

DR. ALBERT MICHELSON

**AMERICA'S FIRST SCIENCE NOBEL LAUREATE
AND HIS FAMOUS OPTICS EXPERIMENT
AT THE IRVINE RANCH IN 1930**

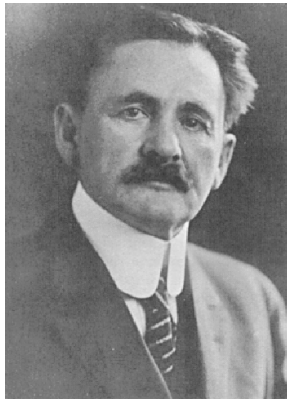


Albert Michelson won the 1907 Nobel Prize in Physics For the development of optical precision instruments. He accurately measured the SPEED OF LIGHT and confirmed that light is a wave motion. By the principle of Interferometry, which he established as an important experimental tool, he determined fundamental properties of matter and radiation. His experimental results lead directly to the theory of relativity and the development of lasers.

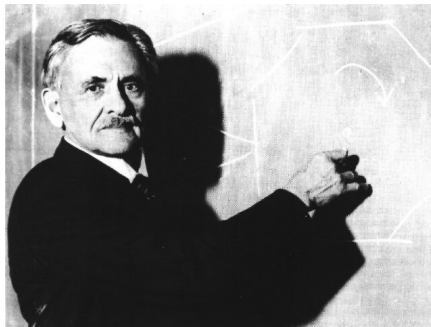


Cadet Midshipman
Albert A. Michelson in 1873
U. S. Naval Academy

President Ulysses S. Grant awarded Albert A. Michelson a special appointment to the U.S. Naval Academy in 1869. During his four years as a midshipman at the Academy, Michelson excelled in optics, heat and climatology, and drawing. After his graduation in 1873 and two years at sea, he returned to the Academy to become an instructor in physics and chemistry, from 1875 to 1879. During this time in Annapolis he conducted his first experiments of the velocity of light, as part of a class demonstration in 1877.



"The velocity of light is so enormously greater than anything with which we are accustomed to deal that the mind has some little difficulty in grasping it. . . we can, perhaps, give a better idea of this velocity by saying that light will travel around the world seven times between two ticks of a clock." – Albert A. Michelson, Light Waves and their Uses (1903), p. 146



**"My greatest inspiration is a challenge to attempt the impossible."
-- Albert A. Michelson**

Velocity of Light Measured on Ranch

In 1929 James Irvine granted Polish physicist Dr. Albert Abraham Michelson land on which to build an experimental tube to refine Michelson's previous measurements of the velocity of light. Michelson, who had been living in Chicago and was in poor health, was encouraged to move to California and join the Mount Wilson staff, which he did.

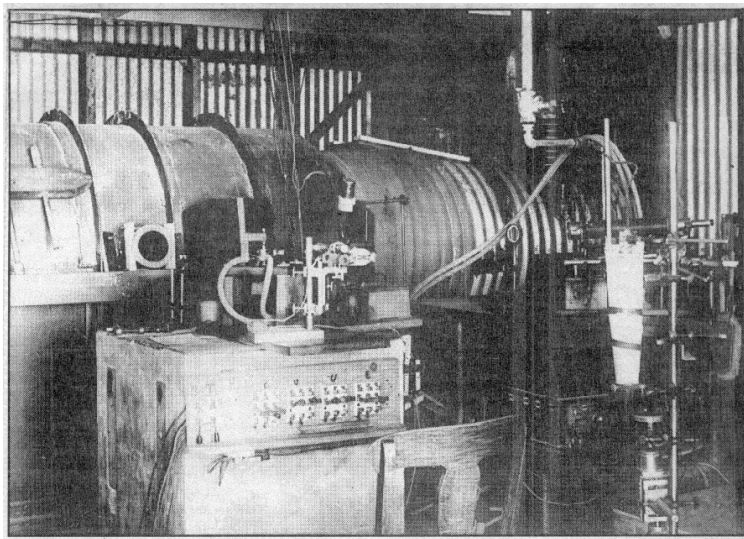
As told by Michelson's daughter and biographer, Dorothy Michelson Livingston, the ranch terrain was flat and well-suited to Michelson's purpose, varying only a few feet in elevation over the distance of a mile. At a cost of \$50,000, the California Corrugated Culvert Company furnished 36-inch steel pipe in 60-foot lengths, which was set up to extend the distance of slightly over one mile.

