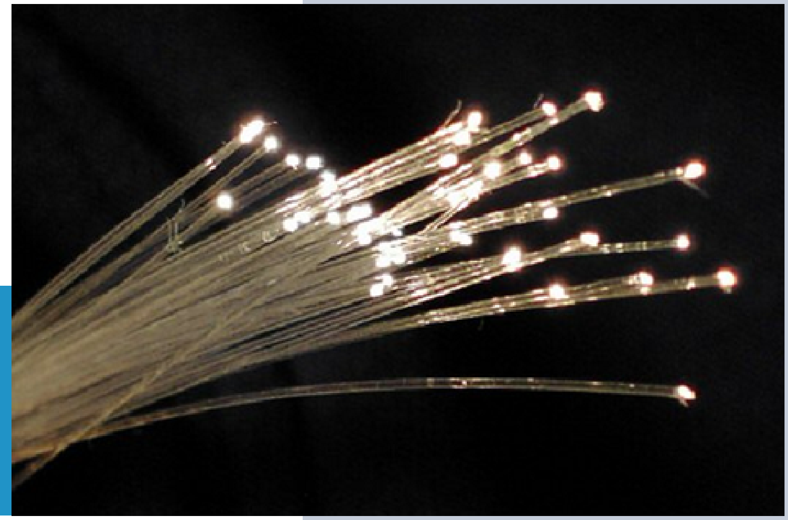
EarthDate

Light Speed, Under the Sea



Bundles of fiber-optic glass guide pulses of light, forming the foundation of the world's long-distance communication network.

Credit: BigRiz - https://commons.wikimedia.org/w/index.php?curid=46561

In 1858, Queen Victoria sent a telegraph to U.S. President Buchanan, via the first undersea cable. The cable worked for just a few weeks, but it launched an international cable network that still dominates global communication.

We think we live in a wireless world. But it's just the short hop from our phones and wifi to a receiving antenna. Nearly everything after that is transmitted by cable, on land and undersea.

Undersea cables made of copper served the world for more than a hundred years. Then, in 1988, the first fiber-optic cable was laid.

They're made of strands of ultrapure glass, no thicker than a human hair. Hundreds of strands are bundled together and protected by braided metal and nylon, jacketed in plastic.

At one end, electrical signals are converted to light by a laser, then shot down the fiber-optic cable, sometimes more than a thousand miles, between countries and continents. In the shallows, they're buried in trenches to protect them. In deep water, they're simply laid on the seabed, which is less expensive, but exposes them to harm.

There are now thousands of subsea fiber-optic cables, stretching almost 1 million total miles, transmitting 95% of international internet and voice traffic. And more cables are being laid each year.

So next time you make an international call, pause for a moment to imagine your voice rocketing along at the speed of light, under the sea.

I'm Scott Tinker.

SWITCH ENERGY ALLIANCE

Background: Light Speed, Under the Sea

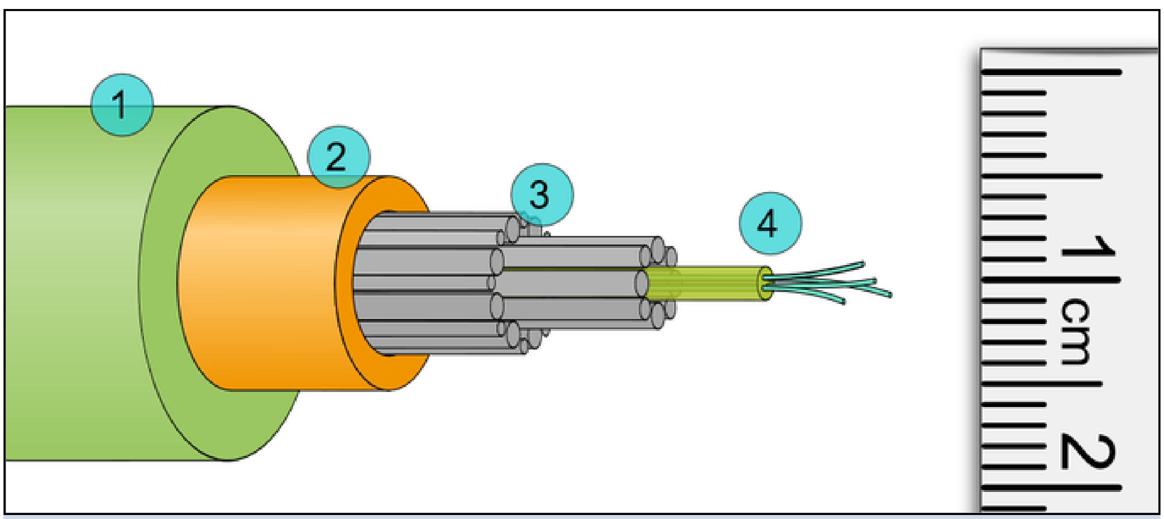
Synopsis: A vast network of fiber-optic cables lies hidden beneath the oceans, carrying more than 95% of global communication. These cables guide pulses of light through thin strands of glass, linking continents at high speed. Their construction.

