2009.4.20

Development of Optical Communications

presented by
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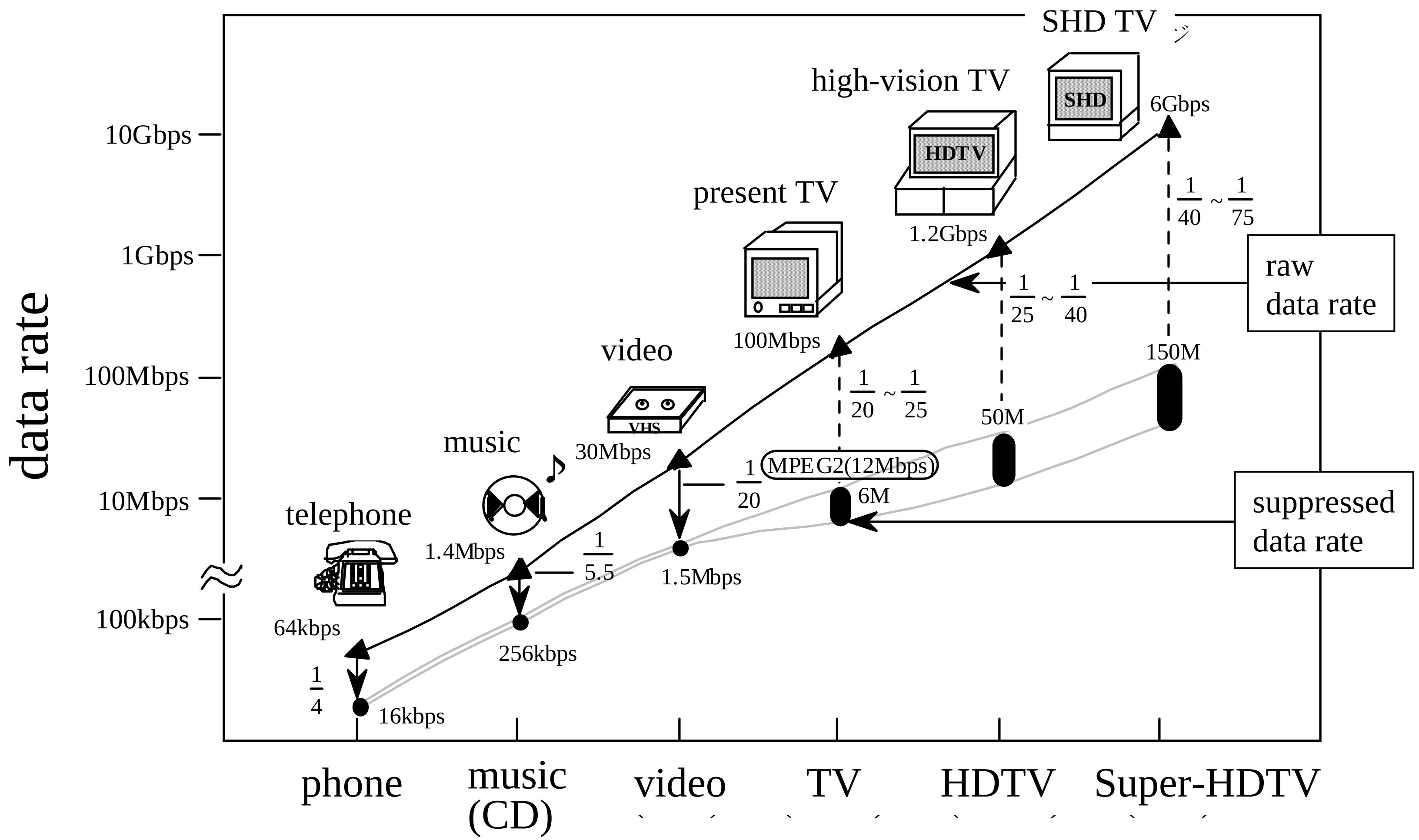
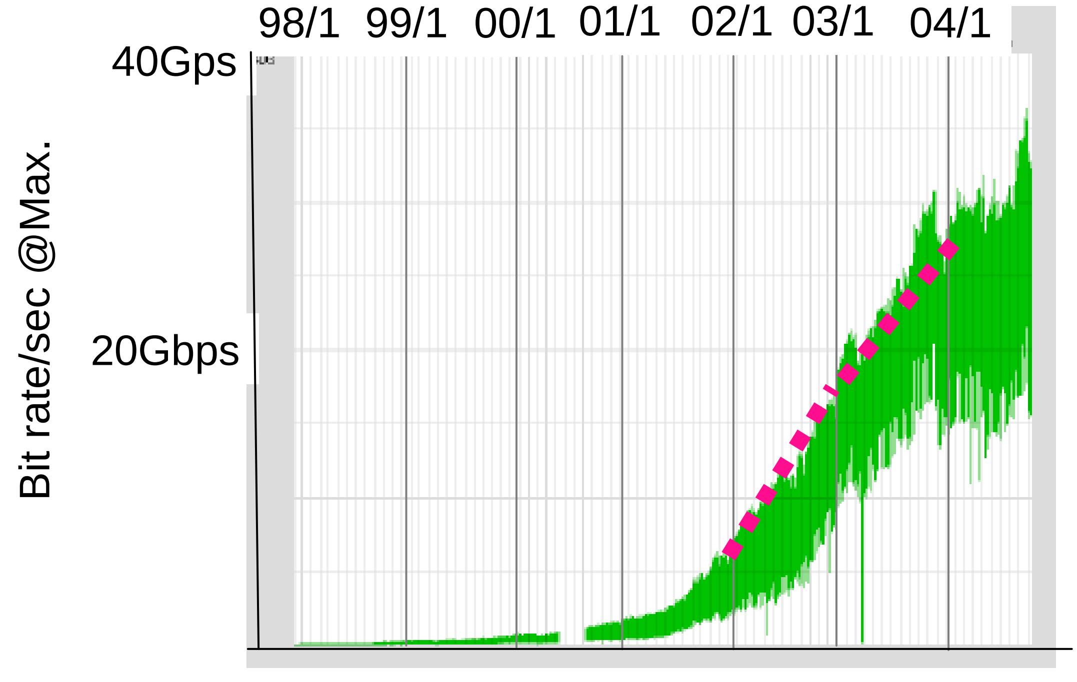
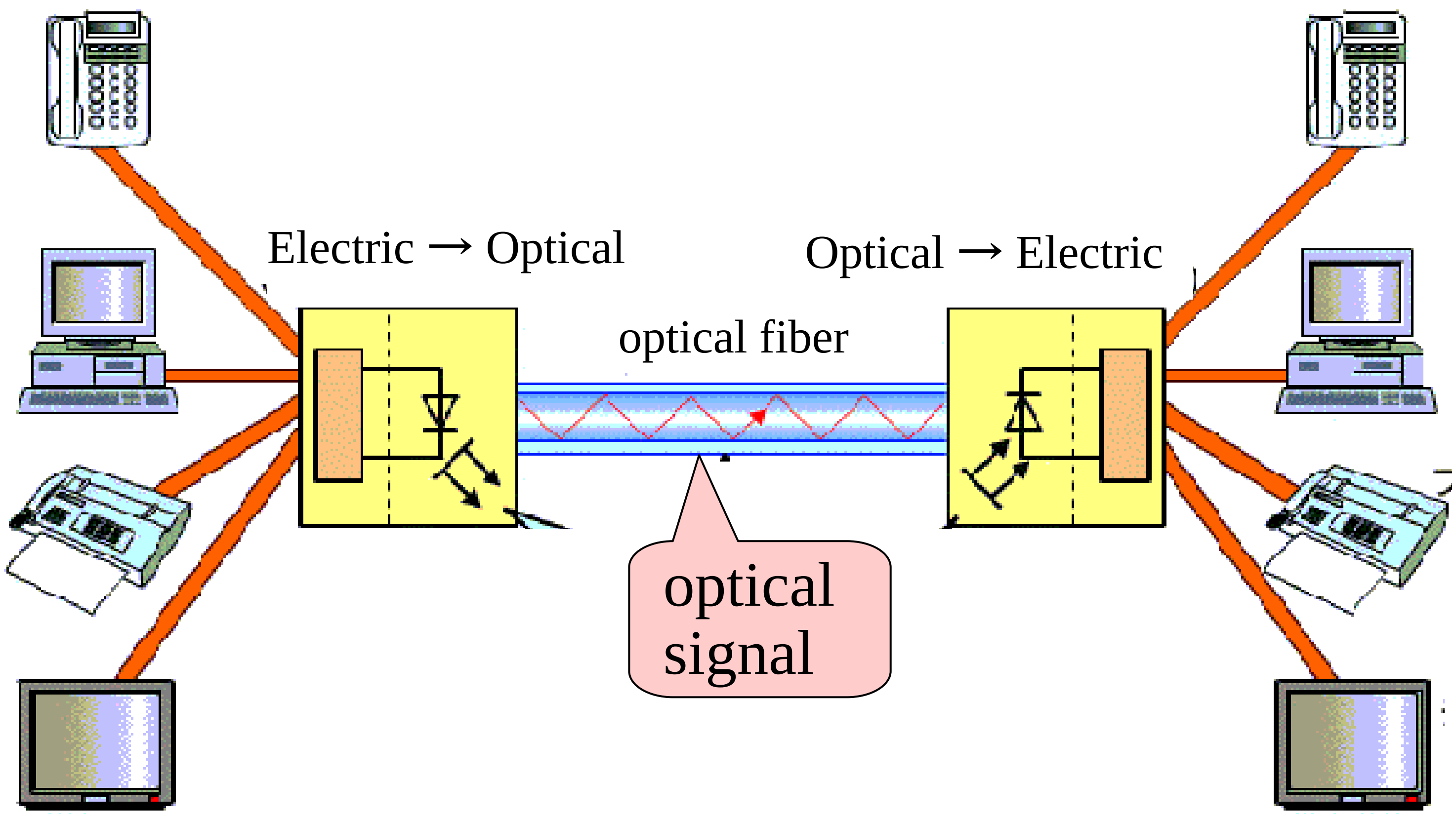
Data rate is growing.



