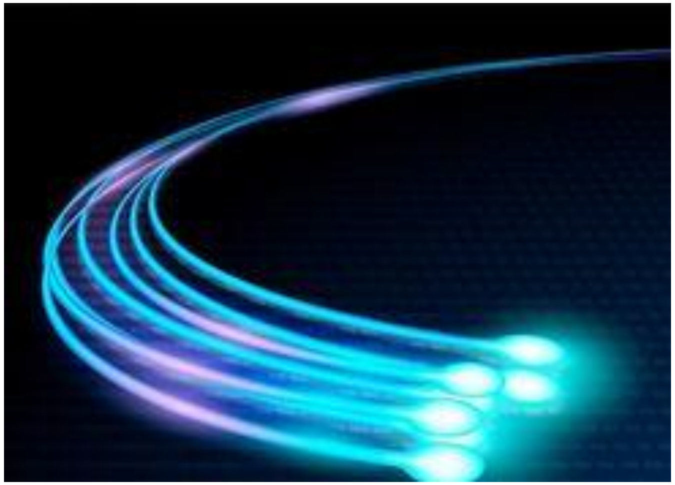
Introduction to Optical Fibres



Wireless Hill 2022

John Paskulich WAHTS

https://oldaustraliantelephones.weebly.com/

The talk

- No need to take notes. On my website (on my card)
- Basic optical fibre principles/applications
- Practical examples
- Brief history
- Optical fibres and the Internet
- NBN and World networks

This presentation is based on the speaker's life experience and uses sources from public internet sites. All sources acknowledged. No copyright infringement is intended.

SAFETY!

- Telecommunications optic fibre systems use **laser** light transmitters outside the visible spectrum. Risk of serious eye injury!
- The fibres are superfine glass. Can easily penetrate skin and break off!
- Only the speaker will demonstrate equipment and handle bare fibres

Glass

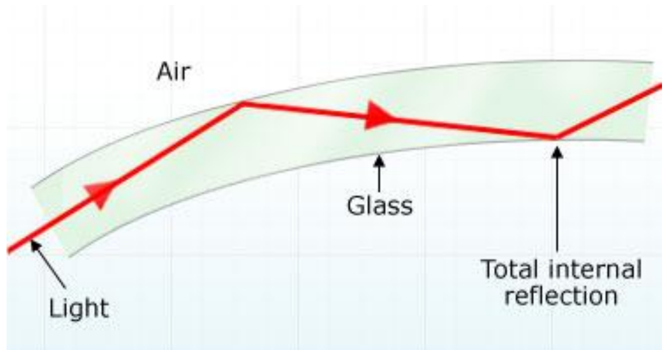
- **Silica glass:**
  - Pure silicon dioxide (SiO_2) Ideal for optic fibres; Wide wavelength range, very good optical transparency, low absorption and scattering In the near-infrared region e.g. 1.5 µm
  - Can be drawn into fibres at reasonably high temperatures
  - Very high mechanical strength, chemically stable and high damage threshold to laser-induced breakdown
  - Can be doped with various materials in order to alter properties.

- **Soda–lime–silica glass: *most common type*** - used for windowpanes and bottles/jars for beverages, food etc. About 70% silica (SiO_2) PLUS sodium carbonate (Na_2CO_3), calcium oxide (CaO), magnesium oxide (MgO) and aluminium oxide (Al_2O_3) for lower melt point , durability etc.
- **Borosilicate glass:** more resistant to thermal shock etc. - silica and boron trioxide (B_2O_3) are main constituents. Used for chemical containers, lighting, electronics, cookware etc.

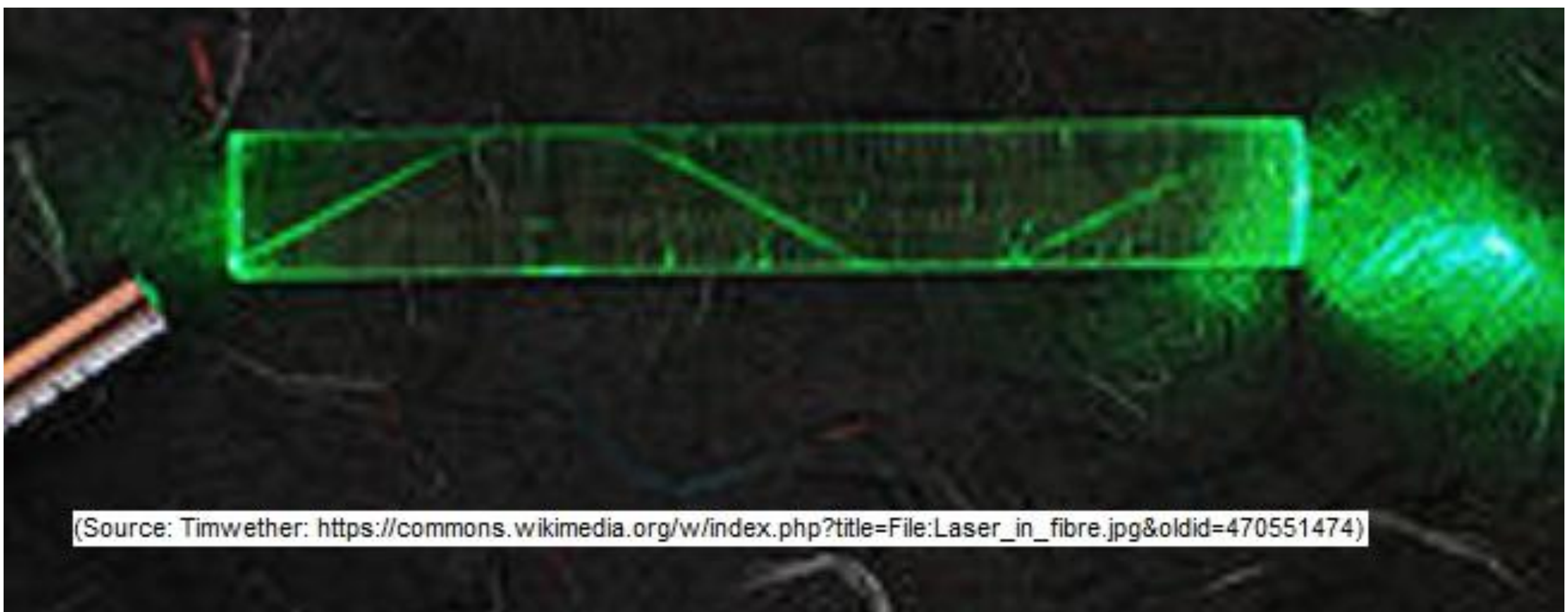
Optical Fibre

- Core is usually a high quality/low loss silica ***glass***
- Comprises a transparent central core surrounded by a cladding with a lower refractive index
- Result is "total internal reflection" - enables light rays to travel the fibre’s length - around bends!
- Data is usually transmitted as pulses of light
- Immune from electro-magnetic radiation
- Fine glass fibres are very flexible. Can be in cables

Total Internal Reflection



https://www.preproom.org



(Source: Timwether: https://commons.wikimedia.org/w/index.php?title=File:Laser_in_fibre.jpg&oldid=470551474)

Simple application: Fantasia lamp

www.ebay.com/itm/284270520505

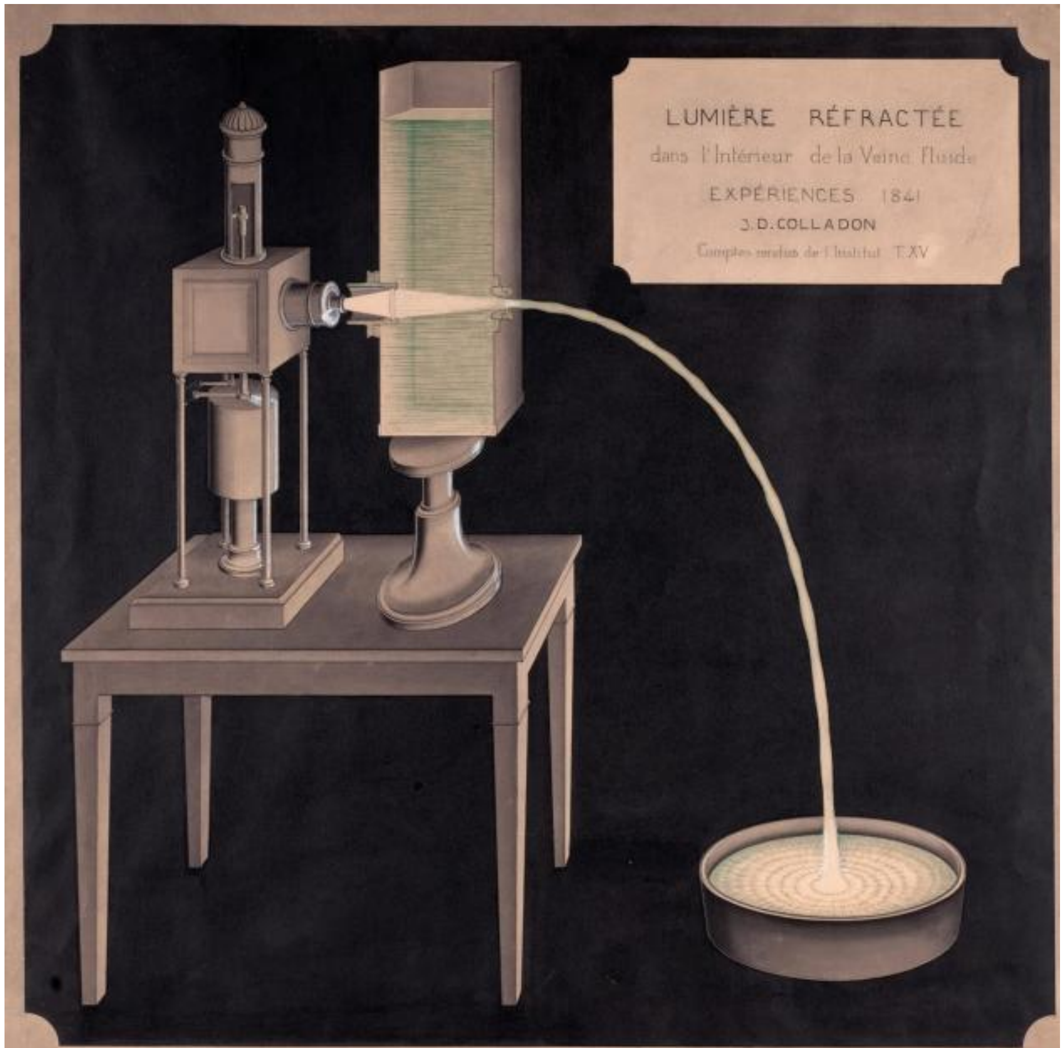
Typical Applications of Optic Fibres

- Internet and telecommunications systems
- Computer Networking
- Automotive Industry
- Surgery and Dentistry
- Decorations and Lighting
- Mechanical Inspections
- Military and Space Applications
- etc. etc.

