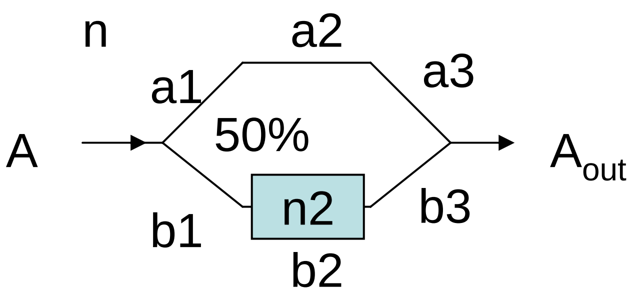
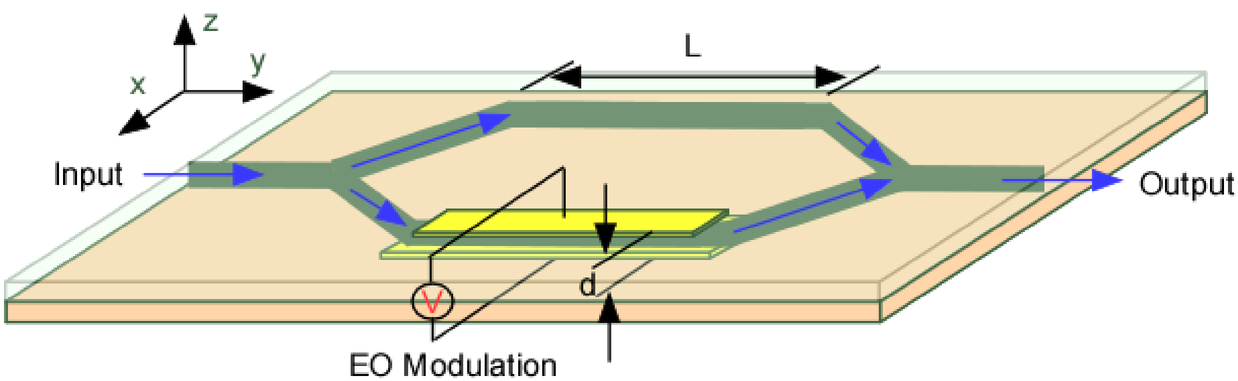
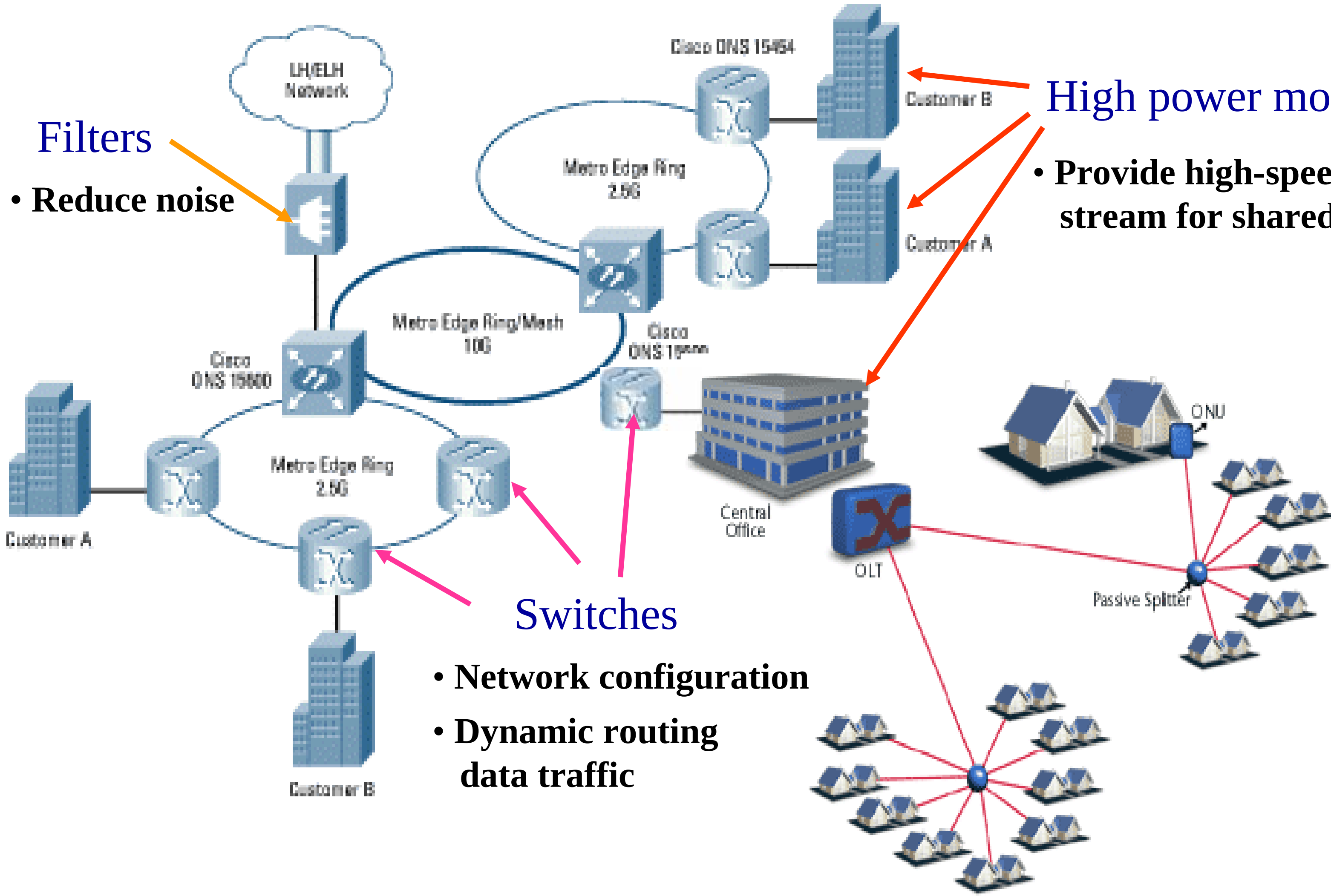
1. Mach-Zehnder EO modulator



