All Optical OXC Configurations

All Optical OXC Configurations

- Focus the discussion on understanding some of the issues associated with the all-optical configuration.
- The configuration can be highly cost-effective relative to the other configurations, but lacks three key functions: low-speed grooming, wavelength conversion, and signal regeneration.
- Low-speed grooming is needed to aggregate the lower-speed traffic streams properly for transmission over the fiber.
- Optical signals need to be regenerated once they have propagated through a number of fiber spans and/or other lossy elements.

All Optical OXC Configurations

- Wavelength conversion is needed to improve the utilization of the network.
- We have two lightpaths currently set up on each link in the network as shown and need to set up a new lightpaths from node A to node C.
- Figure 7.10(a) shows the case where node B cannot perform wavelength conversion.
- Even though there are free wavelengths available in the network, the same wavelength is not available on both links in the network.
- As a result, we cannot set up the desired lightpath.
- On the other hand, if node B can convert wavelengths, then we can set up the lightpath as shown in Figure 7.10(b).

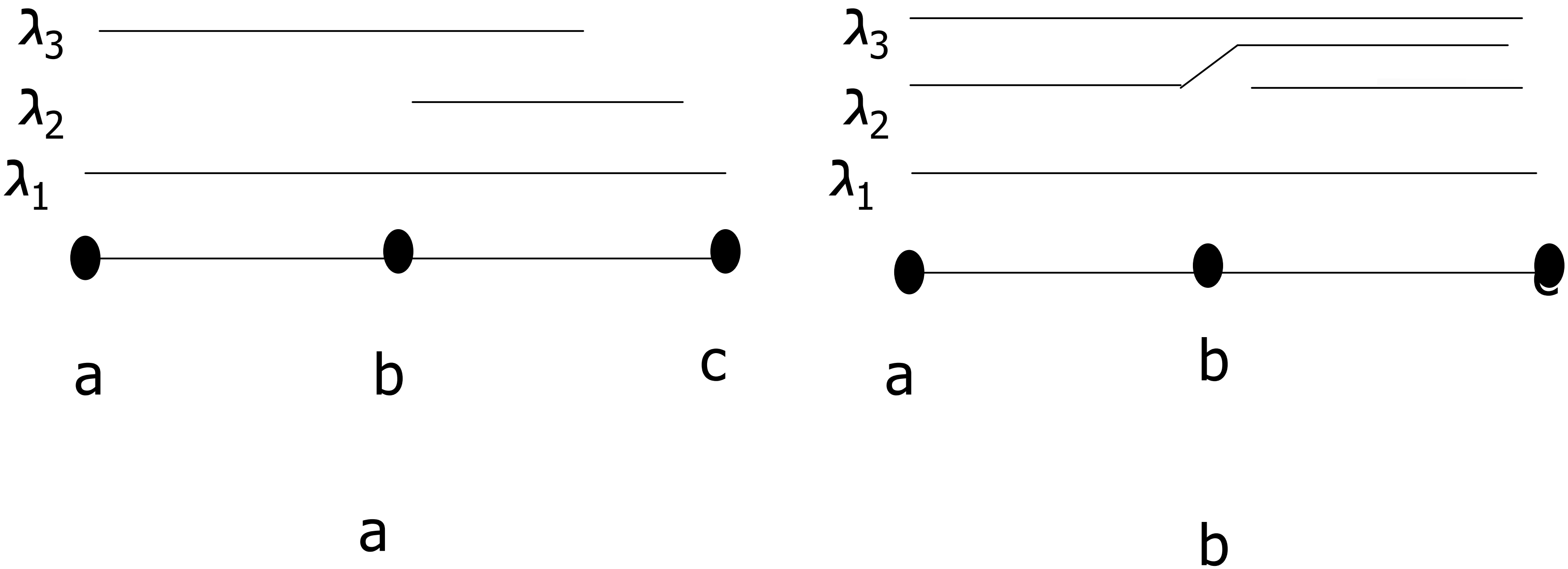


Fig. 7.10 Illustrating the need for wavelength conversion

a. Node B does not convert wavelength.

b. Node B can convert wavelength.

All Optical OXC Configurations

- Note the configurations of Figure 7.9(a), (b) and (c) all provide wavelength conversion and signal regeneration either in the OXC itself or by making use of the transponders in the attached OLTs.
- Figure 7.9(a) also provides low-speed grooming, assuming that the electrical core has been designed to support that capability.
- In order to provide grooming, signal regeneration, and wavelength conversion, the configuration of figure 7.9(d) is modified to include an electrical core crossconnect as shown in Figure 7.11.

