Katherine Chamberlain: A Snapshot of the Life

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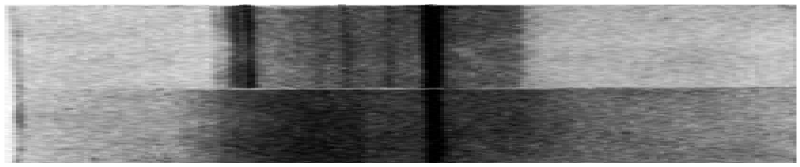

The picture shows black lines on a muted gray background; less than a millimeter wide and a few centimeters tall. Varying line thickness and irregular spacing add the only contrast to the photograph. At a glance it seems a failed picture; residual marks on film discarded by an amateur. Few would imagine that it helped to reveal the secrets of the atom. In fact this image, taken in an X-ray spectrograph in the early 1920's, provided some of the first tests of predictions made by quantum theory.

This photograph tells a much more personal story as well. It represents the first professional accomplishments of a true pioneer. Dr. Katherine Chamberlain was one of the first few scientists to study X-ray spectroscopy. In 1924, she received a PhD in Physics from the University of Michigan for this work, the first awarded to a woman. There would not be another for eight years. Dr. Chamberlain was a committed Professor of Physics and Mathematics, a advocate for world peace in a time of chaos, and a tireless promoter of the study of science. Her life story reveals a lost era of academic life and inspires us to renew our commitment to the scientific community.

Early Life

Katherine McFarlane Chamberlain was born on June 28, 1892 in Saginaw, Michigan to Fenton and Elizabeth Chamberlain.[1] By 1900, the family, which included Katherine's younger brother Elmer, moved to Port Huron. [2] Given a camera by an aunt at the age of ten, Katherine's lifelong love of photography quickly emerged. Pictures taken of a nearby oil refinery adorned the darkroom her father built for her. [3] Chamberlain's passion for photography never waned. Later in life she would enlist it as an innovative tool for the teaching of science.

After graduating from Port Huron High School in 1909, Katherine taught grammar school for two years in Port Huron while also working toward her degree at the University of Michigan. Upon receiving her B.A. in 1914, Katherine focused on education; teaching in Saginaw for a year and Port Huron for another two. In 1917, she returned to the University of Michigan to work toward her master's degree but continued teaching high school chemistry in Detroit from 1917 to 1922. [4]

<u>Research and the University of Michigan</u>

After completing her Master's degree in 1919, she pursued her doctorate under the guidance of Professor George A. Lindsay. [5] At that time, the University of Michigan was one of the leading institutions in the world in the area of spectroscopy. Chamberlain took advantage of the university's prominence, corresponding with the leading spectroscopy researchers in the world.[6] Working with Lindsay, she devoted her time toward using the new technique of x-ray spectroscopy to study the atom.

Earlier in the century, Niels Bohr's quantum theory revolutionized the study of physics. Bohr's theory predicted that the electrons that surround the nucleus of the atom could only have distinct energies. Electrons could move from one energy level to another by absorbing or emitting packets of light, known as photons. The electron would only make the transition if the photon's energy was the same, to within the limits of the uncertainty principle, as the difference the between the energy levels. If an electron absorbed a photon, it would move to a higher energy level, and, similarly, if an electron emitted a photon, it would move to a lower energy level. Scientists could deduce the energy levels of the atom by measuring the energy of the photons that were absorbed or emitted. However, quantum theory also required scientists to change the way they measured the energy of light.

Before quantum theory, scientists believed that the energy of light depended on its intensity. However, a consequence of quantum mechanics was that the energy of a photon depended only upon its frequency. This proved monumental for physicists because they had known for some time that they could separate light into its various frequencies through a phenomenon known as diffraction. With quantum mechanics, separating light based on its frequency meant separating the photons of light based on their energies. Physicists such as Chamberlain used these ideas as the basis for their spectroscopy experiments.

In x-ray spectroscopy, scientists produced x-rays with a wide range of energies with a high voltage source. The x-rays bombarded a sample of atoms, and each atom absorbed a different amount of energy and moved to a different energy level. As the electrons decayed back to a lower energy level to assume a more stable configuration, the atom emitted a photon with an energy corresponding to the difference between levels. With a spectrograph, scientists used diffraction to separate the photons based on their energies. Every photon with the same energy would hit the same place of the photographic plate and produce a line. The lines produced a sort of map, known as a spectrum, which transforms energy into position.