Electro-optic effect, n2 changes with E -field



2. Optical Switches



Filters

- **Reduce noise**

High power modulators

- **Provide high-speed data stream for shared users**

Switches

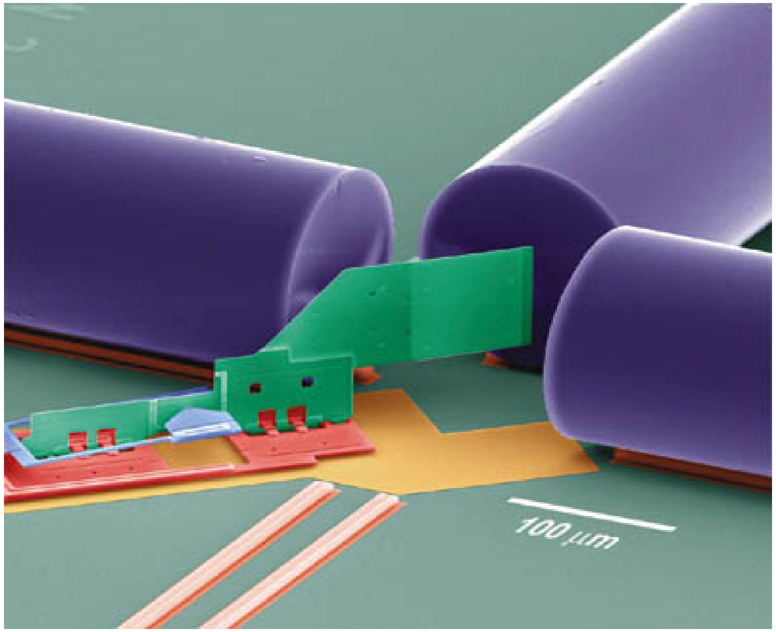
- **Network configuration**
- **Dynamic routing data traffic**

Types of Optical Switches

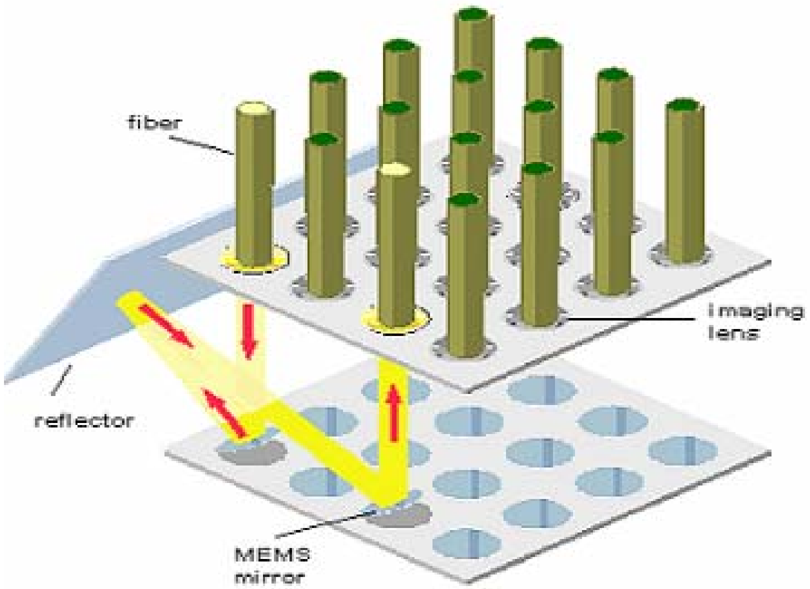
1. Micro-electro-mechanical systems (MEMS)

Disadvantages:

- Hard for switch array
- Hard for alignment
- Reliability issues



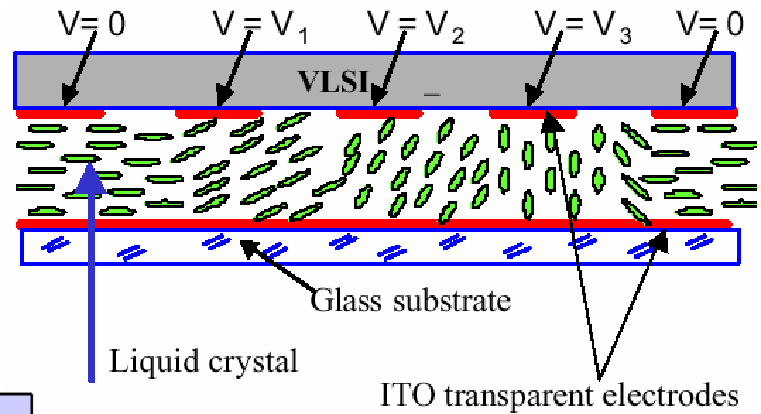
From Lucent, Bell lab

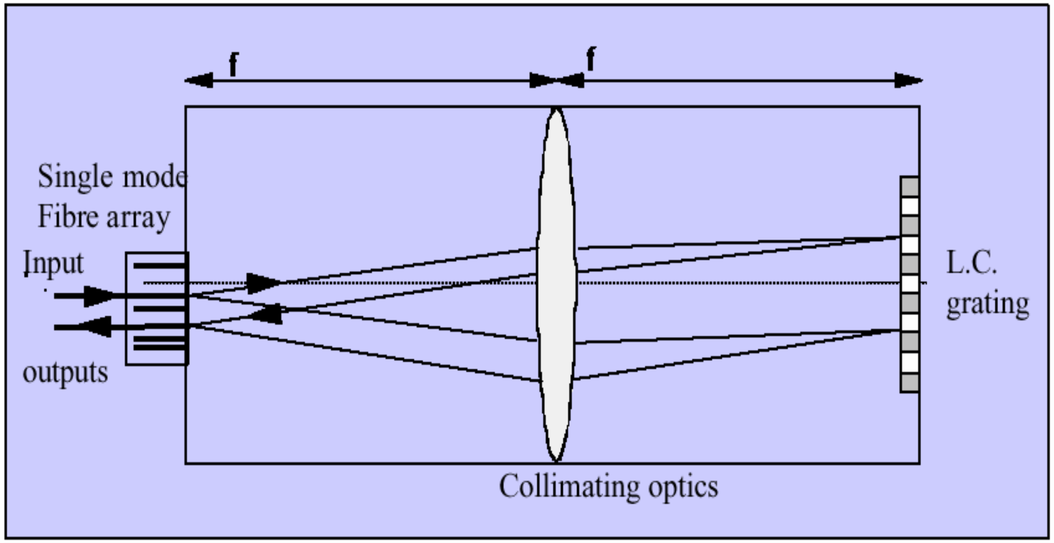


2. Liquid crystal based optical switch

Disadvantages:

- Free space based, hard to integration
- Hard for alignment
- Large size



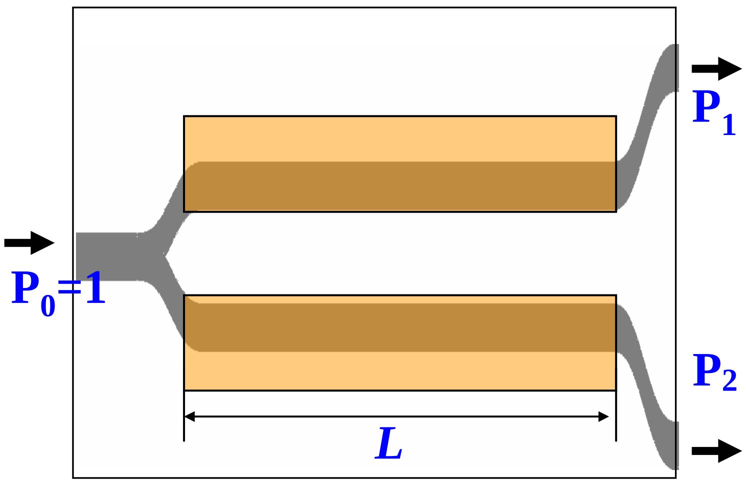


Optics Department
Ecole Nationale Supérieure des Télécommunications de Bretagne
Brittany, France