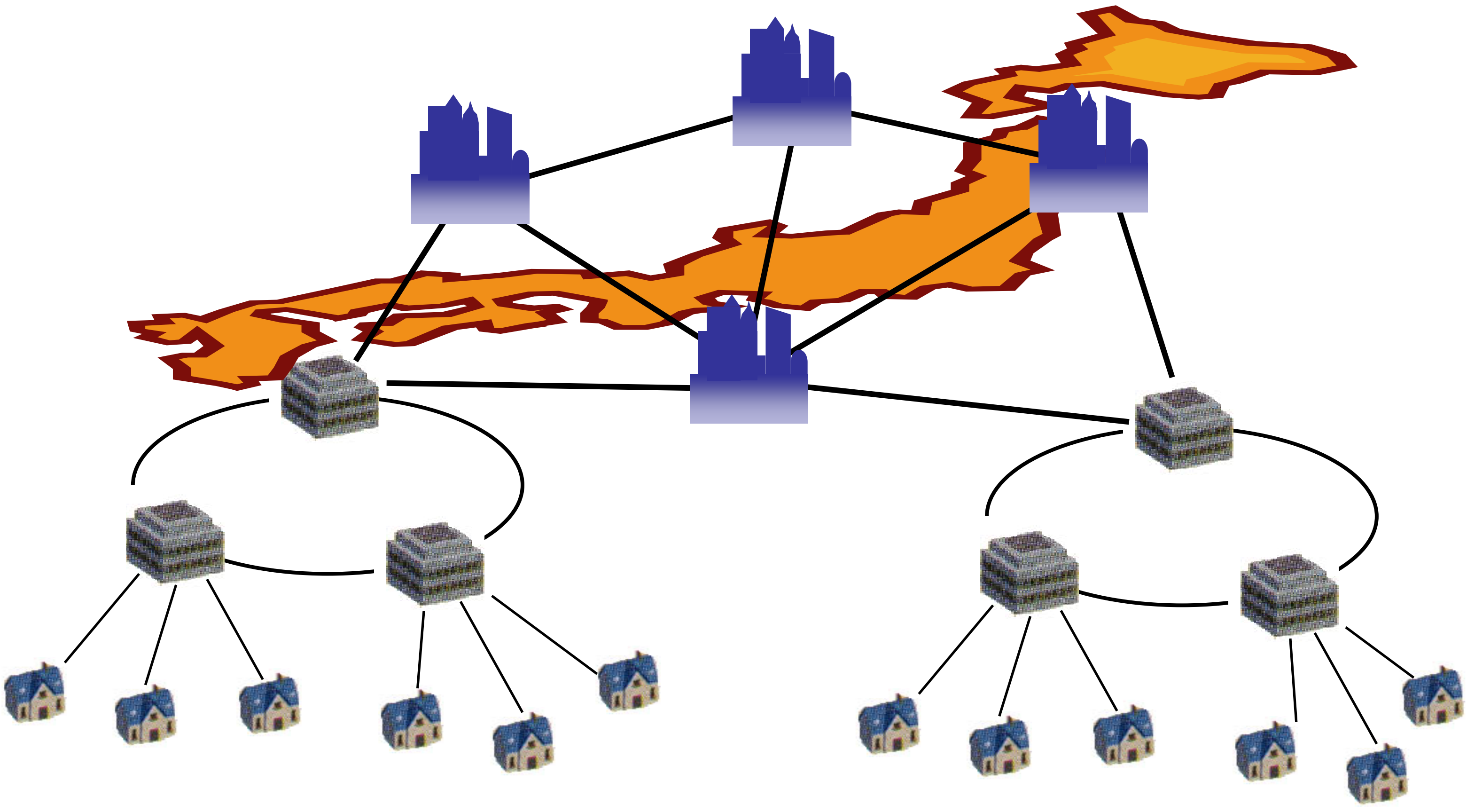
Increase in internet traffic



Optical communication is the infrastructure for the present networks (and future).



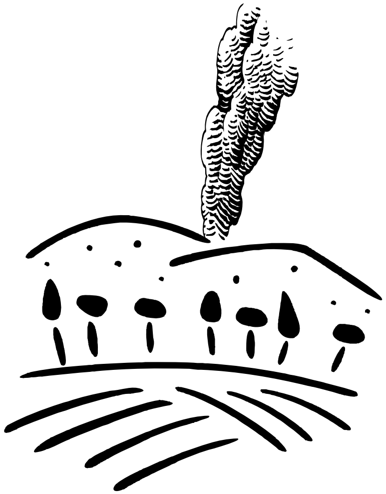
Optical signals travels all around.



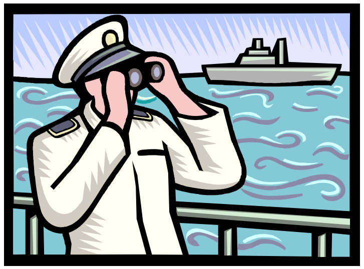
Let's trace the development of optical communication technology.

Old days ....

