

Richard Day Deslattes, 21 Sept 1931 - 16 May 2001: Calibration of light, matter and fundamental constants

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Abstract.

Richard Deslattes passed away on 16 May 2001 after a life dedicated to fundamental metrology. Although the themes of calibrating light, matter and fundamental constants can give three guiding principles through his career, the wide-ranging nature of his areas of interest are encompassed by over 165 refereed publications with several cited over 100 times. He has left an enduring legacy to science.

INTRODUCTION AND EARLY WORK

Richard (Dick) Deslattes was a great scientist, a good colleague and a genius in developing applications to solve intractable problems. His life was his work, so much so that he continued to fight cancer until the very end, remaining active in the laboratory at NIST until his retirement just three weeks before his death. He was a tough boss, who epitomised the dedication he expected from his staff in the pursuit of perfection, and which led to his labs and his Quantum Metrology Division achieving an abundance of major scientific results compared to much larger divisions at NIST. As a guest researcher and Fellow of the English-Speaking Union of the Commonwealth, this author learned from him and his group the meaning of dedication to the methodical pursuit of precision science, and the author is very grateful for his patience with a peculiar Australian theoretician (at the time) from arguably a very different culture. He was a sincere father of five children. His wife Mary has also been dedicated to his causes, and together they demonstrated the care of their visitors with numerous delightful parties at their home, always beautifully catered and always engaging.

Dick (Fig. 1) was born on 21 September 1931 and grew up in New Orleans. He received a B.Sc. degree from Loyola University in New Orleans in 1952 and a Ph.D. from the Johns Hopkins University in 1959, strongly influenced by J.A. Bearden. Following a postdoctoral position at Cornell University, associated with Lyman Parratt, Deslattes joined the staff of the National Bureau of Standards (now the National Institute of Standards and Technology) in 1962. Dick's early years at NIST were devoted to the spectroscopy of molecules, the development of high-resolution x-ray spectrometers and powerful x-ray sources, and the characterization of solution-grown single crystals.

Dick carried out the first definitive study of the photon excitation functions of the principal satellites of the valence emission band of chlorine in KCl closing a chapter on



FIGURE 1. Dick as we will remember him.

these controversial spectra and showing their similarity to the corresponding spectra of atomic argon, whose gas phase fluorescence spectrum was recorded for the first time. He continued these studies with colleagues and staff in later years. [1] [2]

He showed the applicability of the, then novel, technique of double crystal diffraction topography to the characterization of solution grown single crystals and demonstrated that this technology yielded dislocation free, dynamically perfect specimens. [3] Dick developed high resolution x-ray spectrometers, powerful x-ray sources, and new approaches to the operation of gaseous detectors in the x-ray region.[4] He pioneered the application of high resolution x-ray spectroscopy to the study of the electronic structure of molecules and discovered extraordinary resonance structures in absorption spectra and the systematic interpretation of the emission spectra from families of gas phase molecules with diverse structures.[5] This was the beginning of an almost 39 year career that was extremely varied and productive.

His subsequent research continued these interests progressively and centered on recurring themes of high precision metrology, x-ray spectroscopy, and development of novel experimental technology and devices. From 1980-1981, he was the director of the Division of Physics at the National Science Foundation. He was the Chief of the successful Quantum Metrology Division at NIST from 1987-1996, with numerous similar positions and titles in different divisions and sections of NIST, and was a Senior Fellow Emeritus on his retirement.

He was unstinting in his activity and support of national scientific bodies, and was a Fellow of the American Physical Society, Fellow of the American Association for the Advancement of Science, Fellow of the Washington Academy of Sciences, and a Member of SPIE. He became Chair, 1986-1987, of the American Physical Society, Division of Electron and Atomic Physics after extensive service; was on six different committees or panels of the National Academy of Sciences/National Research Council; Member, International Advisory Board, Journal of Physics B, 1992-2001; Member, Editorial Board for Physical Review A, 1999-2001; Member, Editorial Board of Review of Scientific Instruments, 2000-2003; Member at Large of the Section on Physics (B) for the American Association for the Advancement of Science, 1999-2001; Member, IUCr Commission on

Crystallographic Apparatus of the International Union of Crystallography, 1994-2002; and Fellow and Chartered Physicist, Institute of Physics.

