“The Death-Ray in Your Pocket: 50 Years of Lasers”
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Presented by Hermione Cockburn
Produced by Mike Hally
Square Dog Radio

(Music)

Jonathan Ross: In the ’60s it was a tool that people could use as light shows, which is probably where most people saw lasers. I think I first saw them at a Who pop concert.

Sean Johnston: To see holograms you needed the laser, and the general public were literally awestruck. It was a sublime experience.

Colin Webb: The very first application of lasers, commercial, anything was a sterile way of drilling tiny holes in the nipples of baby bottles.

Jeff Hecht: You can make lasers from optical fibres, 10 kilowatts, that can cut pieces of metal, very precisely. It is amazing how far we have gone.

(Sound of laser machine operating)

Hermione Cockburn: This machine is using a laser to engrave tiny coded marks inside the glass of little medicine bottles. Unlike conventional engraving, the extremely short pulse of laser light marks the bottle without scratching or heating or any risk of cracking, and only a laser can do this. The sound you can hear is the bottles shuttling ’round. It's just one of an astonishing range of applications in this exhibition hall in Brussels, the venue for SPIE Photonics Europe, the biennial conference dedicated to advances in laser science.

It's a special year for this conference because it's the golden anniversary of the invention of the laser and over here is a giant display commemorating the key developments in lasers over the past 50 years and some of the people who made them possible. And I'm joined now by Eugene Arthurs, who is head of SPIE, the international industry body that's putting on these events this week. So how significant is this anniversary?

Eugene Arthurs: We think it's rather important because the laser is one of the more exciting developments over the last century in science. And really prior to the laser, optics was considered a sleepy backwater of physics, nothing was happening; it was all known, it was all 19th-century stuff. And then the laser was invented and optics really flourished after that, as the laser moved into many applications and made a lot of things possible that were impossible before, and that explosion is still continuing.

Cockburn: An explosion that's made possible by something called the "stimulated emission of radiation", first defined by ... who else? ... Albert Einstein, in 1917. Just as materials can absorb light, he said, some could also under certain conditions amplify it -- put energy in, shine the right kind of light onto it and out will come more light. Decades passed before the idea became a practical proposition, and not at first using light. Charles Townes, working at Columbia University in New York in the 1950s, invented something he called the maser -- short for "microwave amplification by the stimulated emission of radiation". It was used as a sensitive amplifier in radar, and radio astronomy.

The next step was to use light. Townes roped in his friend, colleague and brother-in-law, Arthur Schawlow, who knew a lot about optics and worked at Bell Laboratories, and on the 15th of December 1958 the journal Physical Review Letters published their landmark paper, outlining the principle of “the optical maser”. If it could be made to work it would produce the Holy Grail of optics, a pure beam of coherent light.

White light is actually a mixture of different colours, different wavelengths, just as white noise like this (sound of white noise) is a mixture of many different sound frequencies. Coherent light is a single precise wavelength, perfectly in phase, like a pure tone in sound (sound of pure tone).

Prior to the laser, that couldn't be done with light, and that was important because only coherent light can be precisely controlled. Ordinary light splits and spreads as it passes through optical equipment. And Townes and Schawlow realised that using stimulated emission could produce that precisely-tuned light, a single pure colour. Their paper started a race to see who could make one work, but Townes wasn't one of the runners, as he explains in this oral history, recorded 25 years later for the American Institute of Physics. He'd been appointed to the Institute of Defense Analysis in Washington, an offer he felt he couldn't refuse though he was reluctant to leave Columbia.

Charles Townes: I also hated to leave the laser work, but I felt it was just terribly important to go to Washington. Matter of fact, I remember Walter Brattain was urging me, “Oh, don’t do that, you must build a laser”. I felt the laser was really in the bag. It was obvious it could be built and it just wasn’t critical for me to build one. I would have liked to build one, be the first, but I felt there were more important things.