By the spring of 1930, the pipe was in place and the optical system was installed. The alluvial soil of the ranch and rapid changes of temperature during the day combined to introduce large discrepancies in the measurements - fluctuations up to 12 miles per second - and Michelson's 1927 Mount Wilson tests proved to be the most precise measurements of the velocity of light. However, the Irvine Ranch figures - 299,774 kilometers per second - are frequently quoted.

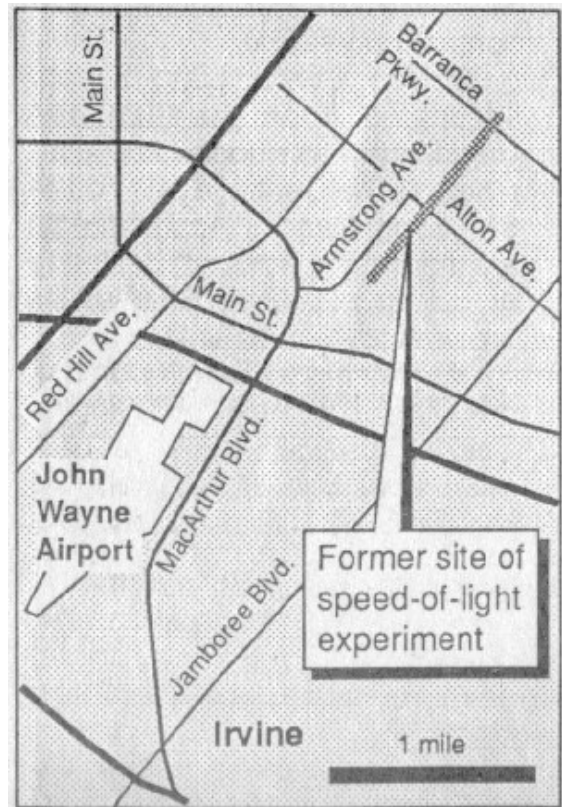
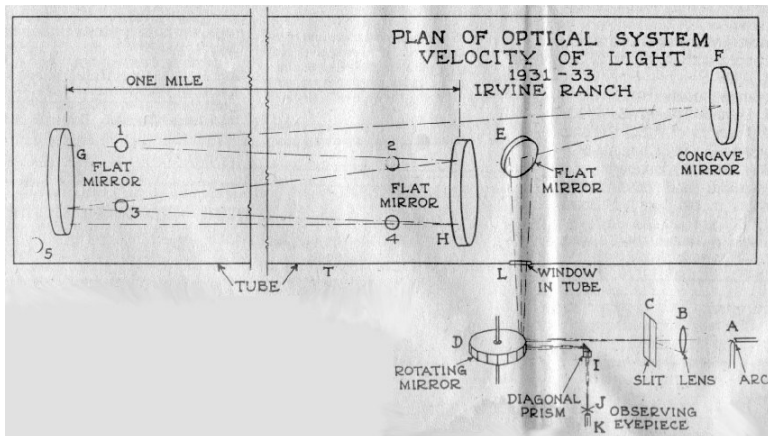
Michelson died on May 9, 1931, two days after the experiment was complete. Michelson Drive, in Irvine, is named in honor of this great physicist.

Albert A. Michelson was the first person to "accurately" measure the speed of light. His final experiment was conducted in a mile-long vacuum tube erected on the Irvine Ranch.

