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[Gordon Gould] The Man, the Myth, the Laser

The disputed origin story of one of the 20th century's most important inventions.

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They're at the grocery checkout. They kill cancer cells. They're in pointers that drive cats crazy and in the fiber networks that connect us to the internet. Lasers are so ubiquitous it's hard to imagine a world without them. So you'd think we would know who the inventor was, right? Turns out it's not so easy. There's the guy who wrote down the initial idea, two other guys who got a patent for it, and then another guy who actually built the first laser. We spoke to Nick Taylor, author of *Laser: The Inventor, the Noble Laureate, and the Thirty-Year Patent War* about this story and what it tells us about how inventions happen.

Credits

Hosts: Alexis Pedrick and Elizabeth Berry Drago
Senior Producer: Mariel Carr
Producer and Reporter: Rigoberto Hernandez
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Our theme music was composed by Zach Young
Additional music courtesy of the Audio Network

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Research Notes

For this episode we relied heavily on the book, *Laser: the Inventor, the Nobel Laureate, and the Thirty-Year Patent War*, by Nick Taylor. We used excerpts from an 1962 archival film by AT&T titled, *The Conquest of Light*. We used excerpts from oral histories with Gordon Gould and Charles Townes from the American Institute of Physics. They also generously provided tape of interviews with Gordon Gould conducted by journalist Jeff Hecht in 1983 and 1984.

Transcript

The Man, the Myth, the Laser

The disputed origin story of one of the 20th century's most important inventions.

> **Clip from AT&T film, The Conquest of Light**: These are the patterns of invisible waves we use today for communications. Radio waves, television waves, microwaves. In the same family of vast potential for tomorrow are visible waves, the waves which man calls light. In other centuries they would have called it magic.

Alexis: Hi, I'm Alexis Pedrick.

Lisa: And I'm Lisa Berry Drago. This is *Distillations*, coming to you from the Science History Institute.

Alexis: Today we're talking about the disputed origin story of a very important invention.

> **Clip from AT&T film, The Conquest of Light**: Day by day scientists have under development a new device which could revolutionize man's use of light. It is called a laser.

Lisa: That's from a video called "The Conquest of Light," produced by AT&T in 1962.

Alexis: The story of the laser has everything.

Lisa: There's an underdog inventor and a star university scientist, who both claimed the invention as their own.

Alexis: There's betrayal, twists and turns…

Lisa: Communism!
Alexis: High science, low science…
Lisa: Masers and lasers and optical pumping…
Alexis: And a frantic trip to the candy store.

> **Gordon Gould:** To invent anything important or exciting, obviously you have to have a lot of building blocks in your head to do it. So, if I say that on a certain night in November 1957, suddenly, when I couldn't get to sleep, the idea for the laser popped into my head, the way to make that beam – yes, it popped into my head but only after my head had been working on all the materials for all those years.

Lisa: Our story begins in New York on November 13th, 1957 with our protagonist: outsider- scientist-inventor and physics graduate student Gordon Gould. We just played a clip of an interview with him in 1984. After working intensely for a week, Gould takes a laboratory notebook full of sketches, equations, calculations, and the statement: "written on or before

November 13th, 1957" to a candy store in the Bronx. When he gets there he asks the owner— who also happens to be a notary public—to stamp each of the nine pages he's filled out. They're so squeezed full of drawings and symbols and equations that the notary public can only find room for his stamp in the margins.

Alexis: In the heading of the notebook Gould has written, "Some rough calculations on the feasibility of a LASER: Light Amplification by Stimulated Emission of Radiation."

> **Rigo**: This trip to the candy store proves pivotal, because Gordon Gould would spend the next *three decades* trying to convince the world that he had invented the laser.

Alexis: That's our own Rigoberto Hernandez. He's been nerding out about this story for weeks.

> **Rigo:** Because even though Gould was the first person to figure out how to make a laser, *and* he coined the term, no one knew it! Because he waited a *long* time to share his notebook with anyone else. And in the meantime two other physicists figured out how to make a laser too. And they patented it.

Lisa: In the subsequent years and decades people won Nobel prizes and built entire industries around the laser. And Gordon Gould was left in the dust. No one believed he came up with it first.

Alexis: Because Gordon Gould didn't have a PhD. He hadn't won any fancy scientific awards, he didn't publish in any scientific journals. Oh, and he also dabbled in communism.