Cockburn: But the laser was <u>not</u> “in the bag”, and his colleague Arthur Schawlow didn't drop out of the race. However Schawlow did have second thoughts about their proposed design, which was based on gaseous potassium. This is from the same oral history collection:

Arthur Schawlow: Being at Bell Labs in the transistor era, you felt that if you could do anything in gas, you could do it better in a solid. And so I started trying to learn about solids. Now, ruby was a common material around there because a lot of people were working on microwave masers. So you could go down the hall and find somebody who had a drawer full of rubies or various concentrations, and could borrow a few samples which you'd never return.

Cockburn: And Bell Labs began to put a lot of money into laser development. But there was another scientist already thinking along similar lines: Gordon Gould, who had long been determined to make his name as an inventor. A year before the Townes and Schawlow paper, Gould set out his own design in a laboratory notebook -- and on the 13th November 1957 he had it witnessed by a lawyer. The leading laser historian, Jeff Hecht, says this was an important document.

Cockburn: We're looking at a page of text and pretty scrawly writing, lots of crossings out and the title here says “some rough calculations on the feasibility of a laser light amplification by stimulated emission of radiation”. Is this the very first definition of a laser?

Jeff Hecht: Yes, the little long thin box you see is the first description of a laser resonator. The ends of this long thin box are mirrors that reflect light back and forth, to generate enough light to produce a strong beam, which Gould realised you would get out of the laser.

Cockburn: So here we have a beautiful example of how simple the laser, was in essence, in theory.

Hecht: There are a lot of ideas that look marvellously simple with 20-20 hindsight, but of course they're not very simple to do at the time and that it is exactly what the laser was.

Cockburn: Gould joined a small company, the Technology Research Group, and won a grant of a million dollars from DARPA, the military Advanced Research Projects Agency, to see if he could make his design a reality. But in a bizarre twist he was then banned from his own project, because it was now classified secret, and the military refused him security clearance because of his past association with communists. This should have left the field open to Bell Labs, where Arthur Schawlow and others worked. But a dark horse was coming up on the rails: Ted Maiman, who worked for Hughes Research Laboratories, one of the companies set up by the eccentric recluse Howard Hughes. Maiman died a few years ago, and his widow Kathleen told me about him.

Kathleen Maiman: There was always a lab in the house when he was a little boy and that was a fun place to be. Ted's father was a very creative scientist, an electrical engineer and they competed in experiments about who could make the best fire, and I think that his father gave him a love of science. He was always calm and thoughtful. There was a depth of character to him that you could just feel.

Cockburn: So if he was like that in his private life, what was he like as a scientist?

K. Maiman: He had such curiosity and when he got interested in something he would go into great depth and he was usually right. Mark Twain said it's better to be popular than to be right, but he would rather be right than popular. So he did go against conventional wisdom.

Cockburn: When the famous 1958 paper was published, Maiman had just finished a project where he took a 2-ton microwave amplifier the size of a desk and reduced it to something weighing less than five pounds that would fit in a cigar box. So, as Jeff Hecht explains:

Hecht: He looked then at the idea of making a laser, which he heard Art Schawlow talking about at a conference. He said, well, here is how you would make one with ruby, unfortunately ruby won't work. Maiman listened to that but he knew a lot about ruby and he wondered where the energy was going that seemed to make it a poor candidate for lasers. So he made some measurements on his own and what he found was that the efficiency of a ruby crystal emitting the red light that he thought might be the basis of the laser, was much, much higher than Schawlow had thought.

Cockburn: So Ted Maiman set to work, coming up with a beautifully simple design, a small cylinder of artificial ruby, placed inside a rather unusual photographer's flashlamp, a thin tube that was coiled up like a spring -- this provided the intense light he hoped would stimulate the ruby atoms to start emitting more light -- and mirrored at each end so the light generated would bounce back and forth and multiply exponentially. Finally he and his assistant Irnee d'Haenens were ready for the first full test. Maiman wrote an account of the big moment in his autobiography. It's read for us by his widow, Kathleen:

K. Maiman: “It was the afternoon of May 16, 1960; it was time to confirm or deny all the fears of why the 'ruby can't work.' This was the moment of truth!

