search & discovery

Nobel prize to Richter and Ting for discovery of J/psi

The 1976 Nobel Prize in Physics has been awarded to Burton Richter of SLAC and Samuel C. C. Ting of MIT "for their pioneering work in the discovery of a heavy elementary particle of a new kind." Their surprising and far-reaching discovery of the J/ψ particle was announced in November 1974 (PHYSICS TODAY, January 1975, page 17). The prize of $160 000, to be shared equally by Richter and Ting, was scheduled to be awarded on 10 December in Stockholm.

The J/ψ with a lifetime 1000 times greater than expected for a particle as massive as 3.1 GeV, did not fit into the three-quark classification scheme. Two years after the discovery, nine or ten particles related to the J/ψ have been found. All the members of the J/ψ family of mass below 3.7 GeV (the threshold for the associated production of charmed mesons) have remarkably small widths, typically a few hundred kilovolts or smaller, whereas particles with comparable mass were expected to have widths of several hundred MeV. By now it is widely believed that all the J/ψ particles are bound states of a charmed quark and its antiquark. Further confirmation of the existence of charm has come from the discovery of charmed mesons and charmed baryons.

TING

RICHTER

Richter collaborated on the experiment with a large team of experimenters led by himself, Martin Perl (SLAC), William Chinowsky, Gerson Goldhaber and George Trilling (Lawrence Berkeley Laboratory). The experimenters used the large solenoidal magnetic detector at SPEAR, the electron–positron colliding-beam device at SLAC. It was Richter who led the drive to construct SPEAR, after his pioneering efforts with an electron–electron device done with W. C. Barber, Bernard Gittelman and Gerard K. O'Neill.

The SLAC–LBL team had been studying the behavior of the total cross section for e^+e^- annihilation as a function of energy, varying the total energy in 200-MeV steps. They observed an anomalously high cross section at 3.2 GeV. When the California experimenters returned to this energy region and varied the energy in much finer steps, using a nuclear magnetic-resonance spectrometer to monitor the ring energy, they found[1] a cross section for hadron production at 3.105 GeV that was greater than 100 times the cross section outside the peak. The full width at half maximum was less than or equal to 1.3 MeV.

The actual discovery of the particle the group called "ψ(3105)" took place in one frantic weekend (9–10 November 1974). By the next day the news had traveled far and wide. On 21 November the SLAC–

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Shortest wavelength laser from harmonic generation

Records for the shortest wavelength at which coherent radiation has been achieved in the search for an x-ray laser system are falling with remarkable speed:

- It was only in June that Henry Hutchinson, C. C. Ling and Daniel Bradley (Imperial College, London) reported[1] at the Amsterdam Quantum Electronics Conference that they had extended the range of generation of coherent radiation into the extreme ultraviolet at 570 Å.
- After a preliminary paper in August, at the International Conference on the Physics of X-ray Spectra, John Reintjes, Robert Eckardt, Nicholas Karangelen, Raymond Elton and Ronald Andrews of the Naval Research Laboratory (Washington, DC) and Chiao-Yao She of Colorado State University report in a current Letter[2] that they pushed the record down to 532 Å.
- Now, at the Tucson meeting of the Optical Society in October, the NRL group reported preliminary results indicating they had reached 380 Å.

The methods used by the two groups are quite similar: Both used the nonlinear susceptibilities of noble gases to generate harmonics of an incident laser beam. These methods are extensions of initial work done in 1973 by Stephen Harris and his colleagues at Stanford. The Imperial College group used argon to frequency-triple the radiation from a xenon excimer laser (one in which the active medium consists of excited short-lived Xe_2 molecules). The NRL group obtained the fifth (and, in their latest work, seventh) harmonic of pulses that were already fourth harmonics of Nd–YAG laser light. The noble gases they used were helium, neon and argon, Reintjes told PHYSICS TODAY.

The NRL experiment. The primary radiation wavelength of 2661 Å was obtained from the 1.06-micron output of a Nd–YAG laser by two successive stages of frequency doubling, first in a crystal of potassium dihydrogen phosphate and then in one of potassium dideuterium phosphate. The NRL experimenters then converted this 2661-Å radiation of

If soft x rays may be said to begin at 100 Å, some people believe that coherent x rays are likely to become a reality soon. The uses of such radiation would include the study of crystals and biomolecules, and photolithographic techniques for producing super-miniaturized electronic microcircuits. —HRL

References

1. M. H. R. Hutchinson, C. C. Ling, D. J. Bradley, Optics Comm. 18, 203 (1976); D. J. Bradley, M. H. R. Hutchinson, C. C. Ling, in *Tunable Lasers and Applications* (A. Mooradian, T. Jaeger, P. Stokseth, eds.), Springer, New York (1976), page 40.
2. J. Reintjes, R. C. Eckardt, C.-Y. She, N. E. Karangelen, R. C. Elton, R. A. Andrews, Phys. Rev. Lett. (to be published).
3. I. S. Ruddock, D. J. Bradley, Appl. Phys. Lett. **29**, 296 (1976).