Lisa: It took *30* years, many courtroom battles, millions of dollars, and an epic fight with the

U.S. government *and* the laser industry before Gordon Gould got any recognition for one of the most revolutionary inventions of the 20st century.

Alexis: In the process he got rich, and his case helped change U.S. patent law forever. But sixty years later the central question in this story is still debated: Did Gordon Gould invent the laser?

Lisa: It turns out to be a tricky question to answer.

Act 1: Gordon Gould's Beginnings

Alexis: I think we should pause for a moment and talk about the word "invent."

Lisa: Oooh, good call. Merriam Webster defines it as: "To produce (something, such as a useful device or process) for the first time through the use of the imagination or of ingenious thinking and experiment."

Alexis: But at least in terms of U.S. patent law, you don't actually have to *build* the thing, it just has to be *buildable*. Okay. Just had to clear that up. Proceed.

> **Gordon Gould:** I think I can honestly say that it was my mother who stimulated me to get interested in inventing things and making things. Certainly not my father who couldn't handle a screwdriver. He was a magazine editor.

Rigo: That's Gordon Gould in 1984. He studied physics in college and then went to Yale to get a PhD in optics and spectroscopy. But he was there during the height of World War II, and he was drafted. In an attempt to keep him out of

combat a professor told him to apply for a project other scientists were working on.

> **Gould:** Lo and behold, it turned out later to be the Manhattan Project, and I worked there for the rest of the War.

Alexis: Two significant things happen to Gould there. The first is that he gets a girlfriend who turns him on to communism. He starts going to Marxist study groups in Greenwich Village with her.

> **Rigo:** Not long after that the couple gets fired from the Manhattan Project. Gould thinks it's because he had protested anti-Semitic hiring practices.

Alexis: But it probably also had something to do with his communist ties. His politics would continue to cause him trouble down the road.

> **Rigo**: So Gould goes to work for a company that makes mirrors. His coworkers tease him and call him "college boy." But he makes perfect mirrors. In his spare time he works on his passion: *inventing*. His hero is Thomas Edison.

> **Gould**: He was an inventor as distinguished from a scientist. He didn't pursue that scientific discovery. I never was interested in studying something just for its own sake. There had to be an important application at the end of the road for me to really get excited.

Alexis: Gould uses his knowledge of optics to come up with his first invention: an improved contact lens. He's really excited about it and sets up a meeting with a contact lens manufacturer in New York, but once he's in the office things don't go so well.

> **Gould:** I didn't want to tell them what the invention was, so that's not a very good way of selling yourself and the invention. They were interested, but I was so naive it wasn't possible for us to come to terms.

> **Nick Taylor:** Gould was just very suspicious.

Alexis: Nick Taylor is the author of *Laser: the Inventor, the Nobel Laureate, and the Thirty-Year Patent War.* He thinks Gould's untrusting nature was his Achilles heel.

Taylor: He wanted, again, that Edisonian ability to convert his invention into a revenue stream and he couldn't bring himself to reveal everything he knew because he was too suspicious.

Alexis: Despite not being able to sell his ideas, he keeps plugging away at his inventions, to varying degrees of success.

Rigo: In 1948 Gould becomes convinced that he can grow diamonds.

Alexis: Wait, what?

Lisa: I'm sorry. Come again?

Rigo: He thinks if he puts a small diamond and a chunk of graphite in a vacuum chamber and he heats the whole thing up, the graphite will evaporate and sort of melt onto the diamond—making it bigger. His brother is a chemist and rains on his parade by telling him that the thermodynamics of diamonds make his idea impossible. So Gould decides that if he wants to be a real inventor he needs to learn more physics.

Alexis: So in 1949 Gould goes to college for the third time: this time to Columbia to try *again* to get a PhD in physics. He's very pragmatic though. Remember, Gould is not a science for science sake kind of guy. He wants more knowledge to invent better things, and he picks the program mainly because it's an easy commute to his teaching job.

Taylor: But he was in this hotbed of scientific inquiry with great, great minds that the Columbia physics department was at the time.

Alexis: There are past and future Nobel Laureates on staff, and one in particular stands out. A distinguished young professor named *Charles Townes*—our story's anti-hero. Or is he our hero? It's hard to tell…

Act 2 Columbia and the Race to Invent the Laser

Rigo: The way that I see these two characters, Townes and Gould, Townes is almost aristocratic sounding because of his standing with the academic community, he's a Nobel laureate, and here you have Gould, who went to a less prestigious college, was labeled a communist, which

back in the day was the worst thing you could be called. It's like foils of each other!