Some History

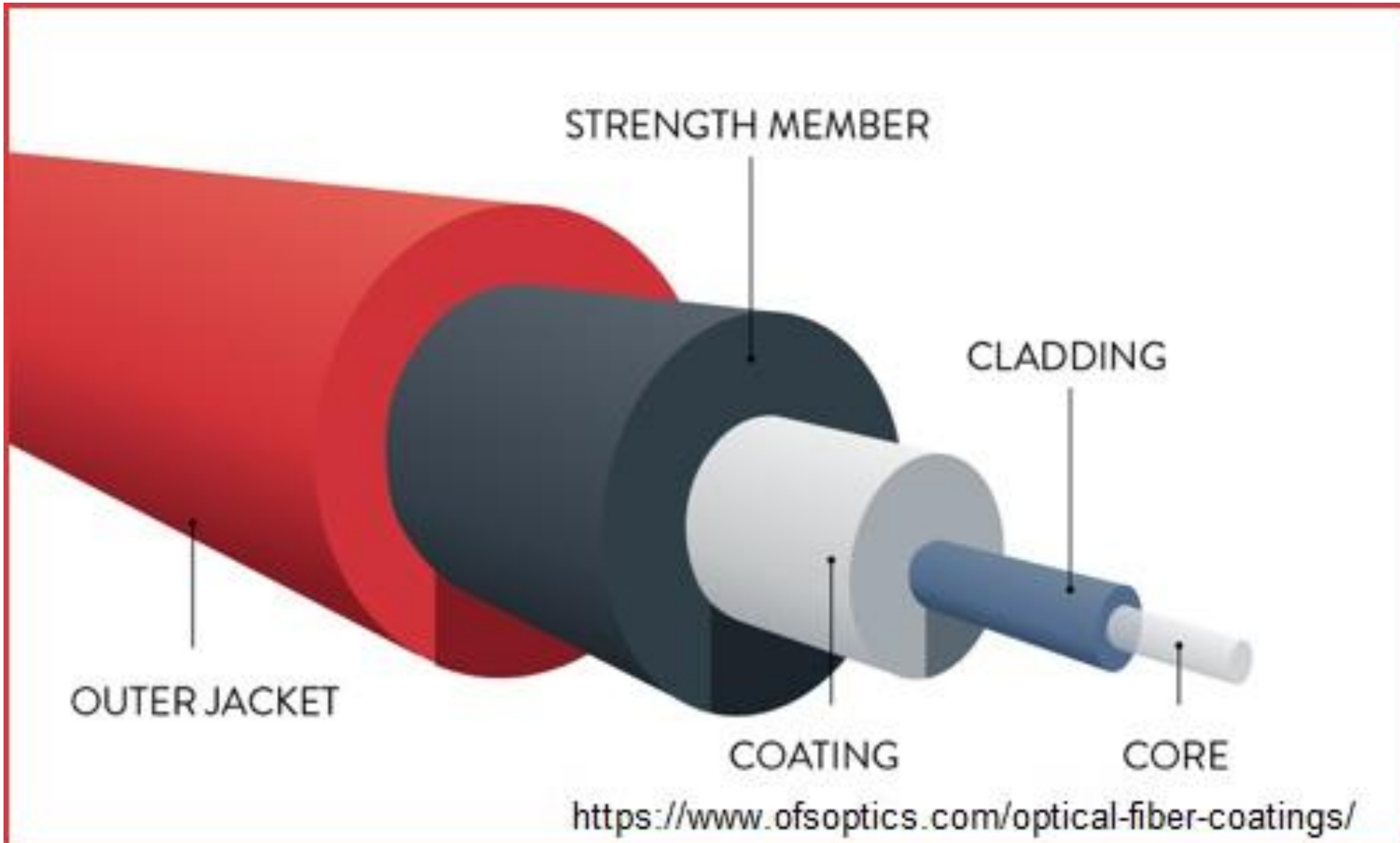
- 1841: Daniel Colladon (Swiss) described his "light fountain“
- 1880: Alexander Graham Bell (USA) invents “photophone”
- 1888 - 1957: Numerous medical applications developed
- 1950s-1970s: Research in telecomm’s applications of fibres
- 1977: Live telephony over fibres in USA and UK
- 1981: BT UK. 140 Mbs over approx 50 km of SMOF
- 1985 Telecom Aust. begins its optic fibre programme
- 1988: First transatlantic fibre-optic cable (TAT-8)
- 2021: Japan researchers 319 Tbs over 3000 km

Colladon’s light fountain 1841

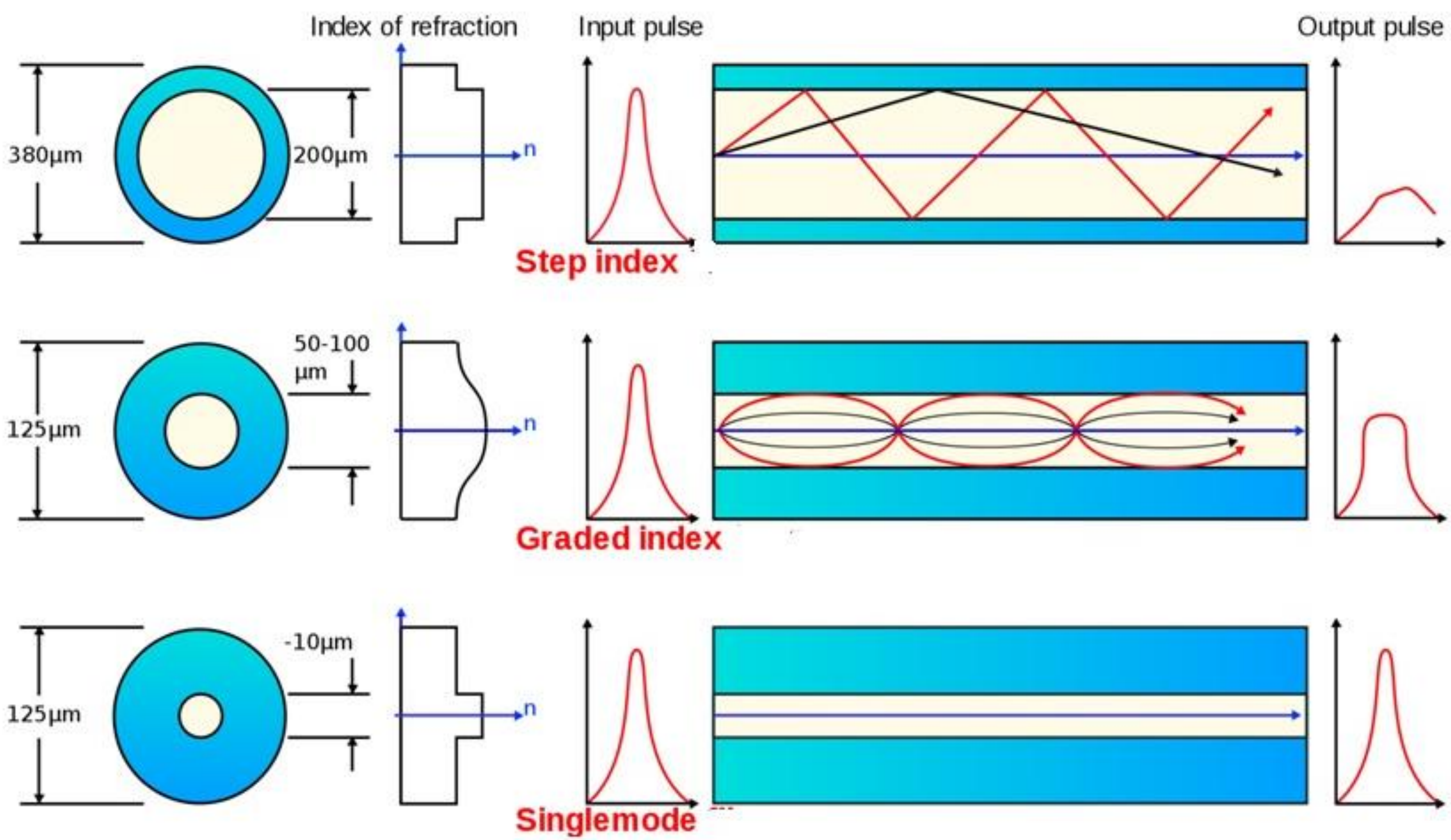


Source https://medialibrary.uantwerpen.be/oldcontent/container50068/files/14959-Artikel%20Tekst-30350-1-10-20191218.pdf/