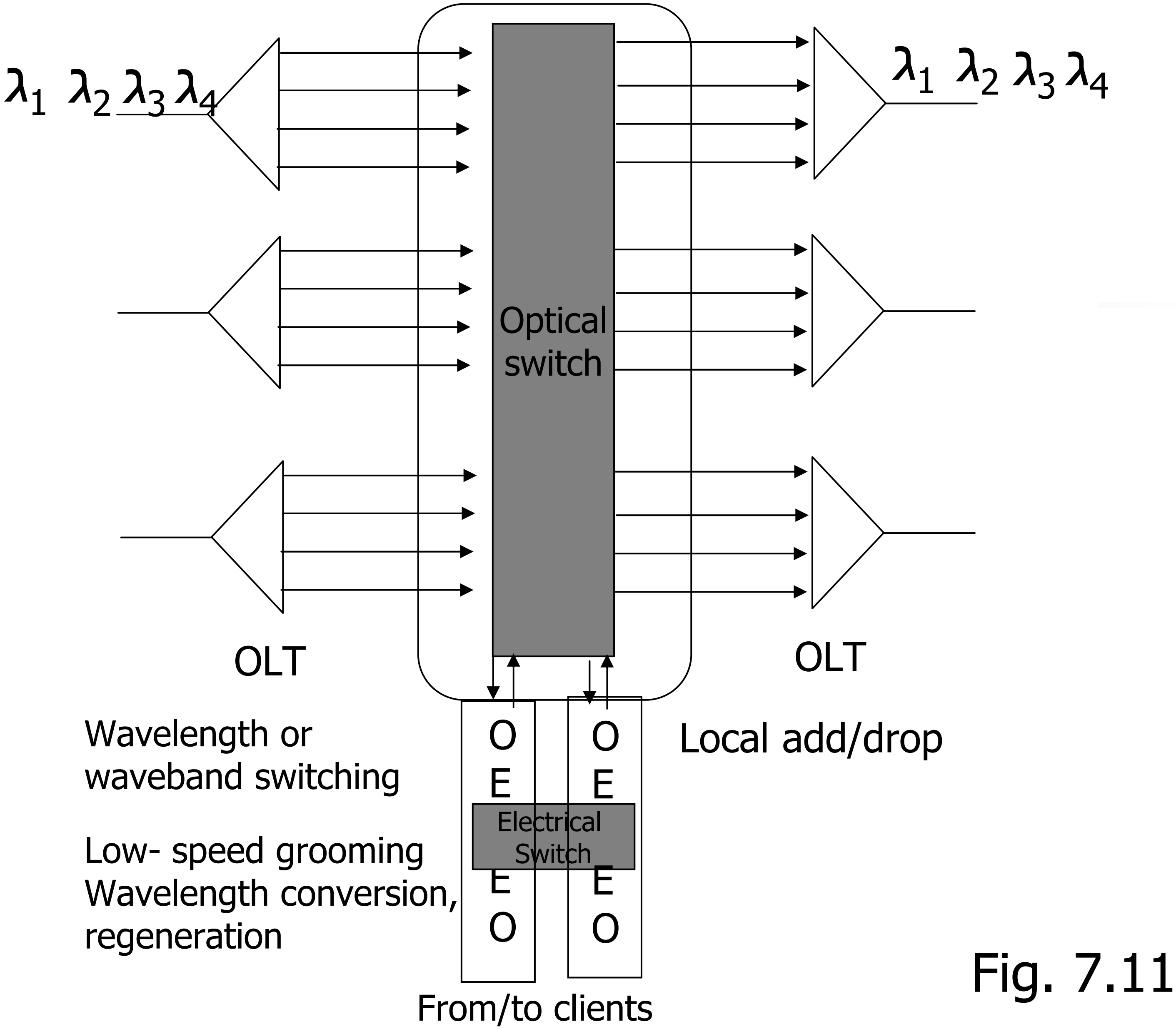


Fig. 7.11

A realistic “all optical” network node combining optical core crossconnects with electrical core crossconnects. Signals are switched in the optical domain whenever possible but routed down to the electrical domain whenever they need to be groomed, regenerated, or converted from one wavelength to another.

All Optical OXC Configurations

- This configuration allows most of the signals to be switched in the optical domain, minimizing the cost and maximizing the capacity of the network, while allowing us to route the signals down to the electrical layer whenever necessary.
- Figure 7.12 shows a wavelength plane OXC.
- The signals coming in over different fiber pairs are first demultiplexed by the OLTs.