Rocket



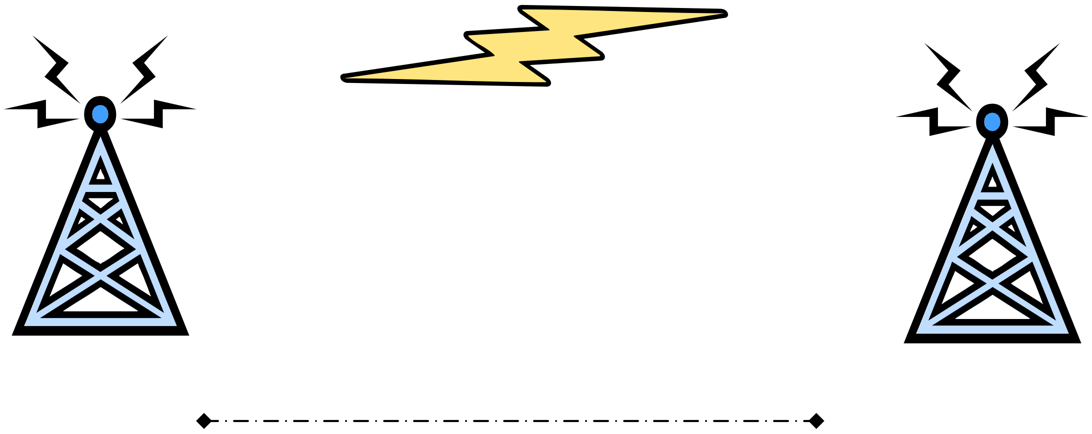
Signal lamp



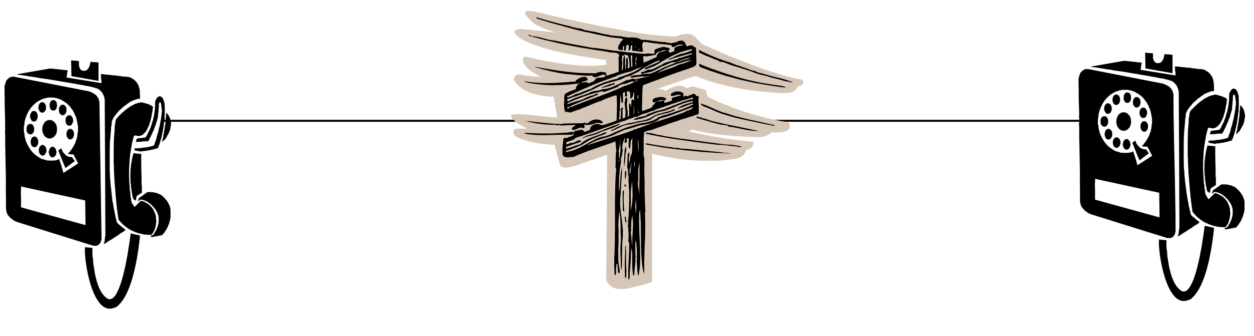
however

Modern communication started with electricity

Wireless communication



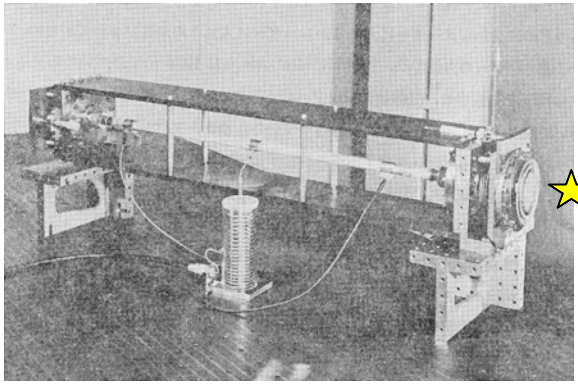
Copper wired communication



then

Seeds of modern optical communication

Invention of laser（1960）

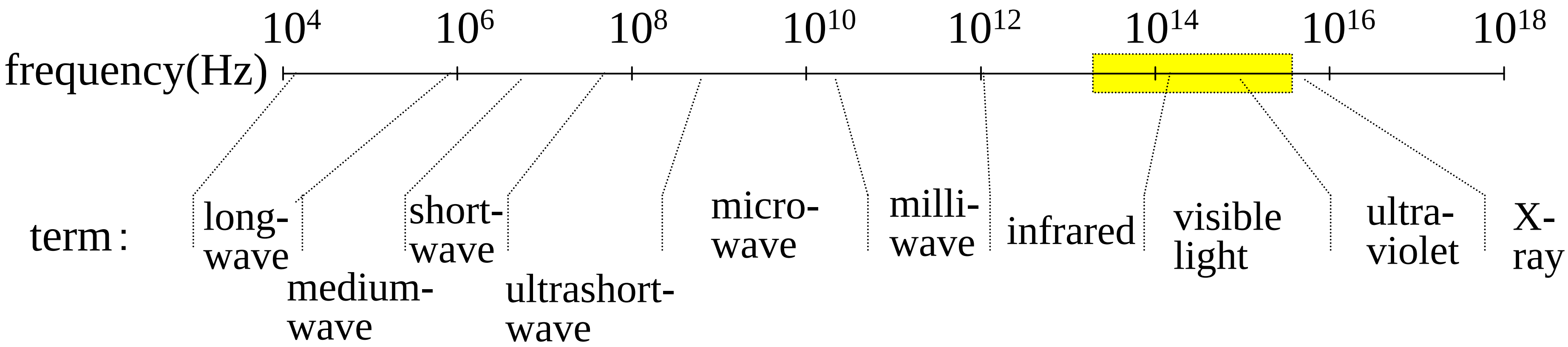


◆high-frequency electromagnetic wave

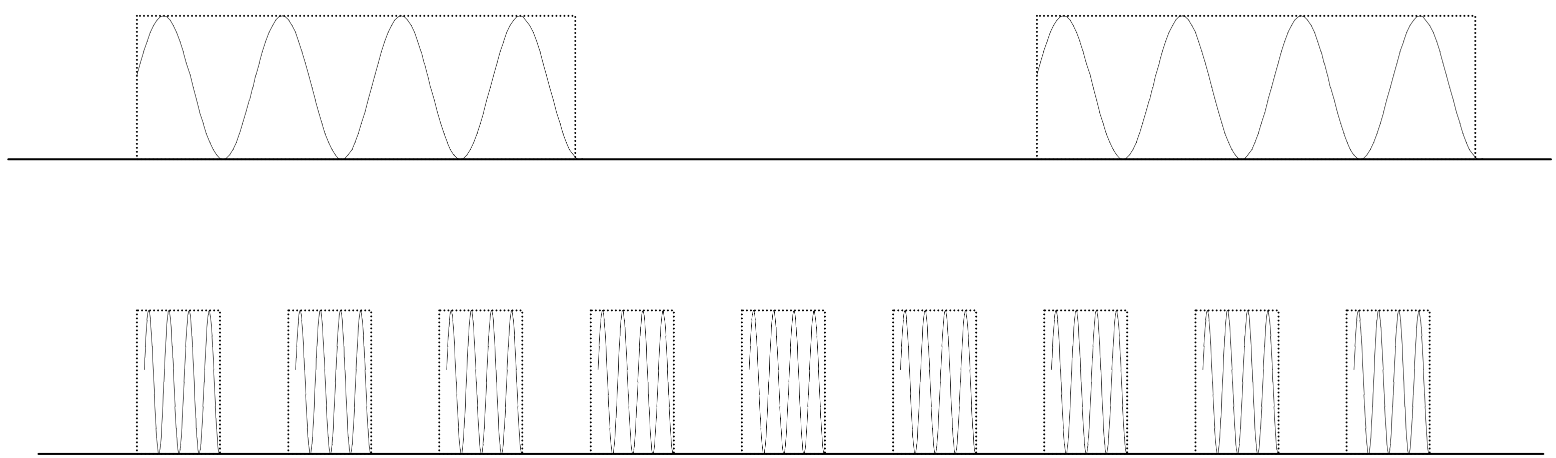
◆monochromatic light

◆good directionality

high frequency

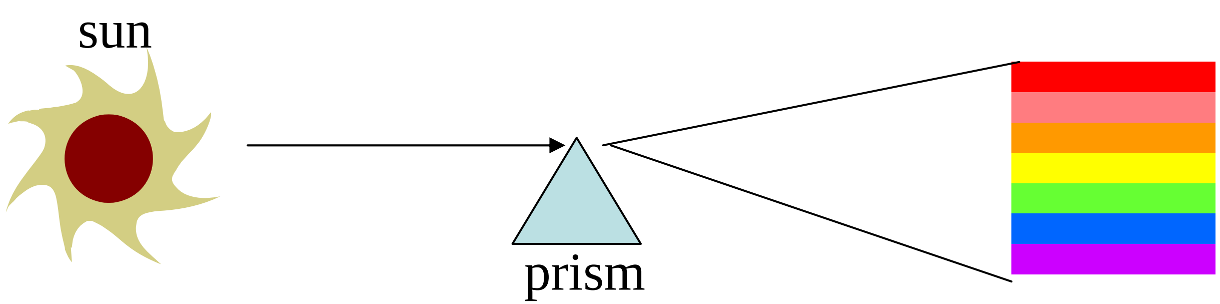


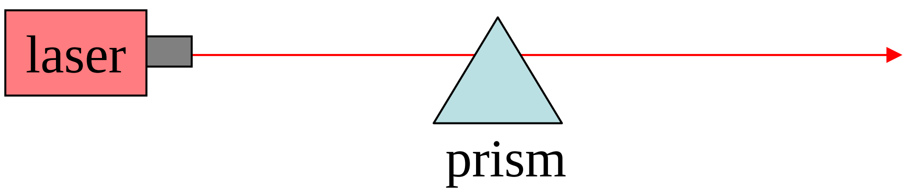
possibility for high modulation rate



monochromatic

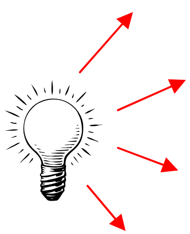
possibility for multi-channels





directionality

efficient use of power



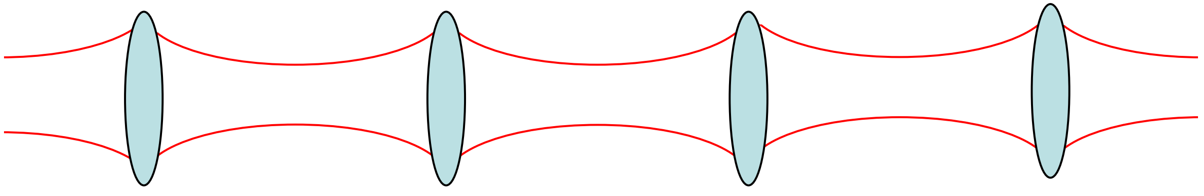
Space optical transmission using He-Ne laser

Kasumigaseki bldg.