Concept: Communications Fibre



Common Fibre Types



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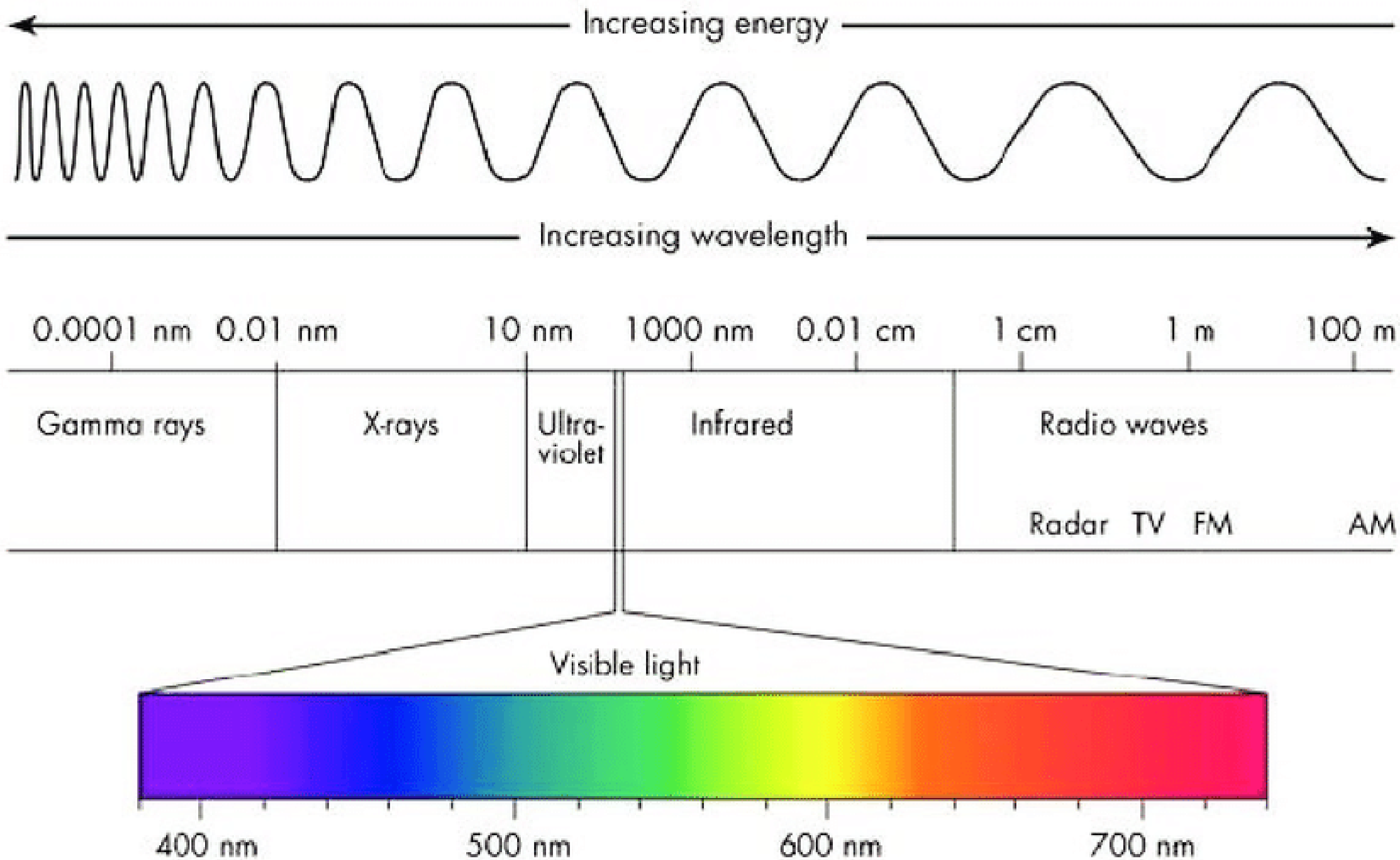
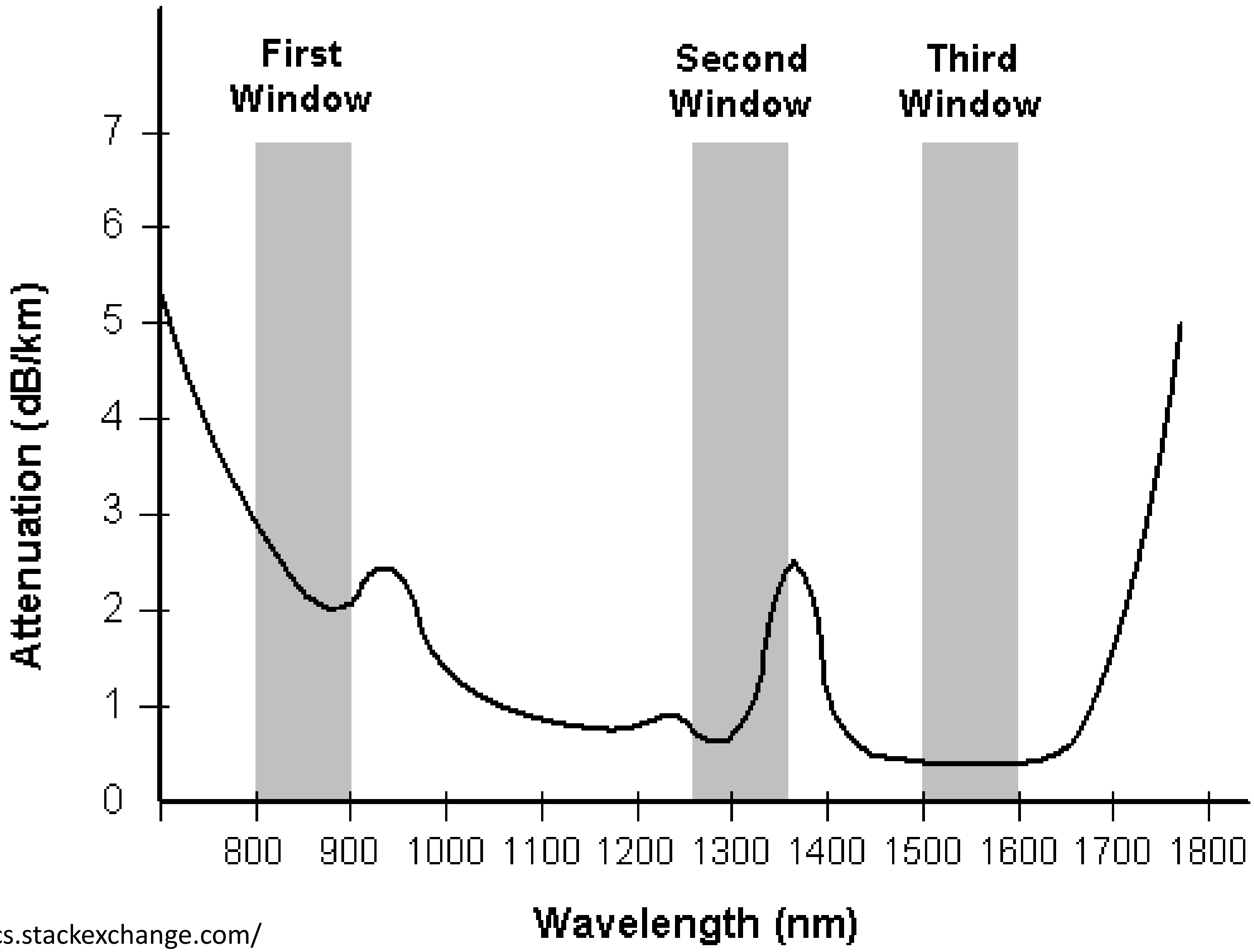
Electromagnetic/Light Spectrum

Most Optic Fibre Telecomm's Systems use Infrared



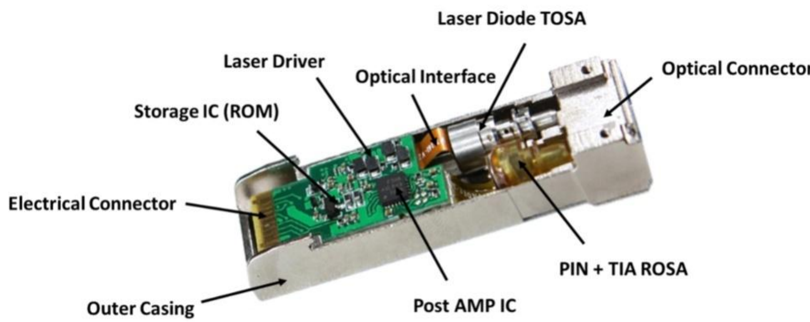
Source: Szantoi, Zoltan. (2013). Review of the use of remotely-sensed data for monitoring biodiversity change and tracking progress towards the aichi biodiversity targets. https://www.researchgate.net/publication/

