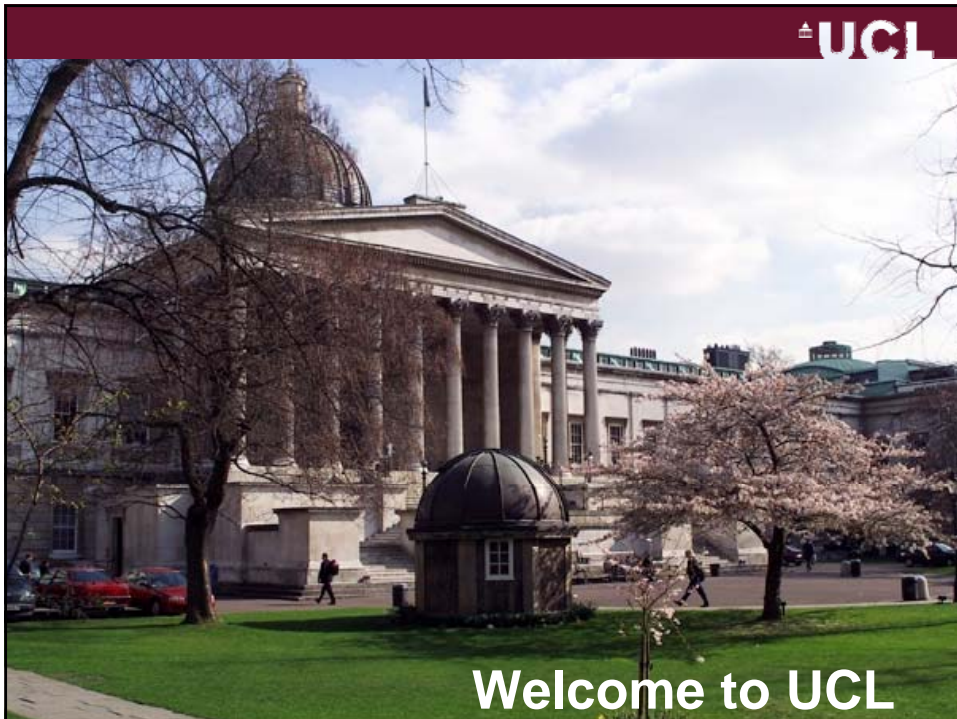




## **21ST CENTURY COMMUNICATIONS**

John Mitchell  
Department of Electronic and Electrical Engineering  
University College London

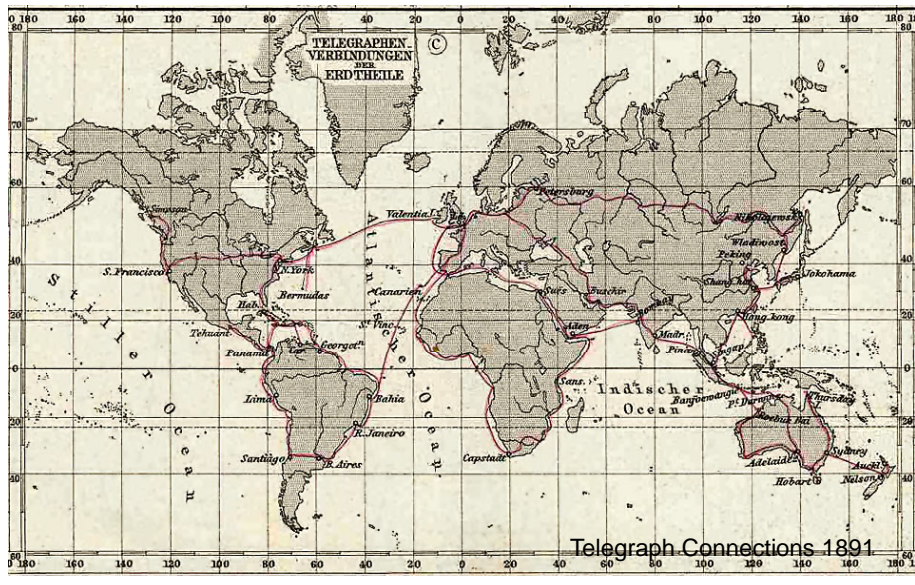


**Welcome to UCL**

### Early Communications



### Telegraphy - 1844



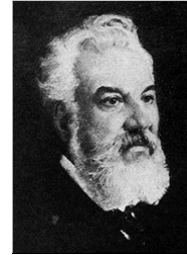
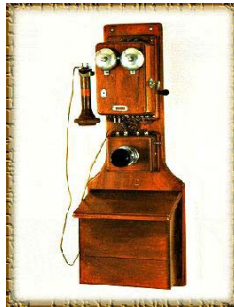
## Telephony - 1876

1890 Hasler  
LB Drop  
Switchboard



Invented by **Alexander Graham Bell** who studied at UCL

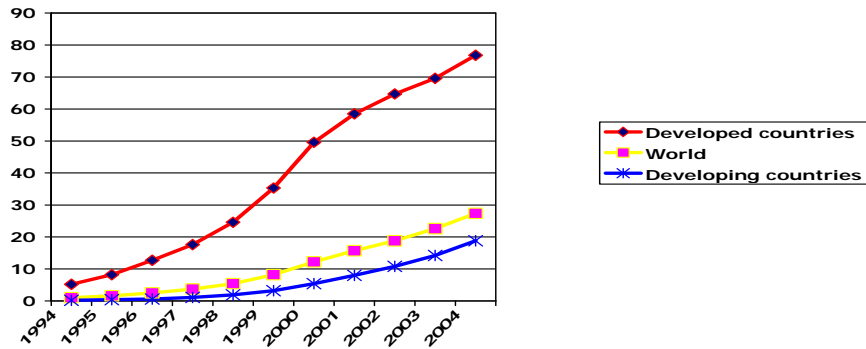
1890 Hasler LB  
telephone



- Originally Sold in pairs!