He chaired or sat on many organising committees of many international and national conferences, and many workshops and related groups throughout his career, especially including seven International Conferences on the Physics of X-ray Spectra; CPEM; SPIE; International Nuclear Physics Conference, Wiesbaden, Germany, July 26 - August 1, 1992; International Committee, Nobel Symposium on "Heavy Ion Spectroscopy and QED Effects in Atomic Systems," Stockholm, Sweden, June 29 - July 3, 1992; Ninth International Conference on Vacuum Ultraviolet Radiation Physics (VUV9) 1989; and CODATA Task Group on Fundamental Constants.

He received many honours including the Department of Commerce Meritorious Service Award (Silver Medal), 1967; the Arthur S. Fleming Award, 1969; the NBS Samuel W. Stratton Award, 1974; the Department of Commerce Gold Medal, 1979; the Alexander von Humboldt Foundation Senior Scientist Award, 1983; the Presidential Rank Award, 1988; the SUN-AMCO Medal, 1990; and was awarded two patents.

He provided generic and friendly support of the whole field of precision measurement and fundamental constants, and of young international researchers in the fields. Many comments from colleagues at X2002 support and confirm this from many fields and sub-fields of physics and crystallography.

X-RAY AND OPTICAL INTERFEROMETER

The motivation for XROI came from the first X-ray interferometer by Bonse & Hart, then at Cornell, in 1965 [6]. Dick was excited by the opportunity here for a real calibration of X-ray spectra, and developed his first X-ray and Optical Interferometer (XROI) from 1968-1969 [7]. Dick's early metrology efforts at NIST were therefore directed in two lines of research toward the development of x-ray interferometry and the iodine-stabilized laser. [9] Dick produced the first combined x-ray and optical interferometer that was able to demonstrate the feasibility of accurate measurements of the lattice periods of silicon single crystals tied to the SI definition of the meter. A schematic of XROI is given in Fig. 2.

The key problem in the calibration of any research using X-rays is the link between the X-ray wavelengths and the optical definition of the metre. This is compounded by the broad natural widths of atomic lines. Consequently the interferometric methods, even when successful, cannot be used as a high-precision calibration of an X-ray standard wavelength. Instead Dick pursued the calibration of the lattice spacing in silicon, which is robust and transferable, via interferometry. The complexity here is indicated by figure 2 where the optical oscillation must be divided by 1600 to be at all sensitive to the X-ray wavelength. Conversely, the X-ray fringe counting must be perfectly linear along the same axis as the optical interferometer, and there can be no fringes lost or missed in 10000 if any accuracy in the final result is to be obtained.

Any who haven't seen XROI will find it hard to comprehend the sensitivity both for any reasonable measurement across such a large range of length scale, and also the sensitivity to systematics of every kind. XROI and NIST led the way in precision

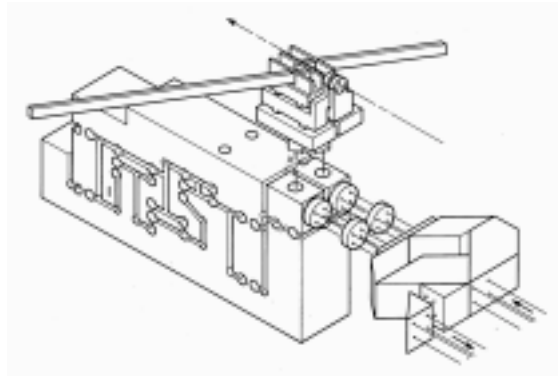


FIGURE 2. Schematic of the first X-ray and Optical Interferometer by Deslattes, Henins et al. Note the optical and X-ray paths must be perfectly aligned, and the motion of the second face is controlled and amplified by a complex but beautifully machined series of weak links.

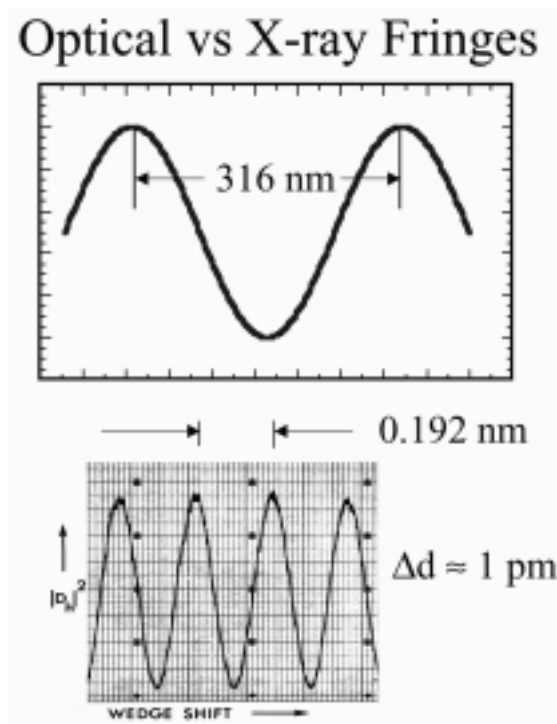


FIGURE 3. The precision needed for any useful link between the X-ray and optical wavelengths is demonstrated schematically in the above comparison between a visible interference wave and a corresponding X-ray period.