THE IRVINE RANCH EXPERIMENT



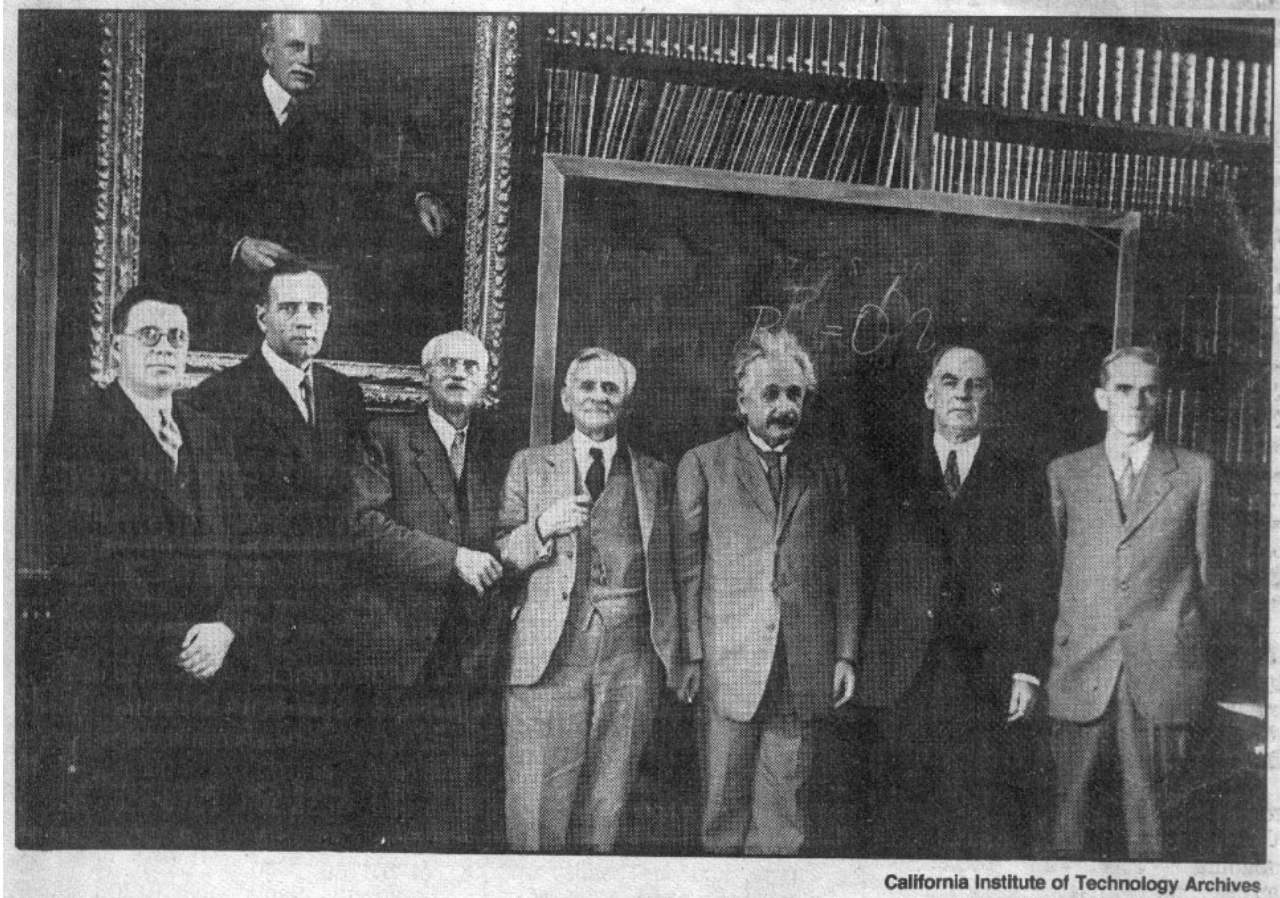
California Institute of Technology Archives



At the heart of the experiment (pictured in the shack and graphic above), an arc light was bounced off a rapidly rotating set of mirrors, back and forth down a mile-long tube and home, to the mirrors, which by then would have moved slightly. If the speed of the mirror, the angle of the bounce and the length of the tube are known, it is possible to calculate the speed of light.

Right above, if rebuilt on its old site today, the speed of light experiment would run through an industrial park, in what is now an industrial area in the city of Irvine near the Newport Corporation.

IN GOOD COMPANY



Albert Einstein and Albert Michelson met at Mount Wilson in 1931, just before Michelson's death. From left to right are Milton Humason, Edwin Hubble, Charles St. John, Michelson, Einstein, W.W. Campbell and Walter S. Adams.