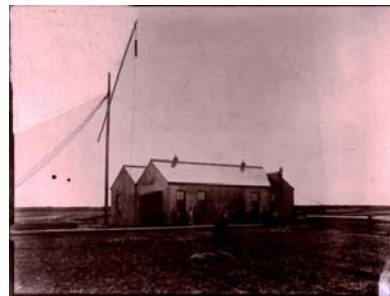
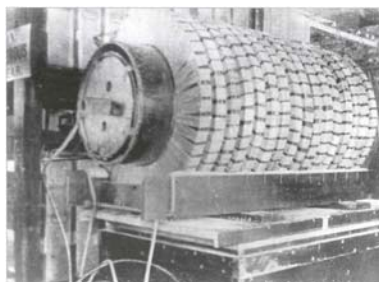
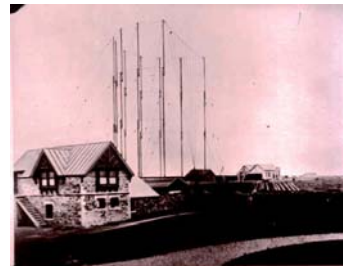
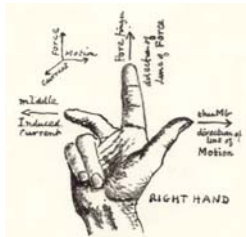
## Mobile Telephony

Mobile Telephone Subscribers  
per 100 inhabitants



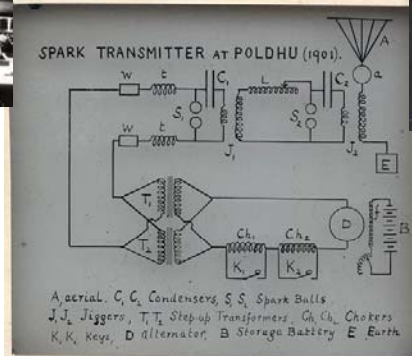
## Electronic and Electrical Engineering

- Founded in 1885 by Prof Sir John Ambrose Fleming
- Inventor of the Diode Valve
- Left and Right Hand Rules



- 1900 Work begin on the Poldhu Site, Cornwall

Courtesy of Marconi PLC



- 1901 Marconi successfully receives the first transatlantic transmission

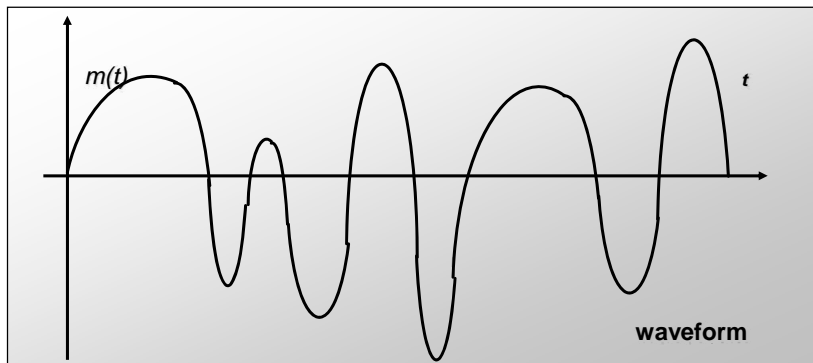


Courtesy of Marconi PLC

What has driven communications today?