Manne Siegbahn of the University of Lunde in Sweden pioneered the field of x-ray spectroscopy by creating and using the first x-ray spectrographs. For his contributions to the field, Siegbahn won the Nobel Prize in Physics in 1924. As a testament to the University of Michigan's leading role in this area at that time, George Lindsay translated Siegbahn's definitive 1925 work, "The Spectroscopy of X-Rays" for publication in the United States.[7] Dr.

Chamberlain and Dr. Lindsay worked alongside the University of Lunde to advance the field by finding the spectra of various elements.

While Dr. Chamberlain conducted her research, she used a spectrograph designed by Siegbahn and built at the University of Michigan. Chamberlain and Lindsay based their research on the work that was taking place in Lunde under Siegbahn's chief researcher, Dirk Coster. Coster had previously earned his Ph.D. under Niels Bohr and moved to Lunde to study the nature of x-rays. In a 1924 paper by Coster, he described a white line on the photographic plates of his spectroscopy experiments that could not be identified using Bohr's theory.[8] These results startled many people because Bohr's theory should have been able to predict every electron transition for each element. An additional line meant that Bohr's theory did not provide a complete picture of the atom.

Chamberlain read Coster's article and believed she had an explanation to his problem. Scientists at the time knew that each element could exist in one of a few different states. The number of electrons that could be in the highest energy level, known as the valence shell, determined the state of the element. Each different state, known as an oxidation state, had its own distinct spectrum. When an element changed its oxidation state, it would either be oxidized or reduced depending on whether the number of electron in the valence shell increased or decreased. Oxidation referred to a decrease in the number of possible electrons of the valence shell, while reduction referred to an increase. Chamberlain believed that during the experiments the x-rays were changing the oxidation state in the atoms of the sample.

Chamberlain took time away from her spectroscopy experiments to test her theory. In her experiment, she first took the compounds that Coster used for his sample and exposed them to x-rays. Since most of compounds that Coster used were highly oxidized forms of the element, Chamberlain chemically tested the samples to determine whether any had been reduced by the x-rays. The results of the experiment confirmed her hypothesis and showed that the x-rays had reduced a portion of the sample. Chamberlain then used her spectrograph to find the spectrum of the reduced form of the element. She found that its spectrum contained a line that corresponded exactly with the unidentified line in Coster's experiment. Chamberlain published her findings in an article in the November 1924 edition of *The Physical Review* titled "The Fine Structure of Certain X-Ray Absorption Edges." [9]

Chamberlain's paper called for the research into the reduction potential of x-rays and work toward an explanation of this potential using Bohr's quantum theory. More importantly, in the last parts of her paper, Chamberlain proposed that this type of research could "…give the key to the solution of that vastly more difficult problem of what occurs in the human body when x-rays are used as a therapeutic agent." With her paper, Chamberlain earned the respect of Coster who she thanks in the paper's acknowledgments for "…his interest in my preliminary report and for the encouragement he offered to carry the work farther." [10]

In 1924, Dr. Chamberlain finished her thesis, "The Determination of Certain Outer X-Ray Energy Levels for the Elements from Antimony (51) to Samarium (62)." Upon finishing it, Chamberlain received her Sc.D. (Doctorate of Science) and became the first woman to ever receive a doctorate in physics from the University of Michigan.[11] Her thesis was not published, however, until October 1927 in *The Physical Review*.[12]

After earning her doctorate, Chamberlain took a job as a senior mathematics instructor at the City College of Detroit.[13] While teaching, Chamberlain submitted her paper on the reducing potential of x-rays to the Association to Aide Scientific Research by Women. Every year since 1911, the association awarded The Ellen Richards Prize of one-thousand dollars to the world's best scientific publication written by a woman. Since its inception, the Ellen Richard's Prize became one of the most prestigious awards for female scientists in part due to the rigorous standards set by the association's review panel. Before 1925, the Association offered the Ellen Richards Prize fourteen times, but, due to the lack of scientific merit, only awarded it six times. In 1925, Chamberlain as well as the seventeen other scientists from South Africa, England, Wales, and the United States applied for the grant. Chamberlain was awarded the prestigious Ellen Richards Prize in the fall of 1925 even though Chamberlain's research did not meet the exceedingly high standards of the association. However, her work "…was of such outstanding character that suggestions in paper should be followed-up."[14] X-ray therapeutics was a rapidly developing field at that time. Consequently, Chamberlain's suggestion that her research could provide significant insight into the effect of x-rays on the human body intrigued the Prize committee.[15]

Even today the magnitude of Chamberlain's ideas can be understood. People can only receive a certain number of x-rays each year, and lead screens need to be in place to minimize the amount of x-rays that the body absorbs. In the 1920's, people knew that x-rays were harmful but no one knew why. Chamberlain showed that x-rays can significantly change the chemical makeup of matter. She speculated that if x-rays could reduce the samples in her experiments, they might have a similar effect on human tissue and cause significant damage. These ideas paved the way for research in the area, and the Ellen Richards Prize provided a fitting tribute for such an influential idea.