A Connected World

- Funny memes, viral tweets, trending videos. Video calls, email, chat, shared files.
- Today we trade information instantly, across a world that feels both distant and right next door.
- But for most of human history, the oceans kept us apart. Explorers would leave home and return months or years later, finally able to share what they've discovered.
- As shipping expanded, letters crossed the sea with them, carrying the news of the day at the speed of the wind.
- We've always wanted to stay connected, but we lacked a way to do it across thousands of miles of open ocean.

Early Attempts to Bridge the Gap

- Despite several failed attempts, perseverance paid off when the first transatlantic communication cable was completed in 1858. The U.S. and Britain worked jointly to lay a cable between Ireland and Newfoundland, one that could transmit only a few words per hour.
  - But the cable survived just a few weeks. An operator attempted to send messages at a higher voltage, which permanently damaged the delicate copper line.
- Through the rest of 1800s, engineers improved cable construction and laying techniques, gradually increasing the speed and reliability of telegraph messages.
- By the mid-twentieth century, telephone channels replaced telegraph lines, and more sophisticated copper cables stretched across the ocean floor to carry voices across continents.
- Then in 1988, the first transatlantic fiber-optic cable switched copper for light, transforming long-distance communication forever.



This cross-section illustrates the Southern Cross cable, which spans 18,000 miles across the Pacific. The numbered layers include: (1) a high-density polyethylene outer jacket, (2) copper tubing for power transmission, (3) steel wires for strength, and (4) optical fibers held in water-resistant gel.

Credit: Mysid - Self-made in Inkscape https://commons.wikimedia.org/w/index.php?curid=2548971

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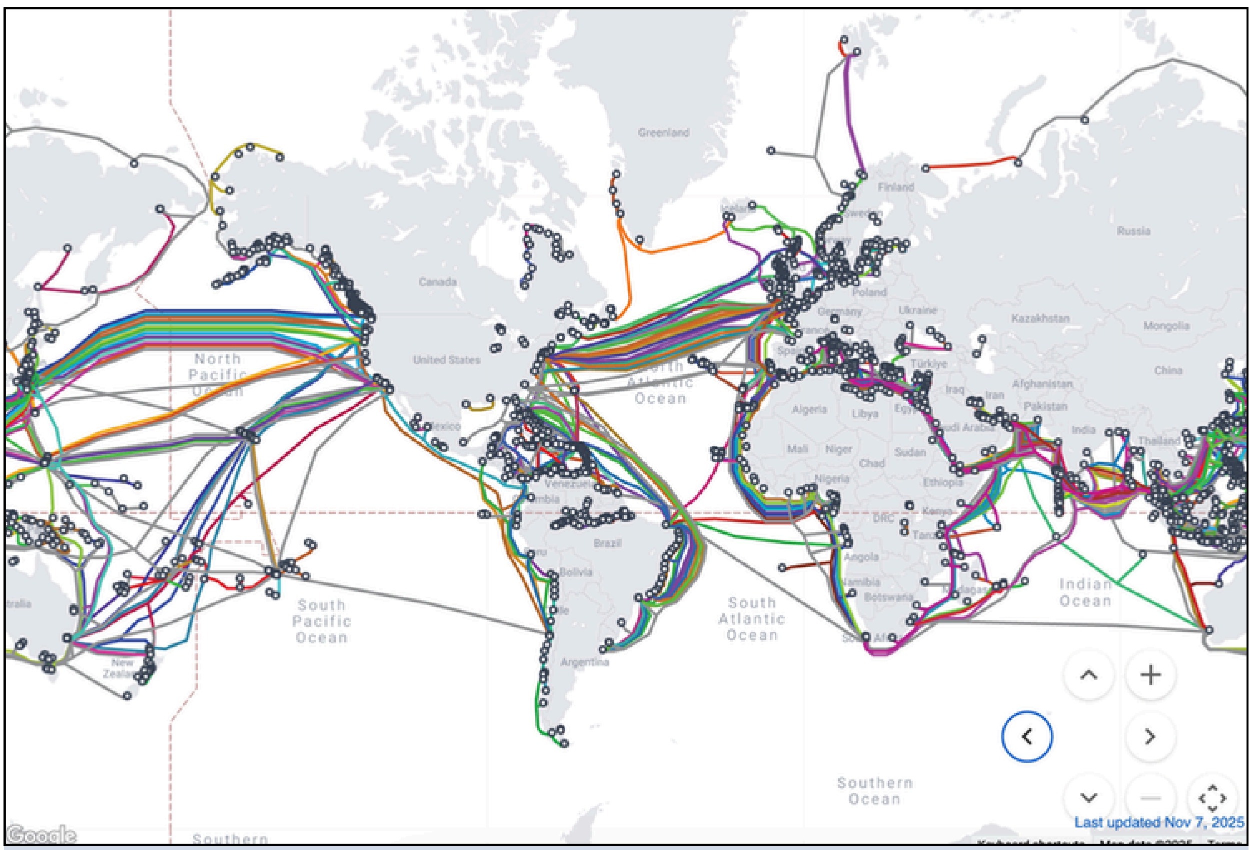
The Magic of Fiber Optics

