and Future - A Subjective View

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Abstract

I describe how I got into the field of plasma polarization spectroscopy (PPS), how the PPS Workshops started, and how the whole field got consolidated and strengthened. Subsequently I describe what kind of present theoretical and experimental activities I am aware of. Finally I explain why I think that the future of PPS is bright.

1. Introduction

First and foremost, I would like to recall the memory of Professor Douglas H. Sampson.

Professor Sampson, who passed away on December 8, 2002, has made an immense contribution to atomic physics, atomic collision physics, and astrophysics in general and plasma polarization spectroscopy (PPS) in particular. The codes developed under his supervision in fact form the backbone of electron-ion collisional- and PPS calculations [1 – 17]. These codes were used for PPS applications at Pennsylvania State University [18 – 21], at Lawrence Livermore National Laboratory [22 – 63], at the Naval Research Laboratory [64], at Kyoto University and other places [65, 66]. These codes are now also being incorporated into Los Alamos suite of atomic data codes. In the person of Professor Sampson the PPS community has lost a magnificent theoretician but his immense legacy will be with us for a long time to come.

Here I would like to give an "Overview": the past, present, and future of PPS the way I see it now and the way I experienced it in the past.

I heard about PPS before (from Professor Fujimoto), but I really got involved with PPS during the Sep 1991 - Aug 1992 period when I spent my sabbatical in Japan. During that time in Japan there was already a group of plasma physicists, atomic physicists, and atomic collision physicists who had regular meetings and were discussing issues related to PPS. I attended two of those meetings in Nagoya. One of the outcomes of those meetings was the report entitled "Atomic Processes

Relevant to Polarization Plasma Spectroscopy" [67]. As of today this report remains a fundamental compendium on PPS and a great help for a scientist working in this field.

Simultaneously, I started to work with Professor Fujimoto on PPS which meant in part reading the manuscript of what later became the report by Fujimoto *et al.* [68]. This report formulates the population alignment collisional radiative (PACR) model based on the impact and the impact parameter approximations and formed the basis of much future work. I also started work with Professor Fujimoto on a complete quantum-mechanical formulation of the relaxation rate equations for cylindrically symmetric baths, based on the work of Fano [69] and Ben-Reuven [70]. This work still remains unfinished [71]. After having returned from Japan to Los Alamos I started to read the fundamental review articles of Professor Kazantsev and collaborators on PPS [72, 73] and many of the references quoted there. I learned about the massive amount of experimental work that had already been done in Professor Kazantsev's laboratory (mainly on discharge plasmas) and the significant work in France and Russia on the PPS of the sun (especially solar flares). Shortly afterwards the first U.S. - Japan Workshop was held at Los Alamos organized by D.C. Cartwright and T. Fujimoto. This workshop was attended by four scientists from Japan, including Professors Fujimoto and Y. Kato, by Professors Kazantsev, Cornille, Dubau, and Kieffer, and numerous scientists from the U.S. This workshop, which was extended to be the International Workshop on PPS, was held subsequently in Kyoto in 1998 (organized by Fujimoto and Beiersdorfer), in Livermore in 2001 (organized by Beiersdorfer and Fujimoto) and now in Kyoto again (organized by Fujimoto and Iwamae). The PPS workshops, all of which I had the opportunity to attend, brought together the principal participants, both theoreticians and experimentalists, working on PPS, from all over the World. Throughout these years there occurred a consolidation and strengthening of this field. This was documented by two books published on PPS by Kazantsev and Henoux [74] and by Kazantsev, Petrashen, and Firstova, [75], as well as by the joint review of Fujimoto and Kazantsev [76].

Turning now to the recent past and to the present, PPS appears to be teaming with activities. In the theoretical area (which is my area) I am aware of the following major activities,

1. The development, testing, and implementation of the population-alignment collisional- radiative (PACR) model for a variety of systems by Iwamae, Fujimoto and associates and collaborators. First results from the PACR model were reported by Iwamae *et al.* for berrylium-like oxygen [77] . Subsequently detailed calculations were performed for helium-like carbon [78] and current work deals with helium itself [79].

