DOUBLE CHANNEL SIDE-COUPLED INTEGRATED MICRO RING RESONATORS FOR OPTICAL FILTERING

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All praises belong to the One

Alhamdulillah

To all the beloved person in life especially

My Supportive Mom and Dad,

My Dearest Husband and My Lovely Family

No Love

can cross the path of our destiny without leaving some

mark on it forever.......

To my dearest friends:

There are no limits to our possibilities.

At any moment, we have more possibilities that we can act upon.

When we imagine the possibilities, our vision expands,

We capture our friends and our life is meaningful.

We can reach out and touch the limits of our being.

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ABSTRACT

Recent developments in the materials technology have made possible the fabrication in dimensions of optical wavelengths. The progress in microfabrication techniques have resulted in increasing the requirement of more accurate models for understanding the behaviour of electromagnetic radiation in such small structures. Numerical simulations provide a low-cost feasibility study enabling one to optimize the design before actual device fabrication. Accurate simulations based on reliable models provide deep insight into complex phenomena related with optical microstructures. Micro ring resonators (MRR) are key micro-components for powerful communication and computation systems. Free Spectral Range (FSR), full width half maximum (FWHM), quality factor (Q) and finesse (F) are significant properties that characterize the performance of MRR. This thesis presents the modelling of multi-stage ring resonators, Side Coupled Integrated Spaced Sequence of Resonators (SCISSORs). The influence of design parameters including number of rings, ring radii, center wavelength and coupling coefficients is investigated over FSR and FWHM of the output signal in a proposed designed system based on SCISSORs. Computational investigations are performed using OptiFDTD (Finite-Difference Time-Domain), Matlab (2009a) and OptiWave Software V8.0. Double Channel SCISSORs is designed for optical filter application and power at input and output ports and circulated optical field within the ring resonator is simulated. The 2D model structure of SiO_2 wafer is designed with refractive index equal to air's refractive index (i.e. 1.00). Design of the system consists of 4 micro-rings and a waveguide. The refractive index of waveguide is set to isotropic constant real value of 1.54 and no imaginary part. Validity of the model is extensively discussed and the transfer function of proposed micro ring resonator system is derived by using analytical treatment. The performance of SCISSORs is tested at input amplitudes of 1 V/m, 5 V/m, 10 V/m and 15 V/m. Power propagation is studied at input wavelengths of 1μm, 1.25 μm, 1.55 μm, 2.9 μm and 4.25 μm which reveals a higher signal at Through port than Input port. A symmetric trend in 0.9-1.1 μm range with a higher gain was achieved by amplifying the input signal through SCISSORs. Investigations have shown the promise of SCISSORs as an optical filter that can be extremely useful in optical communication systems from transmission and security point of view.

ABSTRAK

Perkembangan terkini dalam teknologi bahan telah membolehkan fabrikasi dalam dimensi panjang gelombang optik. Kemajuan dalam teknik mikrofabrikasi telah menyumbang pada peningkatan keperluan lebih banyak model yang tepat untuk memahami sifat radiasi elektromagnet dalam struktur yang lebih kecil. Simulasi berangka menyediakan kajian kos rendah boleh dilaksanakan di mana ia membolehkan seseorang mengoptimumkan reka bentuk sebelum fabrikasi alat yang sebenar. Simulasi yang tepat berdasarkan model yang boleh dipercayai menyediakan dalam fenomena kompleks berdasarkan struktur mikro optik. Pengalun cincin mikro (MRR) ialah kunci komponen mikro untuk komunikasi yang hebat dan sistem pengkomputeran. Julat spektrum bebas (FSR), lebar lengkap separa maksimum (FWHM), faktor kualiti (Q) dan *finesse* (F) adalah ciri penting yang mencirikan prestasi MRR. Tesis ini menunjukkan model pelbagai peringkat pengalun cincin, Gandingan Sisi Bersepadu Turutan Pengalun (SCISSORs). Pengaruh parameter reka bentuk termasuk jumlah cincin, jejari cincin, pusat panjang gelombang dan pekali pengganding dikaji bagi FSR dan FWHM isyarat keluar dalam rekaan sistem yang dicadangkan berdasarkan SCISSORs. Kajian pengkomputeran dilaksanakan menggunakan OptiFDTD (Pembezaan Terhingga Domain Masa), Matlab (2009a) dan Perisian Optiwave V8.0. SCISSORs dua alur direka bagi aplikasi penapis optik dan kuasa pada port masuk dan keluar dan medan optik beredar dalam lingkungan cincin pengalun disimulasikan. Struktur model 2D bagi *wafer* SiO_2 direka dengan indeks biasan menyamai indeks biasan udara (i.i 1.00). Reka bentuk sistem mengandungi 4 cincin mikro dan satu pandu gelombang. Indeks biasan pandu gelombang ditetapkan pada nilai nyata tetap isotropik 1.54 dan tiada bahagian khayalan. Kesahihan model dibincangkan dengan meluas dan fungsi pemindahan sistem pengalun cincin mikro yang dicadangkan diperolehi menggunakan rawatan analisis. Prestasi SCISSORs diuji pada input amplitud 1 V/m, 5 V/m, 10 V/m dan 15 V/m. Perambatan kuasa dikaji pada panjang gelombang input 1 μm, 1.25 μm, 1.55 μm, 2.9 μm dan 4.25 μm di mana memperlihatkan isyarat yang lebih besar pada *port* laluan berbanding *port* masukan. Trend yang simetri dalam julat 0.9 – 1.1 μm dengan gandaan yang lebih tinggi dicapai dengan menggandakan isyarat input melalui SCISSORs. Kajian menunjukkan kemampuan SCISSORs sebagai salah satu penapis optik yang amat berguna di dalam sistem komunikasi optik dari aspek penghantaran dan keselamatan.