- At just the diameter of a human hair, optical fibers are long, thin strands of extremely pure glass. These fibers are grouped into bundles called optical cables, which then transmit light signals over long distances.
- Each fiber has a core, the tiny central channel through which light travels. Surrounding the core is the cladding, a slightly different type of glass that reflects the light back into the core. This pair works together to trap light inside the fiber.
- This delicate cable is protected first by a plastic buffer coating, then by an outer jacket that shields the fiber from physical damage and moisture. One to several hundred optical fibers wrapped together make up a complete fiber optic cable.
- Digital data from technologies like computers and phones begins as an electrical signal. Inside the device, this electrical energy is converted to photons, tiny packets of electromagnetic energy, using a laser.
- These photons race through the fiber's inner core. They stay confined because the core has a higher refractive index than the cladding. That difference causes the light to reflect completely back inward, a phenomenon known as total internal reflection.
- Because the glass is so pure, the light is barely absorbed or scattered, so the signal stays strong over long distances.
- At the far end, an optical receiver decodes the light and converts it back into an electrical signal, delivering the data to another computer or device.



A global map of submarine fiber-optic cables and their coastal landing points. These connections link continents and route more than 95% of international internet traffic across the seafloor.

Credit: Telegeography.com, https://creativecommons.org/licenses/by-sa/4.0/

Background: Light Speed, Under the Sea

Cables in the Ocean

- We tend to think that we live in a wireless world, that our data floats in "the cloud," or that satellites carry most global communications.
- But the only wireless part is the short hop from your device to a nearby antenna. From there, nearly everything travels through fiber-optic cables on land or across the ocean floor.
- Fiber-optic cables can carry far more data, far faster and at a far lower cost than satellites. Today, over 95% of international internet and voice traffic moves through the labyrinth of cables on the ocean floor.
- As of 2025, these cables stretch more than 1.5 million kilometers (935,000 miles), with more than 600 active systems in place, and many more planned as global data use grows.
- To keep signals strong and protect the fragile glass fibers inside, subsea cables are built in multiple layers.
- The fiber bundle is gel-coated, then placed inside a copper tube that carries electrical power. That power feeds the repeaters (optical amplifiers) spaced along the cable, which boost the light signal across thousands of kilometers.
- Around the copper tube is layer of plastic, followed by aluminum water barrier, then strong steel wires for mechanical protection
    - In shallower or more hazardous areas, additional armor is added including extra steel braid, sometimes a nylon wrap, and even a tar coating. Finally, a thick plastic jacket seals the entire structure, creating a tough, flexible cable roughly the diameter of a garden hose.
- It can take three to four weeks to load as much as 2,000 km (1,245 miles) of cable onto a ship. Near shore, the ship uses a plow to bury the cable in a trench to protect it from anchors and currents. In deeper, calmer waters, cables are simply laid on the seafloor.
- Often, another ship begins from the opposite direction, and when the two sections meet, divers or remotely operated vehicles help splice them together.
- Cables are designed to last at least 25 years, though many become obsolete sooner as faster, higher-capacity systems are built. Retired cables may be relocated to new routes or recovered from the seafloor and salvaged for raw materials.

Who's in Charge?

- Although the very first transatlantic communication in 1858, Queen Victoria writing to President Buchanan, was a diplomatic milestone, the cable itself was built without any government funding.
- New York merchant Cyrus Field (1819-1892) recognized the value of instant international communication and took a leap far beyond his paper business, raising private capital for the risky project.
- Surprisingly, that model hasn't changed much. Today, most submarine cables are still owned by private corporations or consortia rather than governments.

Built for transoceanic cable work, the Cable Innovator uses stern-laying gear, powerful cable engines, plough-handling equipment, and dynamic positioning thrusters to place fiber-optic cables with precision. The ship can remain at sea for weeks and deploy ROVs to inspect or repair cables on the seafloor.