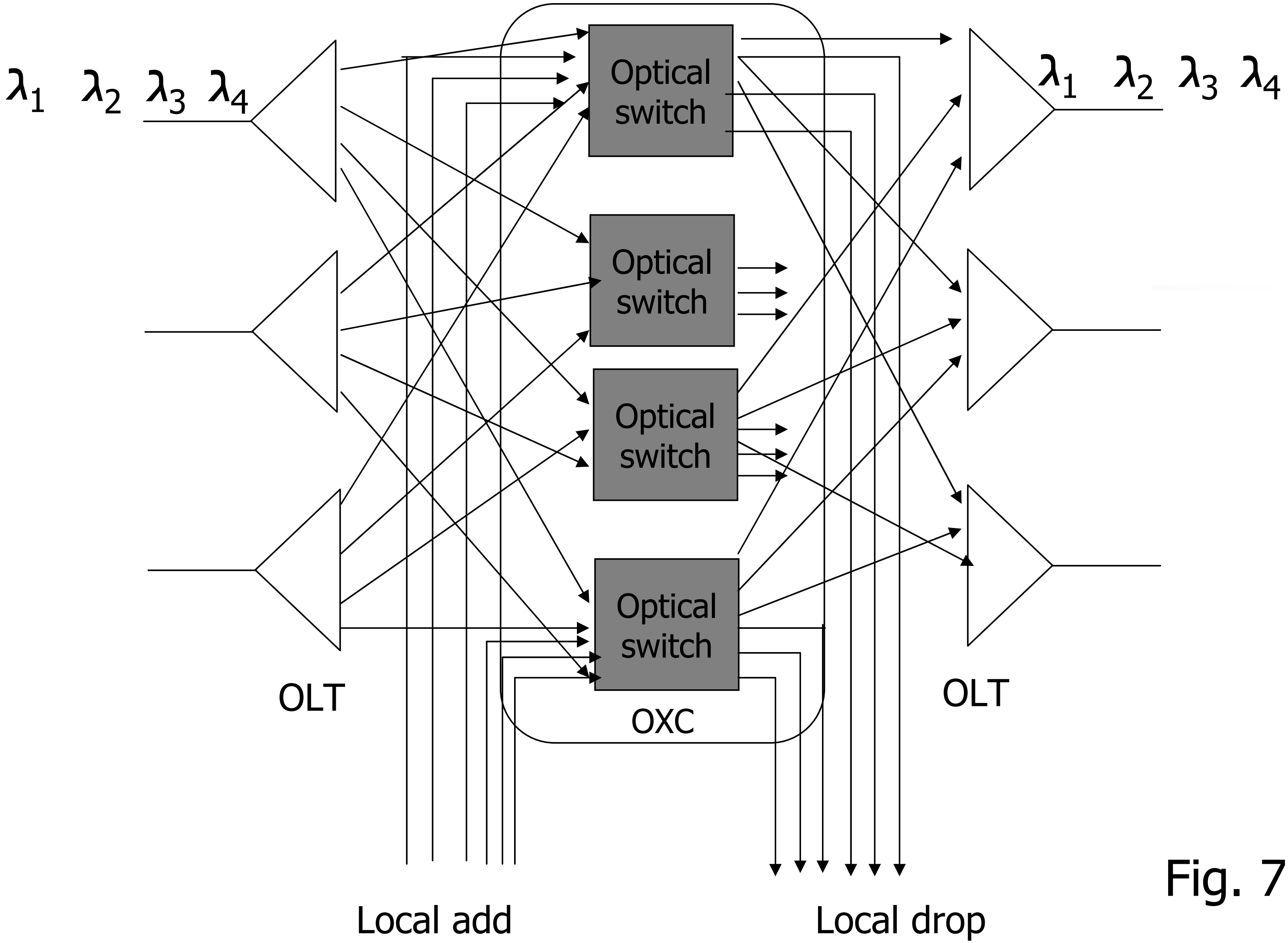


Fig. 7.12

An optical core wavelength plane OXC, consisting of a plane of optical switches, one of Each wavelength. With F fibers and W wavelengths on each fiber, each switch is a 2F x 2F Switch, if we want the flexibility to drop and add any wavelength at the node.

All Optical OXC Configurations

- All the signals at a given wavelength are sent to a switch dedicated to that wavelength, and the signals from the outputs of the switches are multiplexed back together by the OLTs.
- In a node with F WDM fiber pairs and W wavelengths on each fiber pair, this arrangement uses F OLTs and W 2F x 2F switches.
- This allows any or all signals on any input wavelength to be dropped locally.
- In contrast, the configuration of Figure 7.11 uses F OLTs and only one 2WF x 2Wf switch to provide the same capabilities.

All Optical OXC Configurations

- Based on the discussion above, it would appear that the wavelength plane approach offers a cheaper alternative to large-scale nonblocking optical switches.
- Both Figure 7.11 and Figure 7.12 assume that there are sufficient ports to terminate all WF signals.
- To summarize, the wavelength plane approach needs to take into account the number of fibers, fraction of add/drop traffic, number of terminations, and their tuning capabilities as separate parameters in the design.

All Optical OXC Configurations

- With a large-scale switch, we can partition the ports in a flexible way to account for variations in all these parameters-the only constraint is in the total number of ports available.
- Electrical core and optical core OXCs are becoming available.
- Electrical core OXCs with total capacities up to a few Tb/s, capable of grooming down to STS-1 (51 Mb/s), are becoming available.
- Optical core OXCs with over 1000 ports are also emerging as commercial products, and wavelength plane OXCs are being offered by some vendors as well.

Summary

- WDM network provides circuit-switched lightpaths that can have varying degrees of transparency associated with them.
- Wavelength can be reused in the network to support multiple lightpaths as long as no two lightpaths are assigned the same wavelength on a given link.
- Lightpaths may be protected by the network in the event of failures.
- Lightpaths can be used to provide flexible interconnections between users of the optical network, such as IP routers, allowing the router topology to be tailored to the needs of the router network.

Summary

- An optical line terminal (OLT) multiplexes and demultiplexes wavelengths and is used for point-to-point applications.
- It typically includes transponders, multiplexers, and optical amplifiers.
- Transponders provide the adaptation of user signals into the optical layer.
- They also constitute a significant portion of the cost and footprint in an OLT.
- In some cases, transponders can be eliminated by deploying interfaces that provide already-adapted signals at the appropriate wavelengths in other equipment.