As a recipient of the Ellen Richards Prize, Chamberlain joined the company of some of the most famous women in science history. In 1924, Marie Curie, the only person to win the Nobel Prize in two different areas and pioneer of the science of radioactivity, received the Ellen

Richards Prize. Other recipients included Lise Meitner (1928), who discovered nuclear fission, Annie Jump Cannon (1933), who applied spectroscopy to catalogue thousands of stars, and Nettie Stevens (1905), who discovered that the presence of the Y chromosome was the single factor that determined sex. Although Chamberlain's relatively small number of scientific publications may be the reason she never achieved the distinction of these other scientists, the significance of the Ellen Richards Prize provides a glimpse into the magnitude of her work.

To continue her research, Chamberlain used the prize money to study in Europe. For most of her year abroad, she worked under J.J. Thomson, Nobel Laureate in 1905 for the discovery of the electron, at the famous Cavendish Laboratory at Cambridge's Gerton College. After her time at Cambridge, she spent time visiting the famous physics laboratories across Europe. During her travels, she met noted physicists such as Albert Michelson, Marie Curie, and Lord Rutherford.[16]

Although Chamberlain devoted a significant part of the rest of her life to teaching, she never completely left the research arena. As a professor at Wayne University, she periodically published papers on various aspects of photography and spectroscopy. In 1933, Chamberlain and Harold Cutter worked in the laboratories of the University of Michigan to explore the infra-red spectrum of water. *The Physical Review* published their research in a December 1933 article titled "New Bands in the Electronic Band Spectrum of Neutral OH." [17]

A few years later, Chamberlain worked at the University of Michigan to study the growth of potassium bromide crystals. In the 1930's, most spectroscopy research used prism spectroscographs, and growing pure crystals for the prism was very challenging.[18] Chamberlain's research, published in the October 1938 volume of *The Review of Scientific Instruments*, included a detailed description of the procedure for the growth of pure crystals.[19] In

Chamberlain's last venture into research, she helped a graduate student, Emil Kaczor, earn his master's degree. The two studied the spark produced between the electrode gap of high voltage sources. *The Journal of the Optical Society of America* published their work, "An Air Interruptor for Use with the A.R.L. Spark Source," in November 1949.[20]

<u>Education</u>

Even though Chamberlain's research interests varied greatly, her passion to teach never wavered. When she became an associate professor of physics in 1927, she began teaching various physics courses including an introductory course on the science of photography. She continued to teach the course after she became a full professor of physics in 1945 and only stopped when she retired from Wayne State in 1959. The combination of her passions for photography and teaching drove Chamberlain to teach the course for twenty-three years.[21]

Initially, Chamberlain strove to teach physics not only because of her personal interest but also because of her belief that problem solving was an essential skill. Every college student, she believed, needed a full liberal arts education that required an introduction to the physical sciences.[22] In the preface to her 1942 textbook, *First College Course in Photography*, she argued that "…the unique contribution that science offers to a liberal education lies in the cultivation of the spirit of careful inquiry, in the unprejudiced appeal to experiment, and in the opportunity so frequently offered to test our opinions and learn definitely whether or not they are valid."[23] Chamberlain believed that the old introductory courses were failing to interest students, and her course in photography could provide "…an opportunity to introduce many students to the subject matter and methods of the physical sciences who would not have met these otherwise."[24] With her course, she created a new path for students to better appreciate physics and learn vital problem solving techniques.

At this early stage in Chamberlain's teaching career, she began to reach out to other groups to teach the benefits of a sound background in physics. In 1938, she wrote a textbook on math and optics for the Foundation of Optometry in Boston titled, *What Kind of Education?* The textbook contained short discussions of certain topics that were essential for future Optometrists to gain a solid background in problem solving and physics.[25] After the textbook's publication later that year, Chamberlain received distinction for her teaching techniques from the Distinguished Service Foundation of Optometry in Boston. The foundation awarded her a medal and citation for distinguished service to the field and provided Chamberlain with an honorary membership.[26] After this recognition of her teaching ability, Chamberlain realized that she could take physics to a larger audience.