Not good enough for practical use

a trail to transmit light for a long distance

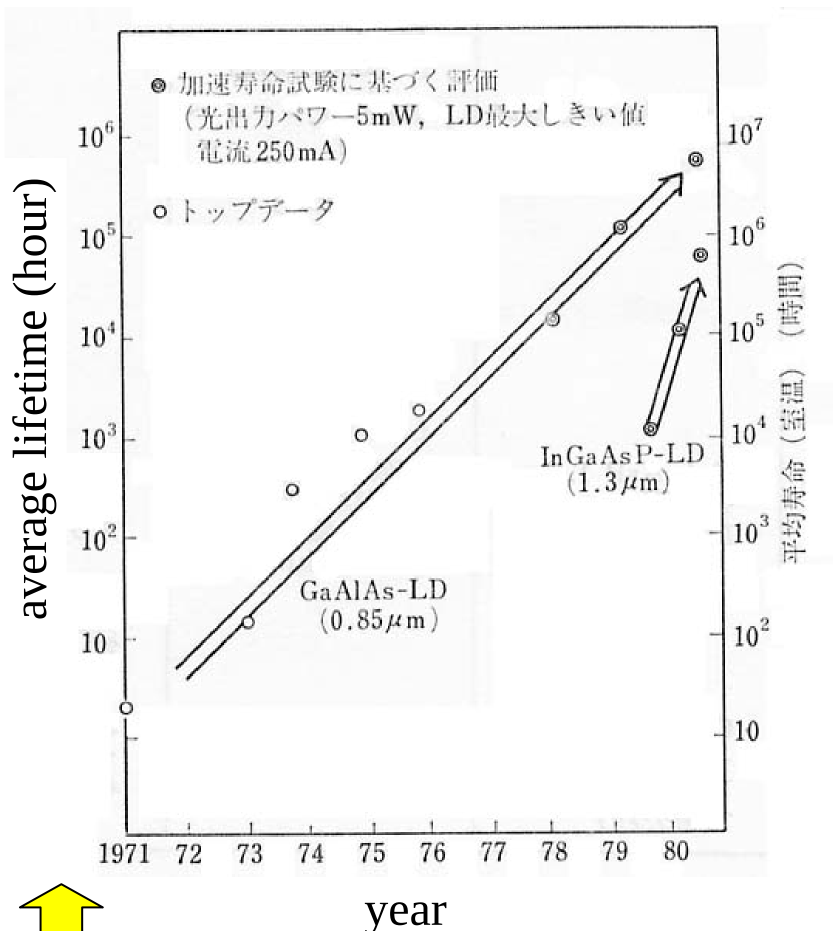
lens waveguide



Impractical, of course.

breakthrough 1

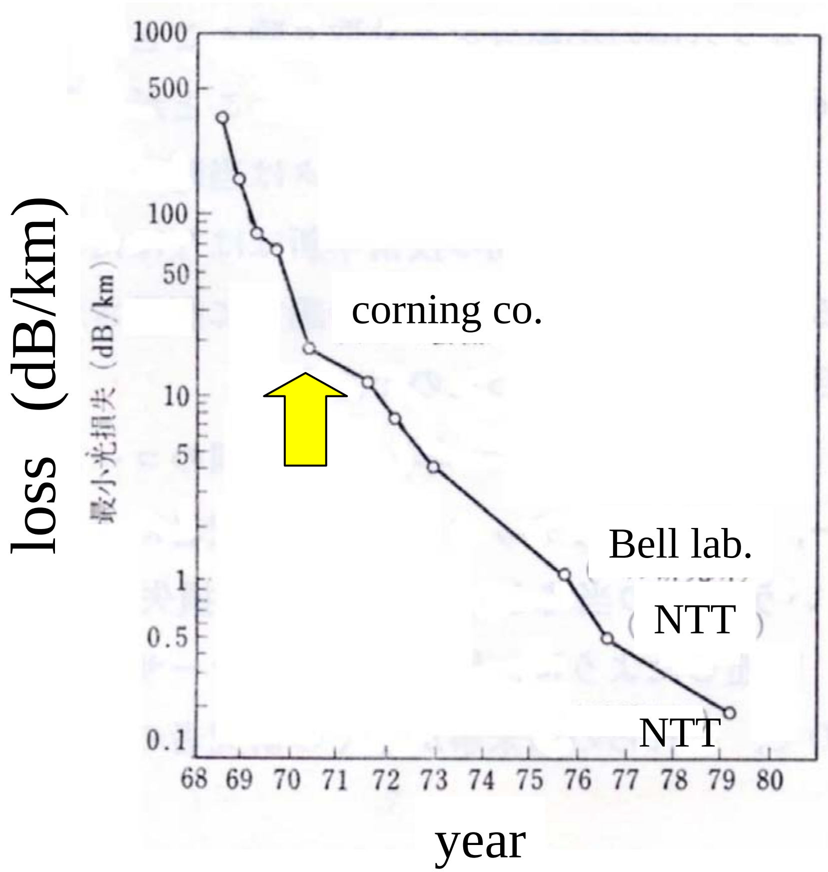
Semiconductor laser @ room temperature



first oscillation

breakthrough 2

Low-loss glass fiber



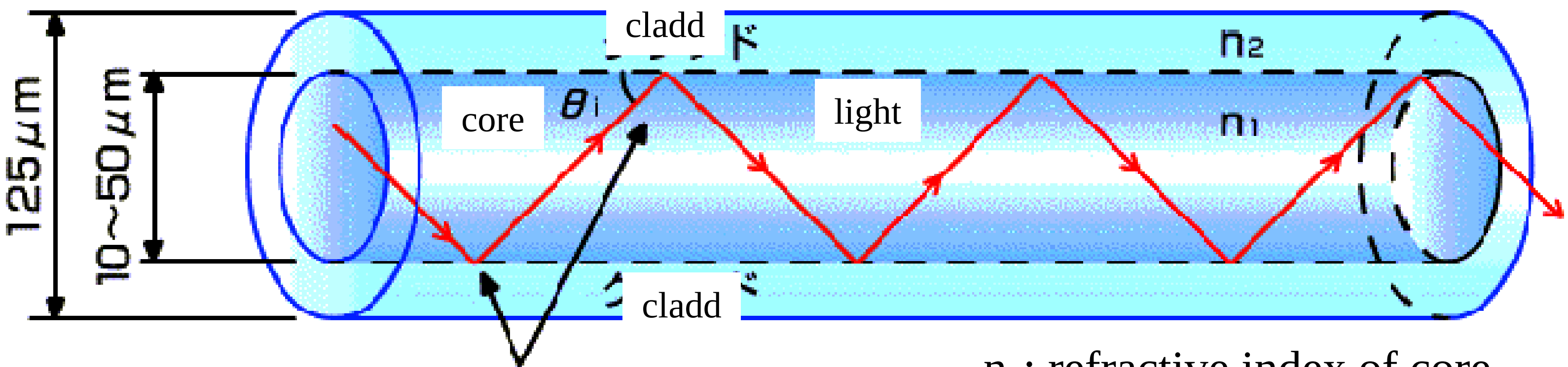
loss L	transmittance T
0 dB	1.0
10 dB	0.1
20 dB	0.01
30 dB	0.001

$$\left(T = 10^{-L/10} \right)$$

Research activity was triggered by these innovations.

Optical fiber

Light propagates along fiber, being totally reflected.