Summary

- An optical add/drop multiplexer (OADM) drops and adds a selective number of wavelengths from a WDM signal, while allowing the remaining wavelengths to pass through.
- OADMs provide a cost-effective way of performing this function, compared to using OLTs interconnected back to back, or relying on other equipment to handle the passthrough traffic.
- OADMs are typically deployed in linear or ring topologies.

Summary

- Several types of OADMs are possible with a range of capabilities based on the number of wavelengths they can add and drop, the ease of dropping and adding additional wavelengths, static or reconfigurable.
- We studied the basic architectural flavors of OADMs: parallel, serial, and band drop.
- We also looked at reconfigurable OADM architectures, which use tunable filters and/or multiplexers, as well as tunable lasers, in order to provide the maximum possible flexibility in the network.
- An optical crossconnect (OXC) is the other key network element in the optical layer.

Summary

- OXCs are large switches used to provision services dynamically as well as provide network restoration.
- OXCs are typically deployed in a mesh network configuration.
- As with OADMs several variants of OXCs exist, ranging from OXCs with electrical switch cores capable of grooming traffic at STS-1 rates to all optical OXCs that can switch wavelengths, bands of wavelengths, and entire fibers.

Summary

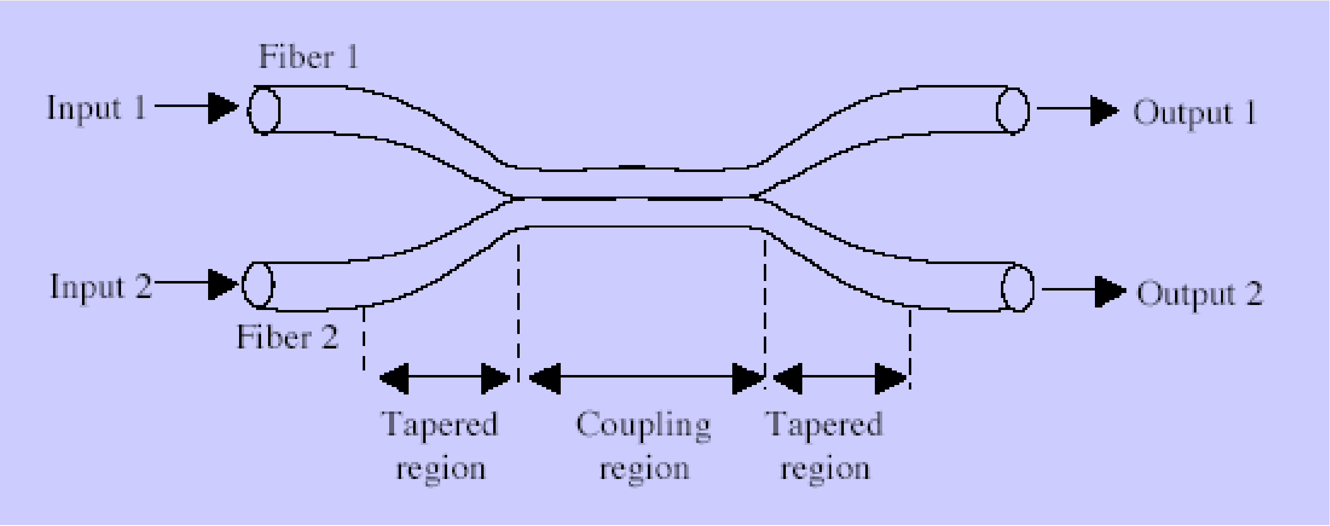
- Optical core crossconnects can also be surrounded by optical-to-electrical-to-optical converters to provide some of the grooming and wavelength conversion capabilities offered by electrical core crossconnects, but are not suited for grooming traffic at fine granularities such as STS-1 rates.
- Each has its role in the network.

OXCs

A bit more

The 2x2 coupler

- The 2x2 coupler is a basic device in optical networks, and,
- It can be constructed in variety of different ways.
- A common construction is the *fused-fiber* coupler.