Systems: Light Wavelengths

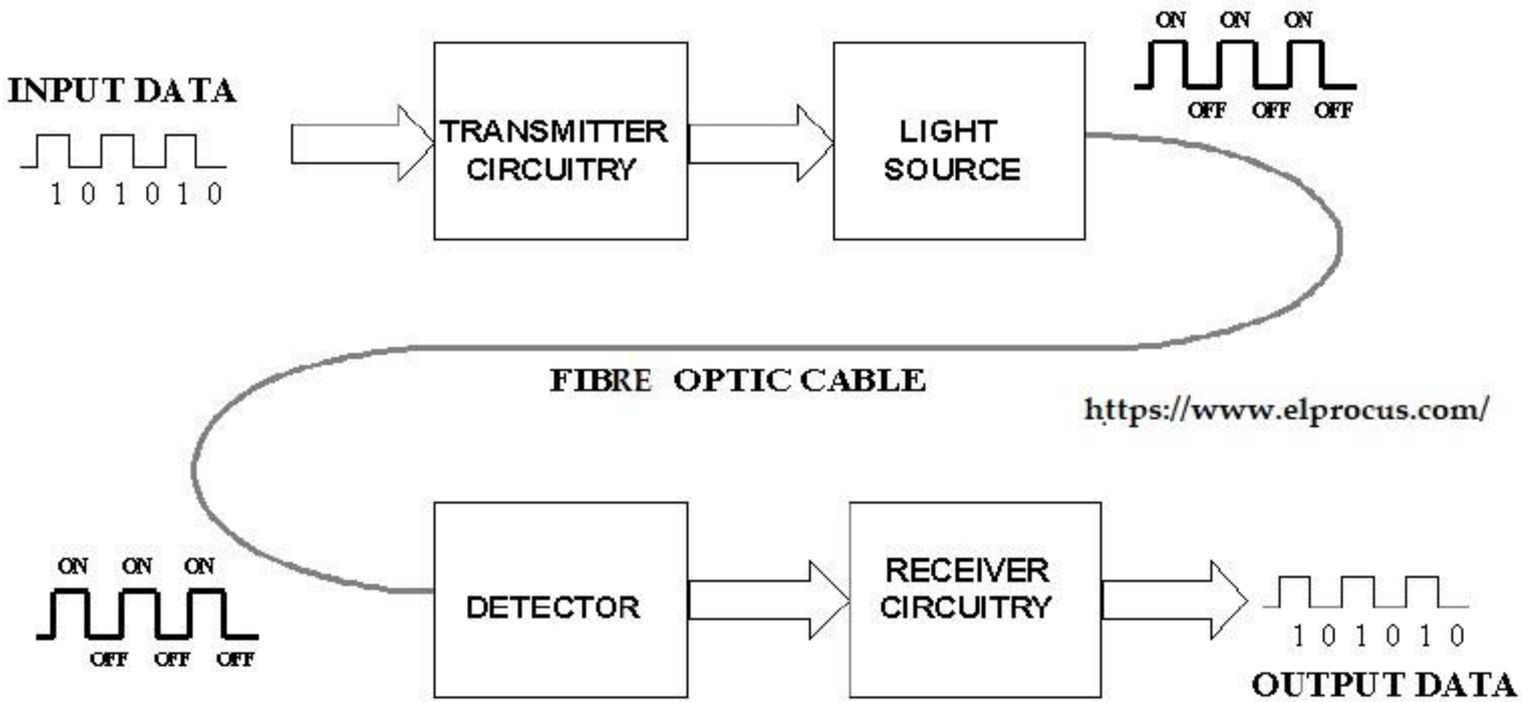


https://physics.stackexchange.com/

Electrical/Optical Conversion



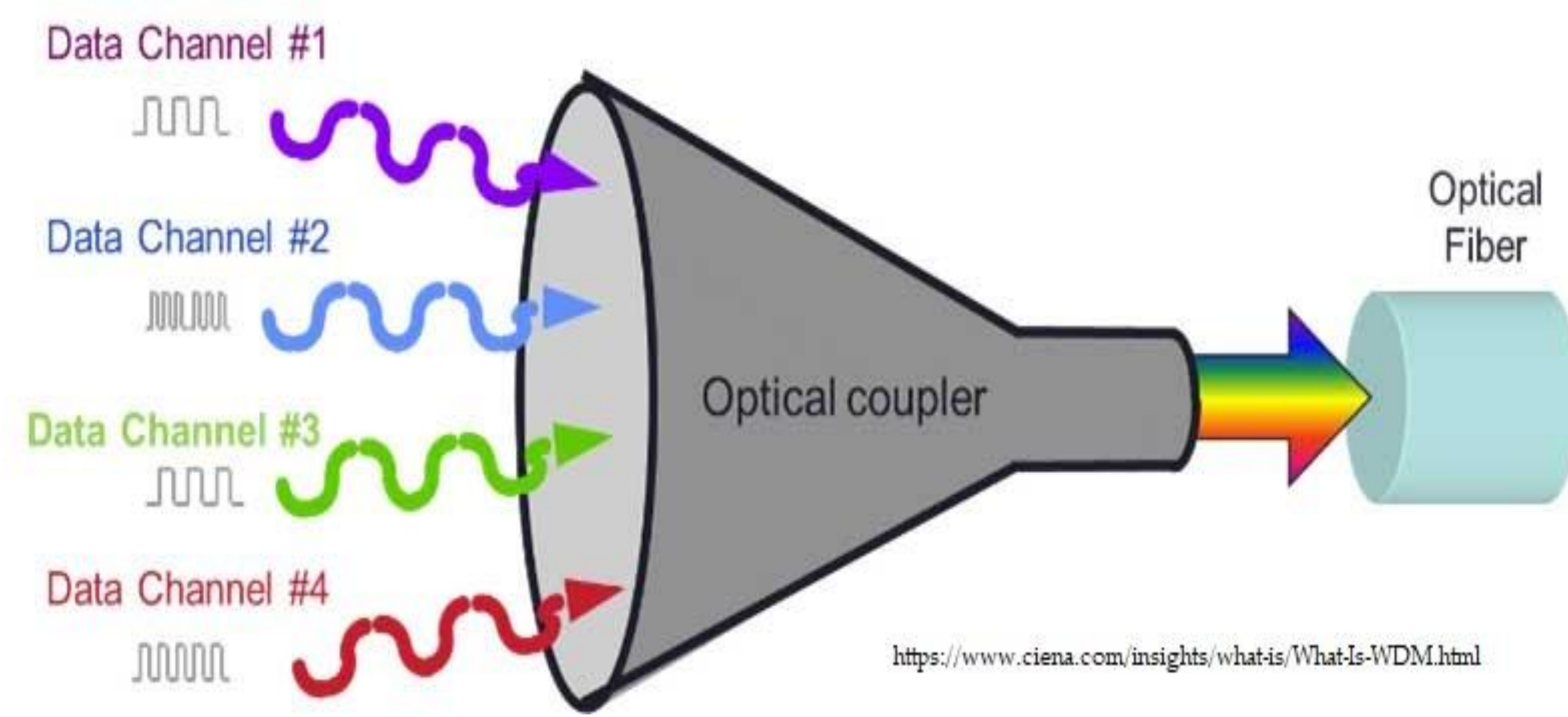
https://www.lumenci.com/post/optical-transceivers



https://www.elprocus.com/

Later innovation: WDM
(Wavelength Div. Multiplexing. Colours for concept only)

Coarse (CWDM)typically 18 ch
Dense (DWDM) typically 200 ch



Some Optic-Fibre Connectors

https://mefiberoptic.com/product-category/fiber-optic-connector/

Practical Fibre Example:
(NBN FTTP Building entry)

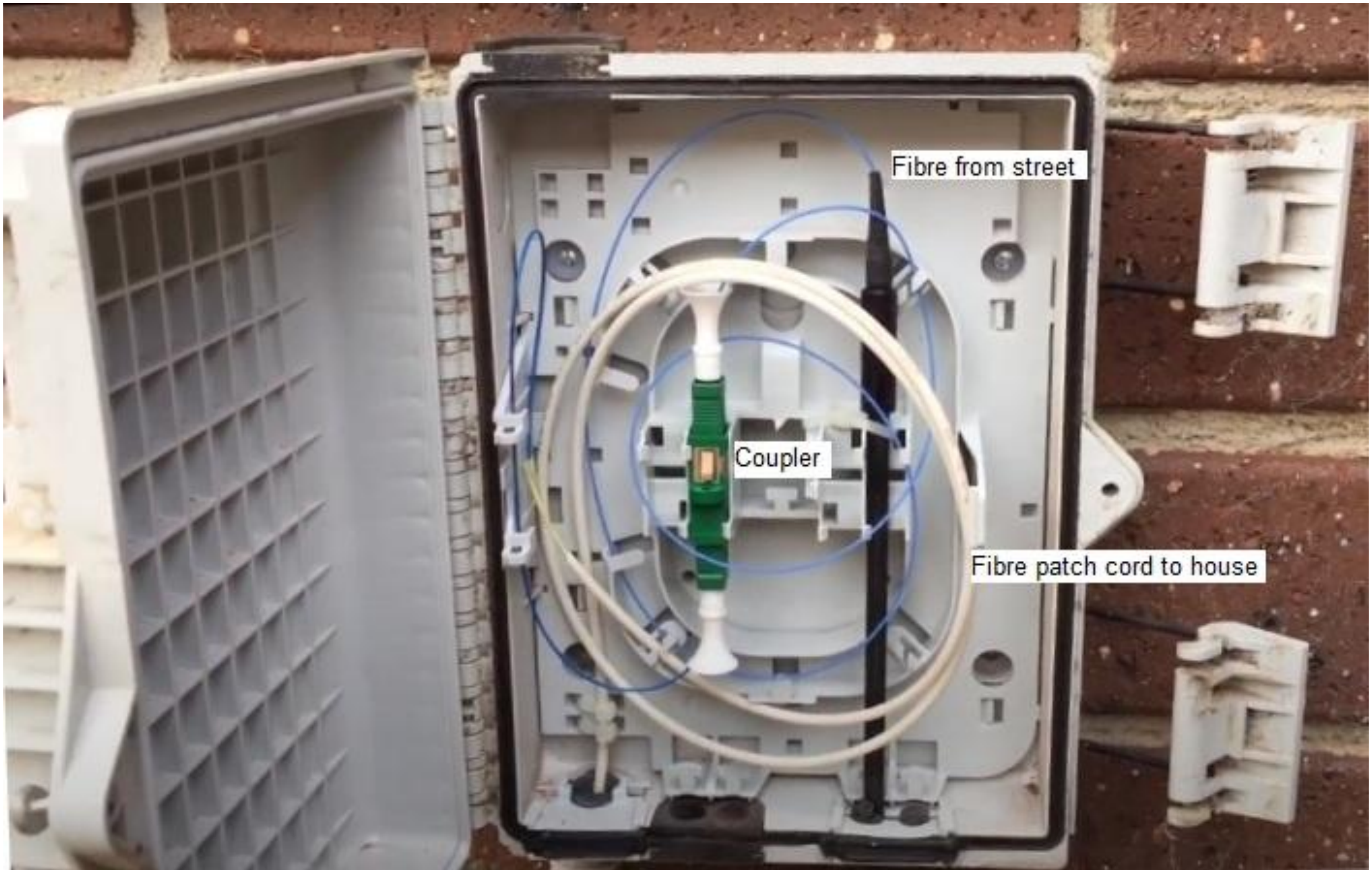


Image source: https://www.youtube.com/watch?v=kChdJcHsYgo

The Internet

- The Internet is a **global**, "wide area network" that connects computer and communications systems across the world
- **95%** of the Internet **"backbone"** comprises **high-bandwidth optical fibre data lines**
- These lines connect major Internet hubs that distribute data to other locations, such as web servers and Internet Service Providers