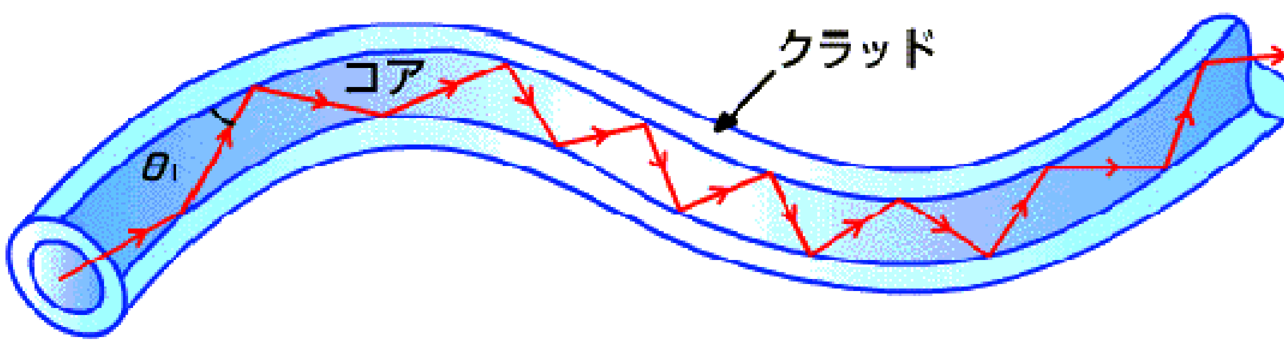


total reflection

n_1: refractive index of core

n_2: refractive index of clad

$(n_1 > n_2)$

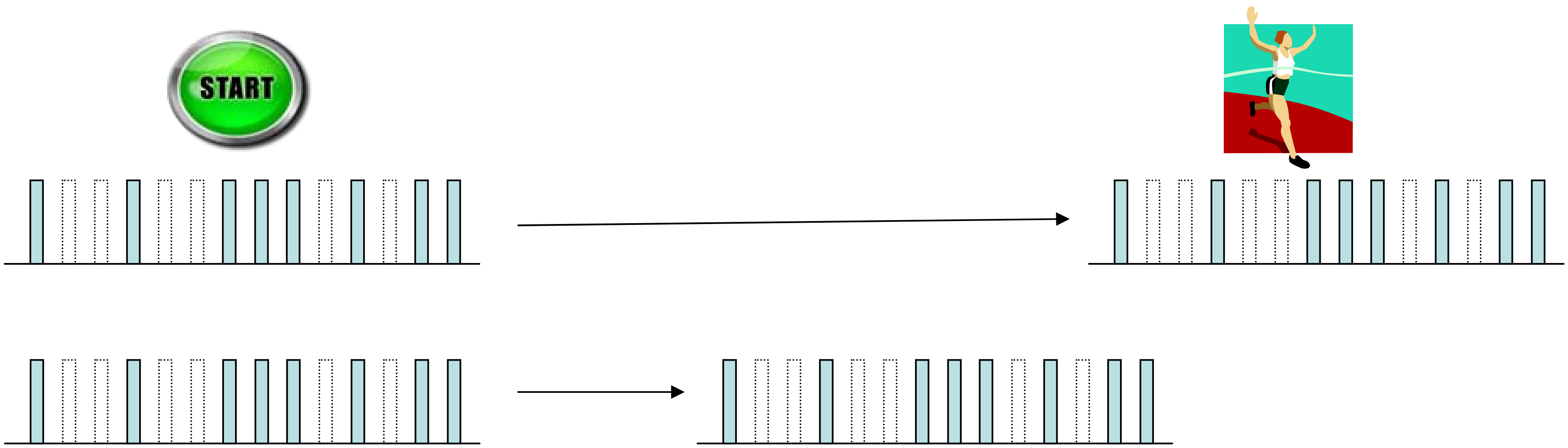


by the way

Why light is good for transmission ?

Frequent answer: “Light is fast” $\longrightarrow$ ×

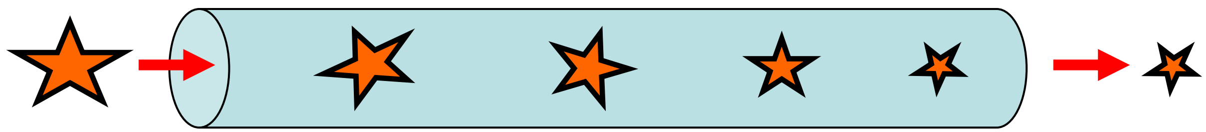
“traveling fast” ≠ “high data rate”



“Bits per second” has nothing to do with the traveling speed.

The main reason is

The propagation loss through fiber is quite low

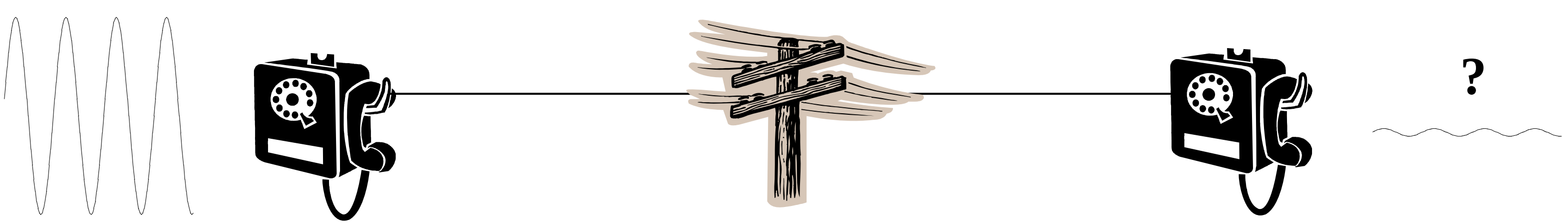


0.2dB-loss @ 1km（transmittance = 95.5%）

2.0dB-loss @ 10km（transmittance = 63%）

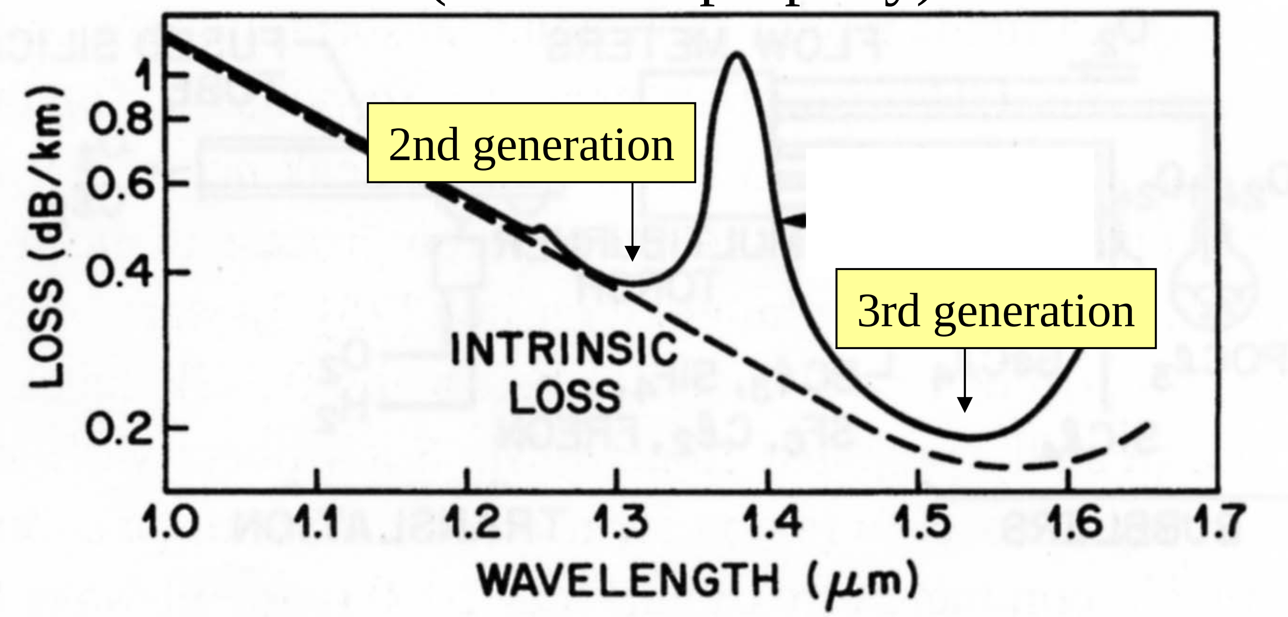
on the other hand

Copper wire is lossy for high frequencies.
(ex. 10dB/km for 10MHz)



Optical communication has been developed, pursueing to fully utilize the low-loss property.

(fiber loss property)



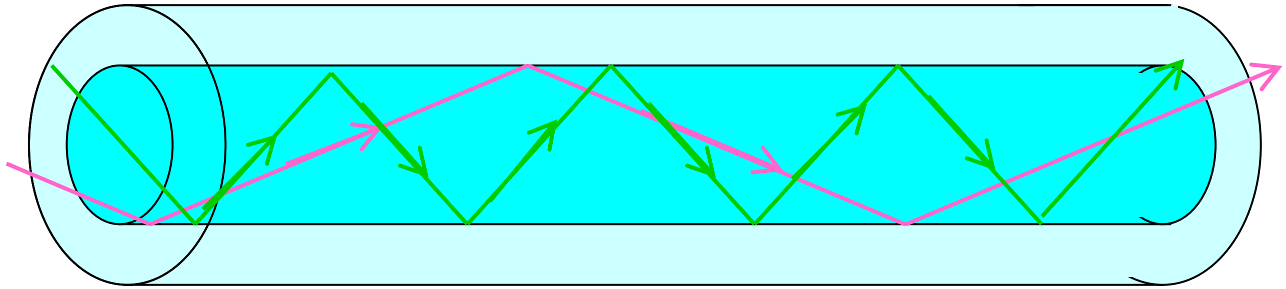
Transmission medium is the most important matter, generally speaking.