Taylor: That's exactly right. Charles Townes was extremely prestigious.

> **NPR clip:** He was a southern gentleman. He was just a very nice person. At the same time, he was very dedicated and single-minded in what he did.

Lisa: Like that 2015 NPR clip suggests, people really liked this guy. They called him brilliant. He was a 34 year-old physics star who had achieved great things and was expected to achieve more. Gould and Townes were on different paths professionally, politically, and personally.

Townes was invested in the esteem of academia:

Taylor: He was involved in all these boards, these advisory groups.

Rigo: Gould just wanted to learn more physics so he could invent something useful.

Taylor: He didn't pursue the same things. He didn't pursue the prestige of being named to boards and being named to advisory groups—and he was raffish. He did have this communist history. He liked a martini and enjoyed the company of

women. He went sailing. His sailing buddies said that he was usually the last person on the deck with a drink in his hand when everybody went to sleep when they were at anchor and so he was a completely different personality.

Taylor: But I do know, having followed Gould's patent war, that Gould was every bit as accomplished a physicist as Townes.

Taylor: Townes just couldn't believe it because Gould was not an academic physicist and he didn't play by the same rules and I think that—

Rigo: —He didn't look the part.

Taylor: He didn't look the part. His history didn't look the part.

Lisa: Maybe we're all conditioned to think that it would make perfect sense for someone like Charles Townes to have invented the laser. He had the title, the pedigree, the awards.

> **Rigo**: That's the assumption Gordon Gould spent thirty years fighting.
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> **Rigo**: Gould was just five years younger than Townes, but he was just a graduate student. But their offices *were* close together and they did know each other. Townes is quick to point that out during this American Institute of Physics oral history from 1987:
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> > **Townes:** I knew Gordon Gould quite well. He'd been a student just next door to me; two offices over.

Lisa: The proximity of the two men's offices is important to note. This was a physics department where people were sharing thoughts and collaborating on cutting-edge ideas.

> **Rigo:** The idea for a laser didn't just come to Gordon Gould out of thin air that November night in 1957. It was an evolution of an invention that Charles Townes had already built: the MASER, which stands for *microwave* amplification by stimulated emission of radiation.

Alexis: Wait, so when we say Gordon Gould came up with the word *laser*, he literally just changed *one* letter from Townes's *maser*.

Lisa: It would seem that way, yes.

> **Rigo**: Yeah. I was actually pretty disappointed when I found that out because it seemed like 'oh he just made this one minor change, anyone could have done that!' But it wasn't that simple. It actually takes a lot to go from a maser to a laser.

Alexis: Okayyyy…we believe you…

Lisa: Maybe you should tell us a little more about the maser. What did it do?

Rigo: The maser was based on one of Einstein's theories about stimulated emission. I'm oversimplifying this but stimulated emission is basically energizing atoms so they'll emit

light—in this case, in the microwave region of the electromagnetic spectrum. When you light a candle for example you're exciting atoms. The maser was a clunky instrument that looked like a large washing machine and it wasn't that useful as a tool. It was mostly theoretical.

Taylor: The problem with the maser was that it emitted its radiation all over the place, a beam here, a beam there. It was not a coherent beam of light.

Clip from AT&T film, The Conquest of Light: Man has long since generated light for vision but this ordinary light by which we see is wayward, undisciplined, a jumble of waves of different sizes and colors radiating outwards in wild disorder. How can light in nature, undisciplined, be harnessed for communications which needs a constant coherent flow of light in only one direction?

Taylor: Gould started thinking along these lines. Townes started thinking along these lines. All over the place people were thinking of how we do this.

Lisa: So scientists already knew how to amplify *microwaves*. Now they were thinking about how to amplify visible *light waves*. And they're *especially* thinking about it at Columbia. Even though Townes isn't Gould's professor, they do talk about this *how-to-turn-a-maser-into-a-laser problem*.

Rigo: In 1956 they talk about optical pumping.

Alexis: Ohhhh, so this is where the optical pumping comes in.

Rigo: Right. This is a technique that gets the molecules inside the box excited using optics–visible light instead of microwaves. Remember Gould's background in optics? The contact lenses? Well, he suggests to Townes that optical pumping could be incorporated into the maser to excite atoms and essentially get it one step closer to the as- of-yet-to-be-named-or-invented laser.