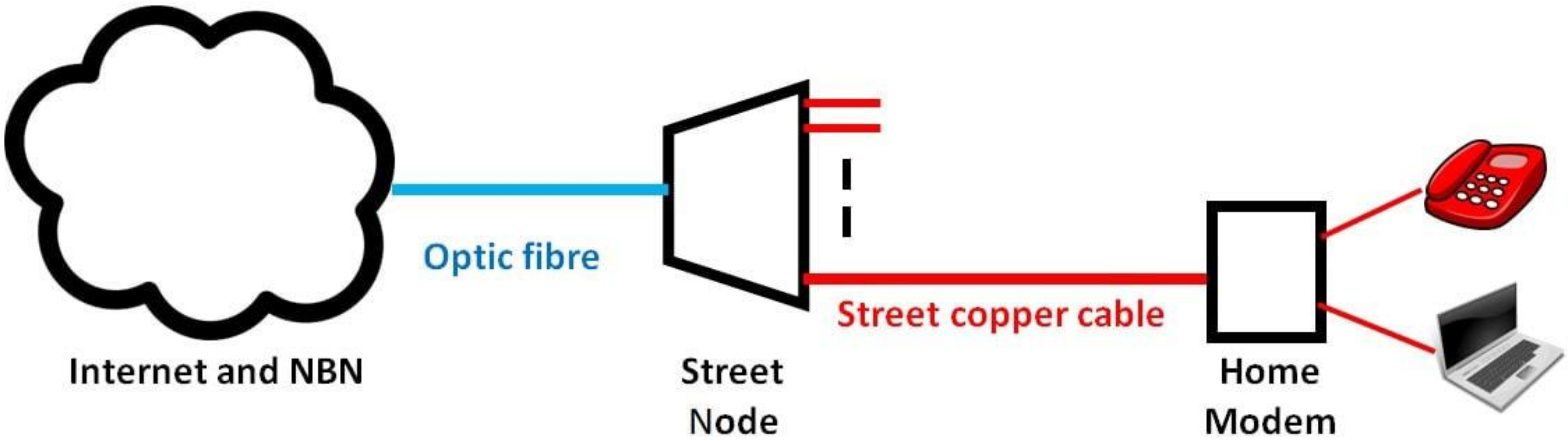
(Orig. source https://techterms.com/definition/internet)

National Broadband Network (NBN)

- An integrated, high speed, digital data communications network. Covers Australia
- Enables customers to access the internet
- The **"backbone"** transmission system is via **optic-fibres**
- Local connections can be by optic-fibre, copper cable, satellite or radio (mobile etc.) systems

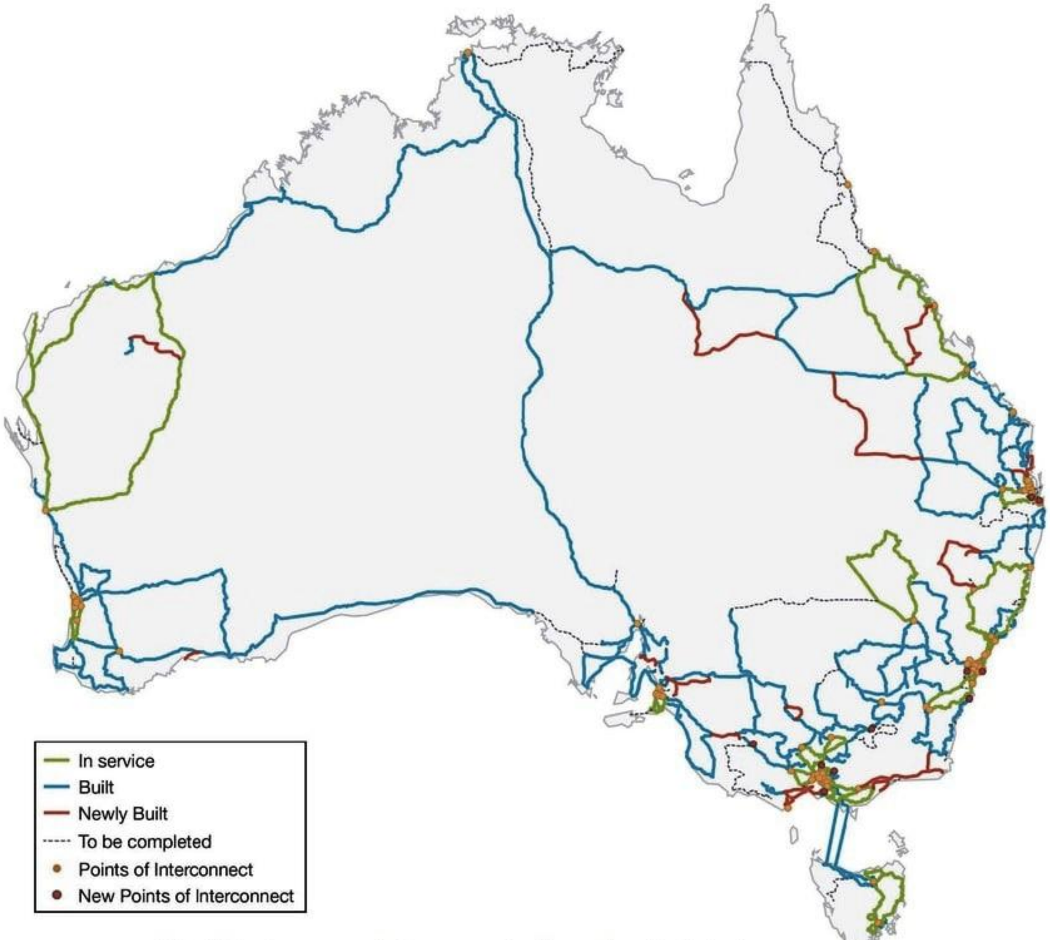
NBN

(FTTN FTTB FTTC HFC FTTP)



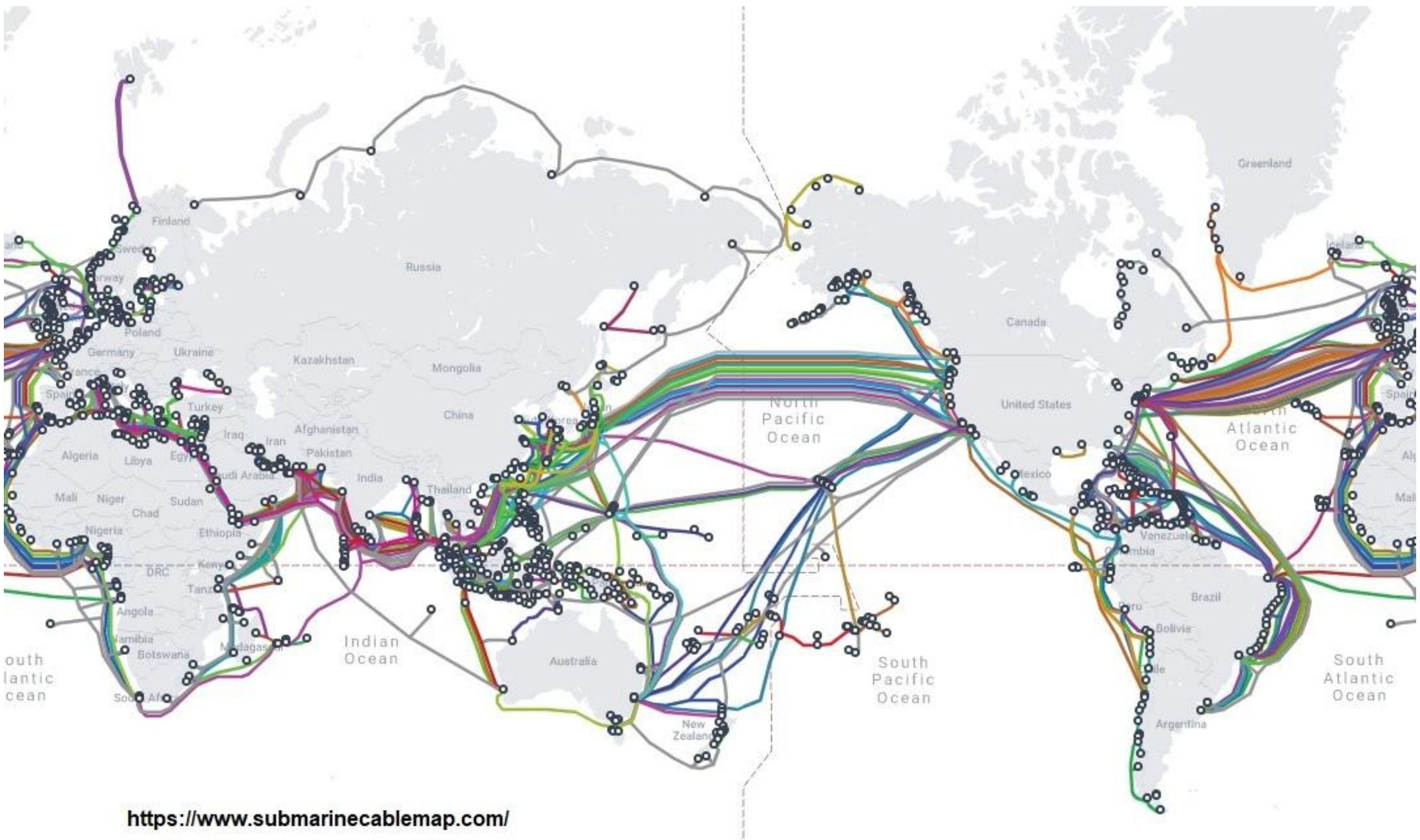
NBN Fibre to the node (FTTN)