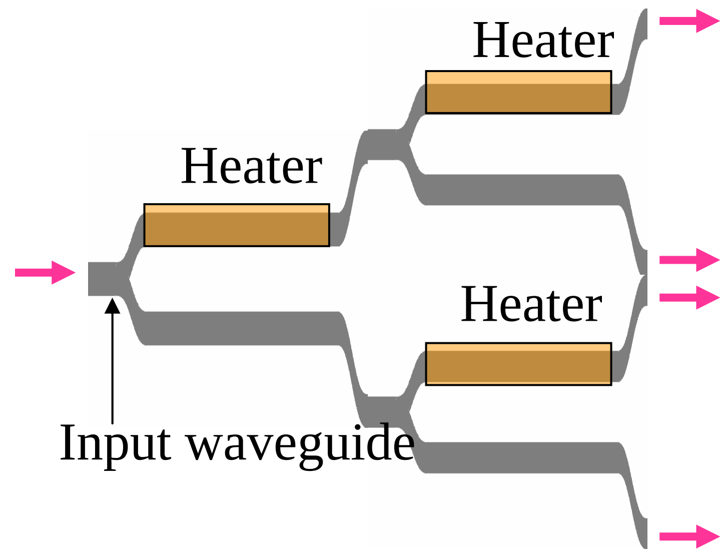
3. Thermo-optic switch, directional coupler based

Disadvantages:

- Wavelength sensitive
- Large size for switch array

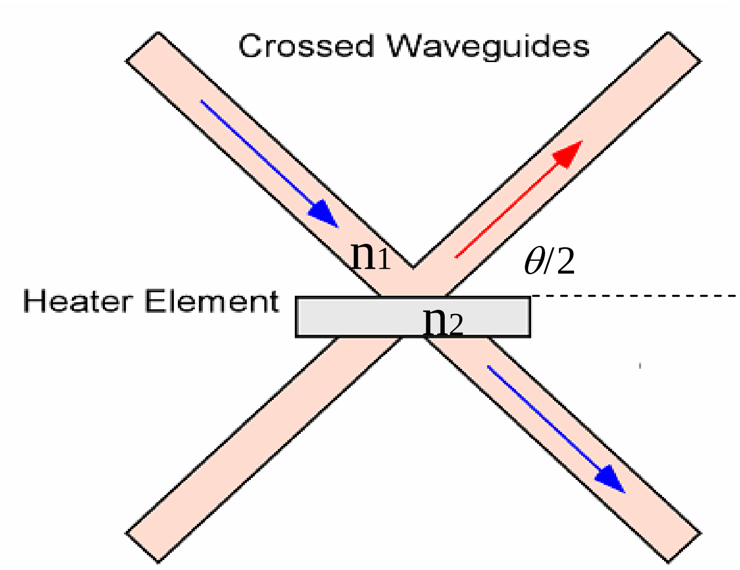


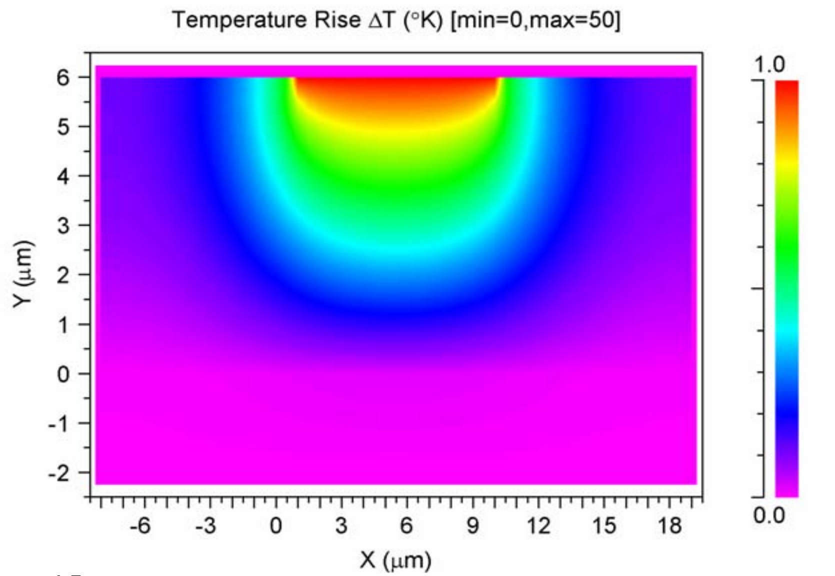
Coupler TO switch



output waveguides

4. Thermo-optic switch, total internal reflection based

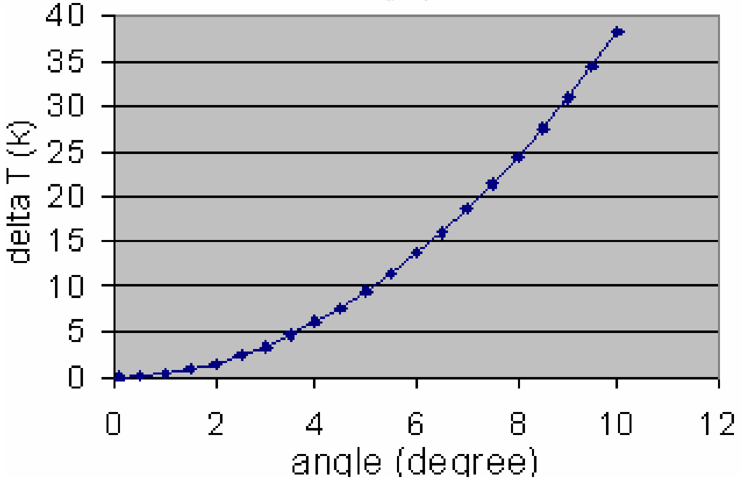




$$n_1 \sin(90 - \frac{\theta}{2}) = n_2,$$

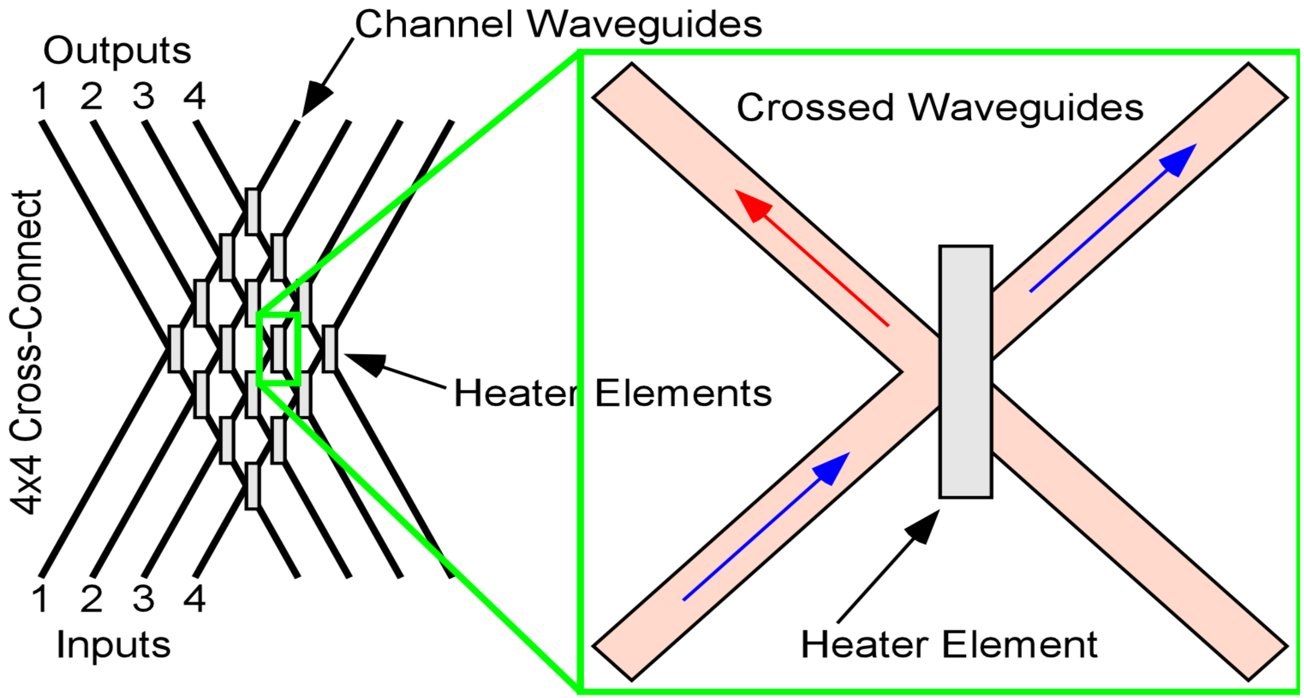
$$n_2 = n_1 - \frac{dn}{dT}\Delta T,$$

$$\frac{dn}{dT} = -1.4 \times 10^{-4} / {}^{o}C,$$



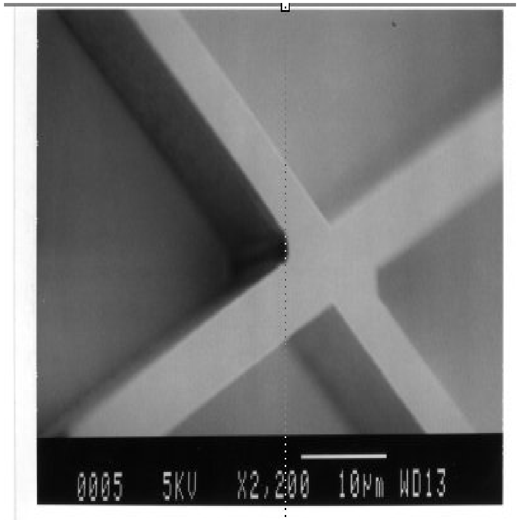
Advantages of TIR based thermo-optic switch

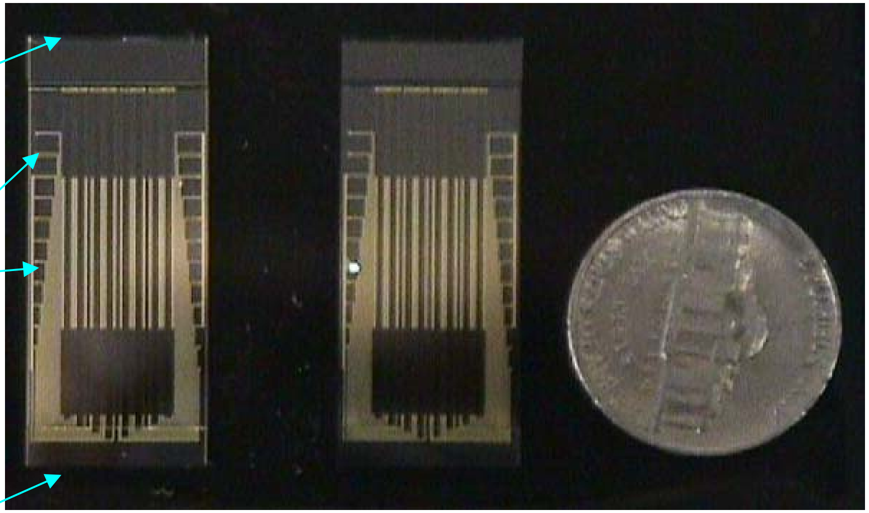
- Wavelength insensitive
- Easy array operation