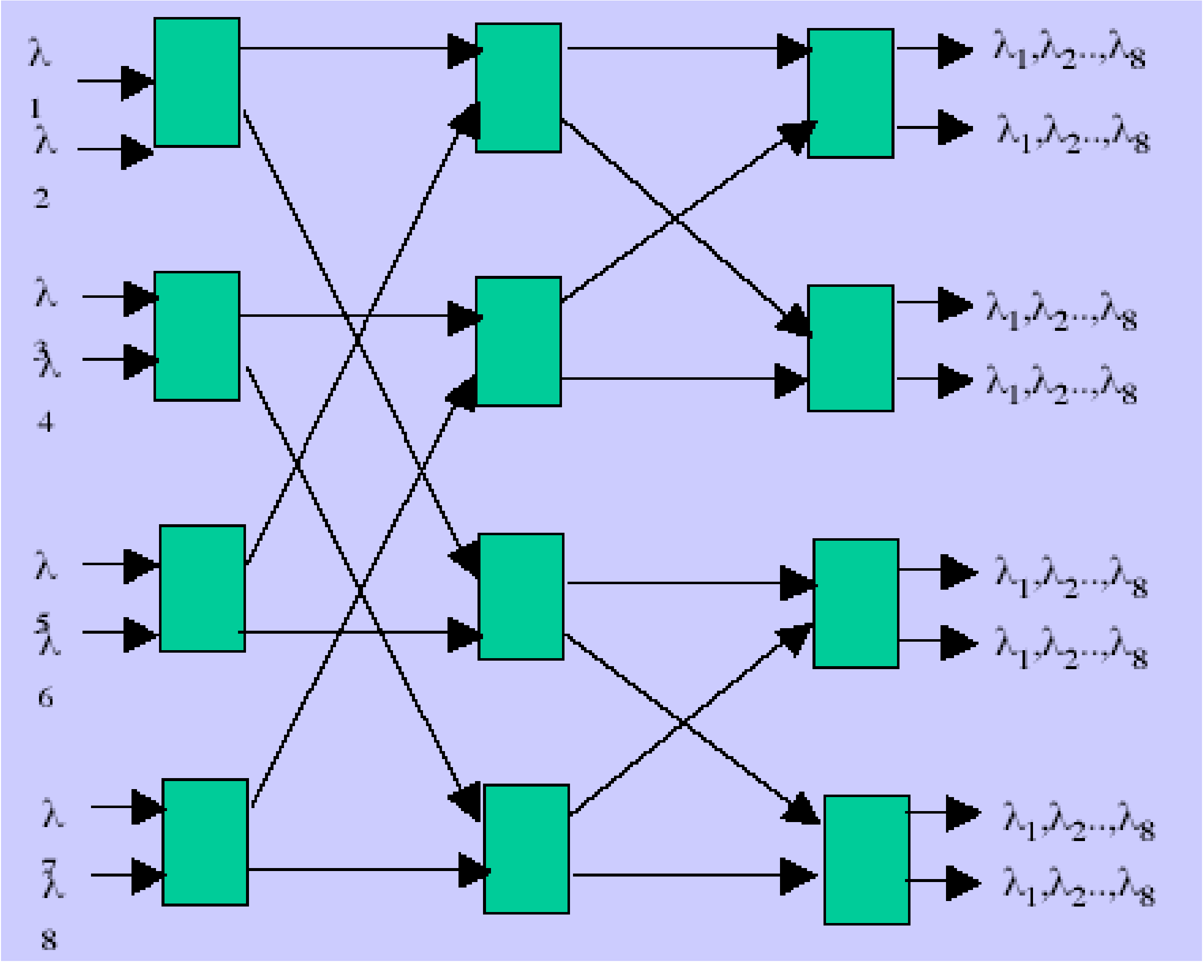


3-dB coupler

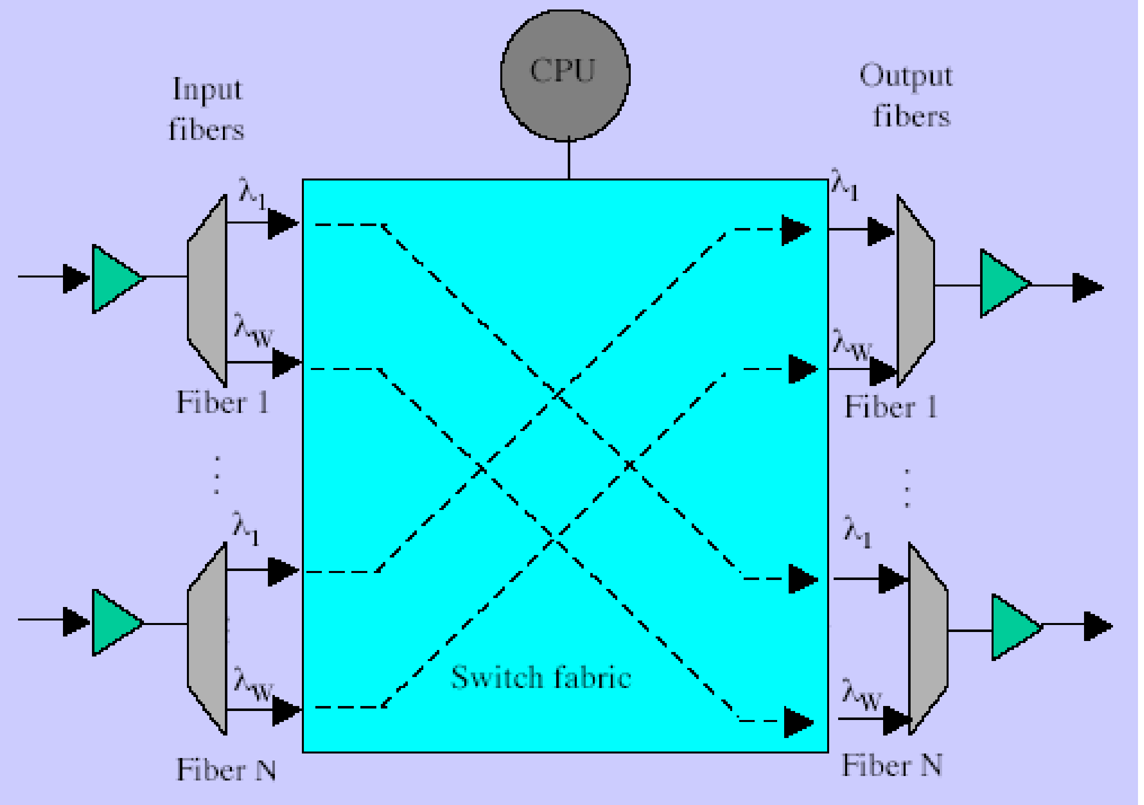
- A 2x2 coupler is called a *3-dB coupler* when the optical power of an input light applied to, say input 1 of fiber 1, is evenly divided between output 1 and output 2.
- If we only launch a light to the one of the two inputs of a 3-dB coupler, say input 1, then the coupler acts as a *splitter*.