NBN Fibre network

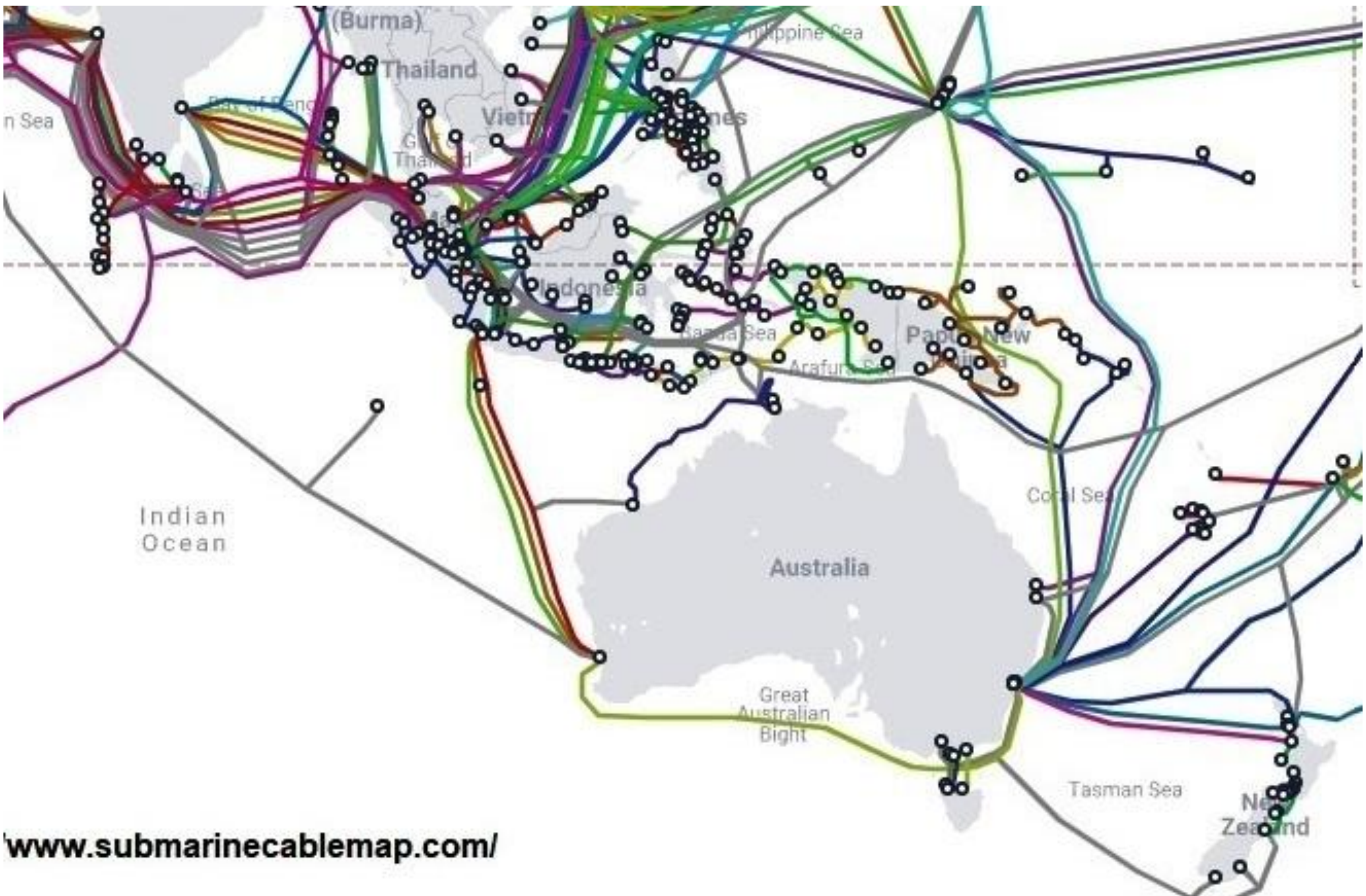


https://blog.jxeeno.com/nbn-co-reveals-18-month-rollout-plan/

World Optic Fibre Network

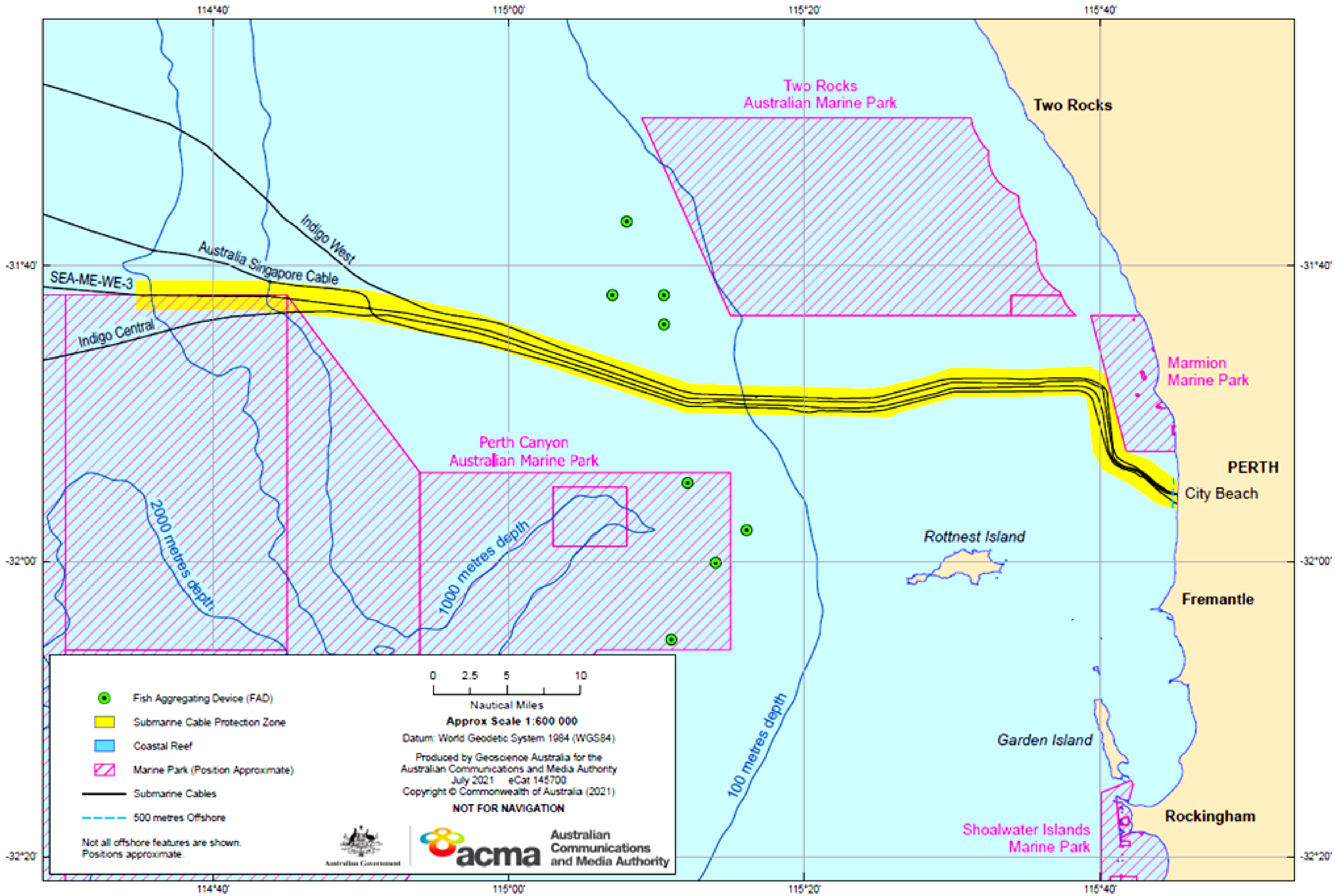


Australia: Subsea Fibre Cables



'www.submarinecablemap.com/

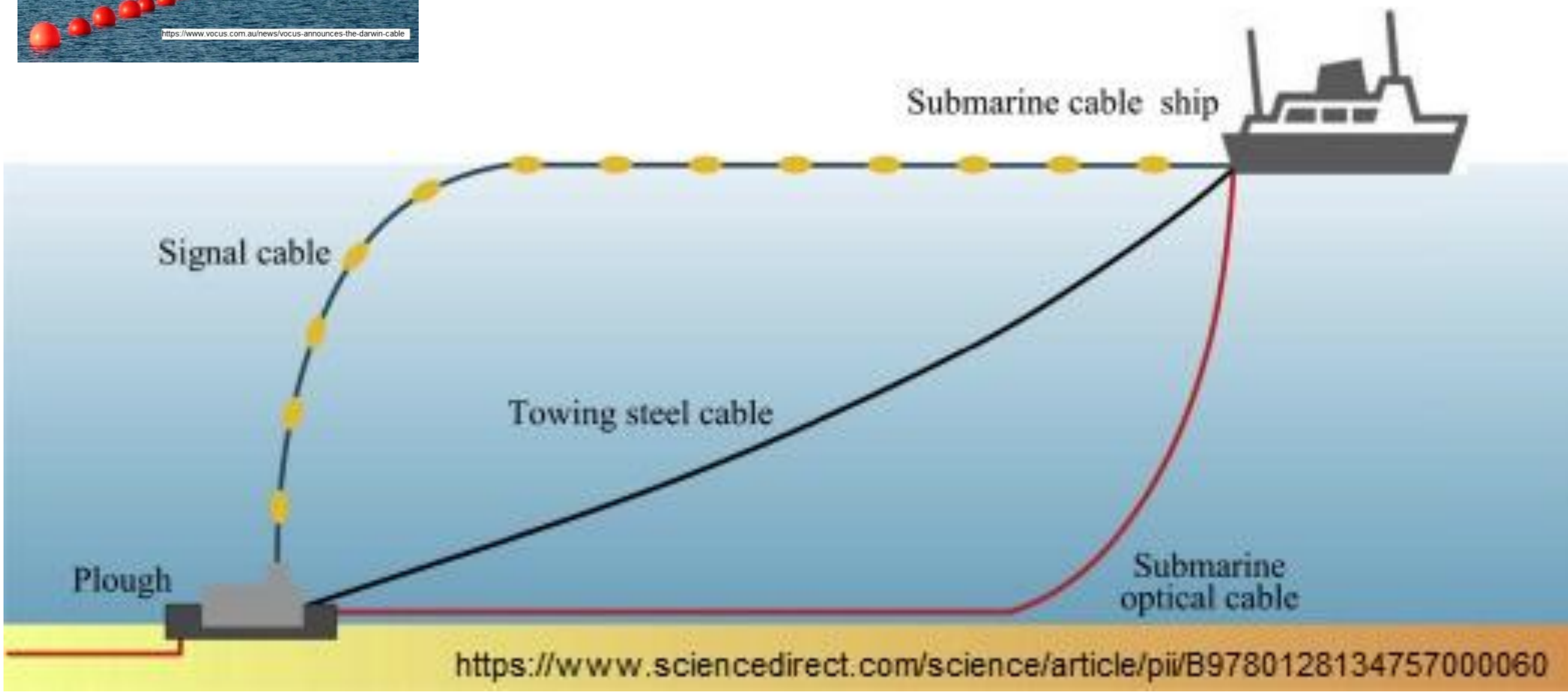
Submarine Cable Protection Zone off Perth, WESTERN AUSTRALIA