measurement of the wavelength transfer standard with the work from PTB, and with the resolution of the discrepancy between the two results which required the development of XROI2 to address. [8]

The room holding XROI is isolated from the basement of the physics building, and vibrations due to the laminar flow of air into the room are shielded by a series of physical

covers and enclosures. Thermal vibrations are measured to high accuracy. The author had the pleasure of working on XROI2 for three years at the end of the 1980's and it is a little known fact that the NIST precision at that time had already exceeded that of the original XROI by over an order of magnitude. It is a mark of Dick's determination to achieve the best possible standard that this was not published at the time.

Silicon lattice spacings have sensitivities of 10^{-6} per degree or per atmosphere, and similar sensitivities to impurity concentrations. Hence for a precision transfer standard these variables must be carefully controlled and measured against a comparator to transfer the standards to other laboratories. The lattice comparator was developed by Kessler, Henins, and Deslattes over several years and was crucial in relating standards measurements of different laboratories and identifying artifacts due to the crystal samples in those measurements. [10] This was reported relatively recently, but had been developed and used with enormous success for many years prior to the dates of publication, in support of standards work and researchers around the world.

SYNCHROTRON DEVELOPMENTS AND PHYSICS

Dick was a pioneer in the use of intense synchrotron radiation for atomic physics studies. He and his colleagues showed the existence and schematic interpretation of the richly detailed supra-threshold absorption spectrum of atomic argon during parasitic operation at the Stanford Synchrotron Radiation Project. He subsequently pursued the design and optimization of primary monochromators and secondary spectrometers for such threshold studies using synchrotron radiation. [4] This early experience with synchrotron radiation led to the establishment of an innovative beamline, X24A, at the Brookhaven National Synchrotron Light Source. This facility has been an active source of new discoveries such as x-ray selection of oriented molecules and polarization spectroscopy. [1]

AVOGADRO'S CONSTANT, AND FUNDAMENTAL CONSTANTS

Early work led to a new methodology for density measurements based on solid objects, [11] and absolute isotopic abundance measurements to determine, for the first time, a value for the Avogadro constant with a defensible error budget near the 1 ppm level. [12]

Uncertainties for the (silicon) unit cell dimension a_0 fell from the previous standard of a ruled grating of 5×10^{-6} to 0.15×10^{-6} in the first round of XROI. Uncertainties in density ρ fell from the previous water standard of 5×10^{-6} to 0.7×10^{-6} in the first round of solid object density standards. Uncertainties of the mean molar mass M fell from the previous geochemical average (not sample specific) of 10×10^{-6} to 0.7×10^{-6} in the first round of calibration with mixtures of separated isotopes. All this was achieved in the 1970's at NIST, leading to an overall major improvement in the X-ray Crystal

Density (XRCD) approach to the determination of Avogadro's constant

$$N_A = \frac{nM}{\rho (a_0)^3}$$

which in turn is helping towards a possible redefinition of the kilogram as (for example) the mass of approximately 5.018×10^{25} free ^{12}C atoms at rest and in their ground state. The current status of this research remains quite complex and quite exciting, and Dick has continued to lead and develop the research towards these fundamental standards goals. The NIST work culminating in 1976 was developed over the years by other groups including PTB, IMGC and MNIJ but the error budget was not improved upon until 1995 in a large scale collaboration across the world's standard laboratories including CSIRO's National Measurement Laboratory with the silicon sphere's, which also involved major efforts and direction from Dick.

The iodine-stabilized laser research led by Deslattes included characterization of this potential new length standard and comparisons with infra-red radiation and the krypton length standard. This effort, along with contributions from other national measurement laboratories, led to the effective replacement of the krypton standard and the ultimate elimination of a separate wavelength standard through a redefinition of the meter in 1983 that fixed the speed of light.