TIR TO switch array

2x2 thermo-optic switch and 8x8 switch arrays





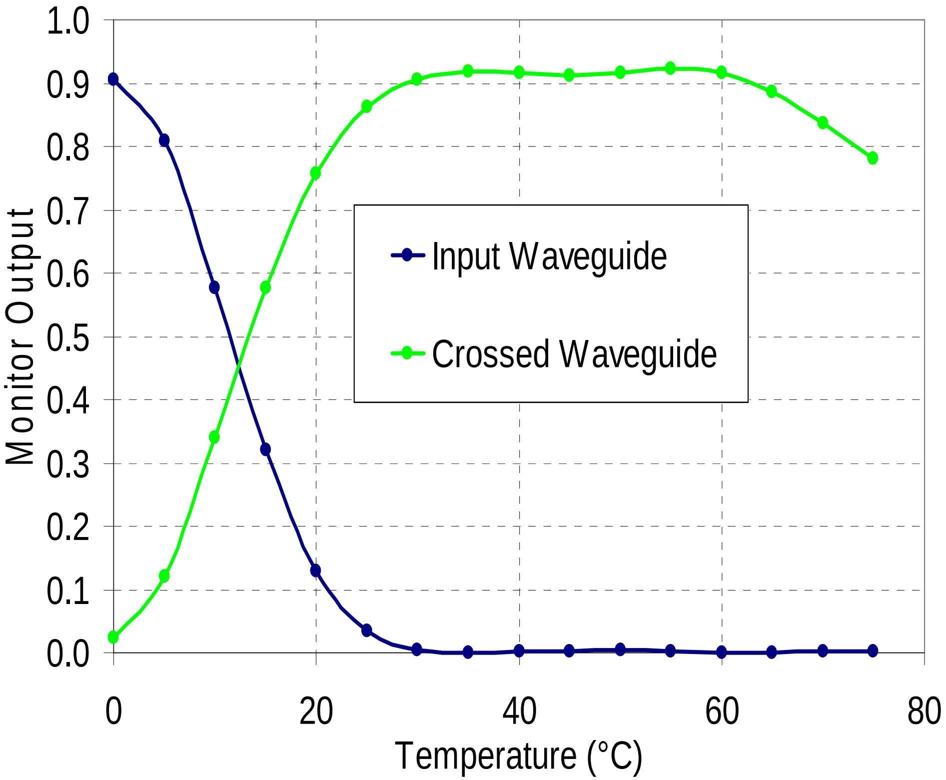
Output Waveguides

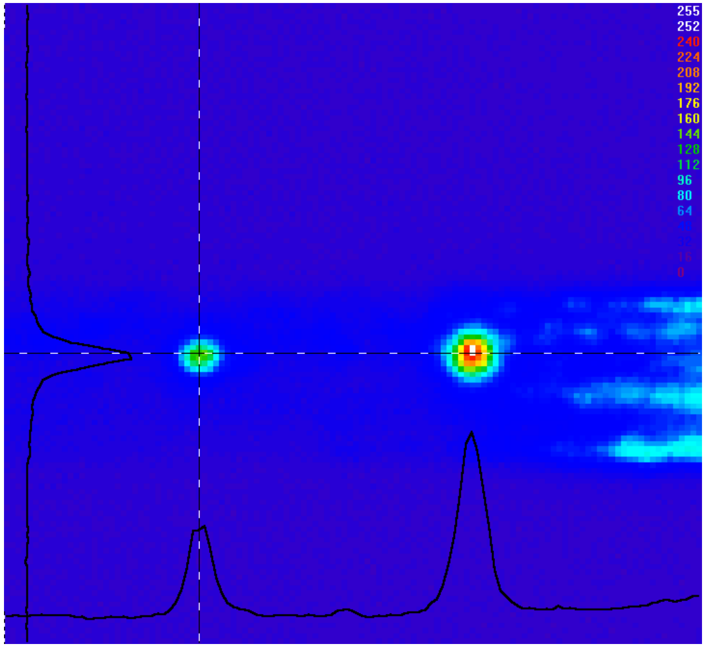
Electrode Pads

Input Waveguides

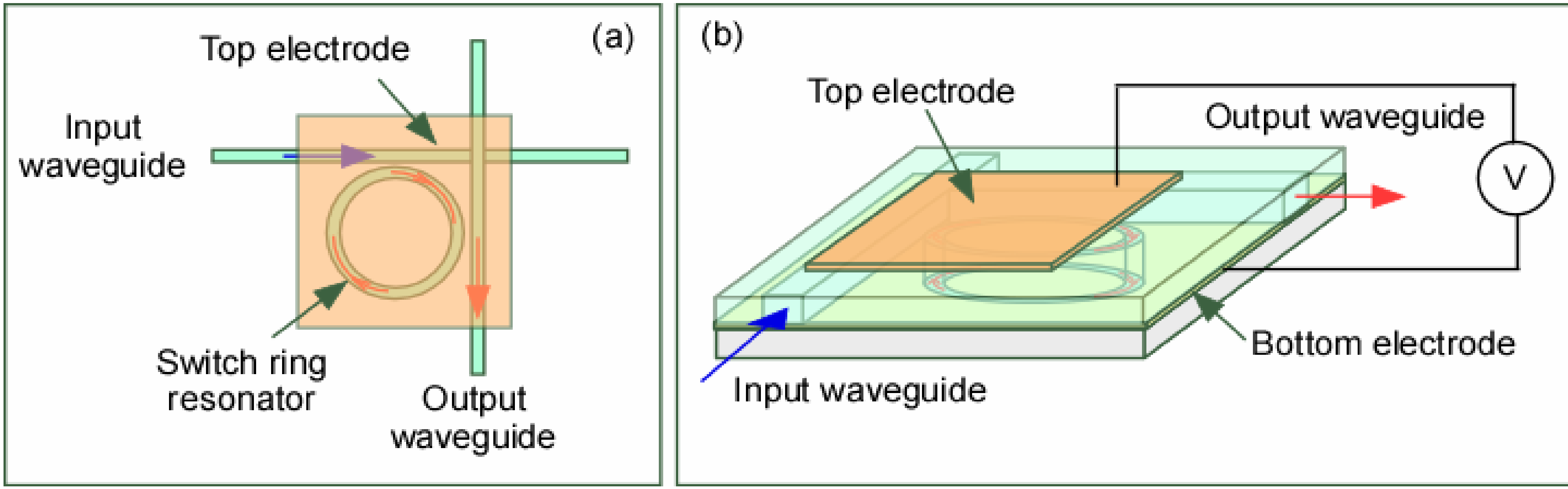
2 optical chips, each with an array of 8x8 optical switches