Some history about Michelson and the Irvine Ranch Experiment.

In 1887, Michelson and Edward Morely used the interferometer to find out how light waves moved through the theoretical "ether" in the universe. According to the principals of classical physics, the movement of the earth through this mysterious substance affected the speeds of light rays moving through it. Michelson and Morely used the interferometer to bounce light waves out and back at right angles, expecting to see one of the beams lag behind.

Instead, the beams returned at exactly the same time. In years to come, these findings would be cited as one of the first proofs this mysterious ether did not exist, that the speed of light was a constant, and that classical physics was not enough to explain the physical universe.

While Michelson and Morely were testing the "ether drift," Einstein had begun to speak of clocks that moved backward, mass that was not constant and light made up of things called "photons." For scientists, these heresies were as profound as those of Copernicus, the first to suggest that the earth was an orbiting planet, and not the center of the universe.

The drama surrounding Michelson's experiments was heightened by this atmosphere of turmoil. Although his work helped trigger a revolution in the study of physics, Michelson never decided which side he was on, according to his biographers.

His daughter, Dorothy Michelson Livingston, wrote that Michelson never gave up his belief in "ether," even though he accepted Einstein's work.

In 1930, that belief may have helped bring Michelson to Santa Ana, for his last and most ambitious test.

Athelie Clark, the oldest living member of the family that once owned the gigantic Irvine Ranch, remembers a day in the late 1920s when Michelson came to lunch.

At the table in the opulent dining room of James Irvine's Victorian home sat Michelson, James Irvine Sr., James Irvine Jr. and the scientist Robert Millikan. Clark sat and listened, understanding little of what was being said.

"I remember being told that he was a very famous man who was looking for a site for an important experiment," said Clark, now 85.

"His hair was gray and unruly. He seemed extremely gracious to me."

"Gracious" was one of the nicer words used to describe Michelson's manner. Throughout his career, as honors piled up, he had earned a reputation as both brilliant and unstable. He was an accomplished tennis player, an excellent painter and violinist, and so good at billiards that opponents complained that his knowledge of physics gave him an unfair advantage. His few close friends described him as extremely loyal, fond of practical jokes, and quite cool under pressure.

Yet Morely, Michelson's early partner, said he feared that Michelson had suffered a "softening of the brain" early in his career, after Michelson was hospitalized for exhaustion in the 1880s. Michelson's first wife tried to have the scientist committed. One of his maids sued unsuccessfully for assault.

Dorothy Michelson Livingston wrote that her father often worked for days without sleeping or eating, that he sat alone at meals so his thinking would not be disturbed, that in turns he could be arrogant, distant, imperious and rude. A messy divorce made front-page headlines for weeks. The physicist also suffered from recurring nightmares, including one in which he rode a motorcycle up an endless hill.

"Americans have this obsession with mad scientists, and Michelson fit the image," said UCLA physicist Wuerkel. "He was the most famous American scientist of his day. Anything he did was news."

Mad or not, he was definitely prodigious.

In 1907 when Michelson won the Nobel Prize for physics, his career was only getting started. He beat off several challenges to his findings and honed his earlier work. In 1920, he was the first to measure the diameter of a star, called Betelgeuse, an achievement hailed in The New York Times as "astounding."

In 1926, the most spectacular of Michelson's experiments split the night sky between Mount Wilson and Mount Baldy.

With mirrors, turbines, his interferometer and an arc light, he measured the speed of light to within two miles per second of its currently accepted speed.

Horace Babcock, the emeritus director of the Mount Wilson observatory, remembers visiting the experiment as a child, seeing the light shooting out of the cracks in the shack where Michelson was at work.

Michelson wasn't satisfied with the results of the Mt. Wilson experiment. For one thing, he worried that "shimmers" of air between the mountains might have fouled his results. He also didn't trust the work of the United States Geodetic Survey team, which had measured the distance between peaks.

He wanted to repeat the test in a vacuum to measure a more precise speed and, perhaps, show the presence of the "ether."