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LIST OF ABBREVIATIONS

CMT	-	Coupled Mode Theory
CROW	-	Coupled Resonator Optical Waveguides
ds-	-	double sided
dc-	-	double channel
CWDM	-	Coarse Wavelength Division Multiplexing
EM	-	Electromagnetic
FDTD	-	Finite Difference Time Domain
FSR	-	Free Spectral Range
FVFD	-	Full Vectorial Finite Difference
FWHM	-	Full Width at Half Maximum
GVD	-	Group Velocity Dispersion
MMI	-	Multi Mode Interference
MZ	-	Mach-Zhender
MZI	-	Mach-Zhender Interferometer
SCISSORs	-	Side-Coupled Integrated Spaced-Sequences of Resonators
SOI	-	Silicon-on-Insulator
TBC	-	Transparent Boundaries Conditions
WDM	-	Wavelength Division Multiplexing
WGW	-	Waveguide Width

LIST OF SYMBOLS

$\mathbf{E}(t)$	-	the time dependent vectors of the dielectric
$\mathbf{H}(t)$	-	magnetic field
$\mathbf{D}(t)$	-	the electric displacement
$\mathbf{B}(t)$	-	the magnetic induction
z	-	coordinate
β	-	the propagation constant
$\beta 1$	-	propagation constants
$\mathbf{E}0$	-	is a complex amplitude
ω	-	the angular frequency
E_0^*	-	Complex conjugate
$\epsilon(\omega)$	-	scalar dielectric constant
μ	-	scalar magnetic permeability
nI and nII	-	refractive index of two waveguides
$n0$	-	refractive index
$n2 \approx \epsilon/\epsilon 0 = \epsilon r$	-	the dielectric constant
$\widetilde{\mathrm{E}}_p$	-	uncoupled electric field eigen modes
$\widetilde{\mathrm{H}}_p$	-	uncoupled magnetic field eigen modes
N^2	-	Refractive index distribution
ω	-	wave angular frequency
β	-	arbitrary propagation constant
$neffp$	-	effective index
λ	-	wavelength
$A(z)$	-	the modal amplitude coefficient
kpq	-	mode coupling coefficient of the directional coupler

bcpq	-	butt coupling coefficient between the two waveguides
χp	-	mode coupling effects all the coefficients
δ	-	the difference of the propagation constants/ mismatching
$P(z)$	-	normalized optical power flowing along the z-direction
F	-	the maximum power-coupling efficiency
X	-	the coupled-waveguide parameter
Lc	-	coupling length
L	-	the length of the coupling section (not to be confused with the coupling length
k	-	Cross-coupling coefficient
κ	-	amplitudes cross-sectional integral over the section of the two waveguides of the co-directional coupler κ_1, κ_2 coupling coefficients
c	-	coupling loss parameter
c_1 and c_2	-	upper and lower coupling losses
α	-	roughness and radiation losses
βb and βs	-	bend and straight propagation constants
αd	-	some constant
βt	-	transverse component of the propagation constant
d	-	distance
Ψe , Ψo	-	even and odd normal modes
Pcoupled	-	amount of (normalized and dimensionless) fraction of power coupled to the second waveguide
$ei\beta z$	-	phase shift along the structure
$\Delta\phi$	-	phase difference
A_D	-	Drop signal
T	-	Optical mode intensity at the Through port
D	-	Optical mode intensity at the Drop port
M 2x2	-	Complex coupling matrix
PT	-	transmitted power coefficient
κ_{12} and κ_{21}	-	cross coupling coefficients
κ_{11} and κ_{22}	-	transmission (or ‘straight-through’) coupling coefficients

PC	-	cross-coupling power coefficient
SU_2	-	special unitary group
K	-	coupling matrix
A	-	generic matrix
P	-	(forward and backwards) internal propagation matrix
a	-	half round trip loss factor
α	-	total loss per unit length
R	-	curvature radius
S_3	-	points of the 3-dimensional unit sphere
A_l^j and B_l^j	-	four port fields with (l = 1.m the resonator row index and j = 1..n the resonator column index) characterizing a matrix of resonators
T^1	-	Total transfer matrix
A_1^1	-	Input field at port *In*
A_m^1	-	Input field at port *Add*
B_1^1	-	Input fields at at the Through port
B_m^1	-	Input fields at fields at Drop port
$\mathbf{S}^{11}$	-	scattering matrix
$\mathbf{Q}^{j\ j+1}$	-	external propagation matrix connecting the j-th to j+1-th column resonator
D^{12}	-	distance separating the resonator's first from second straight arm
$\mathbf{T}^{\mathbf{PK}}$	-	Transfer Matrix

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Silicon microphotonics technology opens up new possibilities for the realization of diverse photonic devices and components required for advanced optical communication systems. One of the key building blocks developed on silicon-on-insulator (SOI) platform is the optical micro-ring resonator. Ring resonator is the most widespread single mode cavity. A generic ring resonator consists of an optical waveguide which is looped back on itself, such that a sharp resonance occurs when the optical path length of the resonator is exactly a whole number of wavelengths. Ring resonators therefore support multiple resonances, and the spacing between these resonances, the free spectral range (FSR), depends on the resonator optical length. A large FSR means small bends that in turn force to have high optical confinement. The SOI platform having tight waveguide geometries ensures such high confinement. Usually, ring resonators are coupled with a bus by the co-directional evanescent coupling method. The transmission spectrum of the bus waveguide with a single ring resonator will show dips around the ring resonances. In this way, the ring resonator behaves as a spectral optical filter [1].

Silicon microresonator-based optical filters have garnered significant attention due to key merits of demonstrated filtering performance. The microresonator confines light at a discrete set of wavelengths, which are determined by the cavity resonance condition.

Compared with single-element microresonators, cascaded microresonators exhibit broadband transmission spectra rather than sharp resonances. One of them is the SCISSORs. It is an acronym for side-coupled integrated spaced sequence of optical resonators. As the name implies, it is a series of ring resonators that are coupled to one or both bus waveguides. It is then called single channel (SC-) or dual channel (DC-) SCISSORs respectively. The concept of SCISSORs was first introduced to study the large dispersion and slow light properties [2, 3, 4]. These structures are also referred to as slow-wave structure due to the induced reduction of the propagating velocity. SCISSORs exhibit two types of stop bands also known as the band gaps. The resonator bandgaps occur when the optical path of the resonators is an integer multiple of the wavelength. The Bragg bandgaps arises when the Bragg condition is satisfied. This happen when the optical path of the back-reflected light is an integer multiple of the wavelength. This lends SCISSORs to various types of bandgap engineering [5, 6]. A particularly interesting SCISSORs configuration arises when the two bandgaps overlap. This gives rise to a high order flat band pass filter whose properties depend on the number of parallel side coupled resonators. SCISSORs are of interest for their unique property of conveying almost all the optical power in the drop port due to cascading effect of resonators even when the single resonator is not critically coupled to the bus waveguide. This band engineering and power optimization makes the cascading of several resonators in SCISSORs structures of importance for filtering applications [3].

The SCISSORs configuration is similar to a Bragg grating. Each ring behaves as a frequency dependent ridges in the grating. The main advantage is that the rings are frequency dependent. It also shows a high reflectivity at the resonance of the drop port instead of the small reflectivity achieved with a grating. Hence the in-band response can be obtained with a relatively small number of ring resonators [7].