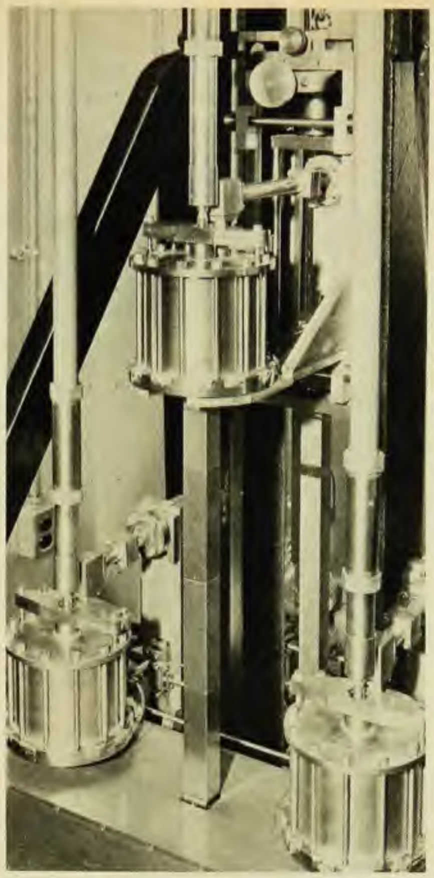
New values for boiling and freezing points

The values assigned to the temperatures of the boiling point of water and the freezing points of tin and zinc on the International Practical Temperature Scale of 1968 appear to be significantly higher than thermodynamic values. The new measurements, done by Leslie Guildner and Robert Edsinger with a very carefully built gas thermometer at the National Bureau of Standards, may lead to a redefinition of the International Practical Temperature Scale.

Although experimenters have made temperature measurements for many years with classical gas thermometers, Ralph P. Hudson, chief of the Bureau's Heat Division, says "They were polishing a slightly rotten apple. We decided to do it right." The project began about 20 years ago, with both Guildner and Edsinger working on it almost from the beginning. Their first determination was the thermodynamic temperature of the steam point, which they found to be 99.975 °C, a discrepancy with the IPTS-68 (the most recent revision) of −0.025 °C. Subsequently they found the tin and zinc freezing points to be 231.924 °C and 419.514 °C, which are lower than the values on the IPTS-68 by 0.045 °C and 0.66 °C, respectively.

The 1968 revision is based primarily on gas thermometry, the work most immediately preceding being done at the Physikalische Technische Bundesanstalt in Braunschweig by Helmut Moser and Wilhelm Thomas and at the National Research Council in Ottawa by Hugh Preston-Thomas and Chris Kirby.

The NBS results differ from and are thought to be more accurate than earlier gas-thermometry values for two reasons: First, the NBS group developed instrumentation to allow the highest level of metrology for the measurement processes such as thermal expansion, thermomolecular pressure and the realization of pressure ratios, Hudson told us. For example, the precision mercury manometer has a total uncertainty in pressure ratios of only 1.5 ppm. Second, the effect of sorption, which is thought to be the principal source of systematic bias between the NBS work and earlier gas thermometry, is believed to be insignificant in the new results because of a comprehensive effort to minimize it.



NBS precision mercury manometer has a total uncertainty in pressure ratios of 1.5 ppm.

The next step for the NBS team will be to measure the freezing point of aluminum, near 660 °C. Eventually they are aiming for measurement at the gold point near 1064 °C to incorporate in a new version of the IPTS. The latter was revised in 1948, 1968, and will be revised again in the not-too-distant future, perhaps as early as 1983, according to one member of the Advisory Committee on Thermometry; this group reports to the International Committee of Weights and Measures. —GBL

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LBL group found a second narrow resonance decaying to hadrons, simply by scanning the entire region in 1-MeV steps. The new resonance had a mass of 3.695 GeV.

Much later, Richter said,[2] "It has been particularly satisfying to have witnessed the birth of a new class of particles; the ψ's with their unexpected properties. Every experimentalist dreams of making the great discovery—a discovery which will change the direction of scientific thought. I don't know yet if the colliding-beam machines and the new particles we have discovered with them will cause a sharp change in that direction, but surely they have bent it a bit."