Device performance

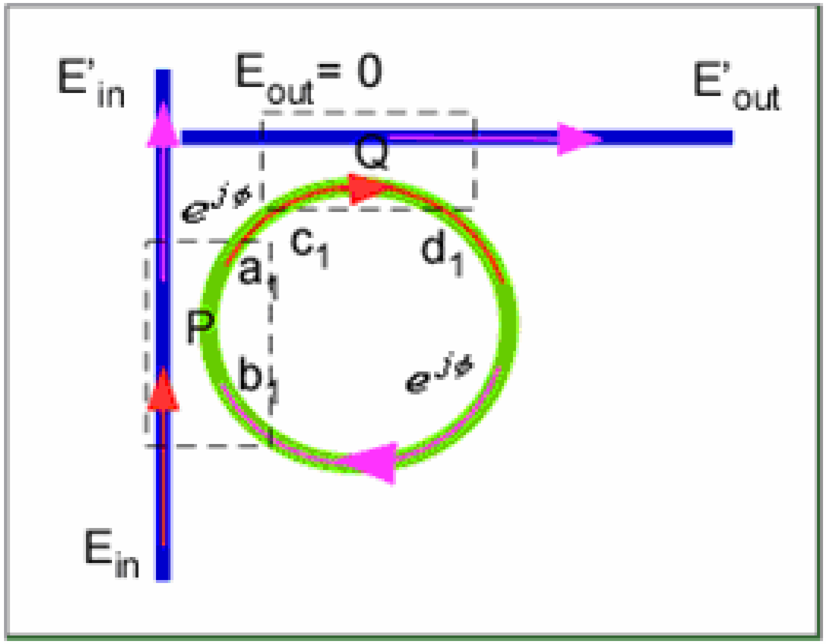


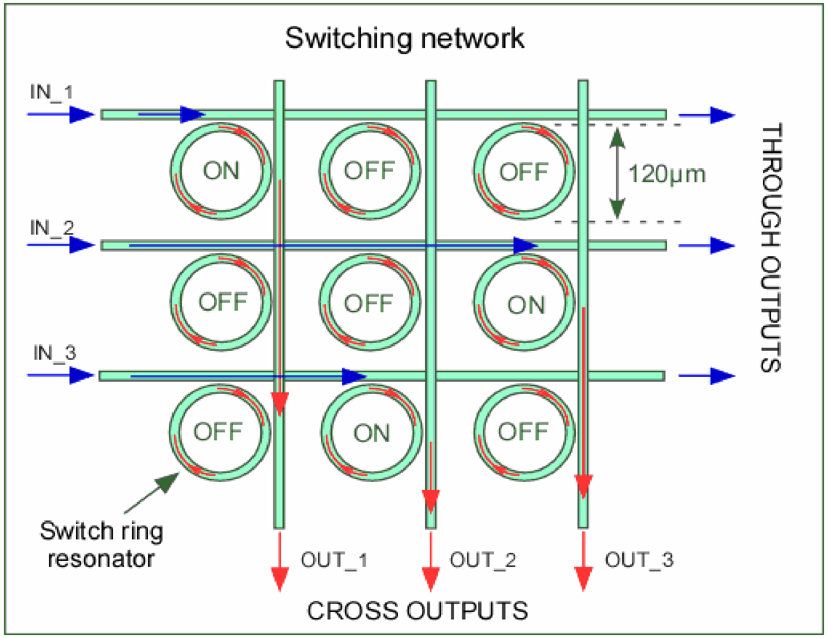


5. Resonator based EO optical switch



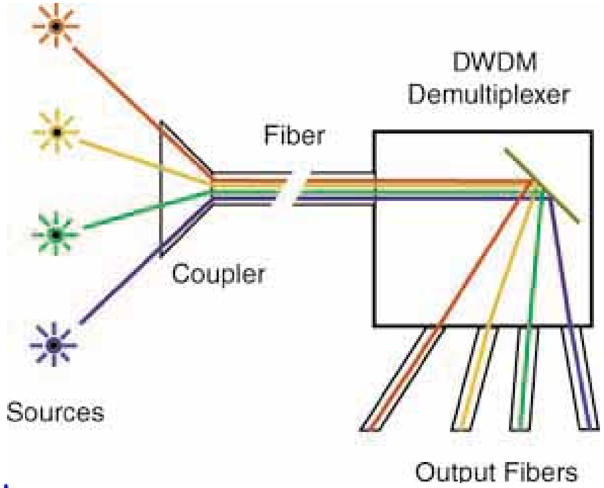
5. Resonator based EO optical switch array

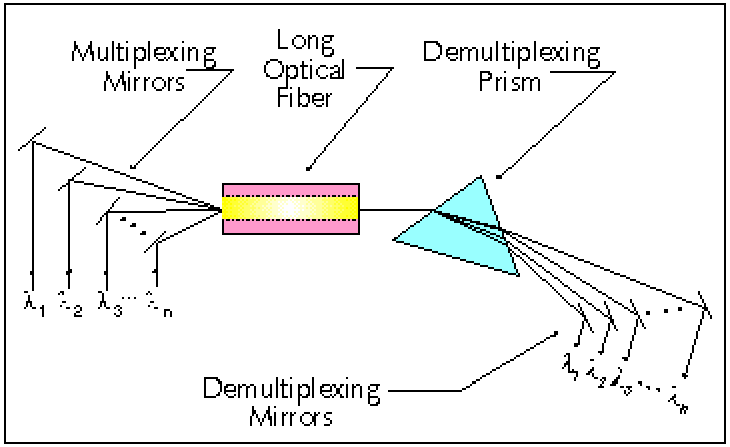




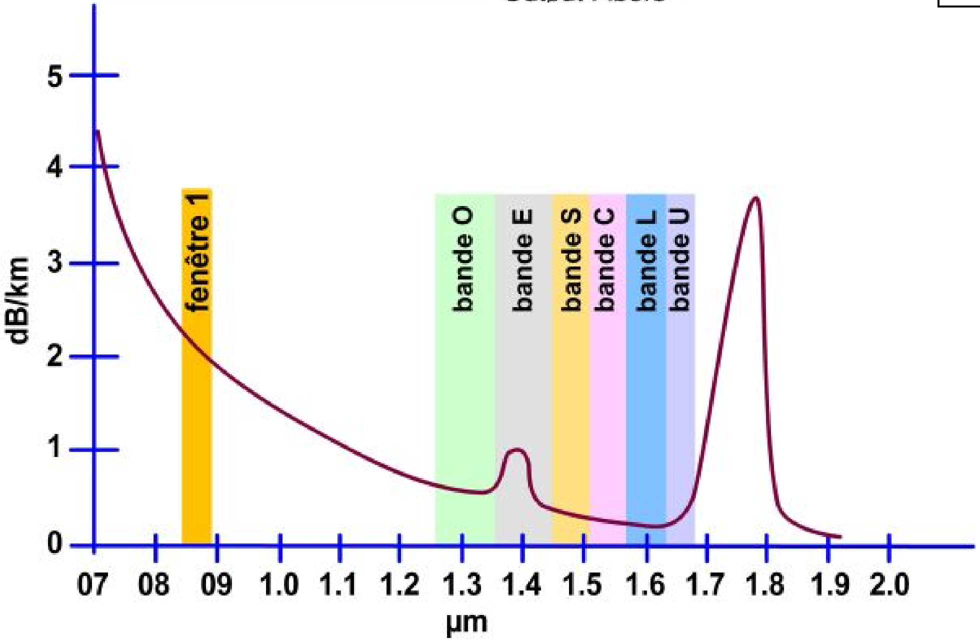
- Very compact size
- Easy scale up to NxN arrayt
- Low power consumption, high yield and high reliability

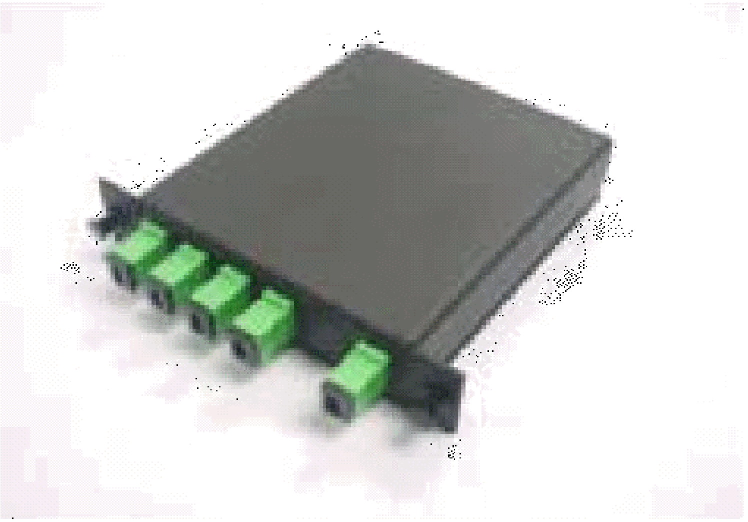
Wavelength division multiplexing (WDM) technology