SCISSORs help to to create slow light modes and mold the light flow. Their strong dispersion allows the engineering of their optical properties. This is possible by the coupling between waveguides and resonators and by the number and spacings of resonators. In system like DC- SCISSORs, there are two kinds of photonic bands. These are the resonator band (RB) and the Bragg band (BB) which satisfies the independent resonance condition. The spectral positions of RB and BB are determined independently by the optical paths of the microring and their spacings, respectively. The two bands are coincident in the entire spectral response if the optical length of the side-coupled waveguide from center-to-center of adjacent rings is half that of a microring circumference under coherence condition. But the two bands can occur at different resonance wavelengths if their respective optical paths are slightly different when it is out of coherence. Due to index dispersion, they may be nearly coincident for few bands but tend to separate with either increase or decrease in their band-orders [7, 8, 9, 10].

1.2. Problem Statement

This thesis will focus on the mathematical formulation, design, modelling aspect of SCISSORs for filtering of optical signals, investigating novel concepts based on side coupled resonators to achieve large bandwidth by multiple cascading and or multiple coupling effects. This section will describe some of the present challenges and opportunities usually neglected in purely theoretical or modelling approaches necessary for the modelling, design of passive micro ring resonators and SCISSORs devices.

The add-drop filtering structure (ADF) is one of the simplest micro ring configurations which have been studied. Coupled micro rings devices have interesting applications beyond filtering and telecommunications. However, from the practical point of view in optical telecommunications, the single micro ring add-drop configuration exhibits several deficiencies. The spectral response of a single add-drop configuration is periodic. Hence as an optical filter it is unable to isolate a single frequency band but rather a set of bands which are separated by the FSR of the micro ring. For optical applications, it is desired that the filter shape would exhibit a flat-top, sufficiently wide, profile and high extinction ratio. The single micro ring filter, on the other hand, possesses a Lorentzian line-shape which is inappropriate for data transmission. In addition, extending the filter bandwidth requires larger coupling coefficients. This in turn, significantly reduces the extinction ratio of the filter. In order to resolve some of these deficiencies, multiple-micro ring configurations can be applied. Multiple micro ring filters can be realized by cascading single micro ring add-drop filters or by coupling the micro rings directly. A specific topic of interest and important in this area of research is the cascading several micro rings known as SCISSORs and PANDA configurations. These structures exhibit slow group velocity and provide an attractive approach for the realization of conventional optical filters. The performance of one-, two-, four-SCISSORs are explored using the design parameters including the number of micro rings, the ring radii, the amplitude inputs in terms of the transmission spectrum at the respective ports by the OptiWave FDTD software. By cascading several micro rings it is possible to achieve a flat-top profile, the desired bandwidth and the extinction ratio. Consequently, only frequencies which are in resonance with all micro rings comprising the filter are passed instead of multiple bands. The employment of micro rings with different radii effectively increases the FSR of the device providing it with a single transmission range within the telecommunication band. Different resonances of the individual micro rings can be combined to achieve a transmission band across the complete band.

Most of the modelling in literature rely on approximations and simplified assumptions which depart from the real physical properties of the resonator. Within certain limits this idealization is justified since it leads to the qualitative understanding of the device behaviour. But with increasing integration densities, resonators have smaller bend radiuses and small coupling gaps. This implies that one cannot neglect in the modelling effects such as coupling losses, effective index differences and modal mismatches between the straight and bend waveguides. For a radius of curvature smaller than $R < 5\mu m$ in a SOI system, the traditional algorithms furnish very rough estimates of the optical response of microresonators, especially for some high-order filtering applications. Moreover, the situation gets worse for devices based on sequences of microresonator in SCISSORs devices.

Thus it is hoped that by addressing this problem statement, we will be able to describe accurately the SCISSORs in order to enhance design technique of complex optical systems which can tackle, at least partially future fabrication, tolerances, narrowing the gap between models and real devices.

1.3 Objectives of Study

The general objective of this research is to design, model and simulate the structure of double channel side-coupled integrated spaced sequences of optical resonators for signal filtering.

The specific objectives of this study are to:

- Develop the mathematical formulation for deriving the spectral response at the through and drop ports of the SCISSORs based on the couple mode theory and matrix formalism,

- Simulate, develop, modify and optimize different SCISSORs configuration using OptiWave FDTD software Version 8.0 and Matlab software version R2009a,

- Parameterize and determine the role of number of rings,ring radii insertion loss, free spectral range, full width half maximum, finesse, quality factor, on-off ratio, shape factor, phase shift, group delay and on the spectrum and operating regimes at the through port and drop port for SCISSORs,

- Obtain and determine the optical filtering characteristics of the transmission peaks and trough for double channel SCISSORs and

- Optimize and analyse the performance of SCISSORs for optical filtering.

1.4 Scope of Study

In order to meet the objectives of this research, the scope of this work has been fulfilled through the following key milestones: First, a review on modeling and experiment work of optical filtering of ring resonators and SCISSORs have been undertaken. In this study the SCISSORs and PANDA configurations with the add-drop as unit cell are investigated for filtering applications. Second the couple mode equations including the matrix formalism governing the spectral response at the through and drop ports of the SCISSORs are derived. Two numerical methods are used in the modelling formulation which are the Bloch Matrix Formalism and Scattering Matrix equations. The simulation is performed by using Matlab software version R2009a. The Finite Difference Time Domain OptiFDTD Photonics Simulation Software Version 8.0 is used for analyzing electromagnetic wave scattering and radiation of the waveguide in the ring structure. Develop FDTD simulation of MRRs. Numerical assessment of SCISSORs through comparison with results in literature. Modeling the performance of SCISSORs.

This work was conducted for different structure of resonators which are the single ring with single bus waveguide, double ring with single bus waveguide, four single rings with single bus waveguide, the double channel SCISSORs and PANDA ring resonators. Mathematical formulation is developed and derived analytically based on proposed design of the SCISSORs. This research is devoted only to the theoretical, numerical and simulation aspects of SCISSORs configuration which will be useful to realize proposed applications experimentally in the future.

1.5 Significance of Study

The ring resonator is an optical waveguide that forms a ring shaped structure whose circumference is in the range of tens of hundreds microns. Light in this manner can be coupled into and out of this structure by placing it in close proximity between another two straight waveguides. It forms the basis for SCISSORs. The goal and novelty of this research work has been focused on the design, modeling and simulation of the structure of double channel side-coupled integrated spaced sequences of optical resonators for signal filtering.