GAMMA-RAY SPECTROSCOPY

Deslattes regarded the accurately-measured, nearly-perfect crystals as laboratory artifacts that were needed to measure x-ray and gamma-ray wavelengths, the real invariants of nature. This led to major efforts in precision angle measurements and to more accurate x-ray and gamma-ray wavelength standards consistent with the SI definition of the meter.

With Ernie Kessler and others, Dick extended optically-based wavelength measuring technology first to low energy gamma-rays at NBS, and later to higher energy gamma-rays at the Institut Laue-Langevin in Grenoble.[13] Already in its earliest phase this work showed that the then current gamma-ray standard was in error and that discrepancies between theory and experiment for high-Z muonic atoms were artifacts of this erroneous scale.

In 1983-1984, collaboration at the ILL developed into a world-class gamma-ray spectroscopy facility that is still active today with emphasis on nuclear and solid state physics as well as precision measurements. At the ILL Deslattes and his colleagues made an accurate measurement of the deuteron binding energy that led to an improved value for the neutron mass and extended the SI based gamma-ray wavelength measurements into the 6 MeV region.

Related work in this area led to new values for the mass of the neutron. [14] The improved standards also resolved discrepancies between theory and experiment for the mass of the negative kaon. [15]

The ILL team in Grenoble exploited the high resolution capabilities of the NIST-developed gamma-ray spectrometer with NIST to obtain sub-picosecond lifetime mea-

surements for nuclear excited states and used the sharp lines from long-lived states to obtain accurate values for elemental scattering factors at gamma-ray energies. [16]

TESTS OF QUANTUM ELECTRO-DYNAMICS

Early work on spectrometers has already been mentioned, but particular value was found in the development of two-dimensional backgammon detectors for synchrotron and precision physics investigations. [17]

With this development but using a variety of techniques, Dick pursued high-resolution, high-precision spectroscopic X-ray tests of quantum electro-dynamics (QED). In collaborations with the University of Heidelberg and GSI in the early 1980's, Deslattes applied crystal-diffraction spectroscopy to spectra of highly-stripped ions produced by large nuclear accelerators and developed a scheme to reduce the large Doppler corrections associated with these spectra.

Initial investigations pursued recoil ions, [18] but it was observed that satellite contamination in these systems cast doubt on the profile fitting of complex spectra, and limited the final results.

The accel-decel method pioneered by himself and Mokler is being developed and pursued actively today for highly stripped ions produced by large accelerators, and has borne fruit in several related fields. It decelerated bare elemental nuclei prior to capture of electrons into excited few-electron states, leading to a clean single-interaction capture process and largely satellite-free spectra. Arguably the best results for X-ray tests of QED, as measured by the quoted error bars (12 ppm or 1.2×10^{-5}), were those first measurements with Dick, providing stringent tests of the theory of quantum electrodynamics for Argon and hydrogenic nickel. [18, 19, 20, 21]

The quality of these results attracted both John Schweppe from California and the author from Oxford to work with Dick at NIST. It was clear that the two most promising techniques in medium-Z QED tests at the time were those of the Lyman α - Balmer β intercomparison technique in Silver's group in Oxford, and the absolute calibration technique of Dick at NIST, both of which were in separate collaborations with GSI.

These investigations and these collaborations continued to produce exciting results and develop techniques at accelerators [22, 23], and have also led to major contributions to exotic atom spectroscopy, particularly aniprotonic hydrogen. [24]

It also led to a major series of efforts in X-ray spectroscopy and QED tests using the novel sources of electron-beam ion traps (EBITs). In this area the author's collaboration with Dick has been very fruitful, and has developed with John Gillaspy, Larry Hudson and other members of Dick's group over the past years. [25] These investigations continue to be pursued, providing additional new results on EBIT sources recently.

In the helium-like ions in particular, there remains a perplexing anomalous discrepancy from the traditional theory of Drake for these ions, [26] which invites further investigation.

PHOTOIONIZATION, EXAFS AND SCATTERING

Dick's early work on xenon and selenium on photoionisation [27] laid the groundwork for further developments linking up with synchrotron studies [4] and X-ray spectrometry [5] already mentioned.

However, the problem of the interaction of X-rays (light) with neutral matter continued to motivate his research and led to studies of extended X-ray anomalous fine structure. [28] This research simply expressed his command of other fields and his ability to make incisive contributions with ease.

