

## Integrated Optics

Integrated Optics, or Planar Lightwave Circuits (PLC), are regarded as an attractive solution to meet the future optical telecom component requirements.

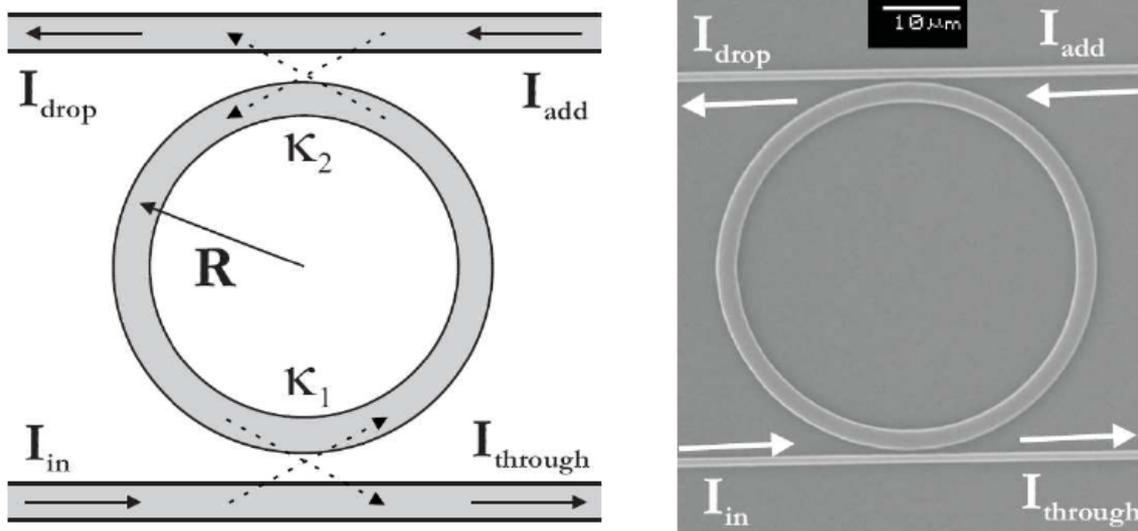


Planar Lightwave Circuit

The PLC provides a flexible platform technology in which components that have filtering and/or switching functions can be fabricated. PLC technology also inherently lends itself to high levels of integration. In addition, PLC devices and systems are already being produced and have gained wide acceptance within the telecom community. The ability to integrate multiple functions in a single PLC circuit provides a significant cost advantage. For the vast majority of optical components, the cost of packaging dominates the overall cost of the component (>90% of cost is due to packaging). Therefore, integration of multiple functions in a single PLC chip reduces the packaging cost per function linearly. This provides a direct route to achieving low cost systems. Integration is especially attractive when the components can be made with standard processes already in mass-production.

## *The Microring Resonator*

The Microring Resonator (MR) represents a fundamental PLC building block component. It is an integrated optics filter element with characteristics very similar to those of a free-space Fabry-Perot filter. The MR offers the advantage, however, that injected and reflected signals are inherently separated into individual waveguides. In addition, since an MR does not require any facets or gratings, it is particularly simple to implement. MRs evolved from the fields of fiber optic ring resonators and micron scale droplets. Their inherently small size (with typical diameters in the range of several to tens of micrometers), filter characteristics, and potential for use in complex and flexible configurations, make these devices attractive for use in many integrated optics and VLSI photonics applications.

