Paul Hartman (1913-2005), a Synchrotron Radiation Pioneer

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Paul Hartman

Paul Hartman, a synchrotron radiation pioneer, passed away in Ithaca, New York on 20 May 2005 at the age of 91. Below is a compendium of materials about Paul's life and a few of his contributions as a professor, scientist, and, from this magazine's perspective, an early pioneer of synchrotron radiation research. Paul's work has been an important "foundation stone" of synchrotron radiation research world-wide and has been the precursor to the use of high-energy X-rays to study such things as the molecular structure of proteins, the time-evolution of fuel sprays in the microsecond-resolved regime, and phase transitions detected in geological materials under high-pressure and high-temperature conditions similar to those experienced far into the earth's interior, etc. We take these current areas of scientific interest for granted at CHESS, yet Paul's initial work provides some of the intellectual underpinnings needed to perform these experiments.

"Hartman was one of the first to investigate the use of X-rays generated as a by-product of a synchrotron. In 1956, he and colleague Diran Tomboulian reported the synchrotron spectrum in the soft X-ray region from an electron beam circulating in the 300 MeV Cornell synchrotron [1], confirming Schwinger's prediction [2]. The spectral distribution in the visible region had been reported in 1947 using the 70 MeV General Electric synchrotron [3]. Paul Hartman and Diran Tomboulian not only observed and characterized the synchrotron radiation spectrum in the soft X-ray region, but were also the first to observe the K- and L2,3-absorption edges of beryllium and aluminum, thus performing the first synchrotron-based XAFS experiment [1]."[4]

Possibly the first synchrotron beamline is shown in Fig 1. This was attached to the circular synchrotron ring, Fig 2.

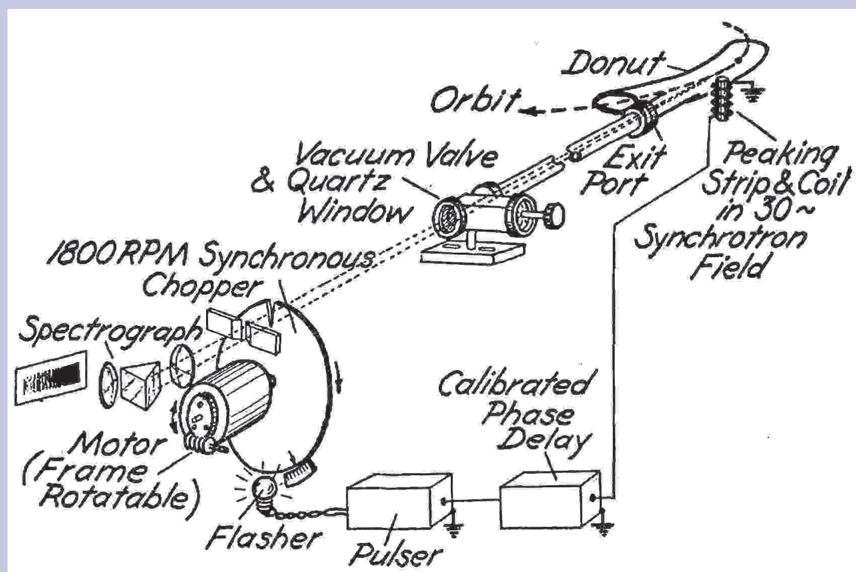

Fig 1: Diagram of the beamline on the Cornell 300 MeV synchrotron used for recording the ultraviolet radiation from essentially monoenergetic electrons. This is Fig 11 of reference [1]. The rotating chopper allowed radiation from monoenergetic electrons to fall on the spectrograph that measured the spectral properties of the source. Arthur Robinson of LBL in his brief history of synchrotron radiation states that "The next step came with the 1956 experiments of Tomboulian and Hartman, who were granted a two-week run at the 320-MeV electron synchrotron at Cornell. Despite the limited time, they were able to confirm the spectral and angular distribution of the radiation with a grazing- incidence spectrograph in the ultraviolet from 80 Å to 300 Å. They also reported the first soft X-ray spectroscopy experiments with synchrotron radiation, measuring the transmission of beryllium and aluminum foils near the K and L edges. However, despite the advantages of synchrotron radiation that were detailed by the Cornell scientists and the interest their work stimulated, it wasn't until 1961 that an experimental program using synchrotron radiation got under way when the National Bureau of Standards (now National Institute of Standards and Technology) modified its 180-MeV electron synchrotron to allow access to the radiation via a tangent section into the machine's vacuum system."[5]. This diagram also serves to document Paul's ability as an artist. We don't make hand drawn drawings like this one much any more, but isn't it beautiful? (The closest person to this tradition currently at CHESS is Ernie Fontes and his hand sketches are sometimes called "ErnieCAD".) The essential parts are all sketched out and appropriately labeled. You can follow the flow of UV photons emitted from the electron orbit in the circular "donut" of a vacuum chamber down through the vacuum window, chopper, and on through the photographic plate. Notice even the detail on the worm gear on the Synchronous Chopper assembly.