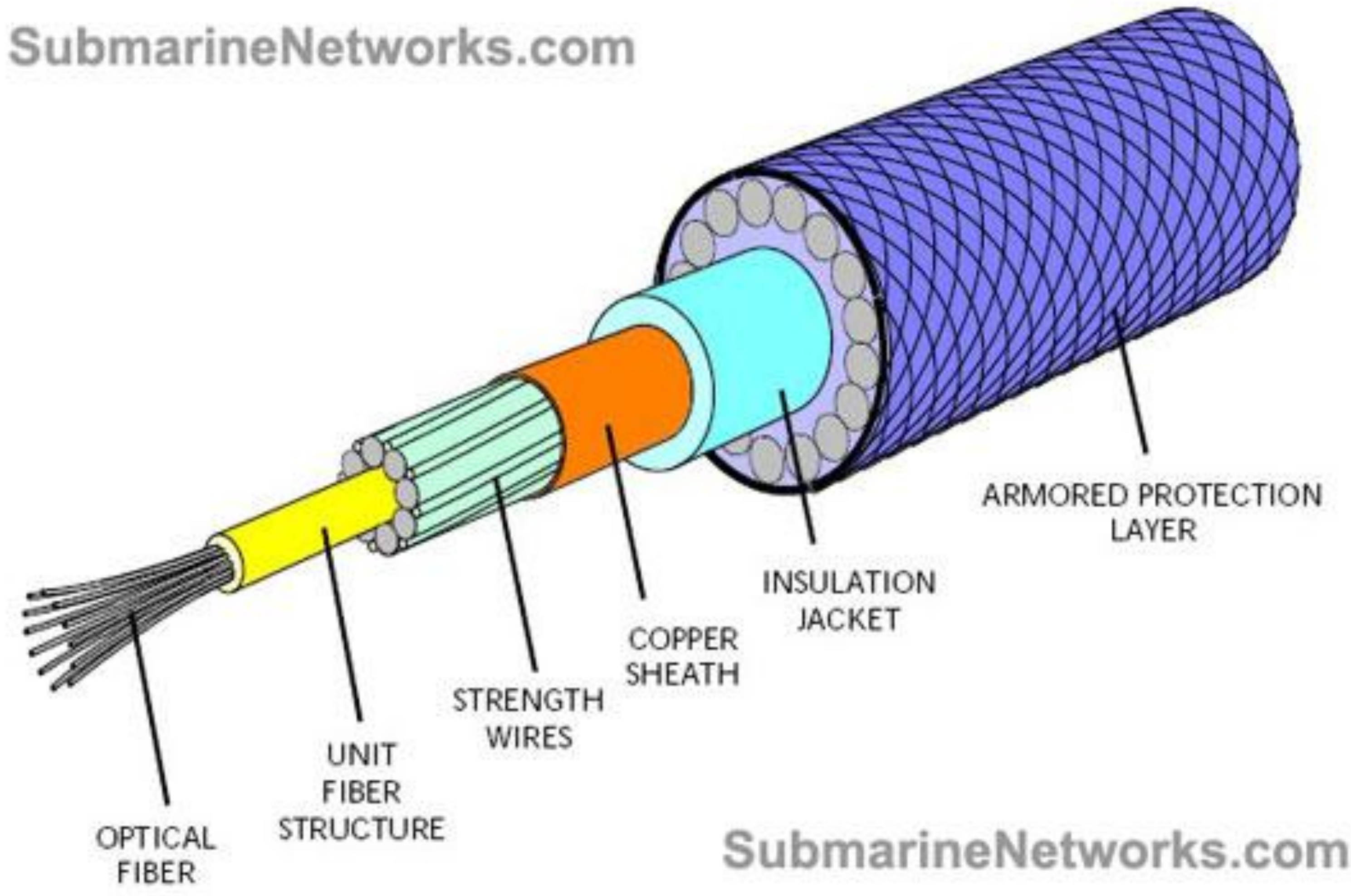
https://www.acma.gov.au/zone-protect-perth-submarine-cables

(Most general activities permitted 0-500m from LWM)

Cable Laying Ships



Typical Subsea Cable



Subsea Fibre Cable (IT&E Guam)

Optical repeaters

Repeaters are required for optical signal amplification.

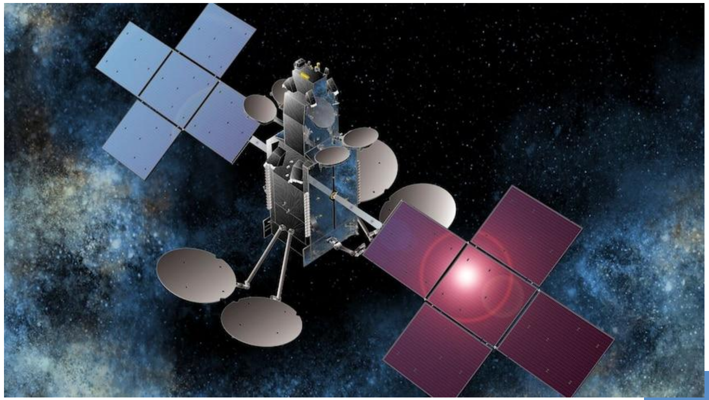
Placed every 60km to 70km.

Powered over the metallic layers in the cable from equipment located on-shore

Optical amplifiers use a doped optical fibre as a gain medium to amplify an optical signal. They are related to fibre lasers

Image and info. sources:
https://www.submarinenetworks.com/ and https://en.wikipedia.org/

NBN Sky Muster Satellite
(the minor player)



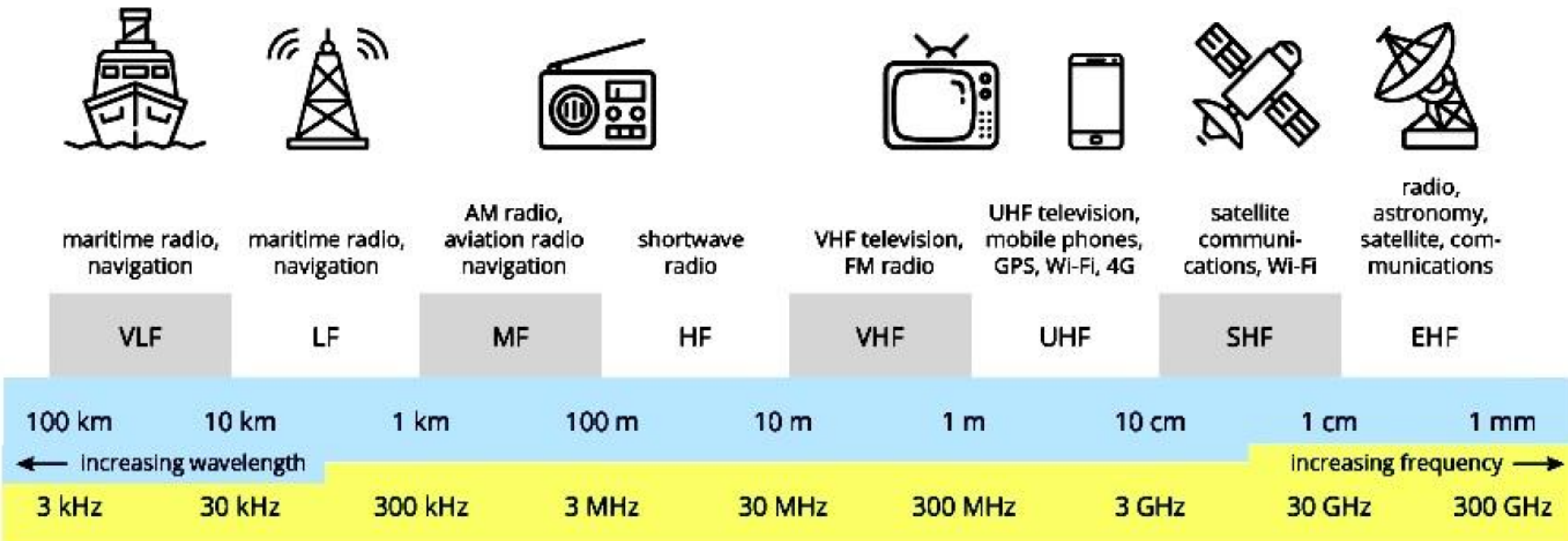
https://www.abc.net.au/news/rural/2015-09-22/skymuster-satellite-launch/6793720

https://www.nbnco.com.au/blog/the-nbn-project/bound-for-bourke-visiting-a-sky-muster-ground-station

Thank You!