Townes is so intrigued he asks Gould to lecture on the subject. He also makes an amendment to his 1953 maser patent to include optical pumping.

Lisa: It's clear that both men are now trying to solve the entire laser puzzle. For Gould, the race is on.

Act 3: Back to the Beginning

Alexis: Then, one night in November 1957 Gould has a realization.

Taylor: He wakes up in the middle of the night and he has this flash of intuition, and so he gets up—he's a smoker. He puts on a pot of coffee, lights a cigarette and he sits down and starts to write. In the very first page of the notebook that he starts to write, he says, "Some thoughts about a laser, light amplification by stimulated emission of radiation." This is the first use of the term, so he created

the word laser. Then beneath that he draws a diagram. And what he draws is the essential way a laser, early lasers worked.

Clip from AT&T film, The Conquest of Light: Inside this laser equipped with special mirrors, atoms are excited with an external light source.

When they are weakly excited the atoms begin to give off light independently of one another. However, when they are strongly excited conditions are created which forced the atoms to release light all to the same beam. The beam gets brighter as it moves within the laser in a fraction of a second it builds up millions of times and bursts through one of the mirrors. A beam of light more intense and more precisely directed than has ever been produced in man's history.

Alexis: When Gould's finished he goes to the candy store slash notary public and has his work signed and stamped. And he buys a carton of cigarettes.

Rigo: Meanwhile, Charles Townes and his brother-in-law, Arthur Schawlow—who's also a physicist—are inching towards the *very* same conclusion about how to make a laser.

Alexis: By now it's the spring of 1958. Gould has kept his laser plans secret for *months*. No one knows about his idea or his notebook. Townes and Schawlow have now solved the puzzle and

they're *about* to file for a patent. But Gould doesn't know it.

Lisa: Wait a second, why hadn't Gould *already* filed a patent if he came up with it first?

> **Rigo:** Well, this is where Gould's ignorance and distrust came to haunt him again. Remember the contact lens?
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> > **Taylor:** He didn't know how to apply for a patent and also Gould was very suspicious.
> >
> > **Gould:** If I was smart and knowledgeable about the way the patent office works I could have written the patent in December of 1957 on what I had written down in my notebook then and I would have gotten my patent. And all of this thing, it wouldn't of have happened.
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> > **Taylor:** He didn't know that the idea was enough to get a patent.
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> > **Rigo:** that proved significant.
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> > **Taylor:** It absolutely proved significant. Actually, it proved significant in two ways. One, it meant that Gould didn't get an early patent on a laser and number two, the fact that he couldn't get an early patent on a laser ultimately made him rich.

Alexis: But we're getting ahead of ourselves here. Before any of that happens Gould is desperate to build a laser and he's decided he can't do it at Columbia.

> **Rigo:** So he leaves—just shy of a PhD. His dissertation is taking too much time and he can't focus on the laser. And he also wants to escape the shadow of Charles Townes.
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> Here's Gould, in an American Institute of Physics oral history interview:

> **Gould:** All the time the idea of this laser was just burning a hole in my head, and I just thought, "I have to get out of here and get some place where I can work on it."

Act 4: Gould Sets Out on His Own

Lisa: So Gould goes to work for a company called the Technology Research Group, or TRG. The entire reason he's there is because they have the resources to make his laser, but once again he's so nervous he can't bring himself to talk about it!

> **Rigo**: But eventually he does. And TRG is so excited about it that it applies for a patent and a government contract to build a laser. They get a million dollars. *Three* times the amount they'd asked for.
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> > **Gould:** They hadn't seen a proposal for a laser up until then, so it came to them out of the clear blue sky that such a thing was actually possible. Of course ray guns and so on were part of science fiction, but to actually build this thing? And he has the theoretical ground for believing it's going to work? Wow!
>
> **Rigo**: But Townes and Schawlow are working at the exact same time, and *they* apply for a patent first. Then, in August 1958 they write a paper in a widely-read journal called *Physical Review*. This paper sets the rest of the physics world on a race to build the first working laser. It also means that it appears to the world that Townes and Schawlow have come up with it first.

Lisa: Meanwhile, the TRG contract for Gould's laser comes with a classified label, which means Gould can't work on it. Remember those Marxist meetings? Here's where they come back to haunt Gould. McCarthyism made life oppressive for many scientists during the 1950s.