1st generation (0.8μm): first semiconductor laser
2nd generation (1.3μm): zero-dispersion
3rd generation (1.5μm) : minimum loss

Light velocity in fiber is not unique

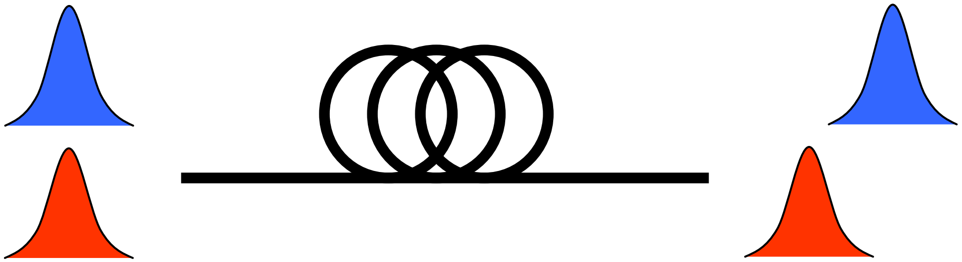
Mode-dispersion

Propagation velocity is different for different angles.

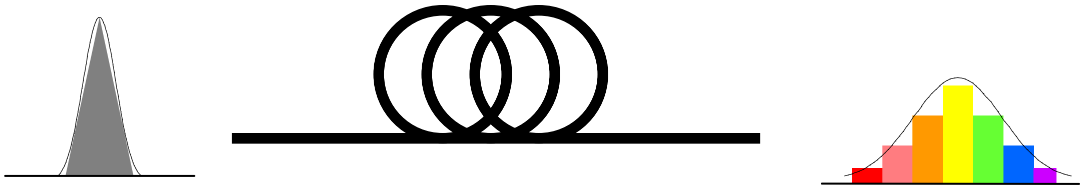


Chromatic-dispersion

Propagation velocity is different for different wavelength.



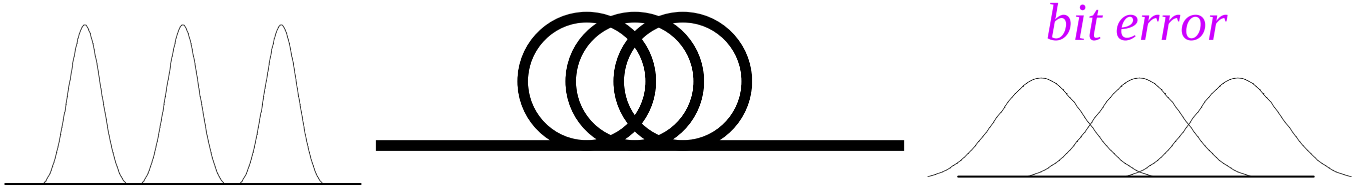
When velocity is different.......



Pulse width broadens.

In case of a pulse train,

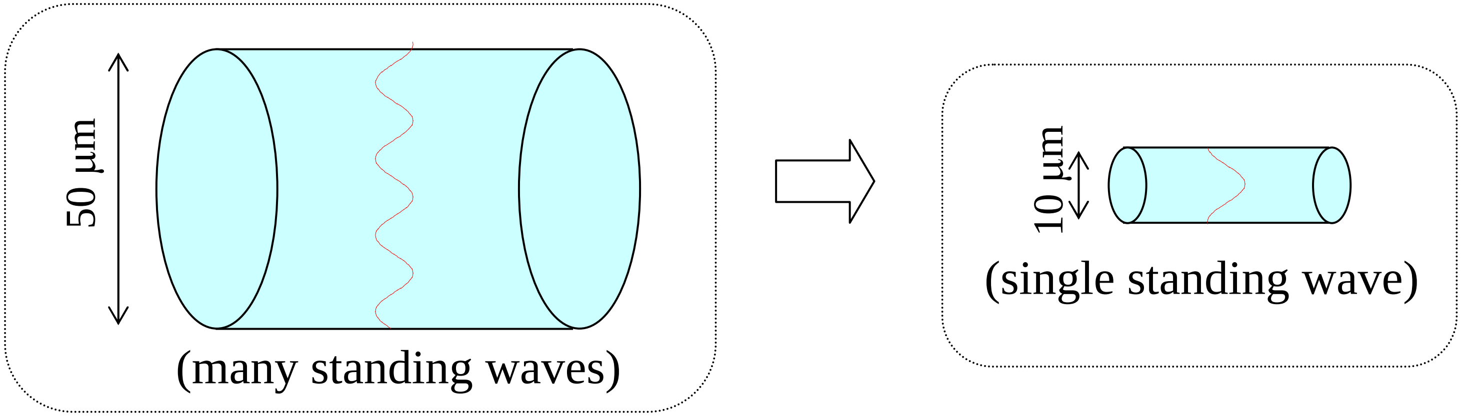
bit error



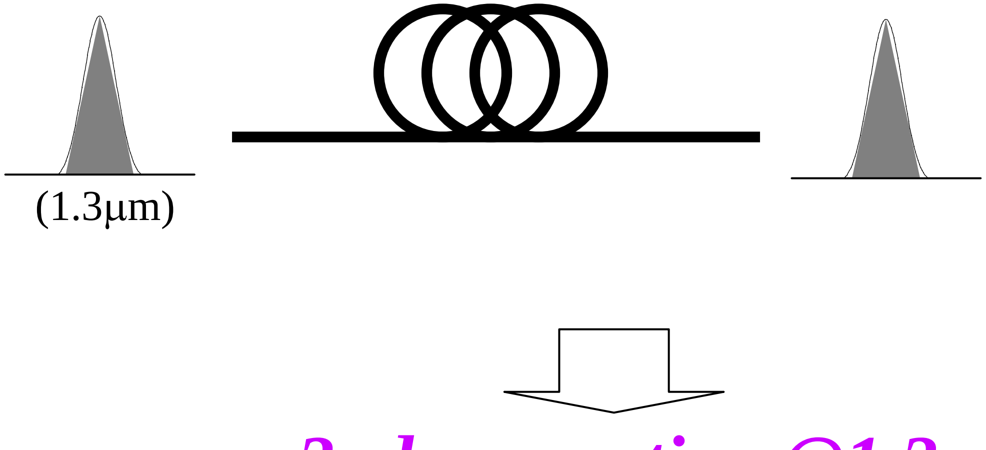
research effort

Combat with dispersion

◆Single-mode fiber



◆Chromatic dispersion is zero at 1.3μm, by chance.

