Wavelength Selective Optical Logic

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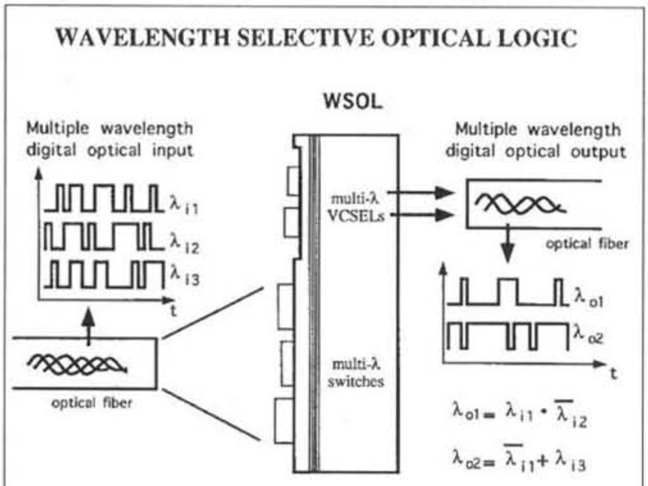
Increasing interest in digital opto-electronic circuits for optical communication systems and potential optical computing applications has created a demand for new device structures capable of optical input/output. Novel designs for photonic switching[1] enabling multiple functions in a single device are desirable for reducing the complexity of optical receivers and transmitters, as well as for avoiding additional time delays due to interconnects. Wavelength-division-multiplexing (WDM) technology, by which multiple optical channels can be transmitted without any interference, is one of the major advantages of the optical signal transmission.[2] However, the present semiconductor optoelectronic switches are limited by their broadband input and/or output response, which limits the number of channels that can be coupled through a single optical fiber and makes the system susceptible to significant amounts of crosstalk between neighboring devices. We have investigated a GaAs-based optical logic element capable of wavelength selective input and tunable monochromatic output functions that allows a discrete wavelength to be assigned to each logic variable.

Wavelength selective optical input is achieved by placing a photothyristor in an Fabry Perot cavity, creating an asymmetric wavelength demultiplexing optoelectronic switch (WDM-OS)[4] that provides a highly selective response at a wavelength determined during the fabrication. A multiple wavelength vertical cavity surface emitting laser (VCSEL) array is proposed to provide a monochromatic output signal.[5] When a high finesse optical cavity is used, as many as 10 distinct wavelength channels around a center wavelength can be realized in GaAs/(Al,In)GaAs devices. Each VCSEL, whose output wavelength is also determined during the fabrication process, is driven by the electrical output from one or more WDM-OS devices and is capable of driving a number of additional WDM-OS devices allowing a cascadable wavelength selective optical logic (WSOL) design. The logic operations on the input variables can be implemented by directly configuring circuits of the WDM-OS devices tuned to different wavelengths.

WSOL is highly suitable for optical interconnect and optical logic applications. Devices can be fabricated to detect and emit within narrow bandwidths (not necessarily the same) at arbitrarily chosen positions across the wafer. As optical interconnects, the low crosstalk of WSOL—resulting from the wavelength selectivity of each device—will allow information from a number of closely spaced wavelengths to be coupled through a single optical fiber. As logic elements, the WSOL device is suitable for optoelectronic integrated circuits having great flexibility resulting from their multiple wavelength operation. The ability to use the input and output wavelengths as variables, its inherent cascadability, and the low crosstalk between adjacent devices are the trademarks of the WSOL device. Complex logic functions between variables assigned to discrete wavelengths can be performed by WSOL devices whose outputs are coupled into subsequent WSOL arrays in a cascadeable design of an arbitrarily large number of levels.

Another attractive prospect would implement the logic functions in an optical-electronic hybrid structure. In this scheme, the WSOL devices can be used as optical interconnects, first to demultiplex the digital optical input signal, converting it into electrical information. The electronics may then perform complex logic operations that could then be converted back to light providing the output in a wavelength multiplexed optical signal format.



Conceptual presentation of a multiple wavelength optical logic unit. The wavelength selectivity at the input is provided by the wavelength demultiplexing optoelectronic switches. The logic operations are performed on the electrical output from these devices and the multiple wavelength optical output is generated by an array of VCSELs tuned during the fabrication. The illustrated simple logic functions can be directly implemented by configuring simple circuits of the WDM-OS devices with corresponding VCSELs, *i.e.*, two devices driving a VCSEL in parallel will perform an OR operation of the input variables assigned to their preset wavelengths.

References

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