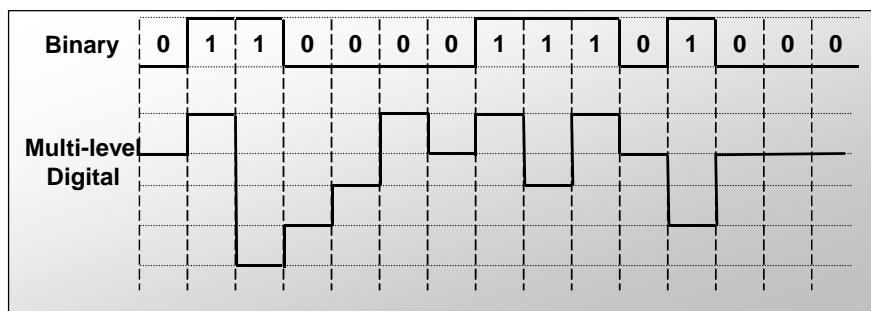
## Digital Signals

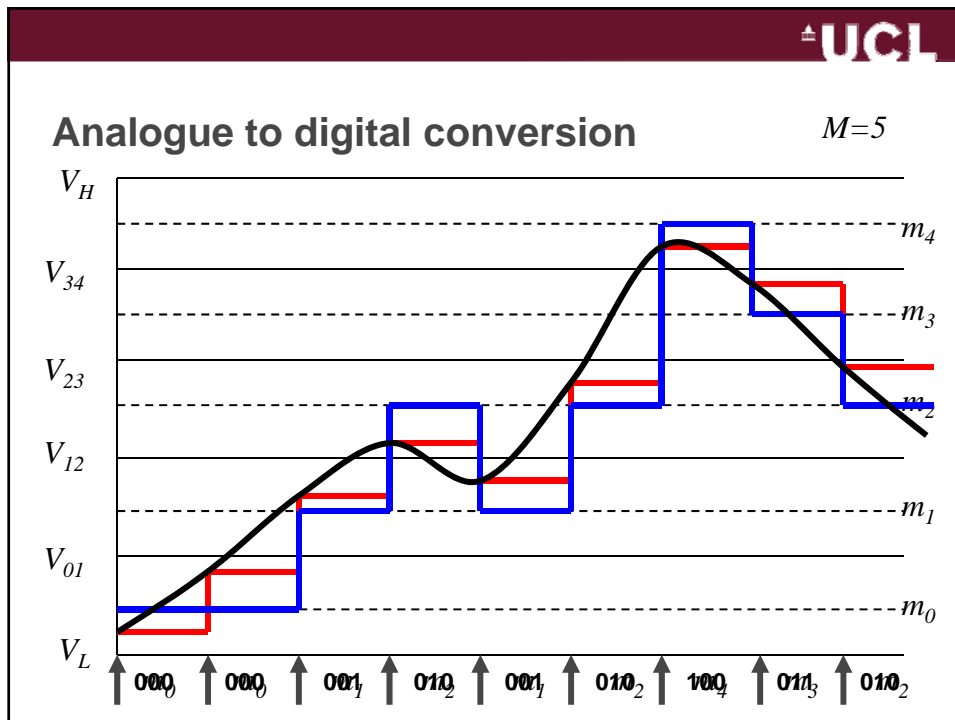
- Telephones for many years used Analogue signals
- A voice signal, for example, is analogue.



## Digital Signals

- Digital signals have advantages
  - Higher Immunity to Noise
  - Able to be compressed and manipulated.





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### Digital Signals

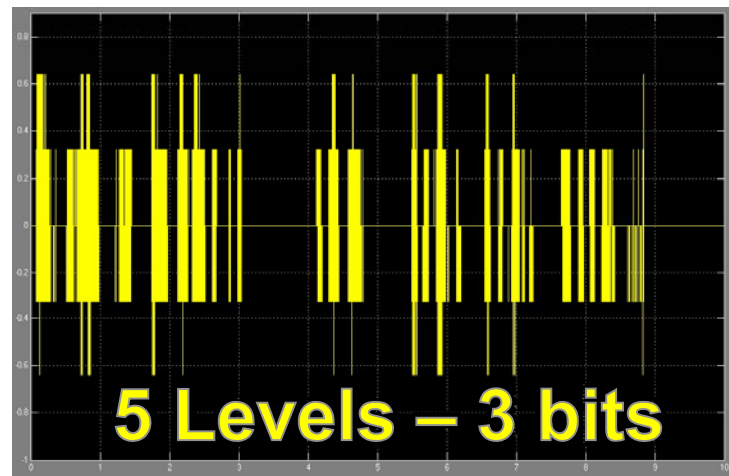
- Each level is represented by a code
- It is easy to see that the more levels we have the more accurately we reproduce the signal
- How many bits do you think we need?

How many bits?

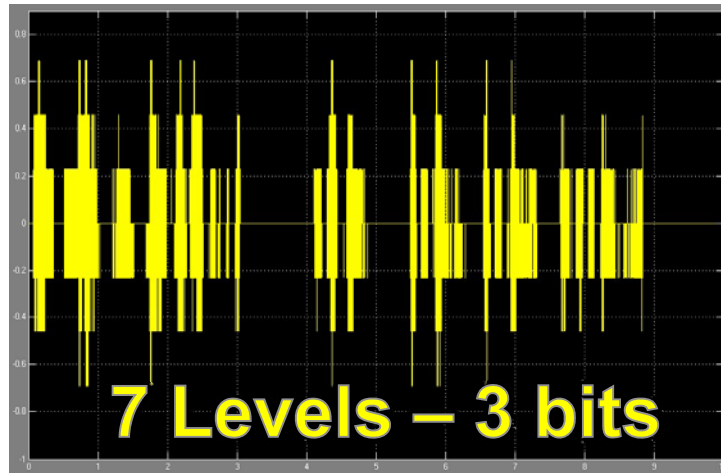
Can you recognise the Clip?



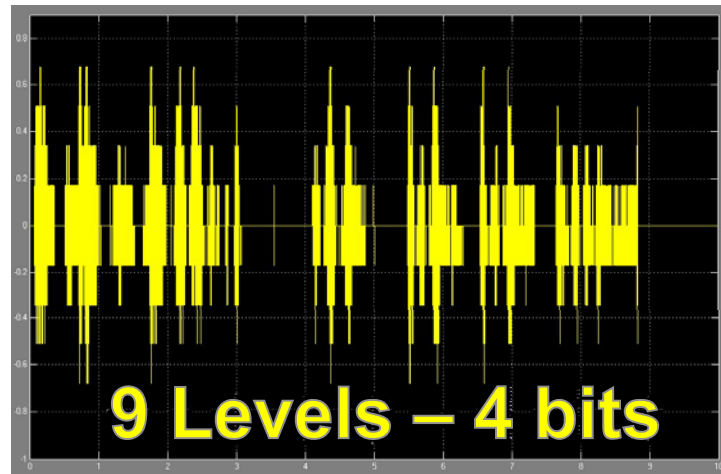
How many bits?