- If we launch a light to input 1 and a light to input 2 of a 3-dB coupler, then the two lights will be coupled together and the resulting light will be evenly divided between outputs 1 and 2.
- In the above case, if we ignore output 2, the 3-dB coupler acts as a *combiner*.

A banyan network of 3-dB couplers



Optical cross connects (OXCs)



A logical diagram of an OXC

OXC functionality

- It switches optically all the incoming wavelengths of the input fibers to the outgoing wavelengths of the output fibers.
- For instance, it can switch the optical signal on incoming wavelength λ_i of input fiber k to the outgoing wavelength λ_i of output fiber m.

Converters

- If it is equipped with converters, it can switch the optical signal of the incoming wavelength λi of input fiber k to another outgoing wavelength λj of the output fiber m.
- This happens when the wavelength λi of the output fiber m is in use.
- Converters typically have a limited range within they can convert a wavelength.

Optical add/drop multiplexer (OADM)

- An OXC can also be used as an OADM.
- That is, it can terminate the optical signal of a number of incoming wavelengths and insert new optical signals on the same wavelengths in an output port.
- The remaining incoming wavelengths are switched through as described above.

Transparent and Opaque Switches

Transparent switch:

- The incoming wavelengths are switched to the output fibers optically, without having to convert them to the electrical domain.

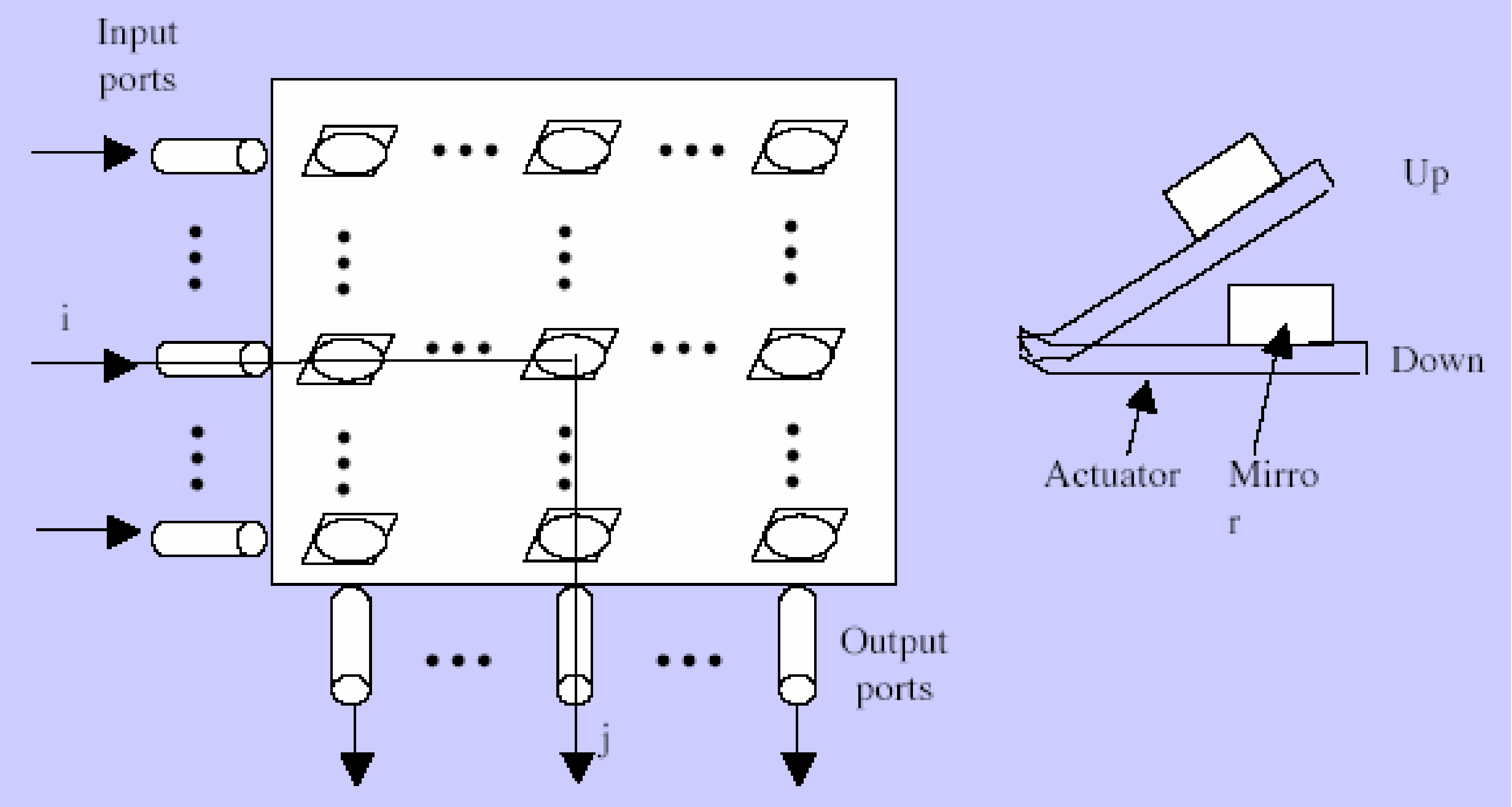
Opaque switch:

- The input optical signals are converted to electrical signals, from where the packets are extracted. Packets are switched using a packet switch, and then they are transmitted out of the switch in the optical domain.

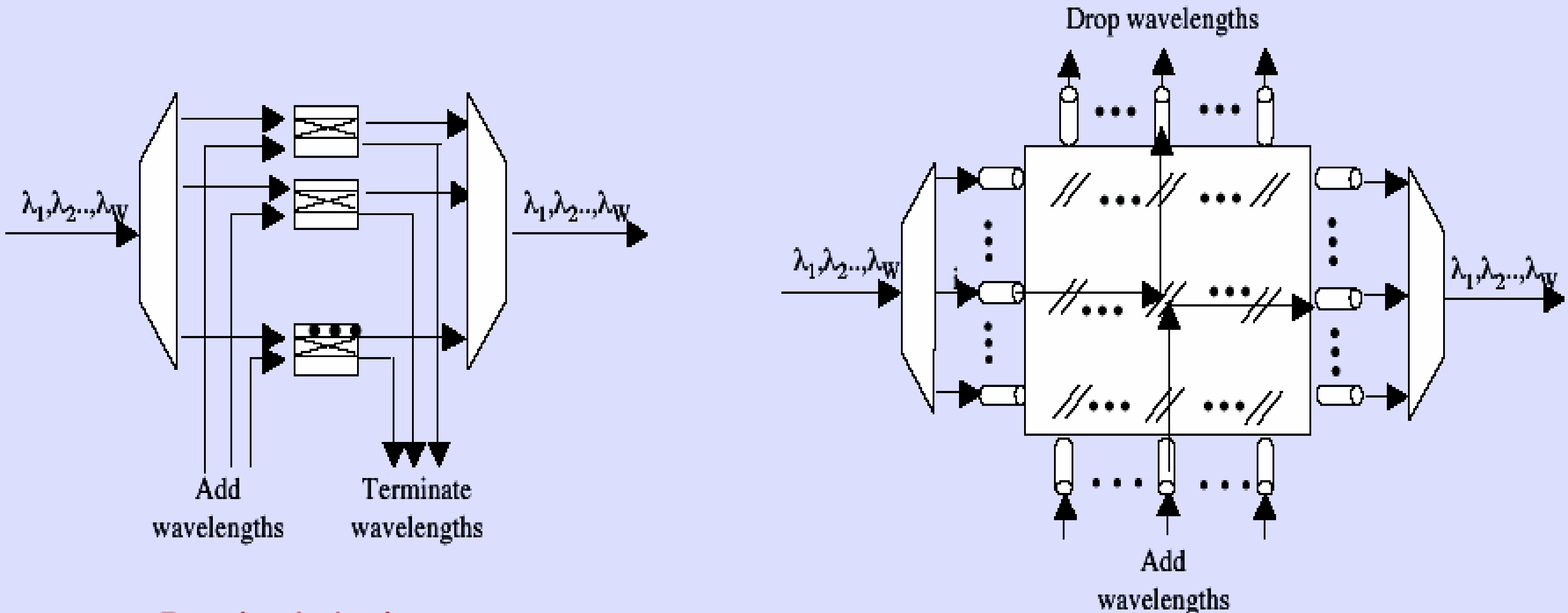
Switch technologies

- Several different technologies exist:
  - *micro electronic mechanical systems (MEMS)*
  - *semiconductor optical amplifiers (SOA)*
  - *micro-bubbles*
  - *holograms*
  - Also, 2x2 directional coupler , such as the *electro-optic switch*, the *thermo-optic switch*, and the *Mach-Zehnder interferometer*, can be used to construct large OXC switch fabrics