The area of scattering investigations [29] was taken up and pursued further by group members such as Cowan, Levin and Southworth in references already cited and in their own work subsequently. This has been a rich field of endeavour and has led to complex and beautiful experiments.

NEUTRAL ATOMIC PHYSICS: X-RAY DIFFRACTION THEORY, ATOMIC FORM FACTORS AND CHARACTERISTIC ENERGIES

Such extensive X-ray spectrometry could not develop without continued and progressive developments in the understanding of theory in general and of X-ray diffraction theory in particular.

Dick contributed directly to some of the earlier developments and ideas, and always had keen intuition and insight in his encouragement and collaborations with later progress.[30]

Dick also enthusiastically supported the author's development of new form factor theory addressing some major problems in the X-ray regime. This is the subject of current development and has become a NIST database. [31]

In the early 1980s, Deslattes and his colleagues initiated a long-term study of the systematics of neutral-atom x-ray spectra that included comparison with progressively refined theoretical calculations. The progressively enhanced reference theoretical structures led finally to the possibility of a new, all-Z, x-ray wavelength database.[32] This now serves as a key reference for future calibration explorations.

APPLICATION OF X-RAY PHYSICS AND THEORY TO MAMMOGRAPHY AND MAJOR FACILITIES

Dick and his staff developed a number of novel experimental devices, techniques, and applications. One of these applications was directed toward a precision calibration device to permit radiologists to record better quality mammograms. We rapidly and effectively addressed the problem of critical high voltage measurement for quality control in mammographic x-ray radiology by application of diffraction spectrometry (US Patents 5295176, 5381458). [33] This was since extended to chest X-ray applications.

Hudson, Henins, Deslattes and others also provided major X-ray diagnostic equipment for NASA, and the mamographic developments led to the provision of major X-ray

diagnostic equipment for one of the largest laser facilities (OMEGA and DOE). [34]

POWDER DIFFRACTOMETRY, GRAZING INCIDENCE REFLECTOMETRY, X-RAY MULTILAYER FABRICATION

With Jean-Louis Staudenmann and Larry Hudson, he initiated a complete reappraisal of powder diffraction standards in light of major anomalies in the characterisation and use of these standards by a wide crystallographic and mineral science community. Major new results have come out of this which address some key issues for this field. [35] Some key issues remain unresolved and invite further investigation.

Dick introduced new technology for the characterization of multi-layer optics in the x-ray region and with Joe Pedulla established a new, advanced technology facility for the production of such structures with a level of perfection not achieved elsewhere. [36]

CONCLUSION

Some select scientists in their career have published more than 165 papers in refereed journals, and a few have been cited as many as 281 times on selected publications (with several publications cited over 100 times); but few in the modern era have had the wide-ranging and fundamental impact across so many fields, in part due to his dedication to issues of fundamental and applied significance, and in part due to his encouragement of different scientists and different areas of study.

His contributions to physics will be cited for an extremely long time but his enormous energy, his ability to lead, and his remarkable creativity will be greatly missed.

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REFERENCES

1. Lindle, D. W., Cowan, P. L., La Villa, R. E., Jach, T., Deslattes, R. D., Karlin, B., Sheehy, J. A., Gil, T. J., Langhoff, P. W., Phys. Rev. Lett. (1988), 60(11), 1010-13; Lindle, D. W., Cowan, P. L., LaVilla, R. E., Jach, T., Deslattes, R. D., Perera, R. C. C., Karlin, B., J. Phys., Colloq. (1987), (C9, Vol. 1), C9-761/C9-763; Lindle, D. W., Cowan, P. L., Jach, T., LaVilla, R. E., Deslattes, R. D., Nucl. Instrum. Methods Phys. Res., Sect. B (1989), B40-B41(1), 257-61; Lindle, D. W., Cowan, P. L., Jach, T., La Villa, R. E., Deslattes, R. D., Perera, R. C. C., Phys. Rev. A (1991), 43(5), 2353-66; Perera, R. C. C., Cowan, P. L., Lindle, D. W., LaVilla, R. E., Jach, T., Deslattes, R. D., Phys. Rev. A (1991), 43(7), 3609-19
2. Deslattes, R. D., La Villa, R. E., Cowan, P. L., Henins, A., Phys. Rev. A (1983), 27(2), 923-33