How many bits?

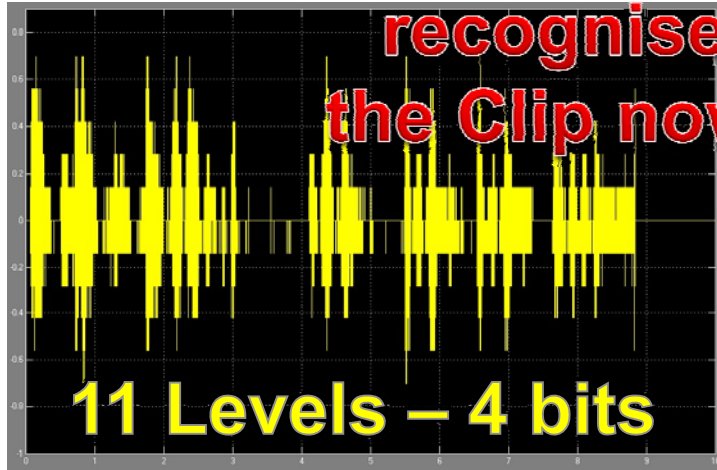


How many bits?

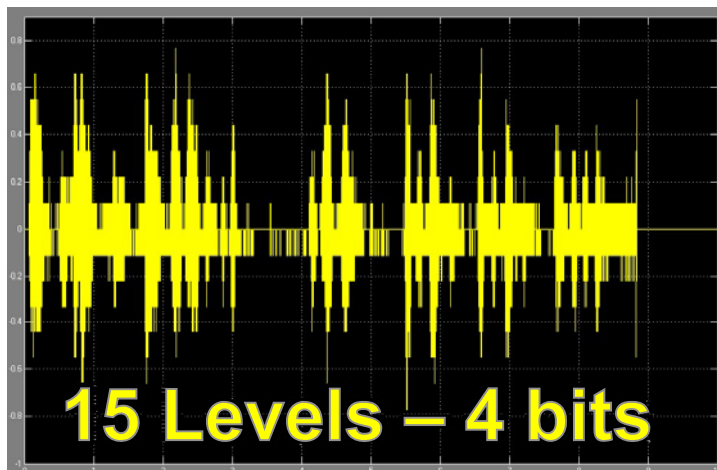


How many bits?

Can you recognise the Clip now?

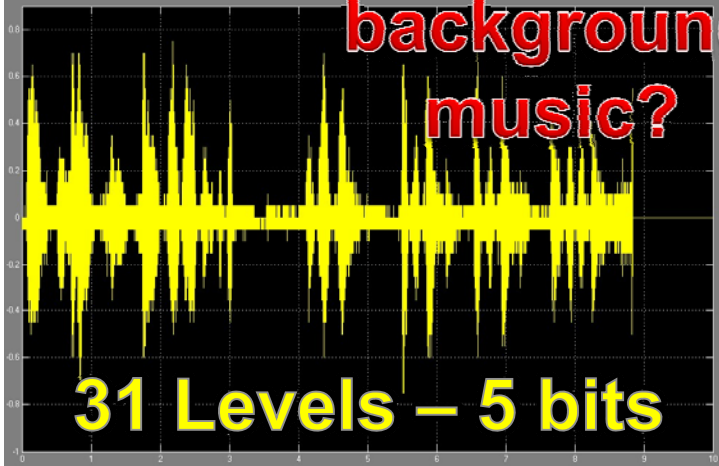


How many bits?




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How many bits? **Also notice the background music?**

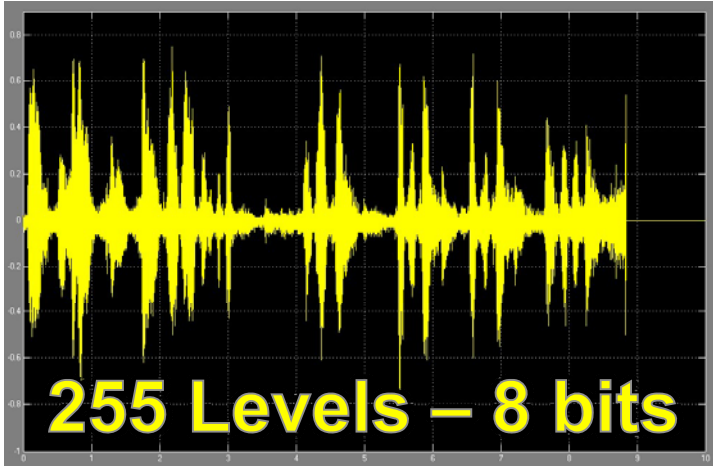


**31 Levels – 5 bits**




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How many bits?