2D MEMS switching fabric



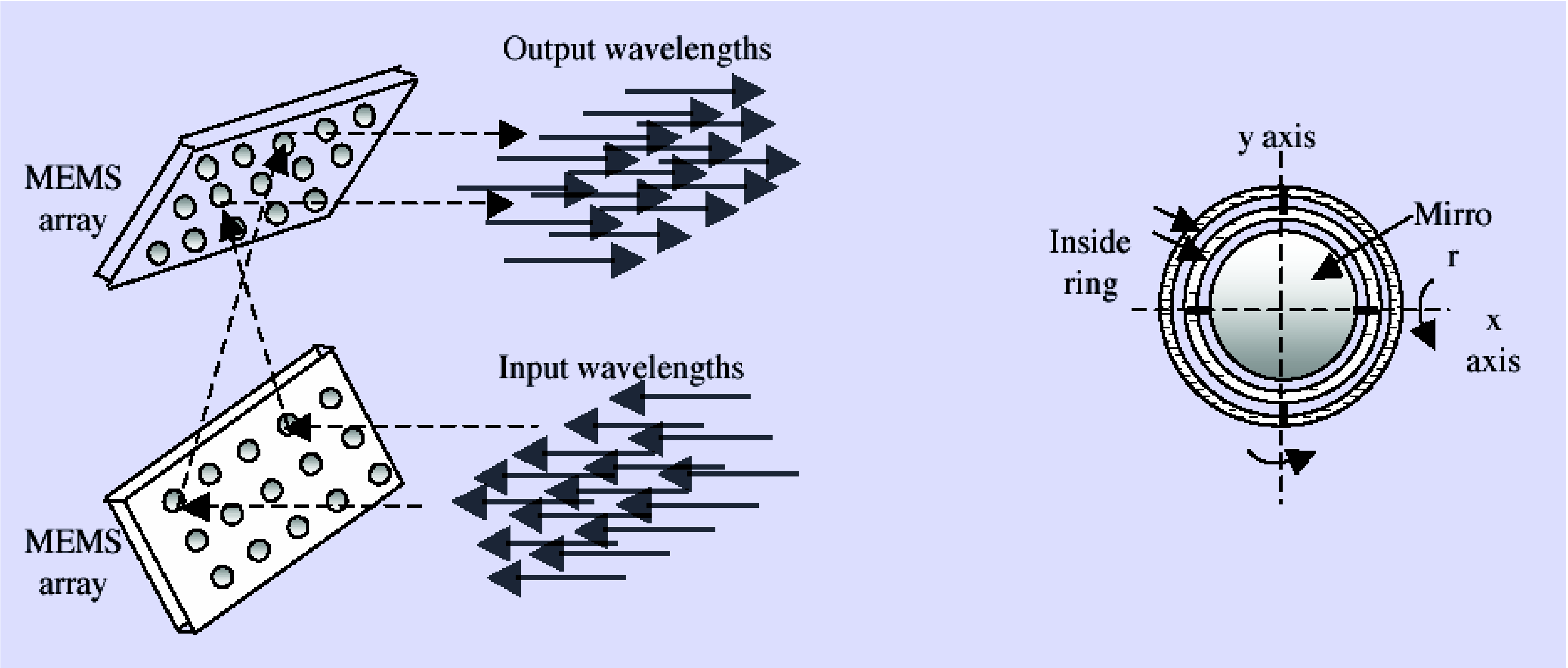
A 2D MEMS OADM



Logical design

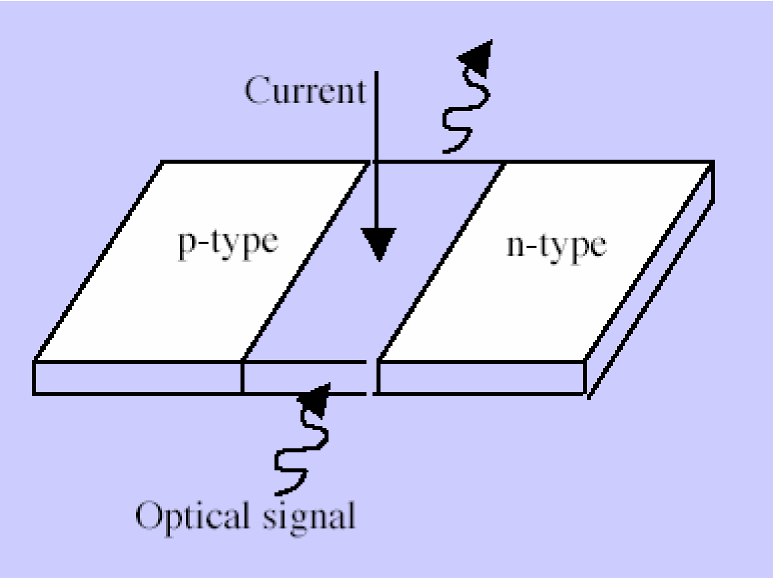
2D MEMS implementation

3D MEMS switching fabric



Semiconductor optical amplifier (SOA)

- A SOA is a *pn-junction* that acts as an amplifier and also as an on-off switch



A 2x2 SOA switch

- Wavelength λ_1 is split into two optical signals, and each signal is directed to a different SOA. One SOA amplifies the optical signal and permits it to go through, and the other one stops it. As a result λ_1 may leave from either the upper or the lower output port.
- Switching time is currently about 100 psec.