Credit: By derlandsknecht - Cable Innovator- https://commons.wikimedia.org/w/index.php?curid=35726913

Background: Light Speed, Under the Sea

- Because these cables span international waters, treaties have long been needed to protect them. The first major agreement appeared in 1884, and modern protections fall under the United Nations Convention on The Law of the Sea, along with U.S. Domestic Regulation of Submarine Cables.
- In the late 1990s, as fiber-optic communication exploded, entrepreneurial companies built a wave of private cables and sold transmission capacity to the highest bidders.
- In recent years, major content providers, including Google, Meta, Amazon, and Microsoft, have become the largest investors in the new subsea systems, building their own global networks to support cloud services and data traffic.

Dangers to the System

- Submarine fiber-optic cables operate in a harsh environment, but surprisingly, land-based cables are subject to more damage and outages. Most terrestrial outages come from construction projects or even animals like rodents and cows.
- A persistent myth is that sharks often damage subsea cables. While fish do occasionally bite them, they are not a significant source of damage.
- As submarine cables cross the seafloor, they can encounter natural hazards such as earthquakes or underwater landslides.
- But the vast majority of faults, nearly two-thirds, are caused by human activity, especially fishing vessels and ship anchors. Trawling, a fishing practice that drags nets along the bottom, is particularly problematic. Globally, more than 100 cable faults occur each year.
- Land cables can usually be repaired quickly, sometimes taking only a day or two. Undersea repairs take much longer.
    - First, the damage must be located; then a specialized ship travels to the site, lifts the cable to the surface, and secures it.
    - Technicians using ropes or remotely operated vehicles carefully splice the damaged section, reseal its protective layers, and lower it back to the ocean floor.
    - The entire process can take several days or even weeks.
- Deliberate damage to cables is extremely rare, but it remains something engineers and governments monitor because these cables are critical infrastructure.
- More commonly, new cable routes can be delayed by international coordination challenges, since they cross multiple jurisdictions and follow maritime regulations.

Protecting the Network

- Engineers rely on several practical strategies to keep submarine cables working. The most effective is redundancy.
    - Many cables link each region, often along different routes, so data can automatically shift to another line if one is damaged.
- Careful route planning adds another layer of protection.
    - Using detailed seafloor maps, crews avoid steep slopes, fault zones, and areas prone to undersea landslides.
    - Near the coast, where anchors and fishing gear are common, cables are buried or built with extra armor.
- Modern cables are also tougher. Stronger jackets, improved steel armoring, and water-blocking materials help each line withstand decades on the seafloor.
    - Operators continuously monitor signal strength, so they can spot problems early.
- Together, smart routing, durable construction, and constant monitoring help keep this global network reliable, quietly carrying nearly all the world's digital traffic beneath the ocean

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For something most of us never see, submarine cables are among the most essential technologies of the modern world. Quietly crossing the seafloor, they carry the information that keeps our planet connected.

EarthNote: What is Index of Refraction?

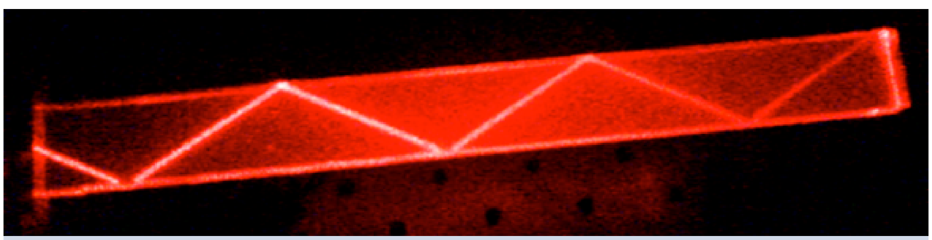
The key scientific principal behind fiber-optics is how light moves through a very thin strand of glass. In a vacuum, light travels at about 186,282 miles per second (3.00 x 108 m/s). But in any other transparent material - water, glass, or air – it slows down. How much it slows depends on the structure of the material. Air slows light only slightly, while diamonds cause it to slow to about 1.24×10^8 *m/s, less than half its speed in a vacuum.*

The ratio of light's speed in a vacuum to its speed in a material is called the index of refraction, written as:

$$\text{index of refraction } (n) = \frac{\textit{speed of light in vacuum}}{\textit{speed of light in medium}}$$

When light crosses from one material to another with a different index of refraction, it bends. And when light moves from a material with a higher index to one with a lower index, it can bend so sharply that it reflects inside instead of passing through – a process called total internal reflection.

In a fiber-optic cable, the glass core has an index of refraction around 1.46-1.47. The cladding around it has a slightly lower index. That small difference causes total internal reflection, keeping the light trapped inside the core as it travels through the length of the cable.



A laser beam reflecting inside a clear acrylic bar demonstrates total internal reflection, the same principle that keeps light trapped inside a fiber-optic cable.

Credit: Sai2020 - Own work, Public Domain - https://commons.wikimedia.org/w/index.php?curid=5712691

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