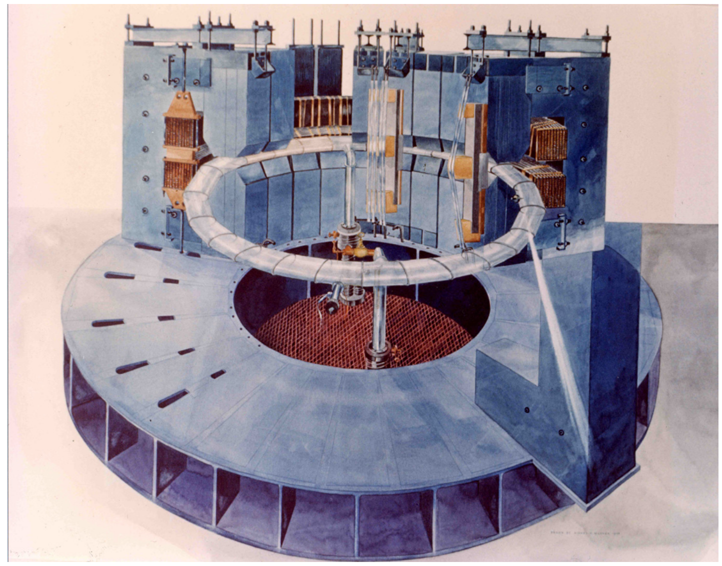

Fig 2: From the Laboratory of Elementary Physics archive is this 1948 painting by Sidney G. Warner (technical illustrator from General Electric) of the Cornell 300 MeV synchrotron that was built in the basement of Newman Laboratory. The illustration shows a bremsstrahlung beam from a target in the machine. The UV beamline is not shown in this original sketch but would also have exited tangent to the ring as in this illustration. Paul Hartman writes [9] about a related measurement made on this machine "....(Dale) Corson [10] did a nice experiment at Cornell on the orbit radius contraction following cut-off of the driving radio frequency voltage. The opaque cover for the exit port was replaced by a transparent window and the radiation imaged with a lens onto a photomultiplier, which had an opaque grid to provide timing markers on an oscilloscope record. The results were in accord with the theory of Schwinger, giving a loss rate accurately proportional to the fourth power of the electron energy."

It is worth recalling this effort in Paul Hartman's words from his presentation at the 2nd National Conference on Synchrotron Radiation Instrumentation held in Ithaca on 15–17 July 1981 [6]: "My own involvement with synchrotron radiation came, in an unlikely way, through some work on the optical properties of alkali halides. Light sources were a problem in the region 2000 to 1000 Angstroms, where we were working. I went down one afternoon to see Leonard Jossem in his laboratory where he worked with Lyman Parratt on fine structure at X-ray absorption edges, not called EXAFS in those days. I wondered if it was nonsense to think of a high-current X-ray tube as generating enough bremsstrahlung to be useful at long wavelengths. He thought it would not be fruitful, but why didn't I consider using synchrotron radiation? That was my introduction. He cited the General Electric observations and Schwinger's predictions of radiation at wavelengths a lot shorter than 1000 Angstroms. I straightaway went down the corridor to see Diran Tomboulian, who had for a long time worked with soft X-rays, to tell him what I had just learned and wouldn't it be a good idea to see if it were all really so, what with an operating 300 MeV synchrotron across the way in the Nuclear Studies laboratory. He had in particular one nice, compact, vacuum spectrograph that could be moved over to the synchrotron without too much difficulty. A small problem came in connecting the spectrograph to the synchrotron without disturbing the vacuum of the latter. We had, of course, to load the photographic plate into the spectrograph in the darkened experimental hall, seal up the vacuum enclosure, evacuate it, and then open it to the machine. I well remember the late Saturday night when we opened the large separating valve to join the two instruments, and saw the vacuum rapidly deteriorating. A generous and quick application of pump oil around the large Wilson seal involved in the valve took care of it. Our first exposure was disturbing: one long dark streak across the plate. We surmised a light leak somehow. But Tomboulian had the wherewithal to check that – some previously utilized thin films of beryllium and aluminum. We put one of these behind the slit of his spectrograph and repeated the operation. It was an exciting moment when the lights went on in the dark room after plate development to see an absorption edge at the appropriate wavelength showing up in the streak in both the first and second order. The radiation was certainly there, and it was not weak, for the exposures were not inordinately long. We looked at the spectrum at two widely different peak energies, and after considerable subsequent laboratory work, were able to say something about the spectral distribution and the vertical distribution of the radiation at different wavelengths as determined by the cone angle. No doubt about it, Schwinger had it right." At the time of his memorial service, friends of Paul were interviewed. Of this particular example of brilliant work came this praise: "It was a gorgeous piece of physics," said Dale Corson, president emeritus, former chair of the physics department and close friend of Hartman's. "The spectrum had been calculated by J. Schwinger at Harvard, but Hartman and Tomboulian essentially confirmed the calculation. It really was a tour de force." [7].