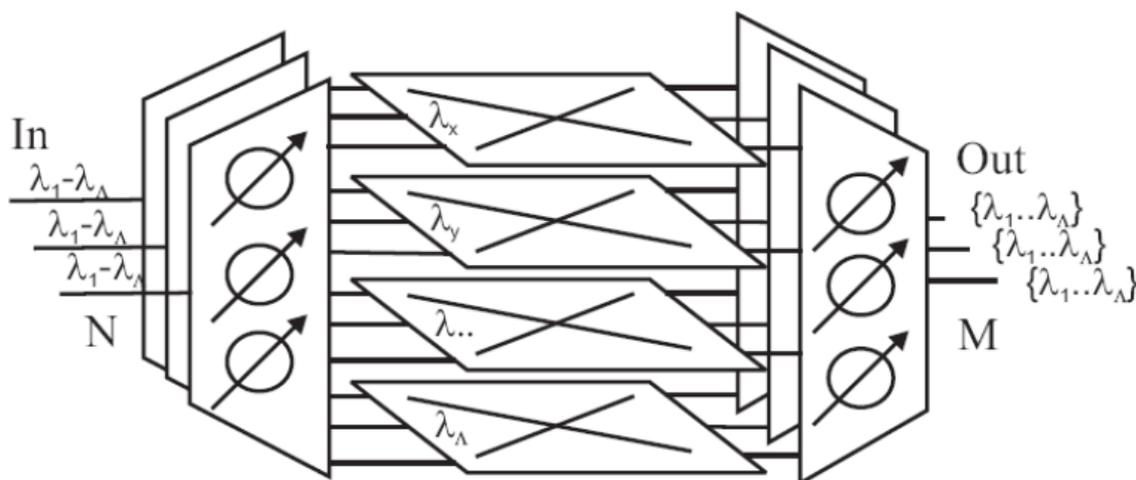


Microring Resonator

The structure consists of a ring waveguide of radius  $R$  and two straight port waveguides. The ring and port waveguides are evanescently coupled; therefore, a fraction of the incoming field is coupled to the ring. When the optical path-length of a roundtrip is a multiple of the effective wavelength, light ‘builds up’ inside the ring and constructive interference occurs. In this state, the MR is referred to as being “at resonance” (or, alternatively, ON resonance). Periodic fringes appear in the wavelength response at the output ports of the MR; the drop port shows maximum transmission since a fraction of the buildup field inside the ring is coupled to this port; and the through port of the ring exhibits a minimum transmission. In the ideal case (i.e., with equal coupling constants and no microring resonator losses), all optical power is directed to the drop port at resonance.

## ***Photonic switching and routing platform***

A photonic switching and routing platform can be produced by means of dense integration of MR filters. Such a platform enables development of flexible and reconfigurable network components such as optical switches, ROADMS, and dynamic gain equalizing filters.

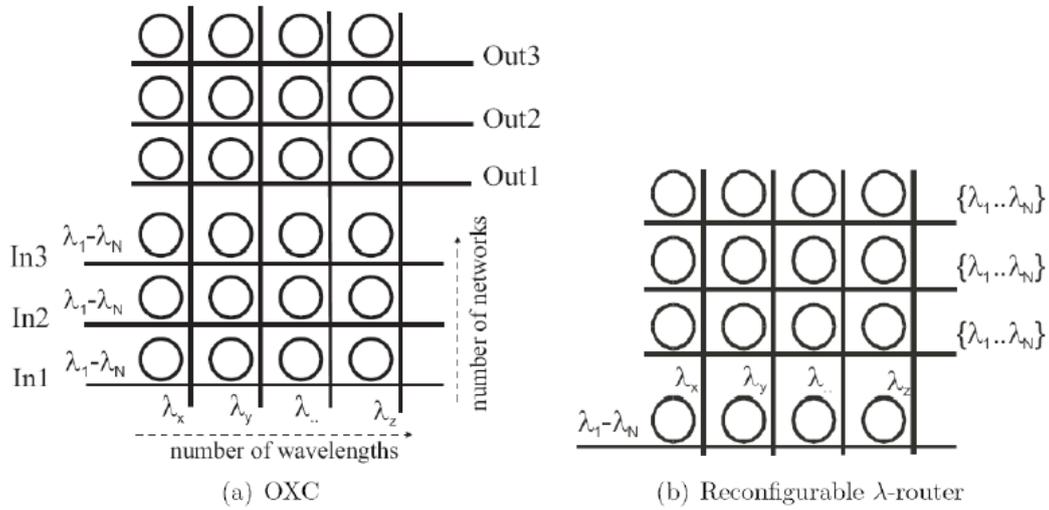


Photonic switching and routing platform

The flexibility of the platform arises from the ability to combine multiple structures of different complexity on a single chip. In addition, individual tuning capability of each MR enables reconfigurability at the individual channel level. Complex switch matrixes can be realized by means of the switching platform. The matrix is scalable and reconfigurable on a wavelength channel basis. Alternative levels of complexity can also be achieved for use in lower-level applications. Three examples of possible implementations for three different network types are:

- First an Optical Cross Connect (OXC) for connecting several wavelength channels of several networks at high speed bit rates
- A reconfigurable I-router which can be used to distribute wavelength in a point to multi point fashion, for example in active access network implementations
- An Optical Network Unit which can be used to actively separate wavelengths at the customer's premises if the network architecture asks for this.

No matter what level of complexity or application, a system based on the photonic switching and routing platform is cost effective and reconfigurable.



Possible implementations of the photonic switching and routing Platform

## Visible Light application field

The Visible Light application field supplies a broad scope of products ranging from consumer mass products to high-end medical applications. Optical integration is the road to adding functionality in a form-factor led by miniaturization and cost price. Reducing the amount of discrete optical components opens the way to a smaller, more reliable and economic viable solution for the next generation products like portable pico-projectors and beamcombiners for fluorescence microscopy.

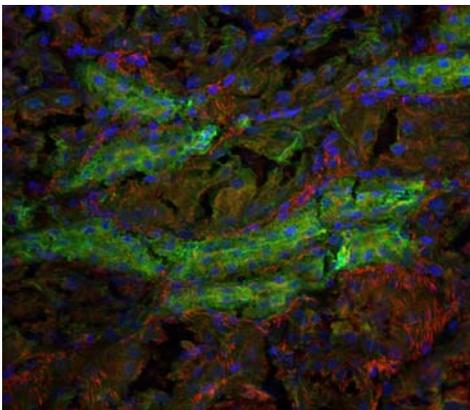


Image obtained using Fluorescence microscopy



Portable pico-projectors

## ***Visible Light Applications***

The Visible Light application field supplies a broad scope of products ranging from consumer mass products to high end medical applications. Optical integration is the road into adding functionality inside a form factor that is driven by miniaturization. Reducing the amount of discrete optical components opens the way to a smaller, more reliable and economic viable solution for the next generation visible light products like portable beamers and beamcombiners for microscopy.

### 400 nm - 700 nm wavelength range

The wavelength range for the application area of the visible light is between 400 and 700 nm. Products are developed that use the visibility property of these wavelengths together with our integration platform that allows for integration of different functional components into one product

### Example: RGB beamguider

An example of this application area is shown in the figure below where three different wavelengths are guided by the same type of integrated optical waveguide. By this means a RGB beamguider based on planar lightwave circuitry is demonstrated. In combination with advanced packaging concepts these RGB waveguide structures allow for very compact beamcombiner structures.



RGB Beamguider

## ***TOADF***

Network components based on the TriPleX waveguide technology are available. These components combine the unique properties like low optical loss, polarization independency and tunability to create solutions with high flexibility and scalability. These unique properties combined give unprecedented performance for example in Reconfigurable Optical Add/Drop Multiplexers (ROADMs), Wavelength-Selective Switches (WSS's) and Tunable Optical Add-Drop Filters (TOADFs).