3. Deslattes, Richard D., Torgesen, John L., Paretzkin, Boris; Horton, Avery T. *Advan. X-Ray Anal.* (1965), 8 315-24; Deslattes, Richard D., Torgesen, John L., Paretzkin, Boris; Horton, Avery T. *J. Appl. Phys.* (1966), 37(2), 541-8
4. Deslattes, Richard D., Simson, Bert G., *Rev. Sci. Instr.* (1966), 37(6), 753-5; Deslattes, Richard D., Simson, Bert G., LaVilla, Robert E. *Rev. Sci. Instr.* (1966), 37(5), 596-9; Deslattes, Richard D., *Rev. Sci. Instrum.* (1967), 38(5), 616-20; Deslattes, Richard D., *Rev. Sci. Instrum.* (1967), 38(6), 815-20; X-ray monochromators and resonators from single crystals. Deslattes, Richard D., *Appl. Phys. Lett.* (1968), 12(4), 133-5; Small set of reference crystals for double-crystal topography. Deslattes, Richard D., Paretzkin, B., *J. Appl. Crystallogr.* (1969), 2(Pt. 2), 81-2; Performance of a tunable secondary x-ray spectrometer. Brennan, S., Cowan, P. L., Deslattes, R. D., Henins, A., Lindle, D. W., Karlin, B. A., *Rev. Sci. Instrum.* (1989), 60(7, Pt. 2B), 2243-6
5. La Villa, Robert E., Deslattes, Richard D., *J. Chem. Phys.* (1966), 44(12), 4399-400; Deslattes, Richard D., La Villa, Robert E., *Appl. Opt.* (1967), 6(1), 39-42; Lavilla, R. E., Deslattes, R. D., *J. Phys. (Paris), Colloq.* (1971), (4), 160-4; Lavilla, R. E., Deslattes, R. D., *Colloq. Int. Cent. Nat. Rech. Sci.* (1971), No. 196 160-4.
6. Bonse, Hart, *Applied Physics Letters* 6, 1965, 155-156; Bonse, Hart, *Zeitschrift für Physik* 188, 1965, 154-164.
7. Deslattes, Richard D., *Appl. Phys. Lett.* 15(11), (1969), 386-8
8. Deslattes, Richard D., Henins, Albert, *Phys. Rev. Lett.* (1973), 31(16), 972-5; Deslattes, Richard D., Tanaka, Mitsuru; Greene, Geoffrey L., Henins, Albert; Kessler, Ernest G., Jr, *IEEE Trans. Instrum. Meas.* (1987), IM-36(2), 166-9
9. Schweitzer, W. G., Jr., Kessler, E. G., Jr., Deslattes, R. D., Layer, H. P., Whetstone, J. R., *Appl. Opt.* (1973), 12(12), 2927-38; Layer, H. P., Deslattes, R. D., Schweitzer, W. G., Jr., *Appl. Opt.* (1976), 15(3), 734-43
10. Kessler, E. G., Henins, A., Deslattes, R. D., Nielsen, L., Arif, M., *J. Res. Natl. Inst. Stand. Technol.* (1994), 99(1), 1-18; Kessler, Ernest G., Jr., Schweppe, John Edward; Deslattes, Richard D., *IEEE Transactions on Instrumentation and Measurement* (1997), 46(2), 551-555; Kessler, Ernest G., Jr., Owens, Scott M., Henins, Albert; Deslattes, Richard D., *IEEE Transactions on Instrumentation and Measurement* (1999), 48(2), 221-224