“We progressively increased the supply voltage. And when we got past 950 volts on the power supply ... the output trace started to shoot up in peak intensity and the initial decay time rapidly decreased. Voila! This was it! **The laser was born!**”

Cockburn: That sharp peak on their oscilloscope showed that the ruby wasn't simply glowing red, but was now producing laser light -- a bright spot so intense that his colour-blind assistant Irnee d'Haenens saw red light for the first time in his life. They were delighted although D'Heanns is said to have responded with the now famous remark, “This is a solution looking for a problem”. Still it impressed Maiman's boss, who had been dubious about him devoting so much time to what seemed like a scientific curiosity. Now he urged Maiman to hold a press conference, and that took place a couple of months later. The press release ran to eight pages and was full of sober technical detail about the holy grail of optical science, but a sizeable section of the press only wanted to know if this was the holy grail of science-fiction.

(“War of the Worlds” excerpt: Sound of death-ray and screaming.)
Announcer: A deep throbbing sound, a silver pencil of light, the whole bunch of them were wiped out, wiped clean off the face of the Earth. The Martians in the pit had turned the heat-ray on them. And a narrow ribbon of bracken and grass and trees and houses that stretched as far as the eye could see was blackened and smoking. This was the sort of weapon I'd been afraid of.

Cockburn: That's an extract from a dramatisation of H G Wells' 1898 novel The War of the

Worlds. The death-ray became a staple of science-fiction so, as Ted Maiman himself recalled in this speech in 1983, one particularly persistent reporter knew exactly the story he was after.

Theodore Maiman: He said “Dr. Maiman, are you willing to say this could not be used as a weapon?” and I said “No”, and he said “That's all I wanted to know”, and the headline said “LA man discovers science-fiction death-ray”. (Sound of audience laughter) That was the headline!

Cockburn: This of course was the country where mass hysteria had broken out when a national radio network broadcast “The War of the Worlds” in 1938. But it wasn't just the American media. I had another recording to play Jeff Hecht -- a BBC TV news report from 1962:

Alan Whicker: In that guarded building, behind that security fence scientists and engineers have just produced a device that could change our whole concept of war and defence -- a science-fiction weapon that melts steel, a death ray that could be more deadly than a nuclear bomb.

Cockburn: What do you make of that?

Hecht: (Laughter) Well, this is the incredible laser. In fact the ruby laser did have enough power to punch holes in razor blades, and for a while people in laboratories using ruby lasers would informally measure power in Gillettes -- the number of razor blades that a laser pulse could penetrate. But that was all, and to blow holes in razor blades you had to put the razor blade right next the laser, go too far away and the laser would dissipate.

Cockburn: So it was a long way from being a death-ray. Arthur Schawlow calculated that you could use one of his ruby lasers to vapourise a 14-stone man -- but it would take rather a long time, in fact he would have to stand in front of it for two years.

Maiman's success unleashed a wave of working lasers from other people, gas lasers, different coloured lasers. They soon began to find practical uses, and some of the first were military. Dr Len Cooke is Head of Optics and Laser Technology Department at BAE Systems' Advanced Technology Centre near Bristol.

Len Cooke: Really the first main application of the laser was what is commonly called the laser range finder. It works almost in the sense of a radar system, an optical radar system where a pulse of light is sent out, and it starts a timing and you measure the reflected light coming back -- and because light travels at a very well-known precise velocity you can measure the range very, very accurately.

Cockburn: And of course another military application that most people will know from television images of the Gulf War and so on, is the so-called “smart” bomb or missile -- where a laser is pointed at the target and a sensor in the nose of the missile homes in on that bright spot. There are also less lethal uses for lasers, such as the so-called “dazzle weapons” that merchant shipping crews might use to repel pirates off the coast of Somalia. Len Cooke again:

Cooke: These visible lasers or optical distraction systems can be used in that environment, provided, of course, it is within the Geneva Convention. We have to be very careful in that arena because the Geneva Convention prohibits the development of lasers which are specifically aimed at blinding people.

Cockburn: So when we talk about a dazzle weapon, how could it work?

Cooke: If there is a boat coming towards you which is considered to be a threat they could be switched on and provide a sort of bright light to the pirates so their vision is impaired -- just simply like shining a torch in someone's eye to distract them. These systems can be effective, they are non-lethal, and, yes BAE Systems is considering developing these systems.