Integrated-optic devices for reconfigurable network components are the key to achieving high system functionality at low cost since they offer:

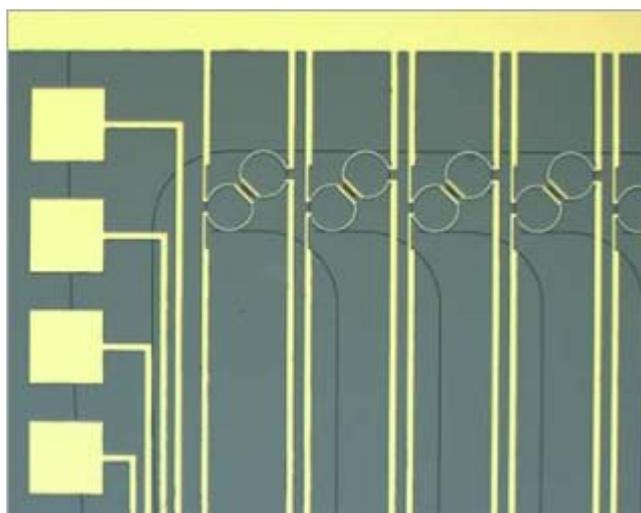
- No electro-optical (EO) conversion in the data path
- Monolithical integration of multiple functions
- Cost savings in packaging, device area and power consumption
- Reconfigurability – increased system flexibility.

## Specifications

The module provides the system designer with a remotely configurable tool to create flexible, wavelength agile optical networks.

The TOADF (Tunable Optical Add-Drop Filter) unit is optimized to drop any specified channel from a DWDM traffic stream. All the other channels are directed to the express port.

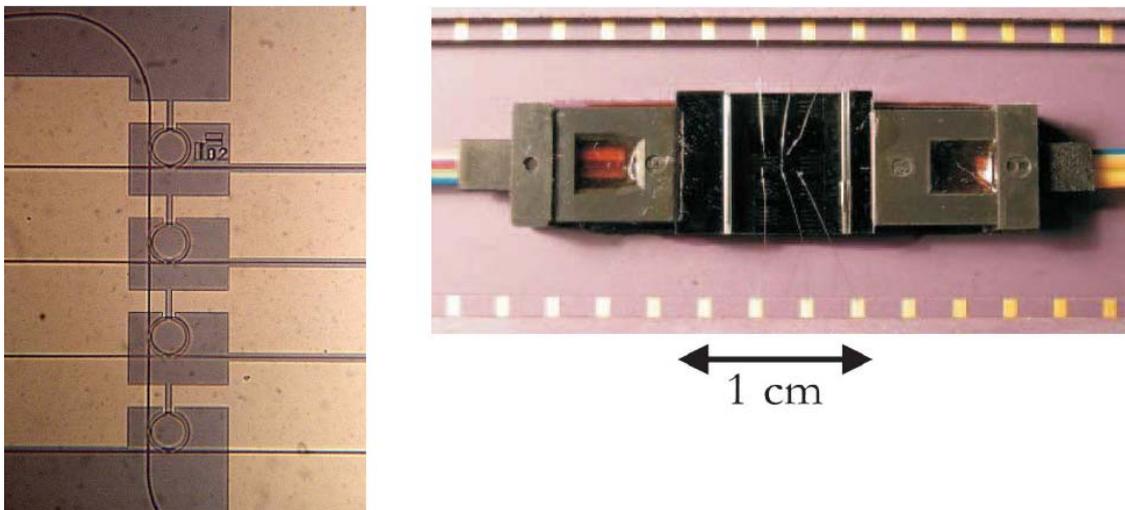
The module is based on established compact siliconnitride-IC technology based chips. The design uses the low cost manufacturing and assembly processes proven in years of splitter and high contrast PLC manufacturing.



Microscope picture of a TOADF

## ***Demonstration prototype: R-OADM based on microring resonator***

An R-OADM forms an interesting component since it combines wavelength selective switching with high bandwidth demands. An R-OADM based on MRs can both meet the network demands as well as the cost aspect (both OPEX and CAPEX). To show the capability of multiple MR structure to create complex functionalities, a demonstration prototype has been realized: a reconfigurable optical add-drop multiplexer. The demonstration model has been fabricated as a proof of principle of the photonic routing and switching platform. The graphic below shows a photograph of a 4 channel R-OADM based on MR technology. The device, that is fully pigtailed and packaged, demonstrated good adding and dropping functionality as well as the ability to switch 40 Gbit/s RZ data signals.



Microscope picture and a photograph of an R-OADM