The new contributions to the body of knowledge will be as follows:

- An attempt is made on deriving the governing equations for SCISSORs from the couple mode theory, Bloch matrix formalism, scattering matrix in obtaining the filtering transmission spectral response. These equations form the basis of describing the cascaded coupled micro ring resonators.

- A model for SCISSORs have been developed. The model can enhance the design of complex silicon microphotonics for numerous applications in optical filtering and narrowing the gap between modelled and real parameters.

- The ADF configuration in a SCISSORs is able to perform optical filtering.

- Provide the underlying physics of cascaded parallel coupled ring resonators-SCISSORs as add-drop optical filters.

- This research is of relevance and benefit in the field of silicon microphotonics. It provides the conceptual framework, analytical aspects and the physics of the structures proposed in order to lay a theoretical foundation for those who will design and fabricate real SCISSORs or other coupled devices.

- The design and simulation plays a crucial role in the development of SCISSOR devices. The design of such devices can become much more efficient with the aid of this modeling tool. Excellent designs model gives good filtering performance and compactness leading probably to the cost effective product development. This accurate and comprehensive model can be used to explore a detailed study of the SCISSORs in the future. Technological applications such as the dynamic add/drop device will provide better control and reproducibility of filter characteristics in designs that are increasingly complex

1.6 Thesis Outline

In this chapter, the parallel cascaded coupled micro ring resonators known as SCISSORs are explored from a bird's-eye view, identifying the research challenges as described in the problem statement. It describes the basic physics of optical ring resonator, it's relation to SCISSORs.

The thesis is organized as follows. Chapter 2 gives a critical analysis on the review of SCISSORs from the perspective of optical filtering in modeling and experiments.

Chapter 3 describes the mathematical derivation of the couple mode equations and matrix formalism for obtaining the spectral response at the through and drop ports of the SCISSORs. In this chapter the theoretical derivation of the side-coupled integrated spaced sequence of resonators (SCISSORs) with the optical micro-ring resonators as the unit cell are developed with emphasis on realization of the filtering optical functionality. First, the basic of coupled mode theory (CMT) is introduced. A full description of the micro ring resonators needs an improved understanding of the behaviour of its constituent parts. Thus an introduction to the application of the theory micro ring resonators is given and outlines its main physical properties which are necessary to understand when they appear in chains of mutually interacting fundamental components in a larger system. After a brief theoretical introduction on the behaviour of add-drop filters, we will discuss the dispersion law of the straight waveguide, the characterization of curved waveguides and the influence of the bending on the refractive index. Also the determination of bending losses, the calculation of the coupling coefficients and length are made. We will use these data for a model of the single ring resonator. A final comparison among the proposed model, an idealized one, and experimental measurements will br made for model validation.

Chapter 4 describes research methodology focusing on methods that are involved in this study such as the theory related with the mathematical solutions and also the methods that have been used in executing the mathematical modelling and simulation for the SCISSORs.

Chapter 5 describes the results of simulation of power distribution in Side Coupled Integrated Spaced Sequences of Resonators (SCISSORs). The discussion have been divided into four parts which covers the power calculation in SCISSORs, designing the structure of a Double Channel SCISSORs using OptiFDTD Photonics Simulation Software Version 8.0, simulation of power amplification in different ring resonator structure and effect of input amplitude to power distribution in SCISSORs. The simulation results obtained to the SCISSORs will then be benchmarked with published experimental data.

Chapter 6 concludes the thesis and provides the basis for further work.

REFERENCES

[1] Driessen, A., Geuzebroek, D., Hoekstra, H. J. W. M., Kelderman, H., Klein, E. J., Klunder, D. J. W.,Roeloffzen, C. G. H., Tan, F. S., Krioukov, E., Otto, C., Gersen, H., van Hulst, N. F., and Kuipers, L.,Microresonators as building blocks for VLSI photonics (2004),

[2] A. Yariv, Y. Xu, R. K. Lee, and A. Scherer, ”Coupled-resonator optical waveguide:A proposal and analysis, Opt. Lett., Vol. 24, pp. 711713, (1999).

[3] J. E. Heebner, Q. Park, ”SCISSOR solitons and other novel propagation effects in microresonator modified waveguides,” J. Opt. Soc. Amer. B, vol. 19(4), pp.722731,(2002).

[4] F. Xia, L. Sekaric, M. O’Boyle, and Y. Vlasov, “Coupled resonator optical waveguides based on silicon-on-insulator photonoc wires”, Applied Physics Letters,vol 89,no.4,pp 041122,July 2006

[5] J. E. Heebner, P. Chak, S. Pereira, J. E. Sipe, and R. W. Boyd, ”Distributed and localized feedback in microresonator sequences for linear and nonlinear optics,” J. Opt. Soc. Am. B 21, 1818-1832 (2004).

[6] J. Capmany, P. Munoz, J. D. Doemenech, M. A. Muriel, “Apodized coupled resonator waveguides”, Optics Express, vol.15, no. 16 (2007).

[7] Sang-Yeon Cho and Richard Soref. Apodized scissors for filtering and switching.Optics Express, 16(23):19078{19090, 2008.

[8] Hsi-Chun Liu and Amnon Yariv. Synthesis of high-order bandpass filters based on coupled-resonator optical waveguides (CROWs). Optics Express, 19(18):17653-17668, 2011.

[9] Yong Xu, Yi Li, Reginald K Lee, and Amnon Yariv. Scattering-theory analysis of waveguide-resonator coupling. Physical Review E, 62(5):7389, 2000.

[10] Mattia Mancinelli, Romain Guider, Marco Masi, Paolo Bettotti, Manga Rao Vanacharla, Jean-Marc Fedeli, and Lorenzo Pavesi. Optical characterization of a scissor device. Optics Express, 19(14):13664-13674, 2011.

[11] Michal Lipson. Guiding, modulating, and emitting light on silicon-challenges and opportunities. Journal of Lightwave Technology, 23 (12):4222, 2005.

[12] Yurii Vlasov, William MJ Green, and Fengnian Xia. High-throughput silicon nanophotonic wavelength-insensitive switch for on-chip optical networks. Nature Photonics 2, 242 - 246 (2008).

[13]. Kaminow, I. P. & San, T. L. (eds) *Optical Fiber Telecommunications IV* (Academic Press, San Diego, 2002).

[14]. Alexander, S. B. *et al.* A precompetitive consortium on wide-band all-optical networks. Journal of Lightwave Technology 11, 714–735 (1993).

[15]. Hibino, Y., Maruno, T. & Okamoto, K. Recent progress on large-scale PLC technologies with advanced functions. *NTT Review* 13, 4–9 (2001).Photonics, 2(4):242-246, 2008

[16]. Kewitsch, A. S., Rakuljic, G. A., Willems, P. A. & Yariv, A. All-fiber zero-insertion-loss add-drop filter for wavelength- division multiplexing. Optics Letters 23, 106–108 (1998).