> **Taylor:** Gould was a thoroughly patriotic citizen by then. He had left the communist party way behind. As an intuitive scientist, somebody who worked more effectively in the laboratory than on a piece of paper, it was really the kiss of death that he couldn't get into the laboratory to actually do his own experiments.

Lisa: Gould is devastated. It's not just that he can't work on the laser—his colleagues can't even talk to him about it.

Rigo: TRG does eventually build a laser, but only after someone else does. And Gould is convinced it's because he was banned from the project.

Lisa: Meanwhile, in 1960 Townes and his brother-in-law, Schawlow, are *granted* their laser patent. They call it the "optical Maser." Gould finds out from the *New York Times*. The rug has been swept out from under him. This patent becomes *the* laser patent for the next 17 years—

that's the length of time a patent can accrue royalties.

Rigo: Less than two months later, in May 1960, Theodore Maiman, a scientist at Hughes Research Labs in California, builds the world's first working laser.

Taylor: It was so small, that when the news broke and it made front page news all around the country, Hughes Labs made pictures of something that was larger that wouldn't actually work but the actual first laser was so small that it looked too insignificant to put on the front pages of the newspapers.

Lisa: So is this the end of our story?

Rigo: No. It's actually just the start of the next complicated chapter. In 1962 Gould and TRG challenge Townes and Schawlow's "optical maser" patent, using Gould's notebook as proof that it was his idea first. By the way, they call it an optical maser because of the "optical pumping" that Gould told Townes about.

Lisa: All along Gould has considered Townes to be his rival, but Townes never saw Gould that way. And when he finds out that Gould has challenged his "optical maser" patent he's *really* confused. And then he assumes Gould stole *his* idea.

Taylor: I just think that Townes was unable to accept that Gould had the intuitions that he had and could have done what he did. He thought that this upstart graduate student was taking his ideas and trying to make them work.

Lisa: It all goes back to those conversations at Columbia. This is Charles Townes, from an oral history conducted by the American Institute of Physics.

Townes: His actual notebook record and notarization was about three weeks after my second contact with him. What I don't know is whether he was or wasn't thinking about it before. I don't know what his ideas were before he talked to me. So I can't say to what extent he had any independent ideas.

Lisa: Before he found out about the notarized notebook, Townes thought Gould had just taken his and Schawlow's ideas from their *Physical Review* article. And not given them credit.

Taylor: He didn't realize that Gould had had independent thoughts and so this was the beginning of a scientific rivalry that ultimately played out over 30 years in Gould's attempt to win credit and recognition and ultimately money for his laser invention.

Act 5: The Courtroom and the Patent System

Taylor: The patent system proved to me to be more complex and more frustrating and vexing certainly than physics which has mathematical rules.

Rigo: Gould's patent challenge begins to hit some legal roadblocks. By this point there's already a budding laser industry, and other patents filed by other scientists. The whole ordeal is starting to take a lot of time and money.

Alexis: It's also starting to make waves in the media. *Businessweek* dubs it "the candy store patent case." A trade journal called *Product Engineering* writes that the case quote, "touches every raw nerve in science and technology: patent ownership, federal security, academic- industrial conflict of interest, research funding, and the rewards of fame- and perhaps fortune."

Rigo: In his testimonies Townes portrays Gould as a slacker. Lawyers fighting Gould and TRG ask: why did he leave Columbia when he almost had a PhD? They pick apart Gould's notebook, claiming there aren't enough details to make an actual laser.

Alexis: While Gould is losing in court, Townes is being rewarded. In 1964, he shares the Nobel Prize with two other Russian physicists for his work on masers and lasers.

Rigo: The 60s pass and the laser industry grows rapidly. A few lasers have already been built. TRG can't keep up with the legal fees and they sell Gould back his patent rights.

Alexis: But Gould doesn't give up, and he sells the right to 80 percent of his future royalties to finance his fight. He basically finds people to invest in his lawsuit. Just like a venture capitalist would invest in a start-up.

Taylor: Ultimately people who invested in Gould's patent fights were making a calculated gamble. They were saying, "Okay, this is a big invention. Okay, we're convinced. The lawyer, tells us that it's quite credible that Gould did invent the laser and can prove that he deserves a certain laser patent so we're going to invest in this because the royalty stream is going to pay us back for our risk here," and that's what happened.

Rigo: In 1977 they get their first big break.