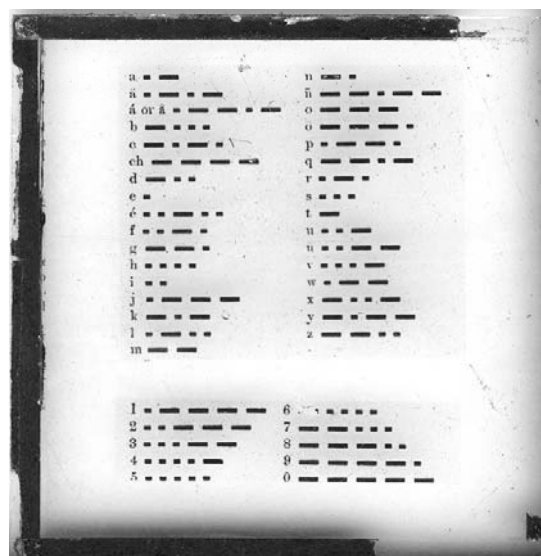
**255 Levels – 8 bits**



- The CD player example you'll see later uses **16 bits** or **65,536 levels**



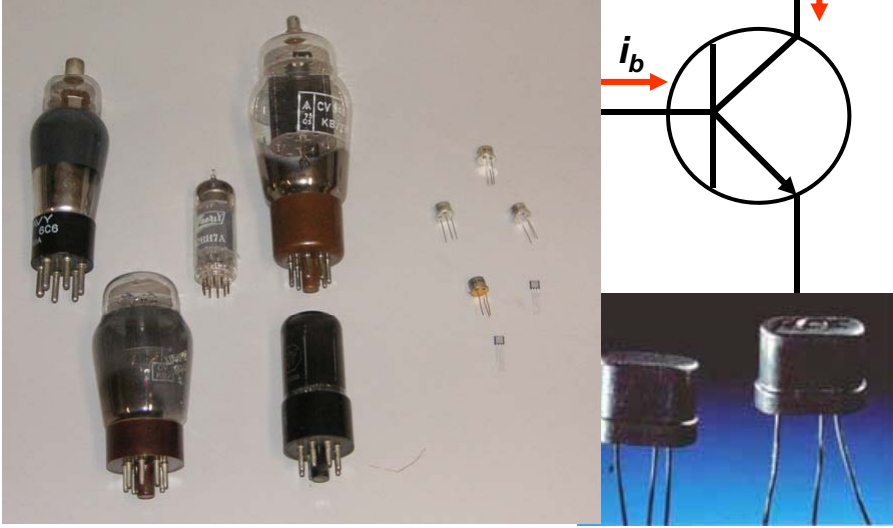
## Morse Code



Copy of Sir  
Ambrose Fleming  
lecture slide  
Circa 1910

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## The Transistor

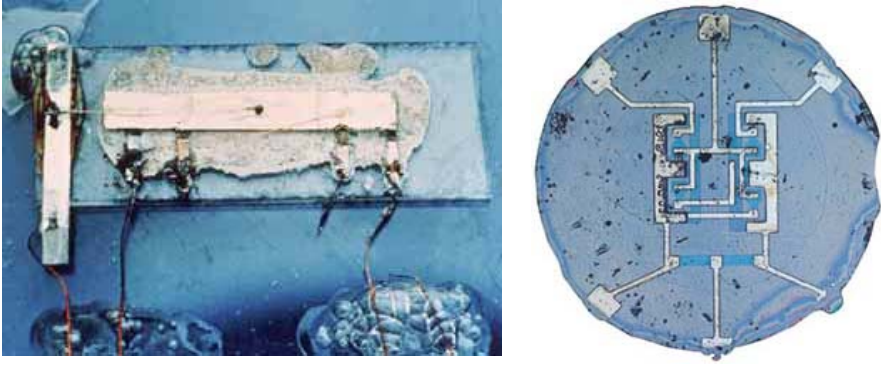


The image displays a variety of transistors. On the left, there are several vacuum tube transistors of different sizes and shapes, some with labels like '6X4', '6X4A', and '6X4B'. To the right, there are several small, modern solid-state transistors. In the top right corner, a schematic diagram of a Bipolar Junction Transistor (BJT) is shown, with an arrow labeled  $i_b$  entering the base and an arrow labeled  $i_c$  exiting the collector. Below the schematic, a photograph shows two TO-18 transistors with their characteristic three leads.

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## Integrated Circuits

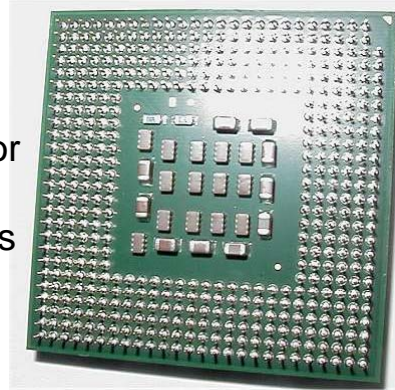
- Jack Kilby of Texas Instruments made this, the first integrated circuit, in 1958



The image shows two views of the first integrated circuit. On the left, a photograph shows the physical device, a small rectangular chip with several wires attached, mounted on a blue surface. On the right, a photograph shows the circular silicon die with its intricate circuitry etched onto its surface.