Cockburn: Another of the earliest uses was also to do with the eyes ... one of what became an array of applications in the field of medicine. Prof. Colin Webb is a British scientist who was in at the very start of the laser revolution, crossing the Atlantic to work at Bell Labs for several years in the mid-sixties

Webb: This is where I think the excitement really started to bubble about 1963. Lots of groups had seen the helium neon laser, and it had lit a fire under the enthusiasm and a lot of people got into it.

Then the real uses came along, things like the first eye operations were done by a medical specialist, who brought trays of anaesthetised rabbits into the lab. And of course, what you want for a medical laser is one that you could steer and we didn't have steerable lasers. We had to clamp it to the bench, but with the rabbits you had the ears at one end and the feet at the other so at least you had a handle on the target and they did look at the effects of laser light on the skin and on eye tissue.

Cockburn: This led to the now familiar way of repairing a detached retina by spot-welding it back in place with a laser. Today they are used in many areas of medicine and one of their strongest advocates is Stephen Bown, Prof. of laser medicine and surgery at University College London and director of the National Medical Laser Centre. One of the most exciting applications, he says, is PDT, photo-dynamic therapy.

Bown: This involves two things, giving the patient a drug that makes their tissues sensitive to light and then activating that drug by light that is applied to the diseased area. The simplest way of using this treatment is for early cancers and precancerous lesions on the skin. We're now developing PDT for a range of internal cancers as well. In our hospital alone, we have treated more than a thousand patients with all stages of cancer of the mouth. The real attraction of PDT is that the technique is simple to apply, we get extremely good cosmetic results, the patient does not need to lose a lot of tissue, which would happen with conventional surgery, and they don't suffer the drying up of their saliva which can happen after radiotherapy.

Going a little further inside the body, this is also an effective treatment for precancerous conditions in the intestinal tract, particularly in the oesophagus, and in the major airways. And if necessary the treatments can be repeated, which can be a major problem with surgery and radiotherapy, which you only get one chance to use. Now we're exploring the application of PDT in cancers of organs like the pancreas and the prostate glands.

Cockburn: If PDT proves effective for pancreatic cancer that will be tremendous news as it's often untreatable by conventional methods and typical survival time is just six months. And applying PDT to prostate cancer, because it can be so precisely targeted, may reduce the rate of unpleasant side-effects such as impotence and incontinence.

On a lighter note, artists were also among the earliest users of lasers, for light shows and to make holograms -- clear photographic film that reveals extraordinarily realistic three-dimensional images when viewed in laser light. Jonathan Ross, no relation to the entertainer, runs the private Gallery 286 in Earls Court, where he has one of the largest private collections of holographic art in the world.

Ross: I've got a book here called Science Year: The World Book Science Annual 1967, and there's a feature in here called “The New Art of Holography”, and it goes into this fascinating new technology and all the kind of optical components that are required to record these images and then you come upon a little sheet of film bound into the book. It's apparently grey film and when you look at it with an actual laser light it is quite remarkable. I've got a little red laser diode here, which is a cheap and low power form of laser light. I can now see a chess set with a magnifying glass and chessboard stretching back eight inches or so behind a sheet of film and that is the magic of holography to me, that something on a thin sheet of film can reveal an enormous volume of space.

Cockburn: Holography was actually devised much earlier, in 1947, in an unsuccessful attempt to improve electron microscopes, and revived in the late 1950s as a technique for processing radar signals. But it took the invention of the laser to turn holography into a tool for creating 3D images. Dr Sean Johnston is a historian of science and culture who has studied holography in particular. He says viewing them in the ’60s was a memorable experience.

Johnston: To see holograms you needed the laser, so you couldn't look at a hologram without a very expensive, rather frightening laser pointed somewhere in your direction. So the first audiences were quite flabbergasted by this experience because it was very much like going to a séance. You were going to a very dark, dimly lit room, and you would peer at some special apparatus typically looking through a window that was the hologram. And through the window you would see this staggeringly realistic, brightly lit red object that looked to all intents and purposes completely real, and those early audiences were allowed very often to put their hands behind these pieces of glass and discover there was nothing there. So it was exciting and baffling, and the laser itself was a big part of that, because laser light has this special quality called speckle, laser speckle. It's like a glistening, grainy kind of appearance to the image. A lot of people went away not believing what they had seen, including optical scientists, and the general public were typically awestruck to use that word in its classic sense they were literally awestruck. It was a sublime experience ... almost frightening in its intensity.