11. Deslattes, Richard D., Peiser, H. Steffen, Bearden, Joyce A., Thomsen, *Metrologia* (1966), 2(3), 104-11
12. Deslattes, R. D., Henins, A., Bowman, H. A., Schoonover, R. M., Carroll, C. L., Barnes, I. L., Machlan, L. A., Moore, L. J., Shields, W. R., *Phys. Rev. Lett.* (1974), 33(8), 463-6; Deslattes, R. D., Henins, A., Schoonover, R. M., Carroll, C. L., Bowman, H. A., *Phys. Rev. Lett.* (1976), 36(15), 898-900; Kessler, Ernest G., Jr., Schweppe, John Edward; Deslattes, Richard D., *IEEE Transactions on Instrumentation and Measurement* (1997), 46(2), 551-555
13. Kessler, E. G., Jr., Deslattes, R. D., Henins, A., Sauder, W. C., *Phys. Rev. Lett.* (1978), 40(3), 171-4; Kessler, E. G., Jr., Jacobs, L., Schwitz, W., Deslattes, R. D., *Nucl. Instrum. Methods* (1979), 160(3), 435-7; Deslattes, R. D., Kessler, E. G., Sauder, W. C., Henins, A., *Ann. Phys. (N. Y.)* (1980), 129(2), 378-434; Kessler, E. G., Greene, G. L., Dewey, M. S., Deslattes, R. D., Borner, H., Hoyler, F., *J. Phys. G: Nucl. Phys.* (1988), 14(Suppl.), S167-S174; Borner, H. G., Jolie, J., Hoyler, F., Robinson, S., Dewey, M. S., Greene, G., Kessler, E., Deslattes, R. D., *Phys. Lett. B* (1988), 215(1), 45-9
14. Greene, G. L., Kessler, E. G., Jr., Deslattes, R. D., Borner, H. *Phys. Rev. Lett.* (1986), 56(8), 819-22; Kessler, E. G., Jr., Dewey, M. S., Deslattes, R. D., Henins, A., Borner, H. G., Jentschel, M., Doll, C., Lehmann, H., *Physics Letters A* (1999), 255(4-6), 221-229
15. Lum, G. K., Wiegand, C. E., Kessler, E. G., Jr., Deslattes, R. D., Jacobs, L., Schwitz, W., Seki, R., *Phys. Rev. D* (1981), 23(11), 2522-32.
16. Dewey, M. S., Kessler, E. G., Jr., Greene, G. L., Deslattes, R. D., Sacchetti, F., Petrillo, C., Freund, A., Borner, H. G., Robinson, S., Schillebeeckx, P., *Phys. Rev. B: Condens. Matter* (1994), 50(5), 2800-8
17. Duval, B. P., Barth, J., Deslattes, R. D., Henins, A., Luther, G. G., *Nucl. Instrum. Methods Phys. Res., Sect. A* (1984), 222(1-2), 274-8
18. Deslattes, R. D., Beyer, H. F., Folkmann, F., *J. Phys. B* (1984), 17(21), L689-L694
19. Beyer, H. F., Mokler, P. H., Deslattes, R. D., Folkmann, F., Scharfner, K. H., *Z. Phys. A* (1984), 318(2), 249-50; Beyer, H. F., Deslattes, R. D., Folkmann, F., LaVilla, R. E., *J. Phys. B* (1985), 18(2), 207-15