Clark says Michelson settled on the Orange County site for the experiment after lunch in the Irvine family home, when James Irvine Jr. took the physicist for a drive in the family Packard. Michelson liked the low, flat bean field on the north end of the ranch, near what is now the Marine helicopter base. The Irvines agreed to donate the use of the land.

The project took shape quickly. Michelson's assistants built a metal shack to hold the turbines, the arc light and other equipment from Mount Wilson and a network of tubing, metal pipes, wires, plugs and switches. From the shack, they built a mile-long tube of 3-foot-diameter, corrugated steel pipes sealed airtight by layers of steel, cloth, innertubes and rubber paint. Inside the tubes were a series of mirrors, each on a motorized balancing machine.

In the center of the shack was the interferometer, which Michelson sometimes called his "she devil." At the heart of the machine, a wheel covered with finely-honed mirrors spun at exactly 512 revolutions per second. When light struck this wheel, it bounced back and forth through the tunnel, eventually returning to the spot it had started from. By then the mirror would have changed its angle slightly, reflecting the light at an angle. By knowing the distance the light had traveled, the speed of the mirror and the angle of the bounce, Michelson could calculate the speed of light.

Clark remembers that the shack was "absolutely spotless" inside. While the experiment was running, her father often would drive house guests over to look at the shack- when he wasn't driving them to the other side of the ranch, where battle scenes were being shot for the film "All Quiet on the Western Front." Once, towards the end of the experiment, she says Michelson asked her to come inside, to look through a window that showed the length of the tube.

"It was very dark," she said. "I looked in the window and saw a long, dark hole that disappeared into nothing. There were little tiny sparks shooting back and forth. I'd never seen anything like it."

Michelson's last experiment did not go smoothly. On the day of his arrival, the pump being used to suck air out of the pipe broke down, halting the project. Leaks in the pipe were a regular problem, and fears of an earthquake were persistent. Michelson and his assistants fought over details.

His daughter described one of those fights, in which an assistant drove to Pasadena and called the physicist to the lobby of the Hotel Maryland. The two men stood in the lobby arguing with each other, wearing pajamas, scribbling diagrams on the back of a Chinese laundry ticket, until Michelson noticed that a crowd had gathered.

Michelson himself was not well. His health had begun to deteriorate years before, in what his doctor referred to as the "vile climate of Chicago," where Michelson had taught. His bladder was removed in 1929. The train trip to California exhausted him. His heart was weak and his circulation was slow. As the Orange County experiment progressed, he began to spend more and more time in bed, alert but physically weak.

Michelson got out of bed in April, 1931, when Einstein came to visit. Michelson's daughter remembers sitting between them at dinner, seeing that neither could keep his hair combed, and struggling to keep from laughing. The two men attended banquets together, and talked to each other privately.

At the end of April, Michelson's doctor confined him to his house, after suffering what the papers said was a nervous breakdown. In early May, his assistants brought him early data from the tests. On May 9, Michelson suffered a stroke, followed by a cerebral hemorrhage. After lingering in a coma for several hours, he died.

The Register of Orange County, California ran the obituary on page 1.

Why would a dying man attempt an experiment as ambitious as Michelson's in Orange County?

R.S. Shankland, a leading historian of physics, believes Michelson came to Santa Ana to look one last time for the ether that had been so central to the science of his youth.

The final report on the Irvine Ranch experiments was published in 1933. The findings were extremely close to those accepted today, but many physicists consider the results of the tests on Mount Wilson more accurate. Some of the metal tubing now is used as drainage pipes at the Mount Wilson observatory.

There are markings at the site of the test, and though a nearby street was named in Michelson's honor, it is commonly mispronounced. The Irvine Company has been sold and resold. James Irvine's mansion burned to the ground and was abandoned. If the vacuum tube were rebuilt on its old site today, it would run through the parking lot of a Home Club and the lobbies of two manufacturing firms on Armstrong Avenue in Irvine.

Wuerkel, a UCLA physicist, thinks Michelson's work in Orange County is worth more than that. For one thing, he says, Michelson can be thought of as the man who gave this country a scientific tradition, on the day he won the Nobel Prize.