2. The development of the magnetic-sublevel population time-dependent collisional radiative atomic kinetics code by Hakel, Mancini and collaborators, and linking it to hydrodynamics and radiation transport codes and implementing it for

the interpretation of polarization spectra of laser-produced plasmas [80].

3. Development and implementation of a theoretical scheme for the use of X-ray spectropolarimetry to measure weak magnetic fields by Kazantsev, Petrashen, Shlyaptseva and collaborators [81, 82].

4. The use of the Zhang-Sampson-Clark code for the interpretation of polarization experiments on the EBIT machine at the Lawrence Livermore National Laboratory and the study of various physical effects in the polarization by Reed and M.H. Chen [83], by Smith [84], and by H. Chen [85] and collaborators.

5. Development of a fully relativistic approach for incorporating resonance contributions to the electron impact induced magnetic sublevel excitation cross sections of ions by Zhang and Sampson [17].

6. Quantum-mechanical formulation of the problem of alignment creation by elastic scattering by Csanak, Kilcrease and collaborators [86]

The following major experimental activities came to my attention:

1. Polarization measurements on an ECR Plasma by A. Iwamae, T. Fujimoto and collaborators [79].

2. PPS on the Large Helical Device by M. Hayakawa, A. Iwamae, and T. Fujimoto [87].

3. PPS of recombining plasmas produced by ultra-short laser pulses, by T. Kawachi, N. Hasegawa, A. Iwamae, T. Fujimoto and collaborators [88].

4. PPS measurement on the laser-produced recombining Al plasma by D.E. Kim and J. Kim [89].

5. X-ray line polarization measurements on the EBIT Machine: principal interest was recently L-shell X-ray lines. These include the 2-3 lines in Fe XVII and in Fe XVII [90]. PPS was also used to diagnose the thermal energy distribution in the Livermore EBIT machine [91].

6. X-ray spectropolarimetry on the pulsed power Z-pinch device at the Nevada Terawatt Facility by Shlyaptseva and collaborators [92].

This concludes the list of those theoretical and experimental activities in PPS in the recent past and currently which I was aware of just before the Workshop. For updated information the reader should consult the Table of Contents of these Proceedings and for details the individual articles.

And now to the future!

It is known to be difficult to make predictions for the future, but I see the future of PPS was bright!

My optimism is based on the following facts:

1. In astrophysics, especially in the physics of solar flares PPS is a solidly established technique. In fact one of the reasons Kazantsev, Petrashen, and Firstova [75] wrote their book was to give the theoretical foundation of PPS for astrophysicists as well as collect PPS's successes in astrophysics. Their main interest was directed to solar physics, but it is known that neutron stars and white dwarfs have very high magnetic fields on their surfaces and therefore radiation emanating from

their surfaces should be polarized too [93].

2. There are now well established PPS laboratories all over the world (Kyoto University, NIFS, JAERI-Kansai, Livermore, Reno, Pohang, Lehigh University).

3. There are well established collaborations between various research groups (Kyoto-Los Alamos-Perth, Livermore-Reno-Meudon-St.Petersburg, Kyoto-Pohang, Kyoto-Toki, Kyoto-JAERI-Kansai). Professors Vainshtein, Urnov, and Dubau have collaborated with several experimental groups in the past.

4. There are experimental-theoretical efforts directed at the same problem: the experimentally obtained data are being interpreted theoretically (Kyoto-Los Alamos-Perth, Livermore,Reno).

I am sure that in the future the field of PPS will undergo further consolidation as the most important technical and scientific problems surface and get solved. Thus we can look forward to the next PPS Workshop with anticipation.

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References

[1] D.H. Sampson, H.L.Zhang, A.K. Mohanty and R.E.H. Clark, *Phys. Rev. A* **40**, 604 (1989).

[2] H.L. Zhang, D.H. Sampson and A.K. Mohanty, *Phys. Rev. A* **40**, 616 (1989).

[3] H.L. Zhang, D.H. Sampson and R.E.H. Clark, *Phys. Rev. A* **41**, 198 (1990).

[4] H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **42**, 5378 (1990).

[5] D.H. Sampson and H.L. Zhang, *Phys. Rev. A* **45**, 1657 (1992).

[6] H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **47**, 208 (1993).