But what was the context in which all of this was occurring? For the answer, we need to delve more deeply into the life of Paul Hartman.

Paul was born on 13 July 1913 in Reno, Nevada, earned a BS degree in electrical engineering at the University of Nevada in 1934 and subsequently obtained his PhD in Physics from Cornell in 1938. On Paul's examining committee was Prof. Hans Bethe, one of Cornell's most famous physicists and winner of the Nobel Prize in Physics (1967) for explaining how the sun produces its nearly inexhaustible energy of radiated light and heat. Paul reminisced (at the time of Bethe's retirement) about his arrival in Ithaca relative to that of Hans that "I appeared on this campus (of Cornell University) first back in 1934. This was a few months before Hans did, albeit as one with a somewhat less illustrious reputation..... To a hayseed from Nevada, like myself, it was an exciting prospect awaiting the arrival of this famous physicist from Europe, student of Sommerfeld's, author already of many important papers and articles, and the like. The rate at which he cranked out really heavy stuff was already legendary. Later, when we got to know him as his students, while he was still awe inspiring, he was rather less formidable. He was always helpful and ever considerate of us. I remember full well the question on the diffraction grating he gave me on my oral qualifying examination, nursing me through it, and even passing me. I must say I did better with the same question a couple of years later when he asked it again of me on my final oral examination. What a memory! An A-1 type of professor he has always been."[8].

During World War II, Paul Hartman helped develop radar centimeter-wave generators for Bell Telephone Laboratories in New York City. He returned to Ithaca in 1946 to join the Cornell faculty as a charter member of the Department of Engineering Physics (now the School of Applied and Engineering Physics) with a joint appointment in the Physics Department, where he remained an Emeritus Professor until he retired. Boris Batterman, the former director of CHESS said, "Paul was a mentor for me for the last 40 years at Cornell. I learned optics, amateur astronomy (see Fig 3) and how important it was to be a fair and supportive colleague. When CHESS was being built, although in the middle of retirement, he designed the exit vacuum chambers that allowed us to get synchrotron radiation from the CESR storage ring. This was a very significant contribution to our project. Paul Hartman was an exemplary human being and a great scientist. He influenced my life enormously and made me a better person".

Fig 3: The photo shows Paul Hartman as a young man after building this telescope. Paul told Ken Finkelstein (CHESS staff scientist) that he built it while an undergraduate at the University of Nevada. Paul fabricated all the components himself including the 8" parabolic mirror, the Springfield mount and the gear system. This style of mounting allows one to sit on a stool and look through the lens without changing orientation while the scope is pointed anywhere in the sky. Paul cast the entire gear assembly and machined the teeth on the two meshing gear wheels. He also ground a number of lenses used with the telescope.

Don Bilderback, Associate Director of CHESS and one of the founding Co-editors of the Journal of Synchrotron Radiation said, "I knew and personally worked with Paul Hartman for a few years just before he went into retirement. He made helium-filled split ion chambers for vertical beam-position monitoring on the CHESS beamlines, which had the name 'Hartman monitors' and were in use for many years. Paul was a great experimentalist and he drew beautiful figures by hand for publication. One of his outstanding figures is the CHESS logo, which Paul designed and sketched (Fig 4). It still is the 'official' CHESS logo that we use!"[4].

"Paul was a kind, gentle person, just a great human being. We will miss him."

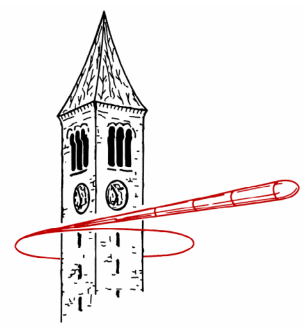

Fig 4: The official CHESS logo as drawn by Paul Hartman, showing the Cornell McGraw Clock Tower encircled by a particle beam emitting synchrotron radiation.

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