Ting and his Brookhaven–MIT collaborators (Ulrich Becker, Min Chen and others) had been studying quantum electrodynamics, photoproduction of vector mesons and e^+e^- pair decay of vector mesons for the last ten years at DESY, where they developed techniques to identify electron–positron pairs from a background of millions of hadrons. They started their experiment at the Brookhaven AGS, searching for new particles in the reaction $p + Be \rightarrow e^+ + e^- + X$ with a precise pair spectrometer that had a mass resolution of 5 MeV. They saw a sharp peak at 3.1 GeV with a width consistent with zero (consistent with their mass resolution). They called it the "J" particle. The peak was first observed in August 1974, Ting recalls.[3] The group decided to make many experimental checks, such as decreasing the magnet current. They then spent late October and the first week in November measuring the anomalous $e^\pm/\pi^\pm$ ratio, hoping that the J could explain this number.

On 6 November Ting decided to publish[4] the work on the J. On 11 November Ting, who was visiting SLAC for a Program Advisory Committee meeting, went to W. K. H. Panofsky's office and told him and Richter of the MIT results. Richter reciprocated with the SLAC–LBL results. Within a short time the Adone storage ring in Frascati also discovered the J/ψ particle. "It was the shot heard 'round the world," at least in the circles traveled by particle physicists.

Biographies. Richter earned his BS and PhD at MIT. In 1956 he went to Stanford University and in 1963 joined the staff of SLAC, where he has been a professor since 1967.

Ting got his bachelor's and doctorate at the University of Michigan. In 1963 he went to CERN and then joined Columbia University's physics department the following year. He went to MIT in 1967, where he became a professor in 1969. Since 1966 Ting has been doing experiments at DESY. —GBL

References

1. J.-E. Augustin, A. M. Boyarski, M. Breidenbach, F. Bulos, J. T. Dakin, G. J. Feldman, G. E. Fischer, D. Fryberger, G. Hanson, B. Jean-Marie, R. R. Larsen, V. Luth, H. L. Lynch, D. Lyon, C. C. Morehouse, J. M. Paterson, M. L. Perl, B. Richter, P. Rapidis, R. F. Schwitters, W. M. Tanenbaum, F. Vannucci, G. S. Abrams, D. Briggs, W.

Chinowsky, C. E. Friedberg, G. Goldhaber, R. J. Hollebeek, J. A. Kadyk, B. Lulu, F. Pierre, G. H. Trilling, J. S. Whitaker, J. Wiss, J. E. Zipse, Phys. Rev. Lett. 33, 1404 (1974).

2. B. Richter, Adventures in Experimental Physics 5, 143 (1976).
3. S. C. C. Ting, Adventures in Experimental Physics 5, 115 (1976).
4. J. J. Aubert, U. Becker, P. J. Biggs, J. Burger, M. Chen, G. Everhart, P. Goldhagen, J. Leong, T. McCorriston, T. G. Rhoades, M. Rohde, S. C. C. Ting, S. L. Wu, Y. Y. Lee, Phys. Rev. Lett. 33, 1402 (1974).

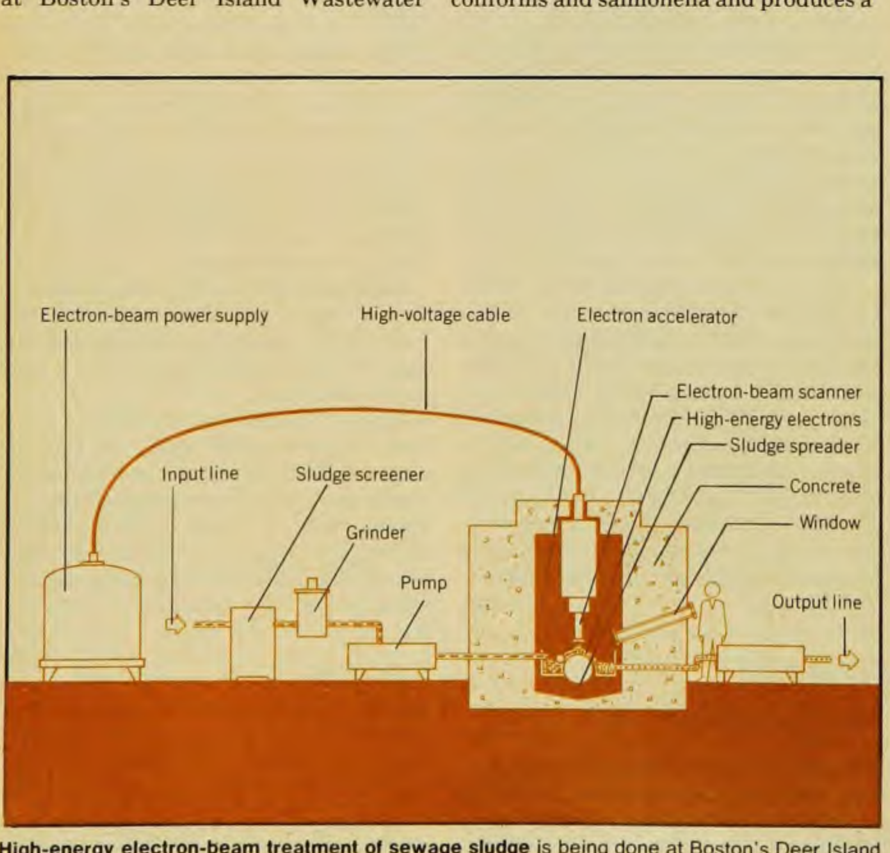
Treatment of sewage by electrons and gammas