[7] C.J. Fontes, D.H. Sampson and H.L. Zhang, *Phys. Rev. A* **47**, 1009 (1993).

[8] C.J. Fontes, D.H. Sampson and H.L. Zhang, *Phys. Rev. A* **48**, 1975 (1993).

[9] C.J. Fontes, D.H. Sampson and H.L. Zhang, *Phys. Rev. A* **49**, 3704 (1994).

[10] H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **52** 3827 (1995).

[11] D.H. Sampson and H.L. Zhang, *J. Quant. Spectrosc. Radiat. Transfer* **54**, 345 (1995).

[12] D.H. Sampson and H.L. Zhang, *J. of Phys. B* **30**, 1449 (1997).

[13] H.L. Zhang, *Phys. Rev. A* **57**, 2640, (1998).

[14] C.J. Fontes, H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **59**, 295 (1999)

[15] H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **61**, 21707, (2000).

[16] H.L. Zhang, D.H. Sampson and Mokhtar K. Inal, *Phys. Rev. A* **63**, 52713, (2001).

[17] H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **66**, 042704 (2002).

[18] M.K. Inal, H.L. Zhang and D.H. Sampson, *Phys. Rev. A* **46**, 2449 (1992).

[19] M.K. Inal, D.H. Sampson, H.L. Zhang and J. Dubau, *Physica Scripta* **55**, 170 (1997).

[20] D.H. Sampson, H.L. Zhang, M.K. Inal and C.J. Fontes, in *Proceedings of the 3rd US-Japan Plasma Polarization Spectroscopy Workshop*, Livermore, California June 18-21, 2001 (Edited by P. Beiersdorfer and T. Fujimoto), University of California Lawrence Livermore National Laboratory Report UCRL-ID-146907, p.271.

[21] M.K. Inal, H.L. Zhang, D.H. Sampson, and C.J. Fontes, *Phys. Rev. A* **65**, 32727 (2002).

[22] P. Beiersdorfer et al., *Phys. Rev. Lett.* **65**, 1995 (1990).

[23] P. Beiersdorfer et al., in ICPEAC XVII, Brisbane, July 1991 section 7.

[24] P. Beiersdorfer, M.H. Chen, R.E. Marrs, M.B. Schneider and R.S.Walling, *Phys. Rev. A* **44**, 396 (1991).

[25] K.J. Reed, M.H. Chen and D.L. Moores, *Phys. Rev. A* **44**, 4336 (1991).

[26] P. Beiersdorfer, *Nucl. Instrum. Methods Phys. Res. B* **56-7**, no. AY, p. 1144 (1991).

[27] K.J. Reed and M.H. Chen, *Phys. Rev. A* **45**, 4519 (1992).

[28] M.H. Chen and K.J. Reed, *Phys. Rev. A* **45**, 4525 (1992).

[29] S. Chantrenne, P. Beiersdorfer, R. Cauble and M.B. Schneider, *Phys. Rev. Lett.* **69**, 265 (1992).

[30] P. Beiersdorfer, T.W. Phillips, K.L. Wong,R.E. Marrs and D.A. Vogel, *Phys. Rev. A* **46**, 3812 (1992).

[31] K.L. Wong, P. Beiersdorfer, R.E. Marrs, B.M. Penetrante, K.J. Reed, J.H. Scofield, D.A. Vogel and R. Zasadzinski, *Nucl. Instrum. Methods Phys. Res. B* **72**, 234 (1992).

[32] M.H. Chen and K.J. Reed, *Phys. Rev. A* **47**, 1874 (1993).

[33] K.L. Wong, P. Beiersdorfer, M.H. Chen, R.E. Marrs, K.J. Reed, J.H. Scofield, D.A. Vogel and R. Zasadzinski, *Phys. Rev. A* **48**, 2850 (1993).

[34] K.J. Reed and M.H. Chen, *Phys. Rev. A* **48**, 3644 (1993).

[35] B.J. Wargelin, P. Beiersdorfer and S.M. Kahn, *Phys. Rev. Lett.* **71**, 2196 (1993).

[36] M.H. Chen and K.J. Reed, *Phys. Rev. A* **50**, 2279 (1994).

[37] K.L. Wong, P. Beiersdorfer, K.J. Reed and D.A. Vogel, *Phys. Rev. A* **51**, 1214 (1995).