In order to most effectively reach a larger number of people, Chamberlain turned to her college course in photography. Instead of solely being a means to teach college students problem solving techniques, she believed her course could teach any photography enthusiast to appreciate physics. In an initial attempt to reach out to photographers, she published a manual called A Darkroom Handbook, in 1948. The manual contained a collection of techniques and experiments to help readers solve common problems faced in developing photographs.[27]

Chamberlain believed she could reach an even wider audience because the handbook lacked a complete explanation of why a photograph can be made. In 1951, she modified her college course to make it more understandable for readers without any scientific background and published it. Chamberlain's book, An Introduction to the Science of Photography, catered to "…those who are studying without a teacher" and contained a complete guide to understanding the fundamental interactions of light and matter that make photography possible.[28] With her book, Chamberlain taught photographers that they could only master their art through an understanding of the underlying physics.

After publishing her book, Chamberlain's focus for her college courses changed: she no longer only wanted to expose students to physics. She believed that introductory physics courses should try to entice students to consider a career in physics. In an attempt to improve the physics curriculum at Wayne State University in the early 1950's, Chamberlain compiled her observations from twenty-five years of teaching. She submitted them to the board of education, calling them "A Study of Certain Trends in the Teaching of Physics."[29] At that point in time, most students were exposed to general physics because it was required by most other concentrations. Chamberlain saw this as an opportunity to draw students into physics, and in order to achieve this goal, the introductory physics classes needed to change.[30]

Chamberlain's major suggestions called for an increase in the number and quality of demonstrations and laboratory experiments. She believed that long derivations and complicated mathematics typified introductory physics courses for most students. Improving the demonstrations could spark student interest. In order to do this, Chamberlain called for the department to replace the ancient demonstrations being used with new ones that students could relate to. In a quote from her paper to the board of education, she explains that a student

> '…takes a dim view of those 1870 experiments that merely confirm general principles that he feels not the slightest urge to question anyway. But, give him an instrument of a type that is in industrial use today and he will gladly let you tie all the principles you please to it and will think as hard as you wish about why these are as they are.' [31]

The physics department, Chamberlain argued, should no longer be at the mercy of other departments that used general physics as "…an elimination contest that will remove the unfit…"[32] Chamberlain urged that the sole goal of general physics should simply be to "…cause students to want more…" physics.[33]

To the Community

Although Chamberlain spent the majority of her life dedicated to her research and students, she found time to devote to a number of causes. Many of her pursuits centered on improving the quality of women's experiences at the University of Michigan. From 1938 to 1940, Chamberlain worked as the women's scholarship coordinator for the University of Michigan Alumni Council.[34] In addition to her responsibilities as scholarship coordinator, Chamberlain began filming an alumni movie in 1938 depicting the everyday lives of women on campus.[35] She filmed many events in the 1938-1939 academic year and released the film after graduation. Additionally, from 1947 to 1952, Chamberlain worked to raise money for the Alice Lloyd Memorial at the University.[36]

In addition to these large contributions to the University, Chamberlain made a point to dedicate time to other community groups dedicated to giving women a greater voice. In 1953, Alice Tarbell Crathern published a history of the women of Detroit titled In Detroit Courage Was the Fashion; The Contribution of Women to the Development of Detroit from 1701 to 1951. Chamberlain planned the illustrations for the book and was one of four women on the book's editorial committee working to mark Detroit's 250th anniversary.[37] Chamberlain was also involved with other community groups such the Inter-group Council for Women as Public Policy Makers, where she was vice-chairman from 1947-1949, as well as the Women's City Club, where she served on the board of directors.[38] Chamberlain effectively channeled her experiences in the male-dominated field of physics into being one of the leaders in the fight for a stronger community of women.

The other major avenue to which Chamberlain devoted herself involved educating the public about the social implications of atomic energy. Chamberlain lost her beloved brother, Elmer, in World War II[39] and focused her grief on arousing the public to take action to calm the current international tensions. In a 1946 article in *Science Magazine* entitled "Another Chain Reaction," Chamberlain spoke to the scientists of the world and urged them to band together to work toward banning the use of atomic research for military purposes. Scientists, she reasoned, had the responsibility to take control of the regulation of atomic energy. In the article she explains,

> 'This is in no sense a proposal that we scientists should become the self-appointed guardians of civilization. But, as the group that is in the best position to appreciate the disastrous potentialities of atomic energy without adequate control…we should be able to arouse other people to the realization that nothing else greatly matters if this problem is not solved.'[40]

Chamberlain embraced the quest to spread the word about atomic energy and continued the pursuit for many years.

