# Optical Multiplexing and Demultiplexing

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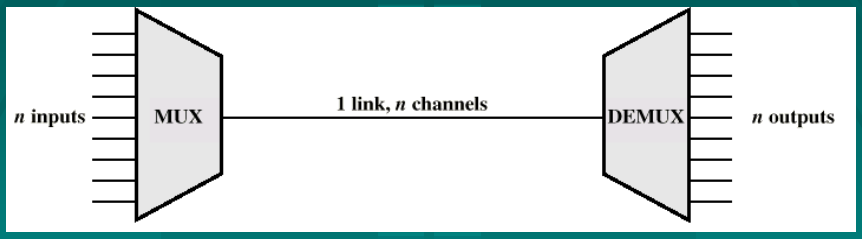
## Abstract

- Optical multiplexing (and demultiplexing) allows for sending multiple signals through a single medium as well as for bidirectional use of that medium.
- Optical Time Domain Multiplexing (OTDM)
- Wavelength-Division Multiplexing (WDM)

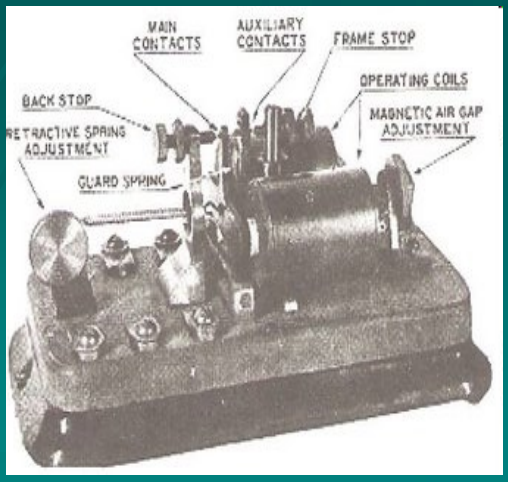
# History

- Multiplexing and Demultiplexing




- When did it start?

# History




- Telegraphy
- 1800s

# History

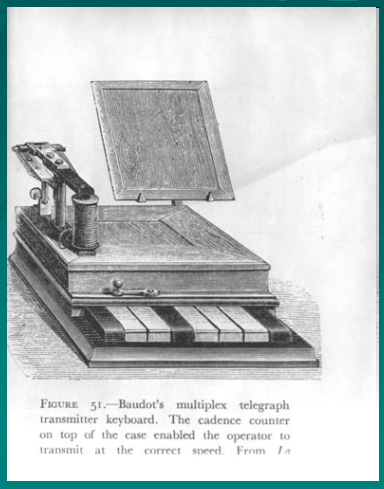
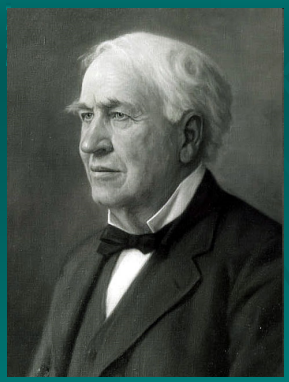


FIGURE 51.—Baudot's multiplex telegraph transmitter keyboard. The cadence counter on top of the case enabled the operator to transmit at the correct speed. From *La*

- 1894
- Baudot's multiplex telegraph

# History



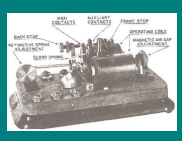
- Western Union problem
- Thomas Edison:
  - Wavelength strength
  - Polarity
- Western Union
  - electrical-mechanical multiplexing device
    - 8 messages in 1913
    - 72 messages in 1936

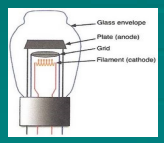
# History

- Data Transmission Speeds
  - Characters Per Minute (CPM)
  - Words Per Minute (WPM)
    - 5 characters and space
  - Bits Per Second (bps)
    - 1950s → 1200 bps
    - Currently → 10 Gbps

# History

- Multiplexing Devices Development:
  - Telegraph lines utilized DC
  - Vacuum Tubes allowed AC in 1930s
  - Transistors replaced Vacuum Tubes in1960s
  - Integrated Circuits