[17]. C.R. Doerr ; L.W. Stulz ; M. Cappuzzo ; E. Laskowski ; A. Paunescu ; L. Gomez ; J.V. Gates ; S. Shunk ; A.E. White. 40-wavelength add-drop filter. IEEE Photonics Technology Letters 11, 1437–1439 (1999).

[18]. Suzuki, S., Hatakeyama, Y., Kokubun, Y. & Chu, S. T. Precise control of wavelength channel spacing of microring resonator add-drop filter array. Journal of Lightwave Technology 20, 745–750 (2002).

[19]. Djordjev, K., Choi, S. J. & Dapkus, P. D. Microdisk tunable resonant filters and switches. IEEE Photonics Technology Letters 14, 828–830 (2002).

[20]. Rabiei, P. Steier, W. H., Cheng Zhang and Dalton, L. R. Polymer micro-ring filters and modulators. Journal of Lightwave Technology 20, 1968–1975 (2002).

[21]. Little, B. E. *et al.* Wavelength switching and routing using absorption and resonance. IEEE Photonics Technology Letters 10, 816–818 (1998).

[22]. Djordjev, K., Choi, S. J. & Dapkus, P. D. Vertically coupled InP microdisk switching devices with electroabsorptive active regions. IEEE Photonics Technology Letters 14, 1115–1117 (2002).

[23]. Yariv, A. Critical coupling and its control in optical waveguide-ring resonator systems. IEEE Photonics Technology Letters 14, 483–485 (2002).

[24]. Soref, R. A. & Little, B. E. Proposed N-wavelength M-fiber WDM crossconnect switch using active microring resonators. IEEE Photonics Technology Letters 10, 1121–1123 (1998).

[25]. Chu, S. T. *et al.* An eight-channel add-drop filter using vertically coupled microring resonators over a cross grid. IEEE Photonics Technology Letters 11, 691–693 (1999).

[26] Grover, R., P. P. Absil, V. Van, J. V. Hryniewicz, B. E. Little, O. King, L. C. Calhoun, F. G. Johnson, and P. T. Ho. Vertically coupled GaInAsP-InP microring resonators. Optics Letters 26, 506–508 (2001).

[27] Little, B. E., S. T. Chu, W. Pan, D. Ripin, T. Kaneko, Y. Kokubun and E. Ippen. Vertically coupled glass microring resonator channel dropping filters. IEEE Photonics Technology Letters, 11(2), 215-217 (1999).

[28] Xuezhe Zheng, Frankie Y. Liu, Jon Lexau, Dinesh Patil, Guoliang Li, Ying Luo, Hiren D. Thacker, Ivan Shubin, Jin Yao, Kannan Raj, Ron Ho, John E. Cunningham, and Ashok V. Krishnamoorthy. Ultralow power 80 Gb/s arrayed CMOS silicon photonic transceivers for WDM optical links. Journal of Lightwave Technology 30(4):641-650, 2012.

[29] Sang-Yeon Cho and Richard Soref. Apodized SCISSORs for filtering and switching. Optics Express, 16(23):19078-19090, 2008.

[30] John E Heebner, Robert W. Boyd, and Q-Han Park. Scissor solitons and other novel propagation effects in microresonator-modified waveguides. JOSA B, 19(4):722-731, 2002.

[31] Trevor M. Benson, Svetlana V. Boriskina, Phillip Sewell, Ana Vukovic, Stephen C. Greedy, and Alexander I. Nosich. "Micro-optical resonators for microlasers and integrated optoelectronics." In *Frontiers in planar lightwave circuit technology*, pp. 39-70. Springer Netherlands, 2006.

[32] E. Marcatili, Bends in optical dielectric guides, Bell Syst. Tech. J, 48 (1969) 2103-2132.

[33] H. Weber, R. Ulrich, A Thin-Film Ring Laser, Applied Physics Letters, 19 (1971) 38-40.

[34] B.E. Little, J. Foresi, G. Steinmeyer, E. Thoen, S. Chu, H. Haus, E. Ippen, L. Kimerling, W. Greene, Ultra-compact Si-SiO< sub> 2</sub> microring resonator optical channel dropping filters, Photonics Technology Letters, IEEE, 10 (1998) 549-551.

[35] S. McCall, A. Levi, R. Slusher, S. Pearton, R. Logan, Whispering-gallery mode microdisk lasers, Applied Physics Letters, 60 (1992) 289-291.

[36] D. Chu, M. Chin, N. Sauer, Z. Xu, T. Chang, S. Ho, 1.5-mu m InGaAs/InAlGaAs quantum-well microdisk lasers, Photonics Technology Letters, IEEE, 5 (1993) 1353-1355.

[37] D. Rafizadeh, J. Zhang, S. Hagness, A. Taflove, K. Stair, S. Ho, R. Tiberio, Waveguide-coupled AlGaAs/GaAs microcavity ring and disk resonators with high f inesse and 21.6-nm f ree spectral range, Optics Letters, 22 (1997) 1244-1246.

[38] J. Hryniewicz, P. Absil, B. Little, R. Wilson, P.T. Ho, Higher order filter response in coupled microring resonators, Photonics Technology Letters, IEEE, 12 (2000) 320-322.

[39] V. Van, T. Ibrahim, P. Absil, R. Grover, J. Hryniewicz, B. Little, F. Johnson, P.T. Ho, Periodically-coupled GaAs/AlGaAs microring array filter with wide free spectral range, in: Integrated Photonics Research, Optical Society of America, 2001.

[40] John Heebner, Rohit Grover and Tarek Ibrahim, Optical Microresonators: Theory, Fabrications and Applications, Springer, USA, 2008

[41] S. Y. Cho, R. Soref, “Apodized SCISSORs for filtering and switching,” Opt. Express 16, 19078-19090 (2008).

[42] C. Chaichuay, P.P. Yupapin, P. Saeung, The serially coupled multiple ring resonator filters and Vernier effect, Optica Applicata, 39 (2009) 175-194.

[43] Y. Goebuchi, T. Kato, Y. Kokubun, Optimum arrangement of high-order series-coupled microring resonator for crosstalk reduction, Japanese Journal of Applied Physics, 45 (2006) 5769.

[44] O. Schwelb, The nature of spurious mode suppression in extended FSR microring multiplexers, Optics communications, 271 (2007) 424-429.