Presented with thanks to the sources listed in the presentation

https://terasense.com/terahertz-technology/radio-frequency-bands/



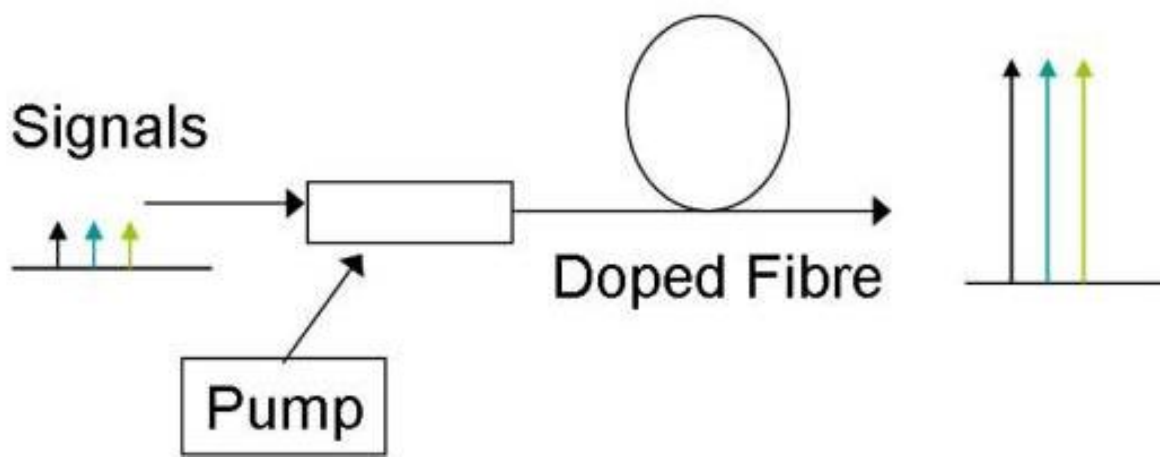
Optical amplification

https://atlantic-cable.com/Article/SA/57/index.htm
https://www.rp-photonics.com/

Optical pumping essentially means to inject light in order to excite the medium or some of its constituents into other (usually higher-lying) energy levels. In the context of laser amplifiers, the goal is to achieve optical amplification via stimulated emission (photon emission is triggered by other photons)

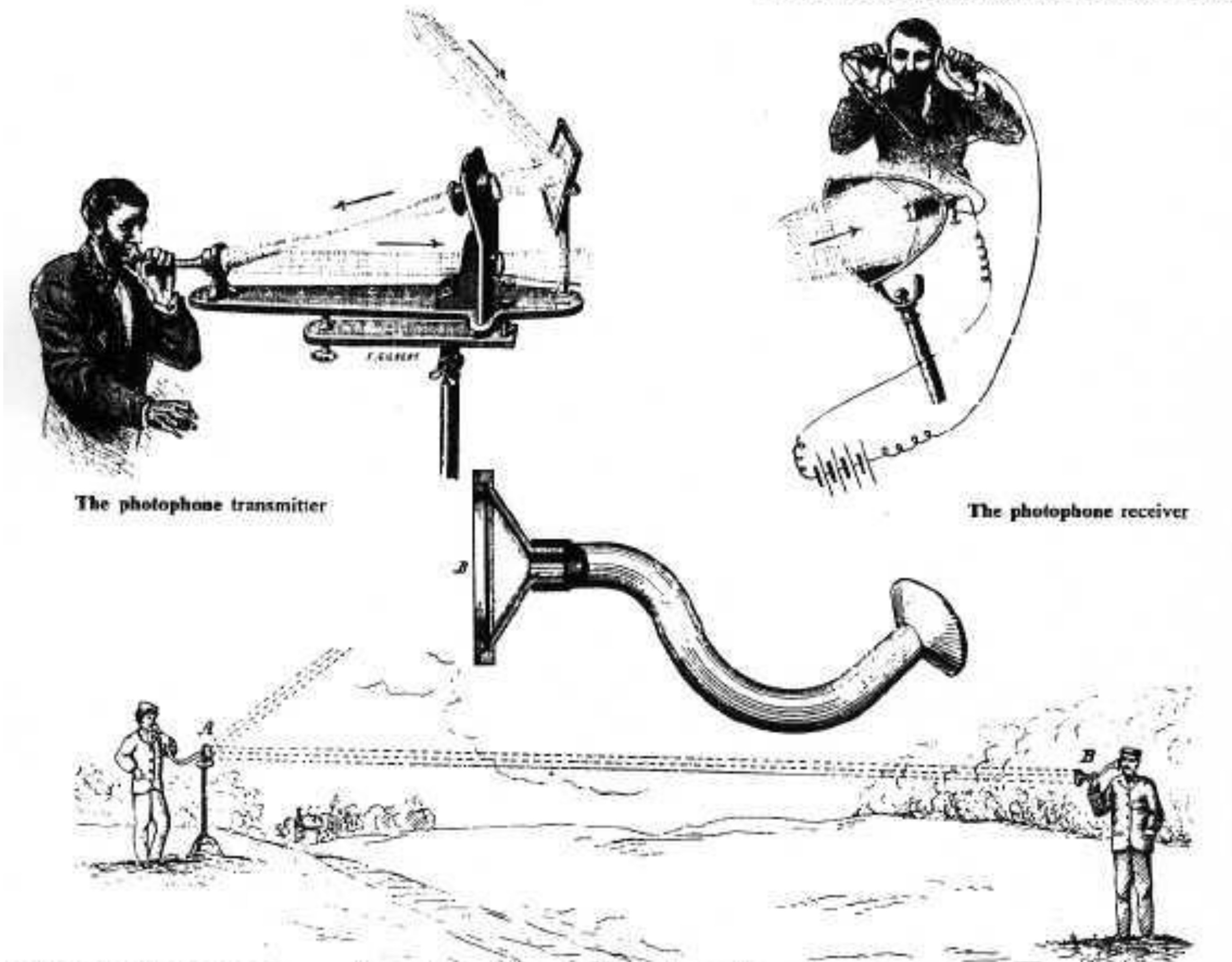
The Erbium Doped Fibre Amplifier (EDFA) was first demonstrated by Professor David N Payne and his team at Southampton University (UK) in 1986.

In simple terms, the EDFA consists of a length of optical fibre doped with ions of the rare earth element erbium. Within the fibre the optical transmission signal wavelengths are mixed with a high powered signal from a pump laser. This excites the ions in the erbium and they give up this energy in the form of additional photons in phase with the incoming data signal, thus amplifying it.



Bell Photophone 1880

https://commons.princeton.edu/josephhenry/photophone/



Bell's photophone made sound waves vibrate a beam of reflected sunlight. The receiver changed the varying light intensity back into sound. Bell found that selenium's electrical resistance changed for different light intensities, and equipped his radiophone receiver with the first true "photoelectric" cells.

The refractive index of fibre core is always greater than that of the cladding. Light is guided through the core, and the fibre acts as an optical waveguide.

light travels fastest through least optically dense materials

Material	Index of Refraction	
Vacuum	1.0000	<--lowest optical density
Air	1.0003	
Ice	1.31	
Water	1.333	
Ethyl Alcohol	1.36	
Plexiglas	1.51	
Crown Glass	1.52	
Light Flint Glass	1.58	
Dense Flint Glass	1.66	
Zircon	1.923	
Diamond	2.417	
Rutile	2.907	
Gallium phosphide	3.50	<--highest optical density

https://www.physicsclassroom.com/class/refrn/Lesson-1/Optical-Density-and-Light-Speed

Refraction of light

As a light ray passes from one transparent medium to another, it changes direction. How much that light ray changes its direction depends on the refractive index of the materials

Refractive Index (n)

- **n = c/v**
- **c**. speed of light in a vacuum - approx 300 000 km/s
- **v**. speed of light in a material

Snell's Law (1621) When light passes from one transparent material to another, it bends according to Snell's law

- Light travelling across an interface from a higher refractive index medium to a lower refractive index medium will bend away from the normal.

Total Internal Reflection

If the light hits the interface at any angle larger than the critical angle, it will not pass through to the second medium. All of it will be reflected back

Binary prefixes vs Decimal/Metric/SI prefixes

- In computing, the units *bit* and *byte* are often expressed using powers of 2 and the small difference between 1024 (2^{10}) and 1000 (10^3) led the IT specialists to adopt the use of kilo - to mean 1024 many decades ago. This was not SI standard
- Decimal prefixes (aka metric or SI) are often used with their original meaning in computing. There was the need of a different set of *binary* prefixes to resolve this ambiguity
- Telecommunications transfer speeds (b/s) and processor speeds (Hz) always use SI decimal prefixes

IEC/IEEE binary prefixes			
* The prefixes zebi- and yobi- were added on August 2005, in the third edition of IEC 60027-2			
Prefix	**Symbol**	**Value**	**Decimal Equivalent**
kibi-	Ki	$1024^1 = 2^{10}$	1 024
mebi-	Mi	$1024^2 = 2^{20}$	1 048 576
gibi-	Gi	$1024^3 = 2^{30}$	1 073 741 824
tebi-	Ti	$1024^4 = 2^{40}$	1 099 511 627 776
pebi-	Pi	$1024^5 = 2^{50}$	1 125 899 906 842 624
exbi-	Ei	$1024^6 = 2^{60}$	1 152 921 504 606 846 976
zebi- *	Zi	$1024^7 = 2^{70}$	1 180 591 620 717 411 303 424
yobi- *	Yi	$1024^8 = 2^{80}$	1 208 925 819 614 629 174 706 176

SI prefixes

Prefix	Symbol	Value	Name
kilo	k	10^3	Thousand
mega	M	10^6	Million
giga	G	10^9	Billion (modern)
tera	T	10^{12}	Trillion
peta	P	10^{15}	Quadrillion
exa	E	10^{18}	Quintillion
zetta	Z	10^{21}	Sextillion
yotta	Y	10^{24}	Septillion