In 1947, Chamberlain joined the Detroit chapter of the United World Federalists and was elected to its board of directors later that year.[41] The United World Federalists strove to create a stronger United Nations that could control the proliferation of atomic energy. Members included, among others, Albert Einstein and Kurt Vonnegut. As word spread and membership in the society grew, the movement came to be known as "Atoms for Peace."

As a part of the society, Chamberlain organized a World Government Week in Detroit in April of 1948 to raise awareness for the need of a stronger United Nations. Obtaining signatures for a petition urging the government to strengthen the UN was the main goal for the conference.[42] As a member of the advisory committee for the conference, Chamberlain helped to carefully plan how to effectively reach the largest percentage of the Detroit area. The committee decided to invite representatives from a wide variety of Detroit organizations. In preparation for the conference, Chamberlain wrote to Albert Einstein, a member of the United World Federalists and founding member of the Emergency Committee of Atomic Scientists (ECAS), to explain the purpose of the World Government Week in Detroit. Einstein had recently published an article in *The Atlantic Monthly* titled, "Atomic War or Peace" in which he argued that the only solution to the international tensions caused by atomic warfare was the creation of a much stronger UN. Einstein sent Chamberlain one thousand copies of his *Atlantic Monthly* article and a written statement by the ECAS urging citizens that by banding together they could have a profound impact on the government.[43]

At the conference held on April 19, 1948, the national president of the United World Federalists and renowned peace advocate, Norman Cousins, gave the keynote address.[44] As a testament to her stature in the community, the committee chose Chamberlain to give the closing remarks at the conference.[45] Although the attendance for the conference only totaled sixteen hundred, the careful planning of the advisory committee spread the message of the conference across southeastern Michigan.

In addition to her work done for World Government Week, Chamberlain published pamphlets and postcards for distribution throughout the Detroit area. In the late 1940's, Chamberlain published a list of common misconceptions about nuclear research in *The*

Newsletter of the World Study Council of Detroit titled “The Atomic Bomb Versus Civilization: A Primer for the Atomic Age.”[46] In it, she posed questions including “Suppose we stop making bomb. What assurance have we that some other country will not keep on and some day conquer us with its atomic bomb?” and “How much sovereignty should we have to give up in order to achieve international control over aggressor nations?”[47] Chamberlain used her experience as a part of the science community to answer these questions. She urged people to “…talk about it to everyone who will listen…”[48] Chamberlain also published a postcard for wide distribution through Wayne State University which described “The Six Steps in the Atomic Age.” The steps led to a conviction to urge the government to create “…a stronger World Authority.”[49]

The University of Michigan noted Chamberlain’s work in the field of energy public policy. In 1952, the University asked Chamberlain to join a group called the Memorial Phoenix Project.[50] In 1947, the University created a War Memorial Committee to find the best way to commemorate those members of the University community lost in World War II. The Memorial Committee decided that the most suitable way to honor those lost would be to create a nuclear energy research center. In 1948, the Memorial Phoenix Project began with the aims to explore the possible benefits of nuclear energy. The Phoenix Project grew to encompass both the Phoenix Memorial Laboratory and the Ford Nuclear Reactor. Both research institutes grew and came to the forefront of energy research.[51] Chamberlain’s contributions to the Project came as a member of the National Advisory Committee. Determining the research done at the centers became the primary focus of the Advisory Committee.[52] With Chamberlain’s technical experience as well as her leadership skills, she became a valuable member of the committee on which she served for nearly a decade.

Chamberlain's influential contributions toward her many avenues of service did not go unnoticed. In 1957, *The Detroit Free Press* named Chamberlain "…one of Detroit's Ten Top Working Women…"[53] The University of Michigan followed suit in recognizing her efforts. Chamberlain received the 1960 Distinguished Alumni Service Award.[54] Additionally, at the 1961 Alumni Week, where Chamberlain was the featured speaker, she received a service citation from the Alumni Council for her contributions to the women's community at the University of Michigan.[55]

As Chamberlain grew older, she took a step back from the public eye to enjoy the later years of her life. Wayne State University named her Professor-Emeritus of Physic upon her retirement in 1958.[56] She moved back to Ann Arbor where she spent the rest of her life concentrating on her photography.[57] Chamberlain passed away on January 9, 1977 and was buried in Evard, Michigan.[58]

The fact that Dr. Katherine Chamberlain contributed to such a broad number of areas makes gaining perspective on her accomplishments difficult. A quote by Chamberlain from a 1938 meeting of the Alumni Scholarship Committee might be able to shed light on her life's goals. In the quote, she tries to explain what type of person most deserves the most prestigious academic scholarships.