# Applications

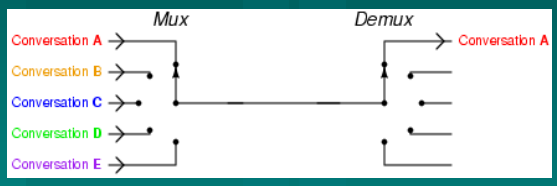
- Optical Multiplexing → Fiber Optic Cable
  - long distance communication at high bandwidths
  - Useful for Fiber Optic Sensors
    - Sensors → multiplexed into a single fiber

# Optical Multiplexing

- Optical Time-Division Multiplexing
  - Based on Time-Division Multiplexing
- Wavelength-Division Multiplexing
  - Based on Frequency-Division Multiplexing of radio waves

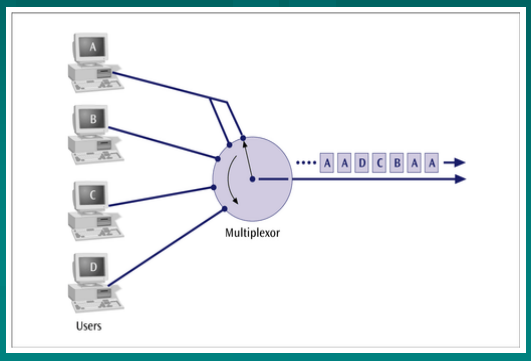
# Time-Division Multiplexing

- Transmitting digitized data over one medium
  - Wires or optical fibers
  - Pulses representing bits from different time slots

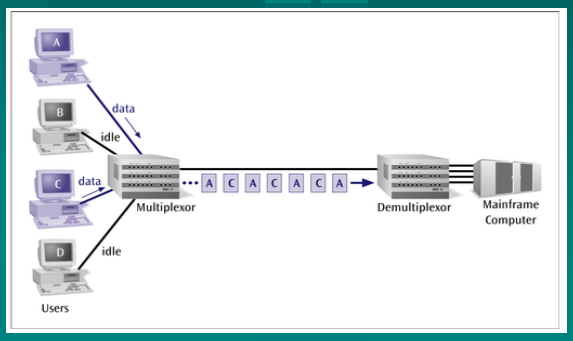



- Two Types:
  - Synchronous TDM
  - Asynchronous TDM

- Synchronous TDM
  - Accepts input in a round-robin fashion
  - Transmits data in a never ending pattern
  - Popular – Line & Sources → as much bandwidth Examples:
    - T-1 and ISDN telephone lines
    - SONET (Synchronous Optical NETwork)

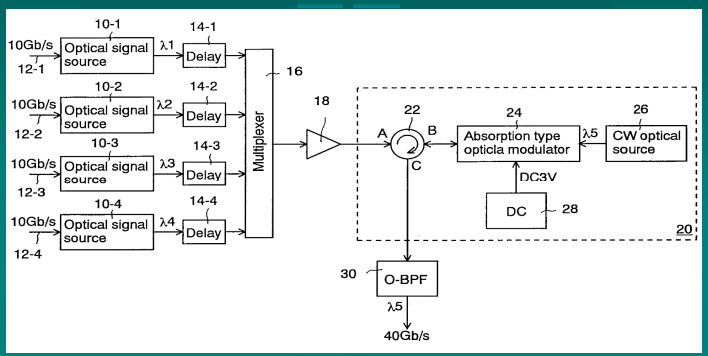


- Asynchronous TDM
  - Accepts the incoming data streams and creates a frame containing only the data to be transmitted
  - Good for low bandwidth lines
  - Transmits only data from active workstations
  - Examples:
    - used for LANs



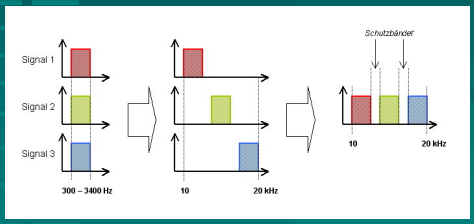

# Optical Time Division Multiplexing (OTDM)

- OTDM is accomplished by creating phase delays each signal together but with differing phase delays