[45] E.J. Klein, P. Urban, G. Sengo, L.T.H. Hilderink, M. Hoekman, R. Pellens, P. Dijk, A. Driessen, Densely integrated microring resonator based photonic devices for use in access networks, Optics express, 15 (2007) 10346-10355.

[46] M.A. Popović, E.P. Ippen, F.X. Kärtner, Universally balanced photonic interferometers, Optics letters, 31 (2006) 2713-2715.

[47] M.R. Watts, T. Barwicz, M.A. Popović, P.T. Rakich, L. Socci, E.P. Ippen, H.I. Smith, F. Kaertner, Microring-resonator filter with doubled free-spectral-range by two-point coupling, in, Optical Society of America, 2005.

[48] Y. Yanagase, S. Suzuki, Y. Kokubun, S.T. Chu, Box-like filter response and expansion of FSR by a vertically triple coupled microring resonator filter, Lightwave Technology, Journal of, 20 (2002) 1525-1529.

[49] K. Oda, N. Takato, H. Toba, A wide-FSR waveguide double-ring resonator for optical FDM transmission systems, Lightwave Technology, Journal of, 9 (1991) 728-736.

[50] T. Chu, N. Fujioka, S. Nakamura, M. Tokushima, M. Ishizaka, Compact, low power consumption wavelength tunable laser with silicon photonic-wire waveguide micro-ring resonators, in, IEEE, 2009, pp. 1-2.

[51] L. Jin, M. Li, J.J. He, Experimental investigation of waveguide sensor based on cascaded-microring resonators with Vernier effect, in, IEEE, 2010, pp. 1-2.

[52] P. Koonath, T. Indukuri, B. Jalali, 3-D integrated Vernier filters in silicon, in: Integrated Photonics Research and Applications (IPRA), Optical Society of America, 2006.

[53] S. Xiao, M.H. Khan, H. Shen, M. Qi, Silicon-on-insulator microring add-drop filters with free spectral ranges over 30 nm, Journal of Lightwave Technology, 26 (2008) 228-236.

[54] P. Dumon, Ultra-compact integrated optical filters in silicon-on-insulator by means of wafer-scale technology, in, Ph. D. Thesis, University of Ghent, 2007.

[55] P. Dong, W. Qian, H. Liang, R. Shafiiha, N.N. Feng, D. Feng, X. Zheng, A.V. Krishnamoorthy, M. Asghari, Low power and compact reconfigurable multiplexing devices based on silicon microring resonators, Opt. Express, 18 (2010) 9852-9858.

[56] X. Zheng, I. Shubin, G. Li, T. Pinguet, A. Mekis, J. Yao, H. Thacker, Y. Luo, J. Costa, K. Raj, A tunable 1x4 silicon CMOS photonic wavelength multiplexer/demultiplexer for dense optical interconnects, Optics express, 18 (2010) 5151-5160.

[57] H. Shen, M.H. Khan, L. Fan, L. Zhao, Y. Xuan, J. Ouyang, L.T. Varghese, M. Qi, Eight-channel reconfigurable microring filters with tunable frequency, extinction ratio and bandwidth, Optics express, 18 (2010) 18067-18076.

[58] Y. Kokubun, T. Kato, Series-Coupled and Parallel-Coupled Add/Drop Filters and FSR Extension, Photonic Microresonator Research and Applications, (2010) 87-113.

[59] M.S. Dahlem, C.W. Holzwarth, A. Khilo, F.X. Kärtner, H.I. Smith, E.P. Ippen, Eleven-channel second-order silicon microring-resonator filterbank with tunable channel spacing, in, Optical Society of America, 2010.

[60] S. Park, K.J. Kim, I.G. Kim, G. Kim, Si micro-ring MUX/DeMUX WDM filters, Optics Express, 19 (2011) 13531-13539.

[61] M.A. Popovic, T. Barwicz, M.S. Dahlem, F. Gan, C.W. Holzwarth, P.T. Rakich, H.I. Smith, E.P. Ippen, F.X. Krtner, Tunable, fourth-order silicon microring-resonator add-drop filters, in, VDE, 2007, pp. 1-2.

[62] W. Y. Chen, V. Van, W. N. Herman, and P. T. Ho, \Periodic microring lattice as a bandstop ¯lter," IEEE Photonics Technology Letters 18(19), 2041{2043 (2006). [63] F. Xia, L. Sekaric, and Y. A. Vlasov, Ultracompact optical bu®ers on a silicon chip," Nature Photonics 1, 65{71 (2006).

[64] J. V. Hryniewicz, P. P. Absil, B. E. Little, R. A. Wilson, and P. T. Ho, \Higher order ¯lter response in coupled microring resonators," IEEE Photonics Technology Letters 12(3), 320{322 (2000).

[65] G. T. Paloczi, Y. Y. Huang, A. Yariv, and S. Mookherjea, \Polymeric Mach Zehnder interferometer using serially coupled microring resonators," Optics Express 11(21), 2666{2671 (2003).

[66] O. Schwelb and I. Frigyes, \Vernier operation of series-coupled optical microring resonator ¯lters," Microwave and Optical Technology Letters 39(4), 257{261 (2003).

[67] J. K. S. Poon, J. Scheuer, S. Mookherjea, G. Paloczi, Y. Huang, and A. Yariv, ”Matrix analysis of microring coupled-resonator optical waveguides,” Opt. Express 12, 90-103 (2004).

[68] O. Weiss and J. Scheuer, ”Side coupled adjacent resonators CROW - formation of mid-band zero group velocity,” Opt. Express 17, 14817 (2009).

[69] F. Xia, L. Sekaric, and Y. Vlasov, ” F. Xia, L. Sekaric, and Y. Vlasov, ”Mode conversion losses in silicon-on-insulator photonic wire based racetrack resonators”, Opt. Exp. 3872, vol. 14, No. 9 (2006)

[70] F. Xia, L. Sekaric, Y. Vlasov, Ultracompact optical buffers on a silicon chip, Nature Photonics, 1 (2006) 65-71.

[71] S. Konar, A. Biswas, Soliton-soliton interaction with power law nonlinearity, Progress In Electromagnetics Research, 54 (2005) 95-108.

[72]C. Ciminelli, D. Conteduce, F. Dell'Olio and M. N. Armenise. Novel Graphene-Based Photonic Devices for Efficient Light Control and Manipulation. *Proceedings in 17th International Conference on Transparent Optical Networks*, Italy, July 2015.

[73]M. Mancinelli, M. Borghi, F. Ramiro-Manzano, J. M. Fedeli, and L. Pavesi. Chaotic dynamics in coupled resonator sequences. *Optics Express 22*, 14505-14516, 2014.