[38] P. Beiersdorfer, A. Osterheld, S.R. Elliott, M.H. Chen, D. Knapp, and K. Reed, *Phys. Rev. A* **52**, 2693 (1995).

[39] R.E. Marrs, P. Beiersdorfer, S.R. Elliott, D.A. Knapp and T. Stoehlker, *Physica Scripta* **T59**, 183 (1995).

[40] P. Beiersdorfer et al., *Phys. Rev. A* **53**, 3974 (1996).

[41] A.J. Smith, P. Beiersdorfer, V. Decaux, K. Widman, K.J. Reed and M.H. Chen, *Phys. Rev. A* **54**, 462 (1996).

[42] K.J. Reed and M.H. Chen, *Phys. Rev. A* **54**, 2967 (1996).

[43] D.W. Savin, P. Beiersdorfer, J.C. Lopez-Urrutia, V. Decaux, E.M. Gullikson, S.M. Kahn, D.A. Liedahl, K.J. Reed, K. Widmann, *Astrophys. J.* **470**, L73 (1996).

[44] P. Beiersdorfer, J.C. Lopez-Urrutia, V. Decaux, K. Widmann, P. Neill, *Rev. Sci. Instrum.* **68**, 1073 (1997).

[45] A.S. Shlyaptseva, R.C. Mancini, P. Neill, P. Beiersdorfer, J.R. Crespo Lopez-Urrutia, K. Widmann, *Phys. Rev. A* **57**, 888 (1998).

[46] G.V. Brown, P. Beiersdorfer, D.A. Liedahl, K. Widmann, S.M. Kahn, *Astrophys. J.* **502**, 1015 (1998).

[47] P. Beiersdorfer, G.V. Brown, S. Utter, P. Neill, K.J. Reed, A.J. Smith, R.S. Thoe, *Phys. Rev. A* **60**, 4156 (1999).

[48] D.W. Savin, B. Beck, P. Beiersdorfer, S.M. Kahn, G.V. Brown, M.F. Gu, D.A. Liedahl, J.H. Scofield, *Physica Scripta* **T80B**, 312 (1999).

[49] M.F. Gu, S.M. Kahn, D.W. Savin, P. Beiersdorfer, G.V. Brown, D.A. Liedahl, K.J. Reed, C.P. Bhalla and S.R. Grabbe, *Astrophys. J.* **518**, 1002 (1999).

[50] D.W. Savin, P. Beiersdorfer, S.M. Kahn, B.R. Beck, G.V. Brown, M.F. Gu, D.A. Liedahl and J.H. Scofield, *Rev. Sci. Instrum.* **71**, 3362 (2000).

[51] A.J. Smith, P. Beiersdorfer, K.J. Reed, A.L. Osterheld, V. Decaux, K. Widmann, M.H. Chen, *Phys. Rev. A* **62**, 012704 (2000).

[52] J.M. Laming, I. Kink, E. Takacs, J.V. Porto, J.D. Gillaspy, E.H. Silver, H.W. Schnopper, S.R. Bandler, N.S. Brickhouse, S.S. Murray, *Astrophys. J.* 2000 **545**, L161 (2000).

[53] R. Radtke, C. Biedermann, T. Fuchs, G. Fussmann, P. Beiersdorfer, *Phys. Rev. E* **61**, 1966 (2000).

[54] G.V. Brown, P. Beiersdorfer, and K. Widman, lines in mid-Z neonlike ions", *Phys. Rev. A* **63**, 032719 (2001).

[55] P. Beiersdorfer, S. von Goeler, M. Bitter, D.B. Thorn, *Phys. Rev. A* **64**, 032705 (2001).

[56] G.V. Brown, P. Beiersdorfer, H. Chen, M.H. Chen, and K.J. Reed, *Astrophys. J.* **557**, L75 (2001).

[57] M.F. Gu, S.M. Kahn, D.W. Savin, E. Behar, P. Beiersdorfer, G.V. Brown, D.A. Liedahl, and K.J. Reed , *Astrophys. J.* **563**,462 (2001).