NBC host: The U.S. Patent office finally decided who invented the laser. Or one type of laser. And the inventor is about to get a patent, which means, to him money.

Rigo: This NBC news segment aired *20 years* after Gould's notebook got notarized.

Reporter: It was that notebook that finally convinced the patent office after years of arguments that Gould was the first to get the idea.

Reporter: Gordon Gould has been puttering around in laboratories without much reward most of his life. But after years of struggle, Gordon Gould has struck it rich.

Reporter: Tomorrow Gould would get a patent, entitling him to collect royalties from all the companies making that type of laser. It could be worth millions.

Reporter: Are you going to become wealthy because of this?

Gould: It looks like I am. I never imagined it would actually happen.

> **Rigo:** Then in 1979 Gould and his team get another breakthrough. He gets two more very powerful patents that apply to *80 percent* of the industry.

Alexis: At this point the laser industry *freaks out*. They've already been paying royalties to Charles Townes and Bell Labs—the company he and Schawlow got their patent with, as well as other scientists. The laser industry is now worth more than *1 billion dollars* and Gould stands to get *three percent* of all of that with his newly won patents.

> **Rigo:** The final decision comes in 1985 when the judge dismisses reexamination cases of Gould's patent. After twenty-eight years Gould has won. Even though he only has 20 percent of the rights to his patents he walks away with 46 *million* dollars.

Act 6: The Legacy of Gould, Patents and Inventions

Alexis: So he won?! He was vindicated after all those years?!.

> **Rigo**: Well, he got rich, so that was cool. But he never *quite* got the recognition he was after. And when he died in 2005 much of the press was hesitant to call him *the inventor* of the laser. *The New York Times* said he was a quote "*figure* in the invention of the
>
> laser." *The Washington Post* went with quote "laser pioneer."

Alexis: So people still didn't know who to believe?

Lisa: Or maybe it's just not that easy to explain. Joan Bromberg was a historian of science Johns Hopkins who died in 2015. She wrote a book about lasers and interviewed Gould for those American Institute of Physics oral histories. She said that inventions are complicated. And that

there's a general consensus among historians of science that it's too simplistic to try to link an invention or scientific discovery to *one* single person or *one* moment in time.

> **Rigo:** Bromberg broke down how both Gould and Townes contributed to the invention of the laser, and it all boils down to this: neither Gould, nor Townes, nor Schawlow, nor Theodore Maiman made a laser on their own. The laser came to be because of *all* of their contributions. And other scientists as well!

Alexis: Right. This is how science actually works...

Lisa: Exactly. Surprise! You thought this was a story about a lone inventor who didn't get his due, but big inventions don't usually work like that. They take a lot of people thinking about things for a lot of time and building off of one another's ideas. It makes answering "who came up with that idea first?" kind of hard.

> **Rigo:** Still, Nick Taylor says that Gould should at least be remembered in the same vein as Thomas Edison.
>
> > **Taylor:** There's no doubt that he deserves a place in the pantheon of laser inventors and in the pantheon of inventors generally. I think that he deserves to be mentioned, if not in the same breath, then certainly in the same paragraph with his idol Thomas Edison.

Alexis: As for the patent system? In 2013 the United States changed its system from first-to- invent to first-to-file. In part to prevent decades-long retroactive cases like Gordon Gould's! The

U.S. was the last industrialized nation to change to this system. And theoretically, it's better for everyone. As long as you know how the patent system works.

>>MUSIC<<

Alexis: *Distillations* is more than a podcast. We're also a multimedia magazine.

Lisa: You can find our videos, our blog, and our print stories at Distillations DOT org.

Alexis: And you can also follow the Science History Institute on Facebook, Twitter, and Instagram.

Lisa: This episode was produced by Mariel Carr and Rigo Hernandez, with a lot of extra reporting by Rigo Hernandez.

Alexis: It was mixed by Catherine Girardeau.

Lisa: And our theme music was composed by Zach Young.

Alexis: Special thanks to Nick Taylor for sharing so much of his knowledge with us, and for answering a lot of follow-up questions.

Alexis: We opened the episode with an amazing 1962 video about the making of the laser. It you want to watch it, you can find it at archive DOT org. It's called "The Conquest of Light."

Lisa: For *Distillations* I'm Lisa Berry Drago.

Alexis: And I'm Alexis Pedrick.

Both: Thanks for listening!