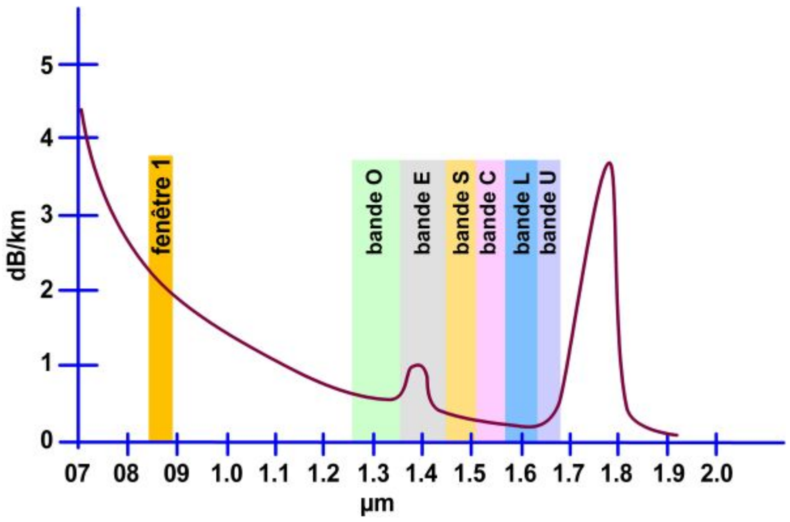


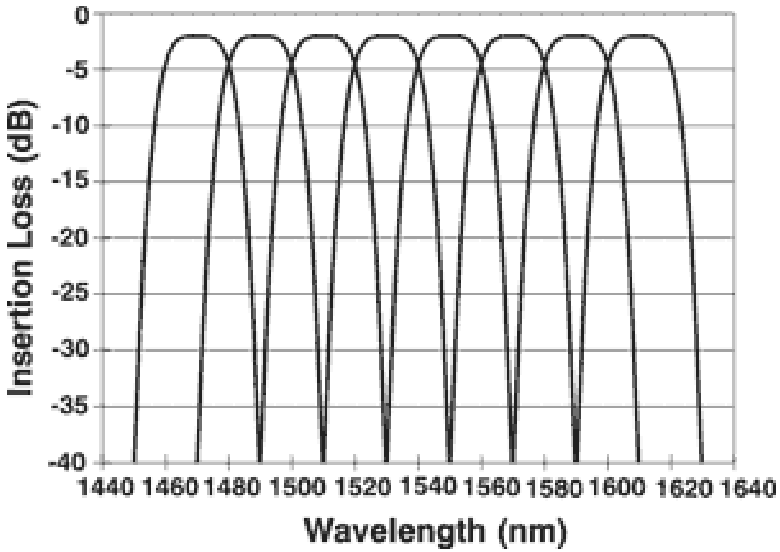
one kind of wavelength-division multiplexer



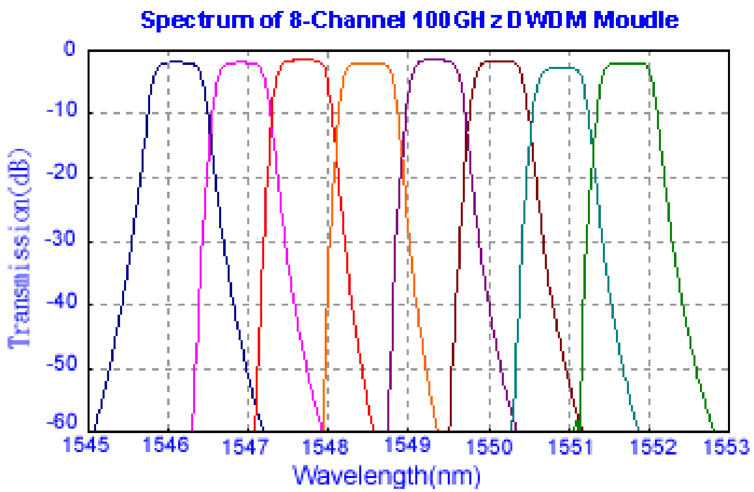


Coarse Wavelength-division Multiplexing (CWDM)