> 'Rhodes Scholars are rarely distinguished in after life for out-standing intellectual achievement, perhaps because the criteria for selection demand that they be too versatile to be remarkable in any definite field. On the other hand, the person exceptionally gifted in a particular direction often suffers from personality defects that make her difficult to assimilate in a group.'[59]

Chamberlain understood that the delicate balance between achieving expertise in a specific area while establishing a base intellect in a wide range of fields was an impossible goal. However, Chamberlain believed that the pursuit of that balance would be the most effective way to make the most impact on her community.

As a physicist, Chamberlain pioneered not only the field of x-ray spectroscopy but, more importantly, the community of women in physics. As one of the first handful of women to earn their doctorate in physics, Chamberlain embodied the successful woman in science and, throughout her life, sought to empower women to become influential members of their community.

As a teacher, Chamberlain broke barriers in the teaching of introductory physics. Her ideas sought to improve introductory physics by inspiring students through experiments and demonstrations. Her unique method of using photography became a valuable tool that motivated students and photographers alike to gain a new appreciation for physics.

As an activist, Chamberlain harnessed her personal experience with the horrors of war and worked for world peace on multiple levels. Realizing that she had a responsibility as a scientist to educate the public on the potential dangers and benefits of nuclear energy, Chamberlain urged her fellow scientists to join the movement. She took it upon herself to help lead the greater Detroit community toward an understanding of the consequences of living in the emerging nuclear age. Her experience in physics also drove her to help direct the new path of nuclear energy research.

Being a part of such a wide range of social communities allowed Dr. Katherine Chamberlain to enact change in many ways. However, one common bond united each area that Chamberlain immersed herself. Basic passions for science and teaching provided the driving force for each aspect of Dr. Chamberlain’s life. One can examine the many things that Chamberlain accomplished and, most likely, come to different conclusions about their significance. However, Chamberlain’s example that passion alone can drive change can hopefully withstand the test of time and continue to be her greatest legacy.

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Images from the Life of Katherine Chamberlain

Katherine Chamberlain's X-Ray Spectrograph that she used for her research at the University of Michigan.
(Spectrograph courtesy of Jens Zorn and the Physics Department of the University of Michigan)

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Dr. Chamberlain (right) and Ms. Lola Hanavan

Carlton, Ruth, "Detroiter Named to Atomic Project," *The Detroit News*, 29 June 1951, Katherine Chamberlain Vertical File, Walter P. Reuther Library, Wayne State University.

Chamberlain, Katherine, “Why I Believe in God,” *The Detroit Free Press,* 5 March 1954, Katherine Chamberlain Vertical File, Walter P. Reuther Library, Wayne State University.

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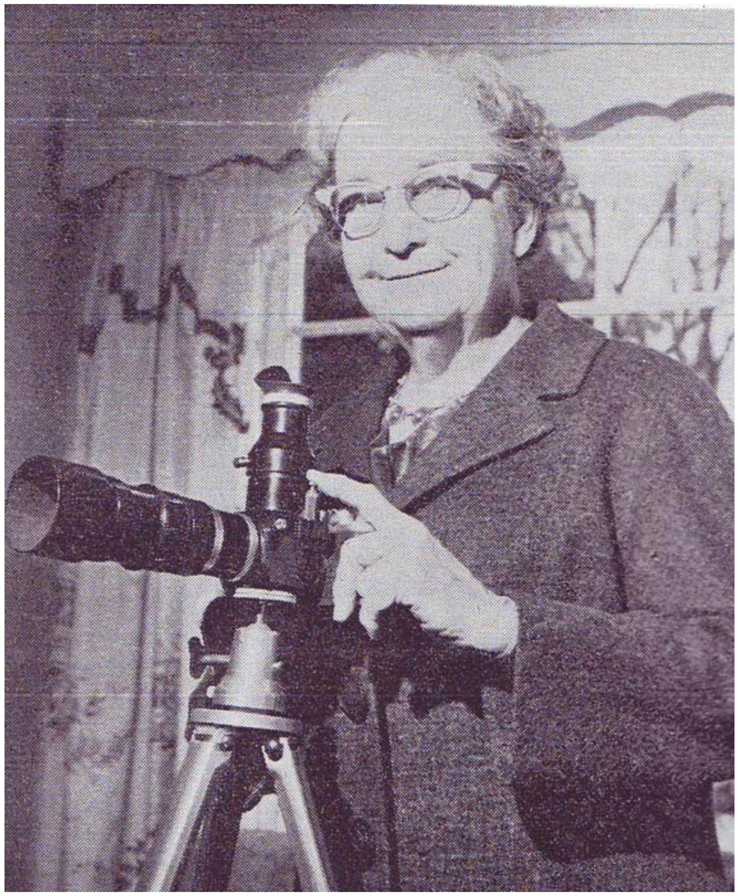
Dr. Chamberlain (far right) was the featured Alumni speaker at the 1961 Alumni Week.