[58] G.V. Brown, P. Beiersdorfer, K.R. Boyce, K.C. Gendreau, M.F. Gu, J. Gygax, S.M. Kahn, R. Kelley, F.S. Porter, D.W. Savin, *Physica Scripta* **T92**, 130 (2001).

[59] H. Chen, P. Beiersdorfer, J.H. Scofield, K.C. Gendreau, K.R. Boyce, G.V. Brown, E.L. Kelley, F.S. Porter, C.K. Stahle, A.E. Szymkowiak, *Astrophys. J.* 2000 **567**, L169 (2002).

[60] P. Beiersdorfer, E. Behar, K.R. Boyce, G.V. Brown, H. Chen, K.C. Gendreau, M.F. Gu, J. Gygax, S.M. Kahn, R.L. Kelley, F.S Porter, C.K. Stahle and A.E. Szymkowiak, *Astrophys. J.* **576** L169 (2002).

[61] P. Beiersdorfer, M. Bitter, D. Hey, K.J. Reed, *Phys. Rev. A* **66**, 032504 (2002).

[62] P. Beiersdorfer, H. Chen, D. Hey, A.J. May, A.L. Osterheld, K.J. Reed, J.H. Scofield, D.B. Thorn, A. Bitter, K.R. Boyce, *AIP Conference Proceedings* v.**635**, p.135-144 (2002).

[63] P. Beiersdorfer, B. Beck, J.A. Becker, J.K. Lepson, K.J. Reed, electron beam in the SuperEBIT electron beam ion trap", *AIP Conference Proceedings* v.**652**, p.131-140 (2003).

[64] A. Dasgupta, K.G. Whitney, H.L. Zhang and D.H. Sampson, *Phys. Rev. E* , **55**, 3460 (1997).

[65] M.K. Inal and R Bensaid, *Hyperfine Interactions* v.**127**, 263 (2000).

[66] U. Kentsch, G. Zschornack, F. Grossann, V.P. Ovsyannikov, F. Ullmann, Fritzsche, Surzhykov, *Nucl. Instrum. Methods Phys. Res. B* **187**, no. AY, p. 1144 (2002).

[67] T. Fujimoto, F. Koike, K. Sakimoto, R. Okasaka, K. Kawasaki, K. Takiyama, T. Oda and T. Kato, *Atomic Processes Relevant to Polarization Plasma Spectroscopy*, Research Report, NIFS-DATA Series, NIFS-DATA-16, Apr. 1992

[68] T. Fujimoto, H. Sahara, G. Csanak and S. Grabbe, *Atomic States and Collisional Relaxation in Plasma Polarization Spectroscopy: Axially Symmetric Case*, Research Report, NIFS-DATA Series, NIFS-DATA-38, Oct. 1996

[69] U. Fano, *Phys. Rev.* **131**, 259 (1963)

[70] A. Ben-Reuven, *Phys. Rev.* **145**, 7 (1966)

[71] G. Csanak, *Two Notes on Atoms in Dense Plasmas*, LA-UR-93-0034

[72] S.A. Kazantsev, *Usp.Fiz.Nauk* , **139**, 621 (1983), (English translation: *Sov.Phys.Usp*, **26**, 328 (1983))

[73] S.A. Kazantsev, N.Ya. Polynovskaya, L.N. Pyatnitskii, and S.A. Edel'man, *Usp.Fiz.Nauk*, **156**, 3 (1988) (English translation: *Sov.Phys.Usp.*, **31**, 785 (1988)

[74] S.A. Kazantsev and J.-C. Henoux, *Polarization Spectroscopy of Ionized Gases*,Kluwer Academic Publishers, Dodrecht, 1995

[75] S.A. Kazantsev, A.G. Petrashen, and N.M. Firstova, *Impact Spectropolarimetric Sensing*, Kluwer Academic/Plenum Publishers, New York,1999

[76] T. Fujimoto and S.A. Kazantsev, *Plasma Phys. Control. Fusion*, **39**, 1267 (1997)

[77] A. Iwamae, A. Tanaka, T. Inoue, T. Fujimoto, H.-L. Zhang, D. Kilcrease and G. Csanak, *Polarization Emission Lines from Beryllium-like oxygen OV: Analysis based on the Population-Alignment Collisional-Radiative model*, in *Proceedings of the 3rd US-Japan Plasma Polarization Spectroscopy Workshop*, Livermore, California June 18-21, 2001 (Edited by P. Beiersdorfer and T. Fujimoto), University of California Lawrence Livermore National Laboratory Report UCRL-ID-146907, p.165