[74] F. Xia, L. Sekaric and Y. Vlasov, "Ultra compact optical buffers on a silicon chip", *Nature Photonics 1* (1), pp. 65-71, 2007.

[75] K. R. Umashankar and A. Taflove, "A novel method to analyze electromagnetic scattering of complex objects", *IEEE Transaction on Electromagnetic Compatibility*, Vol. EMC-24, No. 4, 1982

[76] S. T. Chu and S. K. Chaudhuri, "A finite difference time domain method for the design and analysis of guided wave optical structures", *Journal of Lightwave Technology*, Vol. 7, No. 12, 1989.

[77] C. Chauveau, P. Labeye, J. M. Fedeli, J. Hazart, S. Blaize and G. Lerondel. Validation of an Analytical Model of Si- Ring Resonators for Designing 1 x 8 Multiplexer in SCISSOR Configuration. *Opt. Quantum Electron.* 44, pp 541-547, 2012.

[78] Jaime Cardenas, Paul A. Morton, Jacob B. Khurgin, Carl B. Poitras, and Michal Lipson. "Super-ring resonators: Taking advantage of resonance variability." In *CLEO: Science and Innovations*, pp. CTu3I-4. Optical Society of America, 2012.

[79]. J. Scheuer, A. Yariv, Fabrication and Characterization of low-loss polymeric waveguides and micro-resonators. J. Euro. Opt. Soc. Rapid Pub. 1, 06007 (2006)

[80]. H.A. Haus, Waves and Fields in Optoelectronics (Prentice-Hall, Englewood Cliffs, 1983)

[81]. M. Heiblum, J.H. Harris, Analysis of curved optical waveguides by conformal transformation. IEEE J. Quantum Electron. 11, 75–83 (1975)

[82]. C.K. Madsen, J.H. Zhao, *Optical Filter Design and Analysis: A Signal Processing Approach*, 1st edn. (Wiley-Interscience, New York, 1999)

[83]. J. Scheuer, G.T. Paloczi, A. Yariv, All-optically tunable wavelength-selective reflector consisting of coupled polymeric microring resonators. Appl. Phys. Lett. 87, 251102 (2005)

[84] J. Scheuer, G.T. Paloczi, J.K.S. Poon, A. Yariv, Coupled resonator optical waveguides: towards slowing and storing of light. Opt. Photon. News 16, 36 (2005)

[85] J. Heebner et al., Distributed and localized feedback in microresonator sequences for linear and nonlinear optics. J. Opt. Soc. Am. B. 21, 1818–1832 (2004)

[86] O. Weiss, J. Scheuer, Side coupled adjacent resonators CROW—formation of mid-band zero group velocity. Opt. Express 17, 14817 (2009)

[87] J.B. Khurgin, R.S. Tucker (ed.), *Slow Light: Science and Applications* (CRC Press, Boca Raton, 2008)

[88] J. K. S. Poon, J. Scheuer, S. Mookherjea, G.T. Paloczi, Y. Huang, A. Yariv, Matrix analysis of coupled-resonator optical waveguides. Opt. Express 12, 90 (2004)

[89] A. Yariv, Y. Xu, R.K. Lee, and A. Scherer, Coupled-resonator optical waveguide: a proposal and analysis. Opt. Lett. 24, 711–713 (1999)

[90] I.S. Hidayat, Y. Toyota, O. Torigoe, O. Wada, R. Koga, Application of transfer matrix method with signal flow-chart to analyze optical multi-path ring-resonator, Mem. Fac. Eng. Okayama Univ, 36 (2002) 73-82.

[91] P.P. Yupapin, N. Sangwara, N. Pornsuwancharoen, Generalized optical filters using a nonlinear micro ring resonator system, Optik - International Journal for Light and Electron Optics, 121 (2010) 732-738.

[92] F. Michelotti, A. Driessen, M. Bertolotti, Microresonators as building blocks for VLSI photonics, AIP, American Inst. of Physics, 2004.

[93] S. Emelett, R. Soref, Analysis of dual-microring-resonator cross-connect switches and modulators, Optics Express, 13 (2005) 7840-7853.

[94] O. Schwelb, Generalized analysis for a class of linear interferometric networks. I. Analysis, Microwave Theory and Techniques, IEEE Transactions on, 46 (1998) 1399-1408.

[95] M. Cherchi, Bloch analysis of finite periodic microring chains, Applied Physics B: Lasers and Optics, 80 (2005) 109-113.

[96] D.D. Smith, H. Chang, K.A. Fuller, A. Rosenberger, R.W. Boyd, Coupled-resonator-induced transparency, Physical Review A, 69 (2004) 063804.

[97] M. C. Nuss, W. H. Knox, and U. Koren. Scalable 32 channel chirped-pulse WDM source. Electron. Lett., 32:1311–1312, 1996.

[98] Chang-Seok Kim, Tae Ho Lee, Y.S. Yu, Y-G. Han, S.B. Lee, and M.Y. Jeong. Multi-point interrogation of FBG sensors using cascaded flexible wavelength division Sagnac loop filters. Opt. Express, 14:8546–8551, 2006.

[99] M. D. Feit and J. A. Fleck, "Computation of mode properties in optical fiber waveguides by a propagating beam method", *Applied Optics*, Vol. 19, pp. 1154-1164, 1980.

[100] K.L. Shlager and J.B. Schneider,"A selective survey of the finite-difference time-domain literature."IEEE Antennas Propagat. Magazine,vol. 37,no.4.pp.39-56.1996.

[101] Kampanis, N. A., Dougalis, V., & Ekaterinaris, J. A. (Eds.). (2008). *Effective computational methods for wave propagation*. CRC Press.

[102] A Taflove, A Oskooi, SG Johnson, Artech House, 2013 Advances in FDTD Computational Electrodynamics: Photonics and Nanotechnology

[103] A.Yariv, Coupled mode theory for guided wave optics,IEEE J. Quantum Electron., vol.9, pp.919-933,1973

[104] D.Marcuse, Theory of Dielectric Optical Waveguides,2nd ed., Academic Press, Boston,1991.

[105] M.D.Feit and Jr.J.A.Fleck, Computation of mode properties in optical fiber waveguides by a propagating beam method, Appl. Opt., vol.19, no.7. pp.1164, Apr.1980

[106] H.Kogelnik and C.V.Shank, Coupled wave theory of distributed feedback lasers,J. Appl. Phys., vol.43 pp.2327-2335,1972.