*The Michigan Alumnus***,** Vol. 67, p. 343, 1961**,** Bentley Historical Library, University of Michigan.

Dr. Chamberlain (far left) at the 1962 Alumni Reunion

*The Michigan Alumnus***,** Vol. 69, p. 31, 1962**,** Bentley Historical Library, University of Michigan.



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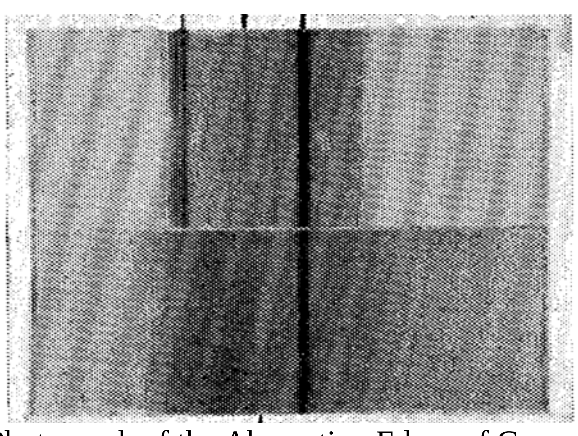

Photograph of the Absorption Edges of Copper

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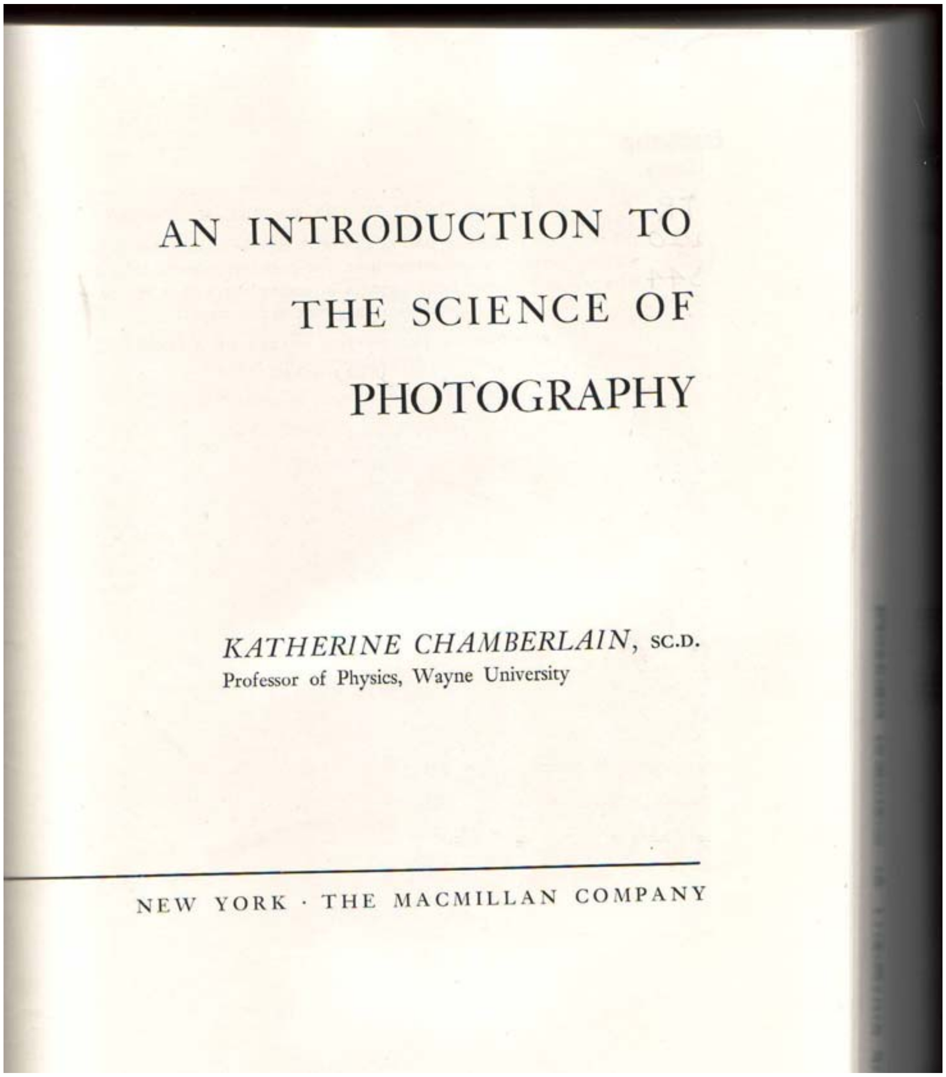