Cockburn: So frightening that those early shows had to have big notices reassuring people that these were safe low-power lasers operated by highly trained engineers. Within a few years artists and technicians found ways to make full-colour holograms by combining red, green and blue lasers, and then to make these holograms viewable in normal white light. Ironically this reduced their impact and before long we started seeing them on banknotes, credit cards and even those iridescent toothpaste boxes. Yet lasers and holograms can still draw in the punters. Jonathan Ross has for three years been sending a travelling exhibition to museums around the country and it's attracting people of all ages. And a group called United Visual Artists have just put on a stunning laser installation over several floors in a disused warehouse on the South Bank. The show's producer, Keri Elmsley, showed us ’round.

Elmsley: We primarily make large-scale installations using light, often in the public realm. For this particular project we were commissioned by Virgin Media to celebrate 10 years of broadband. We approached this by thinking what is it that makes broadband and it was optical fibre, which of course is made up of pulses of light so the laser was a natural way for us to work in the medium in this particular context. We're trying just to create a series of ephemoral installations that look at domestic archaeology and how we are completely surrounded by data and what our input to that is just on a day-to-day level.

Elmsley: This room is the architecture room, where we've used a series of lasers and mirrors to trace out the architecture of the building. Because it is such an old building we've got a series of blacked out windows and really naked brick and columns that run through the building and mirrors and lasers are placed along the walls to trace out all these features, and then it's sequenced with the soundscape.

Cockburn: And how appropriate that this show was celebrating broadband internet, which could not exist without lasers. One man who has been involved in the development of optical fibres from the very start is Prof. David Payne, director of the Optoelectronic Research Centre at the University of Southampton. We caught up with him inside his pride and joy, a state-of-the-art 120 million pound new building.

Payne: We are currently standing in the clean room facility that was built here following a disastrous fire 4 1/2 years ago, which destroyed everything. Today it's one of the best in Europe housing two world-famous research groups involved in optical telecommunications, optical sensing and silicon ultrafast processors.

The very basis of optical telecommunications, the millions of kilometres which span the world under the oceans, across the continents, is based on light. The optical fibre needed first the laser to be developed because the scalpel precision you get from the laser allows you to target this tiny optical glass core. So where we are today, you put light in, in London, and it will pop up in Tokyo, carrying enormous capacity of information. Every time you use a mobile phone or the internet, you look at a site in Japan or you send a vast attachment to your Grandma's photographs, it's all going in optical fibres powered by tiny little semiconductor lasers.

Cockburn: It still seems extraordinary that I can buy a simple laser pointer for a couple of pounds at a market stall, a real laser that fits in my pocket. Not really a death-ray admittedly. Not yet. But some people are no longer ridiculing the idea of "laser cannon". Len Cooke of BAE systems:

Cook: In fact in February of this year the US demonstrated a jumbo jet flying with laser in it, shooting down an intercontinental ballistic missile an ICBM. This was a programme known as the airborne laser, which was interesting in the 50th anniversary year of the laser, but these are very, very large systems, they are very complex and very expensive, and they're certainly not the Flash Gordon or the Star Wars type of laser. But I do believe that these weapons systems will see service in maybe 15 perhaps 20 year time frame, but not earlier than that.

Cockburn: There's no real agreement about who deserves the most credit for the invention of the laser. About 17 Nobel prizes have gone to people working with lasers, including Charles Townes and Arthur Schawlow, though, rather unfairly perhaps, not Ted Maiman. There are many more kinds of laser and it's used in many more ways than we've had room to mention here -- most of them unseen, to most of us. And in the future, the laser looks set to become even more ubiquitous. Truly it is, as the headlines said when it was first revealed 50 years ago, the incredible laser.

(End)