## IC's Today

- Basic Pentium 4 – 55 Million Transistors on a chip that is 131 mm<sup>2</sup>
- An Intel Core 2 Duo processor has 291 million transistors on a 143 mm<sup>2</sup> die (65nm process)
- Core 2 Quad has 582 million transistors
- New Processor (codename NEHALEM) has 731M transistors over four cores



## Voice Compression

- Because we know some details about how speech is formed, we can use this information to reduce the bandwidth require, without overtly effecting the quality

Codec	Algorithm	Bit Rate (Kbps)
ITU G.711	PCM (Pulse Code Modulation)	64
GSM - Full Rate	RPE-LTP (Regular Pulse Excitation Long-Term Prediction)	13
OPEN LPC	LPC (Linear Predictive Coding)	1.4

## Error Correction

- Before the data is transmitted over the air it is encoded using what are called error correcting codes.
- These allow bits that are received incorrectly to be corrected
- CD players use the same process

## Error Correction

- The error correcting codes add '*redundancy*' (extra information) to the data so that errors can be corrected
- Human language has a lot of redundancy
- The brain can '*decode*' the information even when someone is talking in a noisy environment.

- To make sure messages get through correctly people use the *phonetic alphabet*

<b>A</b> - Alpha	<b>J</b> - Juliet	<b>S</b> - Sierra
<b>B</b> - Bravo	<b>K</b> - Kilo	<b>T</b> - Tango
<b>C</b> - Charlie	<b>L</b> - Lima	<b>U</b> - Uniform
<b>D</b> - Delta	<b>M</b> - Mike	<b>V</b> - Victor
<b>E</b> - Echo	<b>N</b> - November	<b>W</b> - Whiskey
<b>F</b> - Foxtrot	<b>O</b> - Oscar	<b>X</b> - X-ray
<b>G</b> - Golf	<b>P</b> - Papa	<b>Y</b> - Yankee
<b>H</b> - Hotel	<b>Q</b> - Quebec	<b>Z</b> - Zulu
<b>I</b> - India	<b>R</b> - Romeo	

- cdnuolt blveiee taht I cluod aulacly uesdnatnrd waht I was rdgnieg

### THE PAOMNNEHAL PWEOR OF THE HMUAN MNID

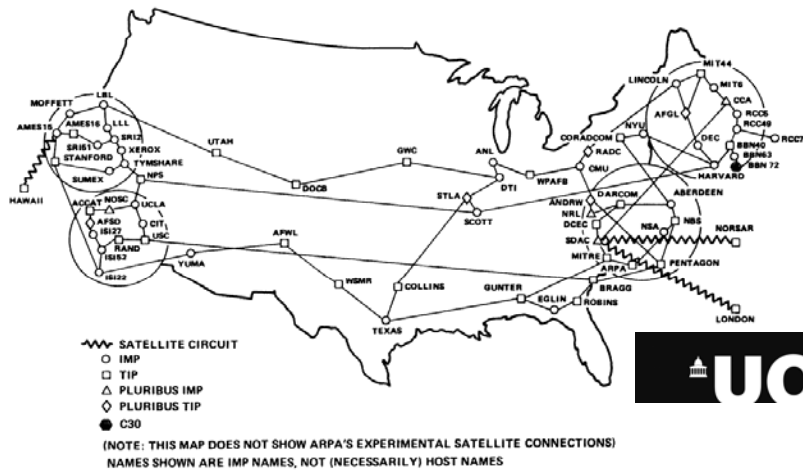
Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttar in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit porbelm. Tihis is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

Amzanig huh?

## What about the internet?

## The Internet

ARPANET GEOGRAPHIC MAP, OCTOBER 1980



## The Internet

- **Internet Traffic** has **doubled every 100 days**. In **1994**, a mere **3 million** people were connected to the Internet. By the end of **1997**, more than **100 million** were using it.
- **Radio** existed for **38 years** before it had **50 million** listeners, and **television** took **13 years** to reach that mark. The **Internet** crossed the line in **just four years**.

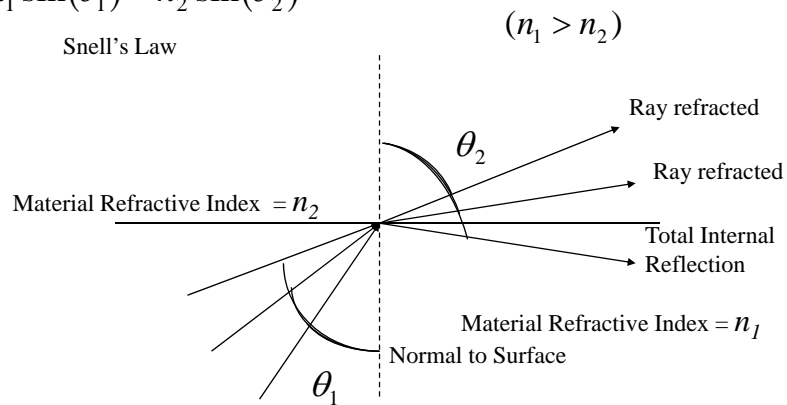
## What enables the Internet

- We take the capacity and the fact the messages 'instantly' span the globe for granted
- but all this is enabled by the high capacity **Optical Fibre** links that connect the world

