**When I was a teenager if I wanted to get a message to one of my friends, I had to go into the kitchen and pick up the receiver of the analogue telephone that was bolted to the wall. You know, the one with a mechanical dial that had to be rotated in the correct sequence to select the number you wanted to call. After a few seconds of listening to various whirrings and clicks, the phone at the other end would start to ring, and if that person happened to be at home then you were in luck.**

**Then in the early nineties a thing called the Internet came along and it turned out we could attach our phones to our computers to send information to other computers. It was like something out of Star Trek, it really was! Admittedly if you wanted to download a colour picture of something…can’t think of any examples off the top of my head, but if you did, then you would have to wait about 5 minutes for the thing load onto your computer screen, line by tortuous line. And the idea of downloading something as massive as a video was just a ridiculous foray into science-fiction.**

**Then, about a decade later, a new technology called Broadband came along and the world was changed forever. And when engineers found out that information could be sent as wavelengths of light down a fibre optic cable at speeds that were thousands of times faster than electrons in a copper wire, and for much longer distances, the global information superhighway was well and truly up and running.**

**But all this wonderful technology needs a lot of energy to run. The internet currently uses about six percent of the world’s electricity and by twenty-twenty-five that’s set to rocket up to more than twenty percent. So, anything that can reduce the energy consumption of each electronic transaction has to be a very welcome thing indeed. And now a research team has successfully demonstrated a single tiny microchip that’s capable of transmitting the equivalent of all the internet’s traffic every second, with massive energy savings over current technology.**

**So, how did they do that? And when can we have one?**

**Hello and welcome to just have a think.**

**Fibre optics really are a miracle of modern technology.** **Essentially just dozens of very thin strands of glass or plastic less than a tenth the thickness of a human hair, wrapped up inside an insulated cable, transmitting data via pulses of light that travel..well at the speed of light. Fibre-optic cables already have a much broader range of frequencies and a much smaller loss of quality for data transfer than copper wire or satellite connections. They’re also much stronger than copper wire, and as an added bonus it’s much more difficult and more expensive to hack into fibre optics than it is to hack into copper or satellite communications, so you get a pretty secure connection too.**

**You’d think that once we’d mastered this astonishing technique then there’d be nowhere else to go right? I mean even the cleverest physicists tell us that nothing can travel faster than light, don’t they? So other than just adding more and more fibre optic cables in bigger and bigger bundles stretching across ocean floors all over the planet, what else can be done to improve data speeds and energy efficiency?**

**Well, this is where we delve into the fascinating world of the electromagnetic spectrum. Now, as I’m sure you know, visible light makes up only a very small part of the entire spectrum. We all know about infrared light and ultraviolet light for example, both of which are invisible to the human eye. The determining factor is wavelength, and light on the electromagnetic spectrum can have wavelengths as small as ten to the minus eighteen metres in the dangerous gamma ray region, all the way up to as much a hundred kilometres at the radio wave end.**

**So, armed with that knowledge, some extremely clever boffins at the Technical University of Denmark asked themselves whether they could make use of a wider variety of wavelengths to send data signals in a fibre optic cable. And the answer was…it’s complicated!**

**Multiple wavelengths are already used to a certain extent in fibre optics. It’s a fairly well-established technique known as ‘wavelength division multiplexing’, or WDM. But, perhaps unsurprisingly, there are big challenges when you try to squeeze all that light into a very confined space, not least of which is something called ‘cross-talk’ between data channels, and signal noise generated by amplification across long distances. It’s already possible to create a high number of different individual wavelengths by using lots and lots of laser diodes, but individual lasers tend to drift randomly in their frequency, causing the spacing between any two lines to fluctuate over time, which is not what you need when you’re streaming your favourite movie. So, engineers have to factor in relatively large buffer regions between each channel where no data can be transmitted. The result of all that is a lot of hardware in your installation, which means it’s not really scalable to cope with the demands of the rapidly growing internet.**

**So, the folks in Copenhagen started experimenting with an alternative transmission method known as a frequency comb. These things are a special type of light source, with equidistant frequency components that resemble the teeth of a comb, hence the name. It turns out that the comb-like structure is very well suited to wavelength division multiplexing. Data can be applied to each comb line separately and transmitted simultaneously. And unlike individual lasers, the frequency separation between each comb line remains constant even if the whole comb frequency drifts slightly. That means you can have much smaller buffer regions between each comb line. In fact, this latest research suggests it may be possible to eliminate them altogether. That allows for much more efficient use of the spectral bandwidth. Another advantage is that all comb lines are phase coherent. In other words, the distance between the peaks and troughs of all the different wavelengths doesn’t wander about, it stays constant. And that has the not inconsiderable benefit of enabling a process called ‘joint digital signal processing’ among channels which makes use of the gap between phases to shoe-horn even more signals into what is essentially the same space.**