The use of high-energy electrons in the treatment of sewage sludge for return to the land as fertilizer is undergoing technical and economic assessment under actual conditions in Boston. The project constitutes a joint effort by MIT's High-Voltage Research Laboratory, High-Voltage Engineering Corp (suppliers of the electron accelerator) and the State and municipal commissions in charge of the treatment plant. Another program, conducted at Sandia Laboratories in Albuquerque, N.M., is concerned with the scientific practicality of decontaminating sewage wastes by exposure to radioactive cesium.

MIT's method. Designed to treat 100 000 gallons of sludge extracted from municipal sewage daily, the new 50-kW facility at Boston's Deer Island Wastewater Treatment Plant employs a 750-MeV electron beam from a high-voltage accelerator. The sludge slurry (2–5% solid matter) flows through the intense beam at a rate of 2 m/s, in a stream about 2 mm thick and 1.2 m long, which disinfects and de-infests it of bacteria that pose the major health hazard in the re-use of such wastes for soil enrichment. Another benefit of the treatment is that the intense ionization process may help break up toxic chemical pollutants like PCB and pesticides.

Principal advantages of the electron-beam approach—which is also applicable to dry, composted wastes—are, according to HVRL director and project head John G. Trump, the availability and controllability (instant on-off switching) of this form of ionizing energy. At the electron energies used, no radioactivity is introduced into the treated matter, thus simplifying its disposal. Preliminary economic-feasibility studies indicate that costs may make the technique acceptable for nationwide use; for sludge with 5% solids, Trump estimates the price at $16 per dry ton of sludge processed. Capital costs total about $500 000, of which 60% is for the accelerator itself, while yearly operating costs are expected to be approximately $120 000.

Trump told us that the Deer Island facility, which commenced high-energy electron-beam treatment this May, is obtaining good disinfection results at its high flow rate. Initial results show that an exposure of 400 000 rads eliminates coliforms and salmonella and produces a reduction on the order of 10^4–10^5 in total bacteria count; it also adequately reduces the much lower viral count.



High-energy electron-beam treatment of sewage sludge is being done at Boston's Deer Island Wastewater Treatment Plant. Sludge slurry flows through the 750-MeV beam at rate of 2 m/s.

Gamma irradiation. Meanwhile, the Waste Management and Environmental Programs Department at Sandia, headed by H. D. Sivinski, is carrying on a sewage-treatment project that employs Cs^{137} as a source of 0.667-MeV gamma rays to destroy pathogens. The $750-thousand-per-year program, which originated in the investigation of sterilization problems associated with the Viking lander, combines heat with radiation to make liquid sewage sludges usable for conditioning and restoring depleted soil; the wastes may also be restored to the food chain by the treatment—Sandia researchers have found that sheep, cattle and other ruminants can readily digest the material, thus permitting possible diversion of animal feed supplements—such as soy beans—to help ease the world's food problem. For the last two years the project has been supported jointly by ERDA and the EPA, with the Department of Agriculture now joining in.

Sivinski told us Sandia's waste-irradiation approach could help in coping with nuclear-waste disposal, greatly increased sewage-sludge production expected to result from the secondary-treatment requirements of the Clean Water Act, and the world food shortage. At a cost of about ten cents per curie for the radiation source, using Cs^{137} capsules from the Hanford storage facility in Richland, Wash., the method could prove economically advantageous, he estimated. A principal advantage of the Sandia technique, according to Sivinski, is the high penetrating capability of gamma rays. Electrons lose their energy quickly in passing through a dense sludge, but gamma radiation is not thus limited; he feels that electrons may be best suited for treatment of waste-water effluents instead.

Sandia researchers are looking into the irradiation of composted sludge at the Agricultural Research Service's center in Beltsville, Md., and elsewhere. Their hope is to eliminate the curing portion of the composting process to permit treatment of larger volumes of waste and the agricultural use of this pathogen-free material as a soil amenity. Treatment costs of $3–5 per ton are projected.

From the mid-1960's until the project's termination in 1972, an Oak Ridge National Laboratory team under the direction of F. N. Case and A. F. Rupp studied the decontamination of liquid effluents. They used high-energy radiation from Cs^{137} and from Co^{60} (the energy released in Co^{60}'s gamma rays is about 1.5 MeV). The Oak Ridge study's largest source was 200 000 curies of radioactive cobalt, and the treatment capacity of the pilot unit was less than 10 000 gallons per day.

—FCB□