## Remember Snell's Law

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

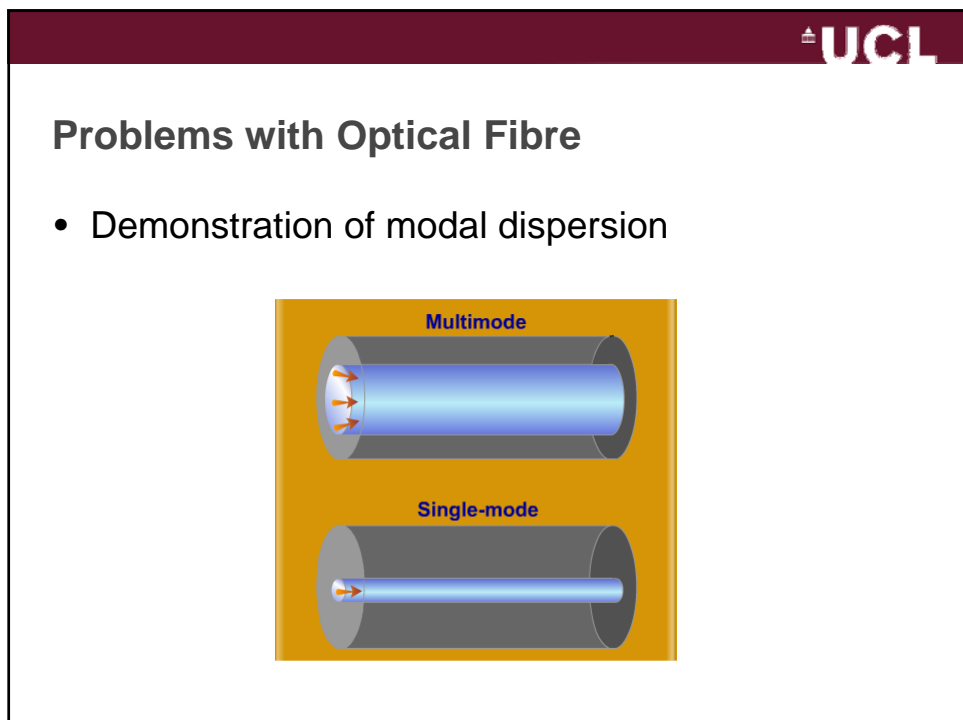
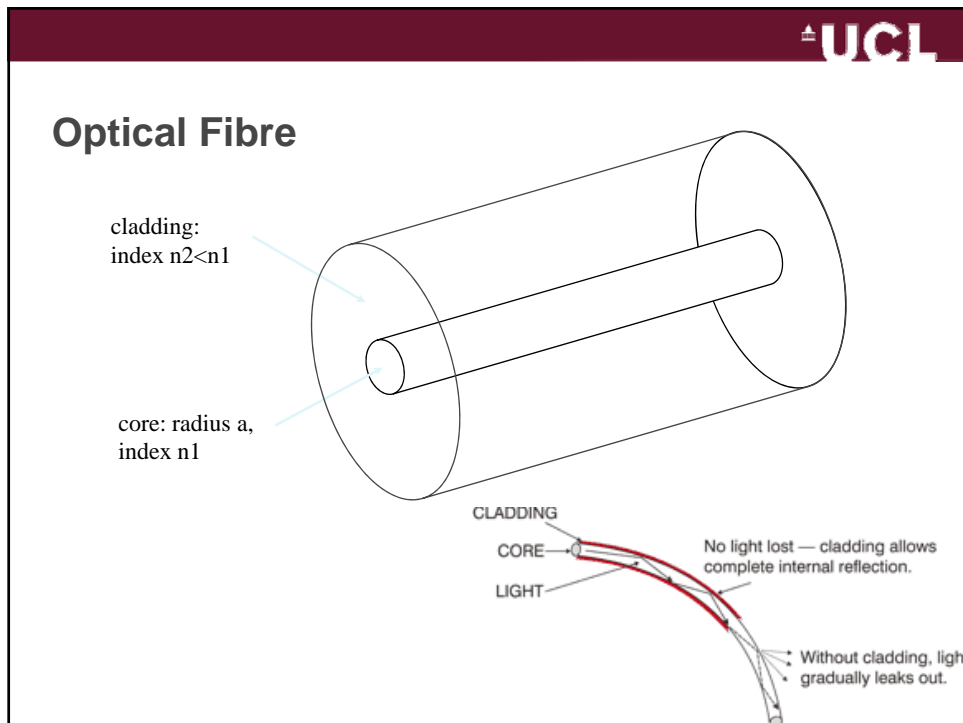
Snell's Law



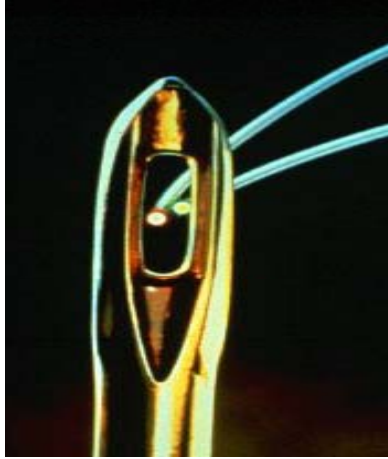
## This has been known for some time

- In 1870, John Tyndall, using a jet of water that flowed from one container to another and a beam of light, demonstrated that light used internal reflection to follow a specific path.