Even though Michelson's work here is not widely recognized, Orange County has become a hotbed for experimental physics. At the University of California, Irvine, this work is helping push physics beyond the edge of Einstein's world.

And in several of those experiments, UC Irvine scientists are investigating incredibly small particles that move near the speed of light. These particles have no effect on the speed of light, but they do appear everywhere, invisible and mysterious, like an ether.

Acknowledgements, Supporters & Collaborators

The Optical Society of Southern California (OSSC), a local section of the **Optical Society of America (OSA)**, has been a starting point for the Optics Institute of Southern California, and has provided some funding for various educational outreach projects. The **Optical Society of San Diego (OSSD)** has also been a partner of the OISC in San Diego County.

OSA Rochester Section, Center for Optics Manufacturing & Institute of Optics, University of Rochester has provided the OISC with the "Optics Suitcase" and the opportunity to use it and promote it to others. This has become part of the foundation for the OISC.

SPIE - The International Society for Optical Engineering, has also supported the OISC with direction and some funding for various educational outreach projects.

Irvine Valley College's Programs in Laser Electro-Optics Technology, Physics, Astronomy and The Center for Applied Competitive Technologies have also been partners in building the OISC and providing equipment for outreach programs.

UC Irvine's Center of Educational Partnership - Gifted Students Academy (GSA) program provided the OISC's first opportunity to deliver an optics based astronomy program to students in 2003. In 2004, the OISC delivered this program again and played a major role in developing the new **Gifted Student Lower Academy (GSLA) – Exploratorium** based on the **Color My World** lessons. Altogether, over 300 students took part in these programs.

THINK Together provides after school learning centers for under-represented K-12 children in Central Orange County. The OISC provided lessons and materials for 2 - two week "Science of Color" programs that reached ~1500 children in December 2003 and April 2004.

General Atomics Sciences Education Foundation, has provided the material for the "Color My World" programs that the OISC provided to THINK Together and the UCI GSLA. These were also used at the Discovery Science Center during the OPTRICKS Day. The Color My World lessons were authored by Wendy Woolf, Science & Art Education Consultant; with consultation from Dr. Larry Woolf.

The Discovery Science Center (DSC) in Santa Ana, CA has allowed the OISC the use of its facility for its Advisory Board meetings and to help with its exhibits, demonstrations and educational outreach efforts to both students and the general public. The OSSC & OISC organized the first OPTRICKS Day event in partnership with the DSC.

Optical Sciences Center & Department of Physics at the University of Arizona have provided encouragement, direction and the use of educational materials from the earliest days before the OISC was established. OISC Director Donn Silberman is a graduate of the UofA Engineering Physics Department and was the President of the Society of Physics Students there from 1981 to 1983 and served as an Associate Councilor for SPS Region 11 from 1983 to 1984.

The OISC thanks these companies who have donated optics materials for OISC programs:

Newport Corporation	Advanced Laser Technologies, Inc.	Precision Applied Products
OptoSigma Corporation	Precision Optical, Incorporated	Kodak Optical Products
Optical Components, Incorporated		Wasatch Photonics, Incorporation

The OISC thanks these companies who have joined the OISC as corporate members:

Ushio America, Inc.	Optical Research Associates
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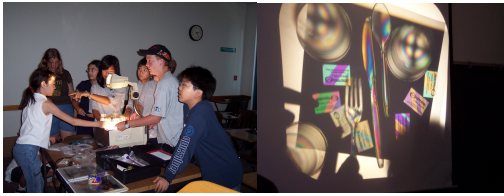
The OISC thanks these companies who exhibited at the OPTRICKS Day event:

Alcon Laboratories	CALTEX Scientific	Davidson Optronics, Inc
Harold Johnson Optical Laboratories, Inc.	Schott Glass Technologies	The Griot Group
Southern California College of Optometry	Ventura Precision	Zemax Development Corporation

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The OISC is proud to be a project of Community Partners, a 501(C)(3) tax exempt organization in the State of California. Donations can be made on-line at <http://oisc.net> or by call Donn Silberman, OISC Founding Director at 949-636-6170.

The Optics Institute Of Southern California



Using Lasers & Optics to make
Science & Technology
Fun & Exciting
For Children of All Ages.