**Large scale examples of this technology have achieved record data rate transmissions of as much as ten-point-six-six petabits per second, which is a number so ridiculously large it probably doesn’t mean anything at all to most of us, but to put it into perspective, the average broadband download speed today is about a hundred and seventy megabits per second, and some lucky folks even get a thousand megabits per second, which is a gigabit. Well, there are a million gigabits in a petabit, so the record transmission I just mentioned is almost six million times faster than the speeds you and I get at home.**

**Now, to be fair, the apparatus that was used to achieve that world record wouldn’t fit down the average fibre optic line, so the whole thing does need to be scaled down to what’s known as microcombs, which is what the Copenhagen team did, with a device called a ring resonator designed to create a frequency comb covering the telecommunication bands known as Conventional or C band and Long Wavelength or L band. The team took a data stream and split it into thirty-seven sections and then sent each section down a separate core of a**[**fibre-optic cable**](https://www.newscientist.com/article-topic/fibre-optics/)**. Then they split each channel into two-hundred and twenty-three individual data chunks, each with a different frequency on the electromagnetic spectrum.**

**After a lot of trial an error and several design iterations, the team managed to create a single microchip that could transmit one-point-eight-four petabits of data per second over a distance of just under eight kilometres, which as I mentioned at the start of the video, is more traffic per second…FROM A SINGLE MICROCHIP… than travels through the entire backbone network of the internet. In fact, it was so much data that there wasn’t a single computer anywhere in the world with a large enough capacity to actually receive it all, so the team had to pass dummy data through each channel, one at a time, and test each one individually to make sure everything was being transmitted and recovered correctly.**

**In a recent interview with New Scientist, the paper’s lead author, Asbjørn Arvad Jørgensen, said “It’s an incredibly large amount of data that we’re sending through, essentially, less than a square millimetre [of cable]. It just goes to show that we can go so much further than we are today with internet connections.”**

**Now obviously eight kilometres isn’t going to quite do it for the world wide web is it, but all these kinds of breakthroughs had to start somewhere didn’t they, so it’s entirely possible that much longer distances will be achieved with further work.**

**The chip only requires a single laser to transmit all the light frequencies, plus a separate device in each of the output streams to do the decoding, but Jørgensen and his team are confident that these components could be integrated onto the chip itself, making the entire device about the size of a matchbox.**

**There are laser driven devices in use today that are about that size, but they only transmit over a single slice of the spectrum. The Copenhagen team reckon their device will be thousands of times more data dense than that existing technology. If they can achieve that, IN THE REAL WORLD at full scale production, overcoming all the usual hurdles that we talk about all the time on this channel, then not only will the world have a very, very future proofed level of bandwidth for global communications, but crucially, from a sustainability point of view, these devices would slash the energy demand for internet usage. In 2017, the United Nations reported that more than half of the world’s population still didn’t have access to the internet, with Asia and Africa facing the lowest connection rates. So the UN has now set a goal for universal access to the internet, which in practice would equate to ninety percent of the world population by twenty fifty. That means the number of users will grow from about three billion today to around nine billion by mid-century. And with the internet of things, and even the so-called internet of everything arriving rapidly over the horizon, this new breakthrough looks to be very timely indeed.**

**So, do you think this one could be a gamechanger or do you think it’s just more laboratory hopium that might never actually see the light of day? If you’re working in the industry and you’ve got some expertise you could share, or if you just want to express your view, then it’d be great to get your thoughts down in the comments section below.**

**That’s it for this week though. Next Sunday is Christmas Day, believe it or not, so I’ll be taking a little break to go and eat far too much food with the rest of my family, but I’ll be back with more news from the world of sustainable energy in a couple of weeks’ time. In the meantime, a massive thank you, as always, to our amazing Patreon supporters who help me keep these videos independent and free of ads and sponsorship messages. And a special thank you to some long-term supporters of the channel, whose names are scrolling up the screen beside me here, all of whom celebrate an anniversary of Patreon membership in December.**

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**As always, thanks very much for watching, have a great week, and remember to Just Have a Think.**

**See you next week**