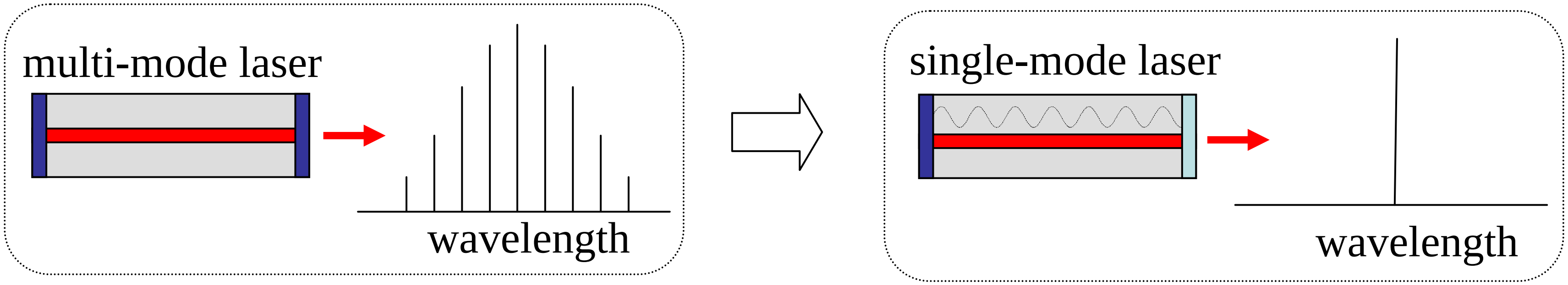


2nd generation @1.3 μm

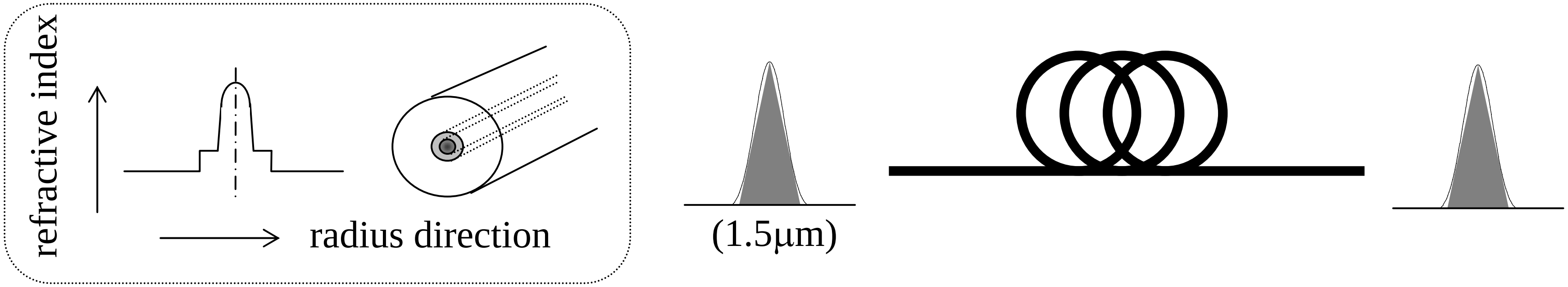
however

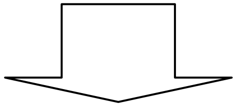
People wanted to use loss-minimum wavelength

◆Laser emitting a single-wavelength



◆ Fiber with zero-dispersion at 1.5 μm (dispersion-shifted fiber)