20. Richard, Patrick, Stockli, Martin, Deslattes, R. D., Cowan, P., LaVilla, R. E., Johnson, B., Jones, K., Meron, M., Mann, Rido, Schartner, K., Phys. Rev. A (1984), 29(5), 2939-42; Deslattes, R. D., Schuch, R., Justiniano, E., Phys. Rev. A (1985), 32(3), 1911-13
21. Beyer, H. F., Indelicato, P., Finlayson, K. D., Liesen, D., Deslattes, R. D., Phys. Rev. A (1991), 43(1), 223-7 [also GSI-Rep. (1990), (GSI 90-1), 143]
22. Beyer, H. F., Finlayson, K. D., Liesen, D., Indelicato, P., Chantler, C. T., Deslattes, R. D., Schweppe, J., Bosch, F., Jung, M., et al., J. Phys. B: At., Mol. Opt. Phys. (1993), 26(9), 1557-67
23. Suleiman, J., Berry, H. G., Dunford, R. W., Deslattes, R. D., Indelicato, P., Phys. Rev. A (1994), 49(1), 156-60
24. Borchert, G. L., Gotta, D., Schult, O. W. B., Simons, L. M., Elsener, K., Rashid, K., Reidy, J. J., Deslattes, R. D., Kessler, E. G., Mooney, T., Ettore Majorana Int. Sci. Ser.: Phys. Sci. (1990), 52(Electromagn. Cascade Chem. Exot. At.), 295-300
25. Paterson, D., Chantler, C. T., Tran, C. Q., Hudson, L. T., Serpa, F. G., Deslattes, R. D. Physica Scripta, T (1997), T73 400-402; Chantler, C. T., Paterson, D., Hudson, L. T., Serpa, F. G., Gillasp, J. D., Deslattes, R. D. Physica Scripta, T (1997), T73, 87-89; Takacs, E., Meyer, E. S., Gillasp, J. D., Roberts, J. R., Chantler, C. T., Hudson, L. T., Deslattes, R. D., Brown, C. M., Laming, J. M., et al. Phys. Rev. A: At., Mol., Opt. Phys. (1996), 54(2), 1342-1350; Gillasp, J. D., Aglitskiy, Y., Bell, E. W., Brown, C. M., Chantler, C. T., Deslattes, R. D., Feldman, U., Hudson, L. T., Laming, J. M., et al., Phys. Scr., T59 (1995), 392-5.
26. Drake, G. W., Can. J. Phys. 66, (1988) 586
27. Photoionization of the M shell of xenon. Deslattes, Richard D., Phys. Rev. Lett. (1968), 20(10), 483-5; K absorption edge of selenium. Deslattes, Richard D., DeBen, Hillery S., Phys. Rev. (1959), 115 71-4; K-absorption fine structures of sulfur in gaseous SF₆. La Villa, Robert E., Deslattes, Richard D., J. Chem. Phys. (1966), 44(12), 4399-400; Estimates of x-ray attenuation coefficients for the elements and their compounds. Deslattes, Richard D., Acta Cryst. A25 (1969), 89-93
28. Application of a high intensity laboratory x-ray source to EXAFS spectroscopy. Cohen, Gabrielle G., Deslattes, Richard D., Nucl. Instrum. Methods Phys. Res. (1982), 193(1-2), 33-9; Extended fine structure in x-ray absorption spectra of certain perovskites. Perel, Joseph; Deslattes, Richard D., Phys. Rev. B (1970), [3] 2(5), 1317-23
29. MacDonald, M. A., Southworth, S. H., Levin, J. C., Henins, A., Deslattes, R. D., LeBrun, T., Azuma, Y., Cowan, P. L., Karlin, B. A., Phys. Rev. A: At., Mol., Opt. Phys. (1995), 51(5), 3598-603
30. Crystal reflectivity for bent crystal spectrometers. Kaerts, E., Van Assche, P. H. M., Greene, G. L., Deslattes, R. D. Nucl. Instrum. Methods Phys. Res., Sect. A (1987), A256(2), 323-8; Chantler, C. T., Deslattes, R. D., Rev. Sci. Instrum. (1995), 66(11), 5123-47; Owens, S. M., Deslattes, R. D., Pedulla, J., Advances in X-Ray Analysis (2000), Volume Date 1999, 43 249-253; Owens, S. M., Deslattes, R. D., Pedulla, J., Advances in X-Ray Analysis (2000), Volume Date 1999, 43 254-259
31. C. T. Chantler, J. Phys. Chem. Ref. Data 24, 71 (1995); C. T. Chantler, J. Phys. Chem. Ref. Data, 29, 597 (2000); see also <http://physics.nist.gov/PhysRefData/FFast/Text/cover.html>
32. Systematics of x-ray transition energies for high-Z atoms. Deslattes, R. D., Kessler, E. G., Kim, Y. K., Indelicato, P., J. Phys., Colloq. (1987), (C9, Vol. 1), C9-591/C9-595; Mooney, T., Lindroth, E., Indelicato, P., Kessler, E. G., Jr., Deslattes, R. D., Phys. Rev. A (1992), 45(3), 1531-43; Schweppe, J., Deslattes, R. D., Mooney, T., Powell, C. J., J. Electron Spectrosc. Relat. Phenom. (1994), 67(3), 463-78
33. Deslattes RD, Levin JC, Walker MD, Henins A, Medical Physics 21 (1) (1994) 123-126; Chantler CT, Deslattes RD, Henins A, Hudson LT, British Journal of Radiology 69 (823) (1996) 636-649; Hudson LT, Deslattes RD, Henins A, Chantler CT, Kessler EG, Schweppe JE, Medical Physics 23 (10) (1996) 1659-1670
34. Hudson, L. T., Henins, A., Deslattes, R. D., Seely, J. F., Holland, G. E., Atkin, R., Marlin, L., Meyerhofer, D. D., Stoeckl, C., Review of Scientific Instruments (2002), 73(6), 2270-2275;
35. Deslattes, R. D., Staudenmann, J.-L., Hudson, L. T., Henins, A., Cline, J. P., Adv. X-Ray Anal. (1998), 40 221-231
36. Egelhoff, W. F., Jr., Chen, P. J., McMichael, R. D., Powell, C. J., Deslattes, R. D., Serpa, F. G., Gomez, R. D., Journal of Applied Physics (2001), 89(9), 5209-5214; Prudnikov, I. R., Matyi, R. J., Deslattes, R. D., Journal of Applied Physics (2001), 90(7), 3338-3346