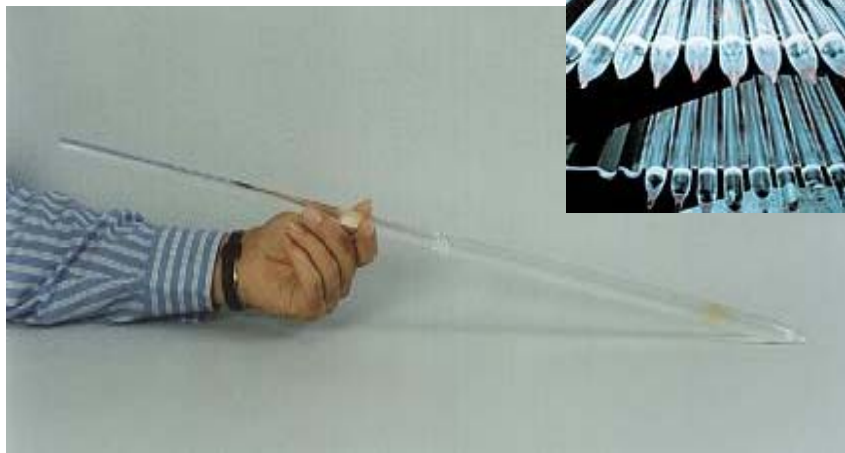




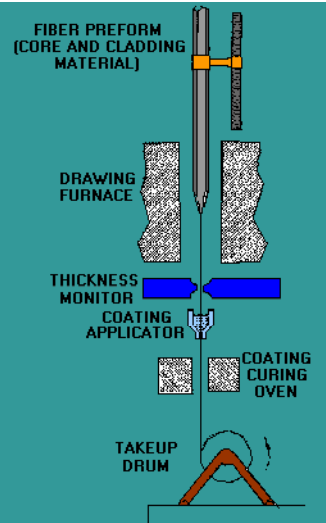
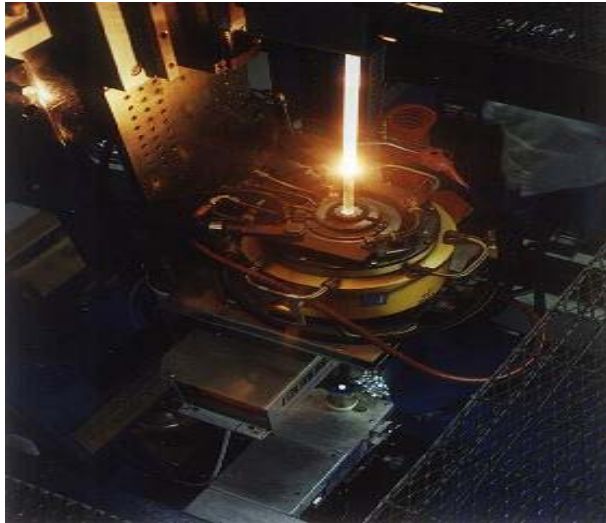
### How do we make it?



### Optical Preform



### Preform Heating



### Optical fibre submarine systems



### How much information can a fibre carry?

- 1 telephone call uses 64kbit/s  
**64,000 bits/s**
- Typical Internet connections are 8Mbit/s  
**8,000,000 bits/s**
- A DVD contains 4.7GBytes (37.6Gbit) of data  
**37,600,000,000 bits/s**

**How much information can  
an optical fibre carry?**

### How much information can a fibre carry?

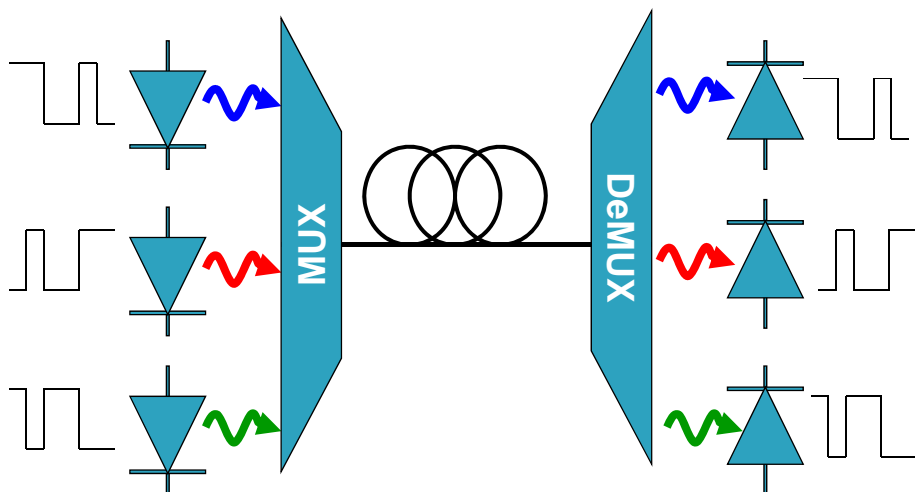
- A single optical fibre has been shown to carry  
**26,300,000,000,000 bits/s**
- Over 400 Million Telephone Calls
- 700 DVDs per second

**26.3 Tbit/s**

## How?

- We could turn the laser on and off 26,300 billion times each second
- At the moment this is not technically possible – only about 40 billion is possible
- So how was this done?
- Well, we know that light has different colours

## Multiple Channels



## UK Access Network

- The existing access network is dominated by twisted copper pairs in most countries
- The BT access network consists of:
  - 34 million copper pairs,
  - 250000 km of underground ducts
  - 74000 primary connection points
  - 3.7 million manholes and joint boxes,
  - 3 million distribution points,
  - 4 million poles
  - about 23 million customers



Thank You!