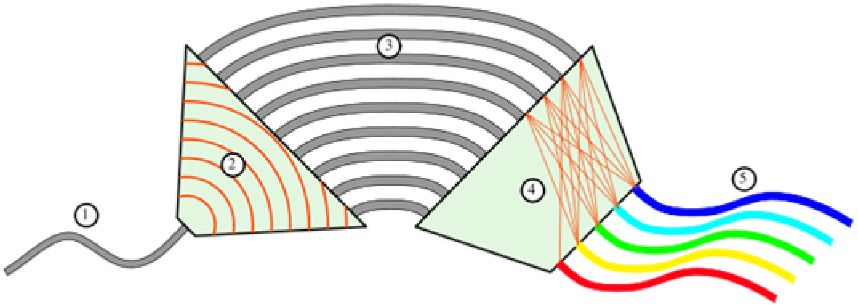


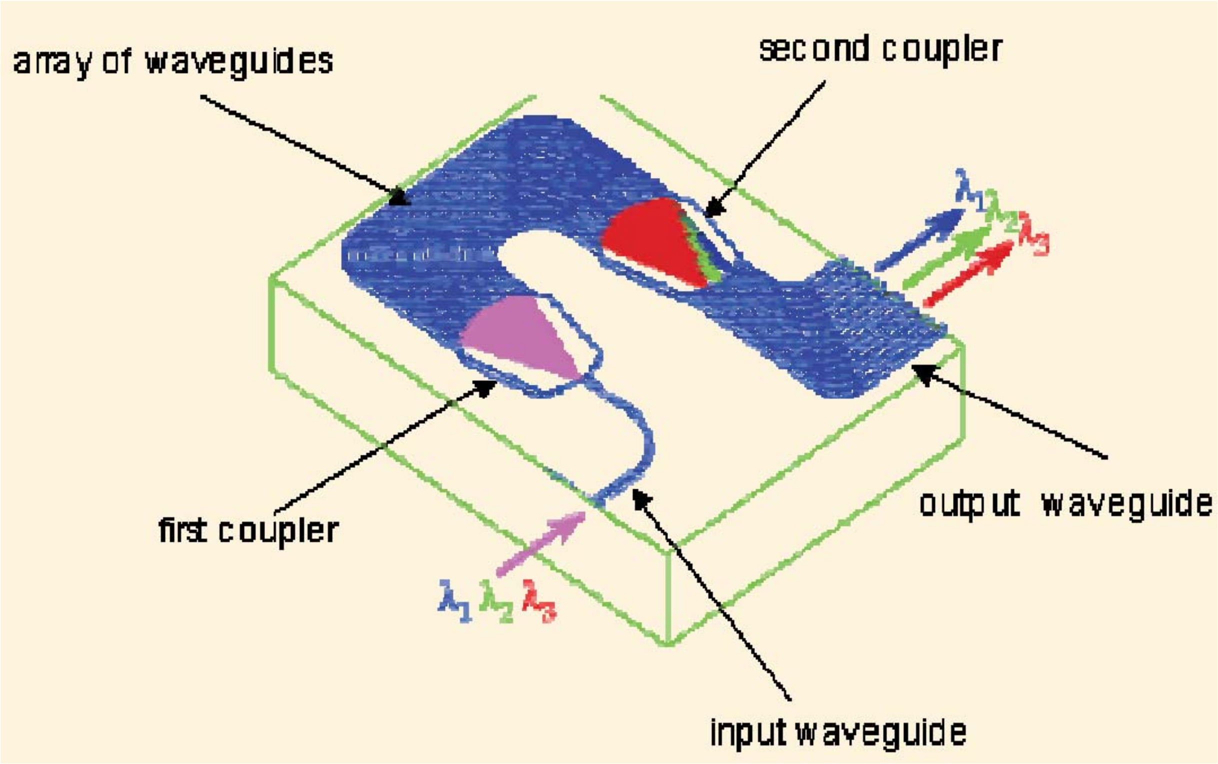


Dense Wavelength-division Multiplexing (DWDM)

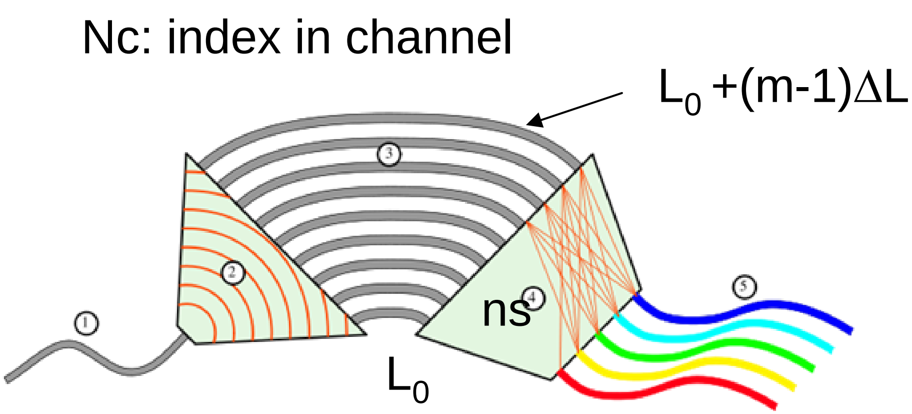


3. Array waveguide grating (AWG)





3. Array waveguide grating (AWG)

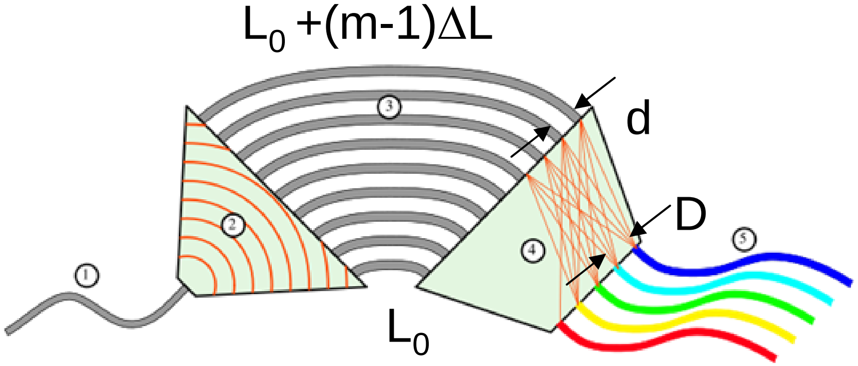


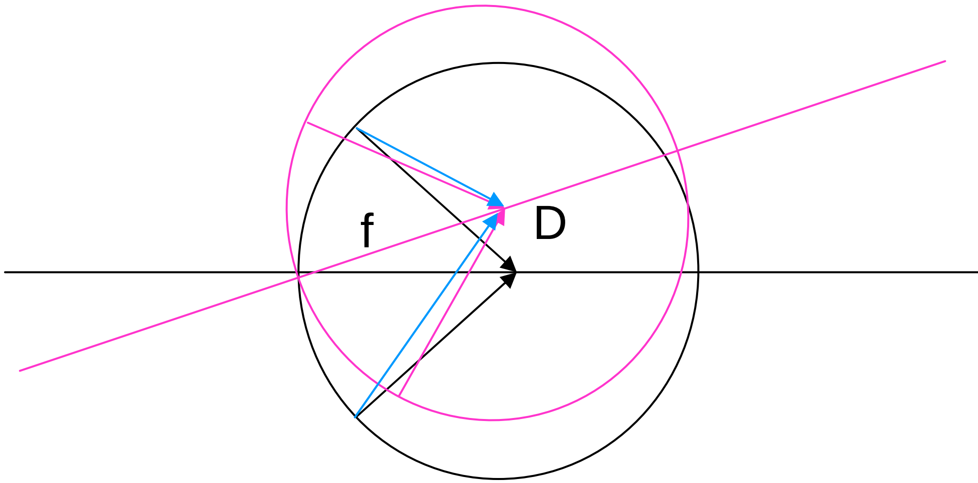
$$\sum_{m=1}^{N} \frac{A_0(\lambda)}{\sqrt{N}} e^{i\beta L_m} = \sum_{m=1}^{N} \frac{A_0(\lambda)}{\sqrt{N}} e^{i\frac{2\pi}{\lambda} L_0 [1+(m-1)\Delta L]}$$

Center channel

$$\frac{2\pi}{\lambda} N_c \Delta L = 2\pi$$

3. Array waveguide grating (AWG)





Upper one channel:

$L_0 + (m-1)\Delta L - (D/f)(m-1)d$

$$\frac{2\pi}{\lambda'}\left[N_c\Delta L - \frac{D}{f}dn_s\right] = 2n\pi \qquad \frac{2\pi}{\lambda}\Delta L N_c = 2\pi$$

$$\frac{2\pi}{\lambda'}\left[\Delta L N_c - \frac{D}{f}dn_s\right] = \frac{2\pi}{\lambda}N_C\Delta L \qquad \frac{\Delta\lambda}{\lambda}\Delta L N_c = \frac{D}{f}dn_s \qquad \boxed{\Delta L = \frac{Dd\lambda n_s}{\Delta\lambda f N_c}}$$