[78] A. Iwamae, T. Fujimoto, H. Zhang, D.P. Kilcrease, G. Csanak and K.A. Berrington, *Population Alignment Collisional Radiative Model for Helium-like Carbon: Velocity Distribution Function in Plasmas*, Research Report, NIFS-DATA Series, NIFS-DATA-78, Aug.2003

[79] A. Iwamae, T. Sato, Y. Horitomo and T. Fujimoto, *Polarization of ECR helium plasma and Population-Alignment Collisional-Radiative model* (This Workshop, 2004)

[80] P. Hakel, R.C. Mancini, J.-C. Gauthier,E. Minguez, J. Dubau, and M. Cornille, *X-Ray line Polarization of He-like Si Satellite Spectra in Plasmas Driven by High-Intensity Ultra-Short Pulsed Lasers*, Accepted for publication in Phys. Rev. E, 2003

[81] S.A. Kazantsev and A.G. Petrashen, Opt.Spekt. **92**, 533 (2002), (English translation: Optics and Spectroscopy **92**, 483 (2002))

[82] V.L. Kantsyrev, A.G. Petrashen, and A.S. Shlyaptseva, Opt. Spek. **94**, 377 (2003), (English translation: Optics and Spectroscopy, **94**, 338 (2003))

[83] K.J. Reed and M.H. Chen, *Relativistic effects on the Polarization of line radiation emitted from He-like and H-like ions following electron impact Excitation*, in *Proceedings of the 3rd US-Japan Plasma Polarization Spectroscopy Workshop*, Livermore, California June 18-21, 2001 (Edited by P. Beiersdorfer and T. Fujimoto), University of California Lawrence Livermore National Laboratory Report UCRL-ID-146907, p.305

[84] A.J. Smith, P. Beiersdorfer, K.L. Wong and K.J. Reed, *Measurement of the Polarization of the K 2 Line of heliumlike $V^2$1+*, in *Proceedings of the 3rd US-Japan Plasma Polarization Spectroscopy Workshop*, Livermore, California June 18-21, 2001 (Edited by P. Beiersdorfer and T. Fujimoto), University of California Lawrence Livermore National Laboratory Report UCRL-ID-146907, p.299

[85] H. Chen, *Effect of Polarization on the measurements of Electron Impact Excitation Cross-Section of L-shell Fe in an Electron Beam Ion Source* , in *Proceedings of the 3rd US-Japan Plasma Polarization Spectroscopy Workshop*, Livermore, California June 18-21, 2001 (Edited by P. Beiersdorfer and T. Fujimoto), University of California Lawrence Livermore National Laboratory Report UCRL-ID-146907, p.319

[86] G. Csanak, D.P. Kilcrease, D.V. Fursa, and I. Bray, *Alignment Creation by Elastic Electron Scattering* (This Workshop, 2004)

[87] M. Hayakawa, A. Iwamae, T. Fujimoto, M. Goto, and S. Morita,*Plasma polarization spectroscopy on Large Helical Device* (This Workshop, 2004)

[88] T. Kawachi, N. Hasegawa, A. Iwamae, Y. Horitomo, and T. Fujimoto, *Plasma polarization spectroscopy on recombining plasmas produced by ultrashort laser pulses* (This Workshop, 2004)

[89] J. Kim and D.-E. Kim , Phys. Rev. E **66**, 017401 (2002)

[90] H. Chen,*Polarization measurements for the 2p-3d and 2p-3s transitions in Ne-like and F-like iron*, (This Workshop, 2004)

[91] P. Beiersdorfer and M. Slater, Physical Review E, **64**, 066408 (2001)

[92] A.S. Shlyaptseva, D.A. Fedin, S. Hamasha, S. Hansen, C. Harris, V.L. Kantsyrev, P. Neill, N. Ouart, P. Beiersdorfer, U. Safranova, Rev. Sci. Instr. **74**, 194, (2003)

[93] J. Weisheit, Private communication, 2004

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