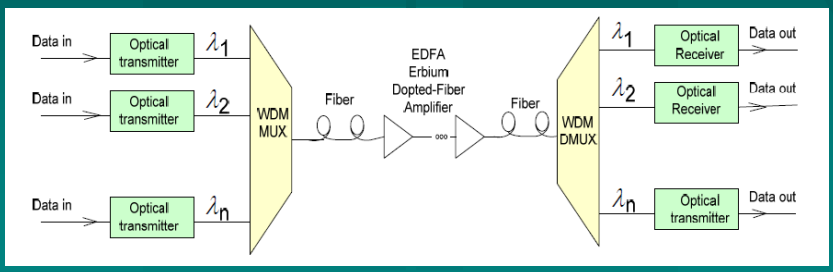
# Frequency-Division Multiplexing (FDM)

- All signals are sent simultaneously, each assigned its own frequency
- Using filters all signals can be retrieved



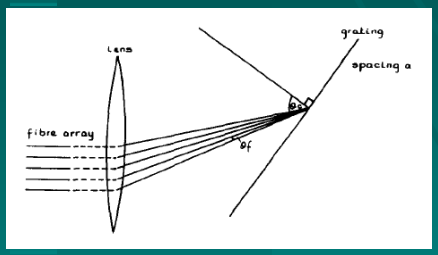

# Wavelength-Division Multiplexing (WDM)

- WDM is the combining of light by using different wavelengths



# Grating Multiplexer

- Lens focuses all signals to the same point
- Grating reflects all signals into one signal

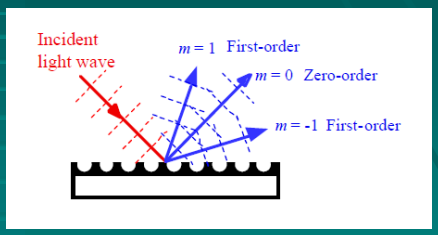



$$a(\sin\theta_i+\sin\theta_o)=m\lambda$$

# Grating Multiplexer

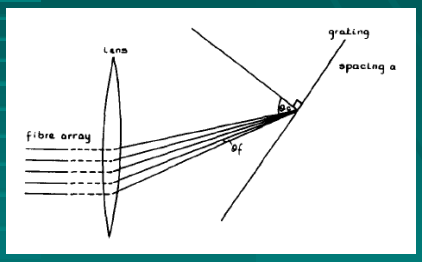
- Reflection off of grating is dependent on incident angle, order, and wavelength

$$d(\sin\theta_i + \sin\theta_o) = m\lambda$$



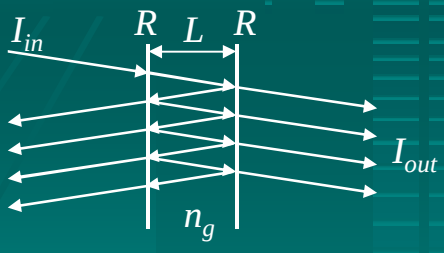
# Grating Multiplexer

- Multiplexer is designed such that each λ and $\theta_i$ are related
- Results in one signal that can then be coupled into a fiber optic cable



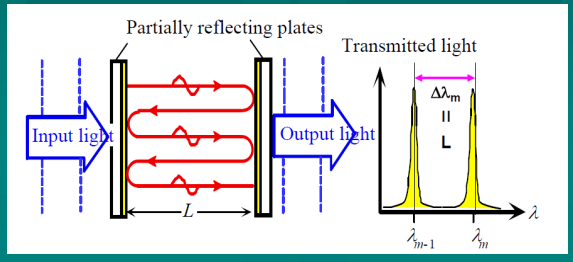

$$a(\sin\theta_i+\sin\theta_o)=m\lambda$$

# Fabry-Perot Filter



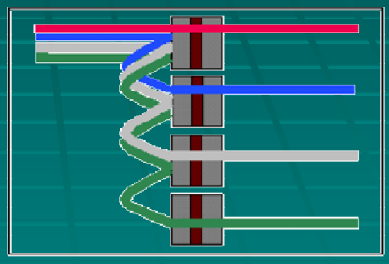

**Transmitted light:**
$\lambda_m = 2L/m$
**where m = 1, 2, 3,....**

**Separation of the modes:**
$\Delta\lambda_m = L$



## Fabry-Perot Multiplexer

- Separates based on wavelength = demux
- Can be reversed for multiplexer



## Conclusion

- History
- Applications
- Optical Time Division Multiplexing
- Wavelength-Division Multiplexing
  - Grating Multiplexer
  - Fabry-Perot Multiplexer