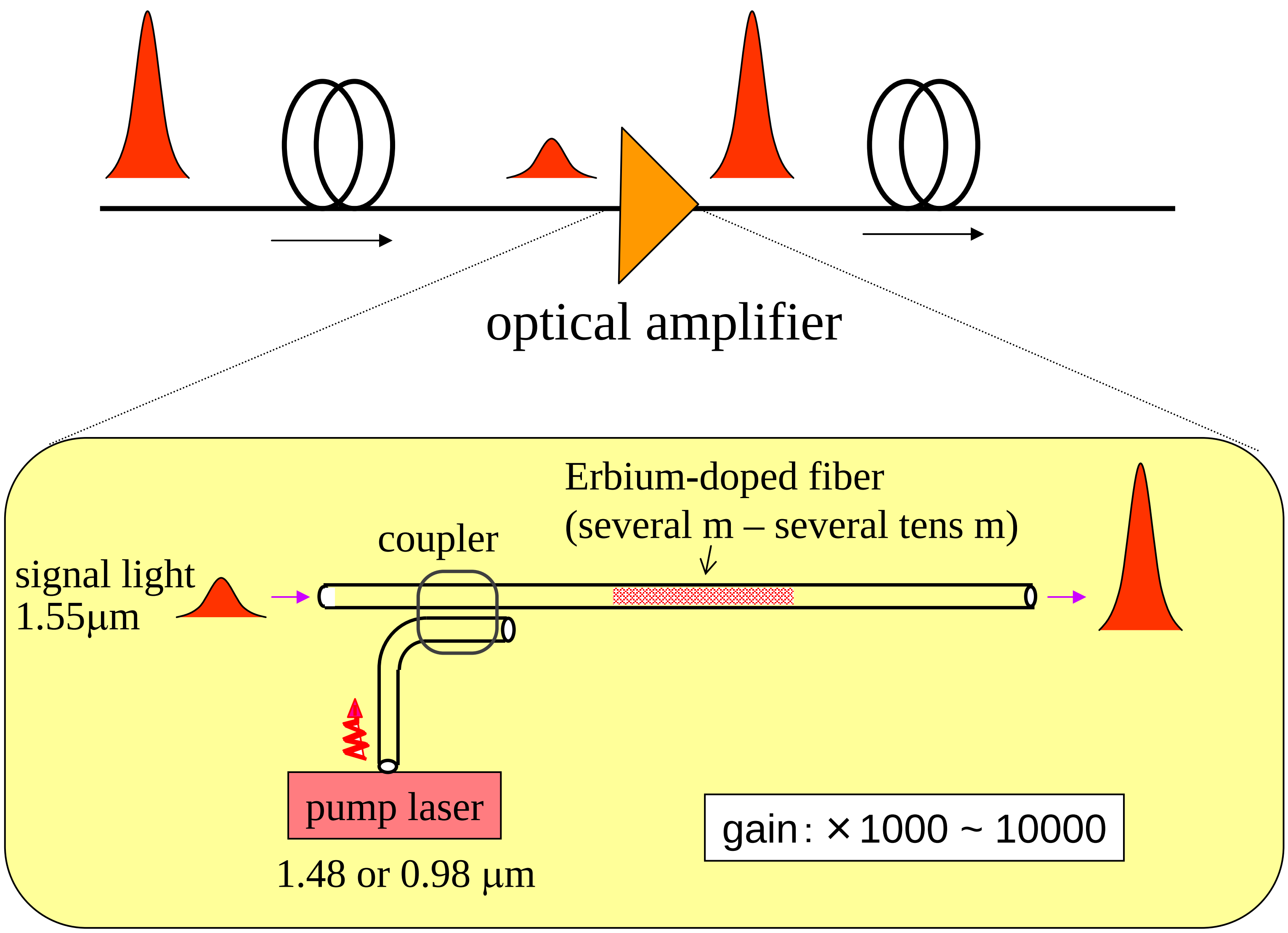




3rd generation @ 1.5μm

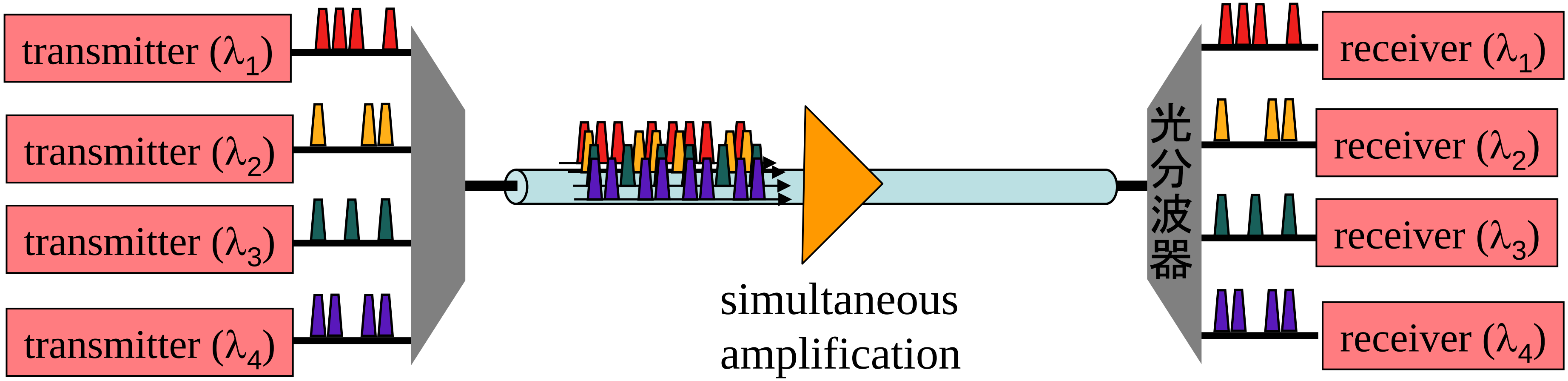
furthermore

Combat with fiber loss



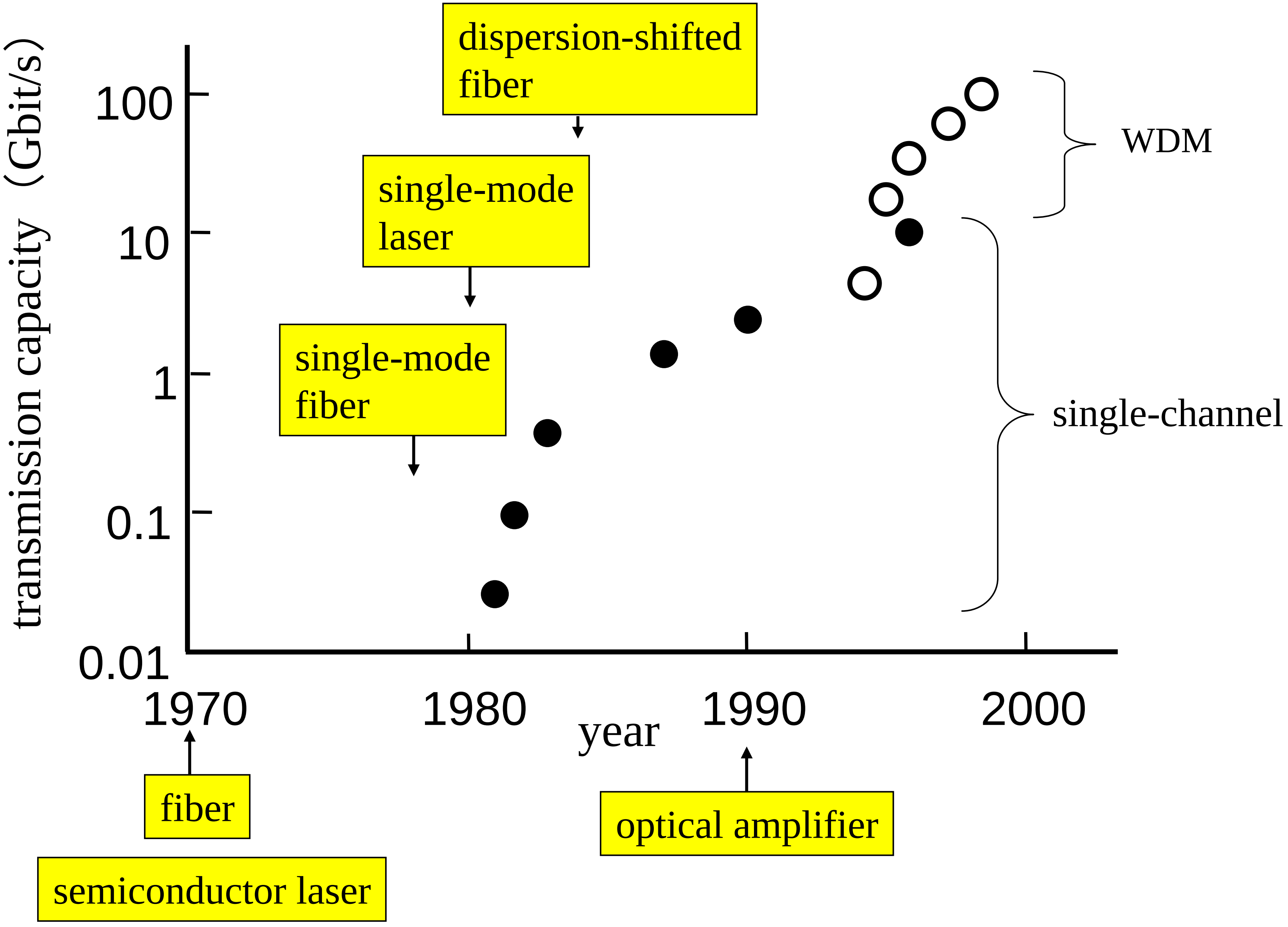
great benefit of opt. amp.

Wavelength Division Multiplex (WDM)

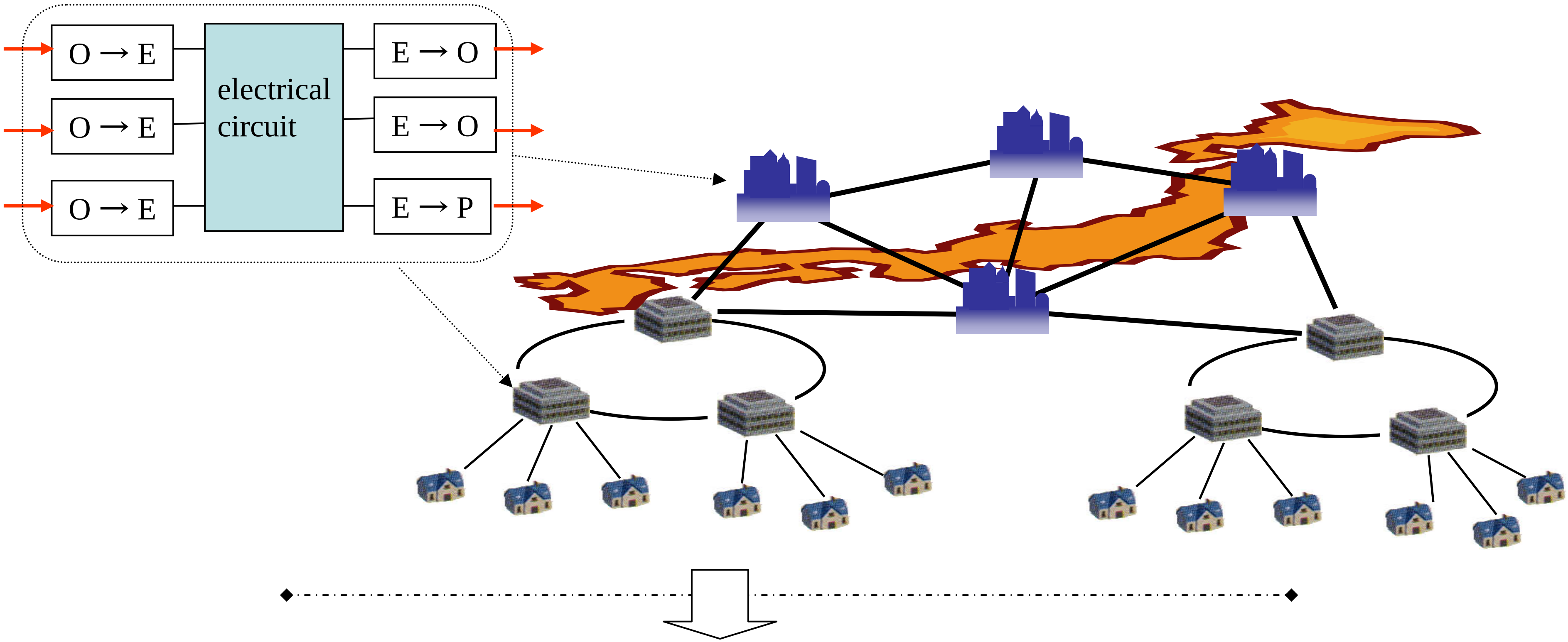


then

Increase in transmission capacity

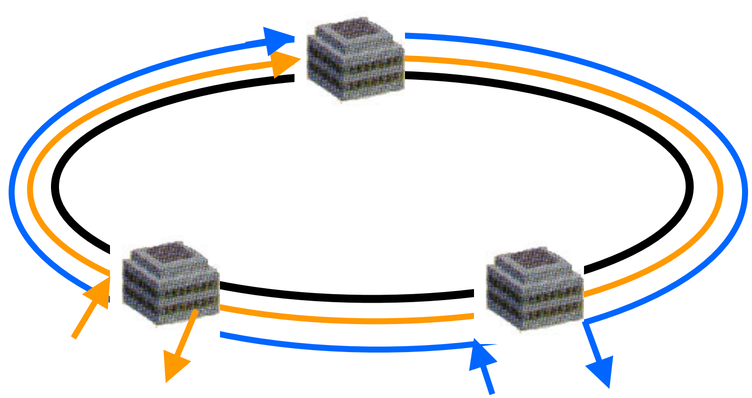


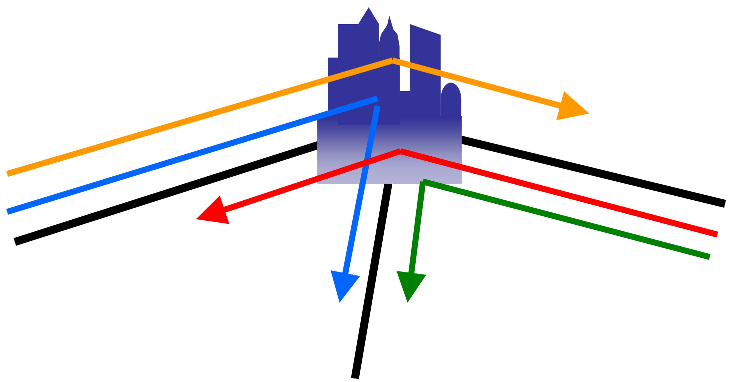
Advanced Optical Networks



<u>Optical Add/Drop</u>

<u>Optical Crossconnect</u>





Advanced Optical Transmission