AN INTRODUCTION TO
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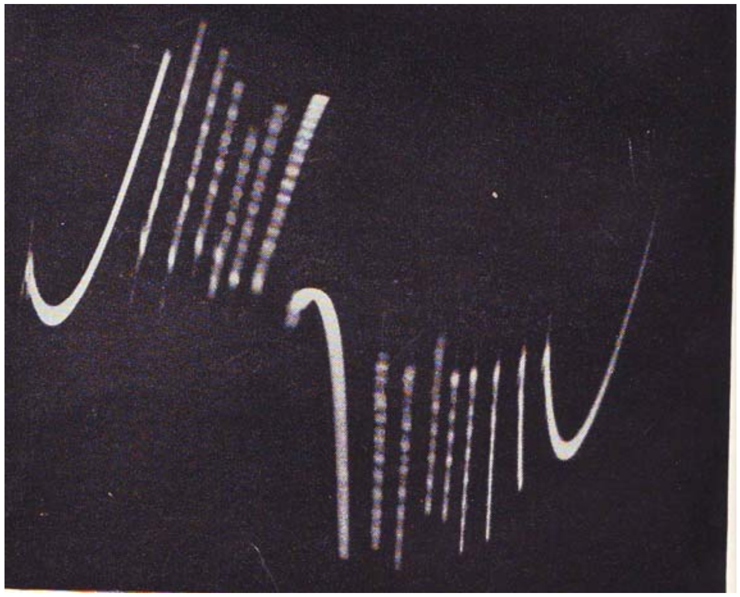
KATHERINE CHAMBERLAIN, SC.D.
Professor of Physics, Wayne University

NEW YORK · THE MACMILLAN COMPANY

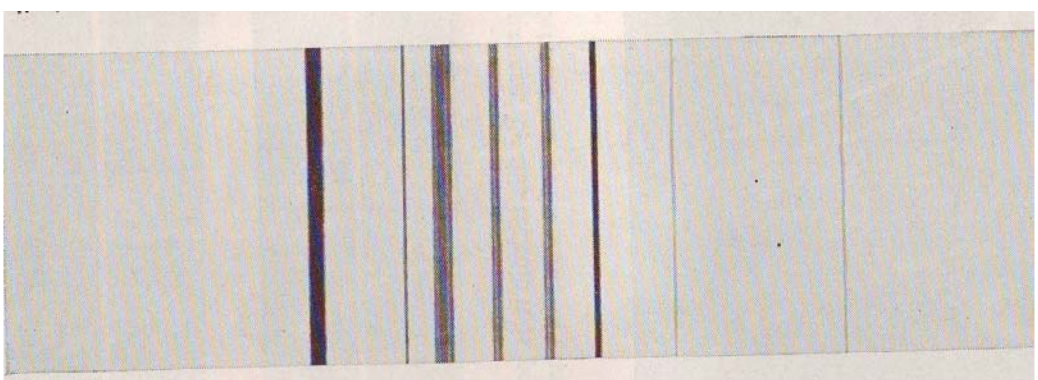
Title page of Dr. Chamberlain’s 1951 book

Chamberlain, Katherine. An Introduction to the Science of Photography. The Macmillan Co.: New York, 1951. Art Architecture and Engineering Library, University of Michigan.



Photograph of the spark produced in electrode gap of a high voltage source.
Photograph taken from Dr. Chamberlain's 1951 Book.

Chamberlain, Katherine. An Introduction to the Science of Photography. The Macmillan Co.: New York, 1951. Art Architecture and Engineering Library, University of Michigan.



Picture of Emission Spectrum used in Dr. Chamberlain's 1951 Book.

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