[107] D.Yevick and B.Hermansson, New formulation of the beam propagation method application of rib waveguides,IEEE J. Quantum Electron., vol.25,pp. 221-229,Feb. 1989

[108] M. N. O Sadiku, A simple introduction to nite element analysis of electromagnetic problems,IEEE Trans. Educ., vol.32 no.2 pp 85-93

[109] W.Yang and A.Gopinath, A boundary integral method for propagation problems in integrated optical structures,IEEE Photonics Technol. Lett.,vol.7 no.7 pp. 777-779, 1995

[110] L.Bersiner, U.Hempelmann and E.Strake,Numerical analysis of passive Integrated optical polarization splitters comparison of finite element and beam-propagation method results,J. Opt. Soc. Am. B, vol. 8,no. 2,pp. 422-433, Feb. 1991.

[111] Blom, F.C., Kelderman, H., Hoekstra, H.J.W.M., Driessen, A., Popma, Th. J. A., Chu, S.T. and Little, B.E., "A single channel dropping filter based on a cylindrical micro-resonator", *Opt. Comm.*, vol. 167, pp. 77-82, 1999

[112] Tan, F.S., Klunder, D.J.W., Sengo, G., Kelderman, H., Hollink, A., Hoekstra, H.J.W.M., Driessen, A., “Characterization of vertically waveguide coupled microring resonators by means of quantitative image analysis”, *Journal of Nonlinear Optical Physics and Materials*, vol. 12, No. 2, pp. 205-212, 2003

[113] Little, B.E., Chu, S. T., Pan, W. and Kokubun, Y., “Microring resonators arrays for VLSI photonics”, *IEEE Photon. Technol. Lett.*, vol. 12, pp. 323-325, 2000

[114] R.G. Hunsperger and J.R. Meyer-Arendt. Integrated optics: Theory and technology,Applied Optics, 31:298, 1992.

[115] R. Stoffer, K.R. Hiremath, and M. Hammer. Comparison of coupled mode theory and FDTD simulations of coupling between bent and straight optical waveguides. In AIP Conference Proceedings: Microresonators as building blocks for VLSI photonics (2004), volume 709, pages 366-377. Springer, 2004.

[116] K. Okamoto,”Fundamentals of Optical Waveguides”, Second Edition, Academic Press, 2006.

[117] H. Kogelnik,”Guided-Wave Optoelectronics: Device Characterization, Analysis, and Design”, T. Tamir (ed.), Springer, Berlin, 2nd edition (1990).

[118] G. Lifante, ”Integrated Photonics: Fundamentals”, Wiley (2003).

[119] K. Lizuka, “Elements of Photonics” Wiley-Interscience ed. 2002.

[120] S. Cho and R. Soref, ”Interferometric microring-resonant 2 x 2 optical switches,” Opt. Express 16, 13304-13314 (2008)

[121] Y.M. Darmawan, S. Chin, M. K. Landobasa, ”Matrix analysis of 2-D microresonator lattice optical filters”, Quantum Electronics, IEEE Journal of Vol. 41, Issue 11 (2005).

[122] C. S. Ma, ; X. Yan, X.Y Wang, ”Matrix analysis of 2D microring resonator arrays”, Jour. of Mod. Opt., vol. 55, issue 1, pp. 143-154, (2008).

[123] J. K. S. Poon, P. Chak, J. M. Choi, and A. Yariv, ”Slowing light with Fabry-Perot resonator arrays,” J. Opt. Soc. Am. B 24, 2763-2769 (2007).

[124] Wesly D. Sacher and Joyce K. S. Poon, “Characteristics of Micro ring Resonators With Waveguide-Resonator Coupling Modulation”, Journal of Lightwave Technology, Vol. 27, No.17, 2009.

[125] K. Okamoto, “Fundamentals of Optical Waveguides”, Second Edition, Academic Press, 2006.

[126] H. Kogelnik, “Guided-Wave Optoelectronics: Device Characterization, Analysis, and Design”, T. Tamir (ed.), Springer, Berlin, 2nd edition (1990

[127] A. Milos, C. Manolatou and M.R. Watts, ”Coupling-induced resonance frequency shifts in coupled dielectric multi-cavity filters”, Opt. Exp. 1208, vol. 14, No. 3, 2006.

[128] F. Xia, L. Sekaric, and Y. Vlasov, ”Mode conversion losses in silicon-on-insulator photonic wire based racetrack resonators”, Opt. Exp. 3872, vol. 14, No. 9 (2006)

[129] Mehmet Bayindir, B. Temelkuran, and E. Ozbay. Tight-binding description of the coupled defect modes in three-dimensional photonic crystals. Phys. Rev. Lett., 84(10):2140{2143, Mar 2000.

[130] Shayan Mookherjea and Amnon Yariv. Optical pulse propagation in the tight-binding approximation. Opt. Express, 9(2):91{96, 2001.

[131] Shayan Mookherjea and Amnon Yariv. Pulse propagation in a coupled resonator optical waveguide to all orders of dispersion. Phys. Rev. E, 65(5): 056601, Apr 2002.

[132] Amnon Yariv, Yong Xu, Reginald K. Lee, and Axel Scherer. Coupled-resonator optical waveguide: a proposal and analysis. Opt. Lett., 24(11): 711{713, 1999.

[133]S Feng, T Lei, H Chen, H Cai, X Luo, AW Poon, Silicon photonics: from a microresonator perspective,Laser & Photonics reviews 6 (2), 145-177

[134] Andrew W Poon, Xianshu Luo, Linjie Zhou, Chao Li, Jonathan Y Lee, Fang Xu, Hui Chen, and Nick K Hon. Microresonator-based devices on a silicon chip: novel shaped cavities and resonance coherent interference. Practical applications of microresonators in optics and photonics, 2009.

[135] J. Heebner, R. Grover, and T. Ibrahim, Optical Microresonators: Theory, Fabrication and Applications, 1st edn., Springer Series in Optical Sciences (Springer, London,2008).

[136] J. Capmany, P. Munoz, J. D. Doemenech, M. A. Muriel, “Apodized coupled resonator waveguides”, Optics Express, vol.15, no. 16 (2007).

[137] A. Vorckel, A. Monster, M. Henschel, P. H. Bolivar, H. Kurz, “Asymmetrically coupled silicon-on-insulator microring resonators for compact add-drop multiplexers”, IEEE Phot. Tech. Lett., vol. 15, no.7 (2003).

[138] P. Trinh, S. Yegnanarayanan, and B. Jalali, Electron. Lett. 31(24), 2097–2098 (1995).

[139] P. Dumon, W. Bogaerts, V. Wiaux, J. Wouters, S. Beckx,J. Van Campenhout, D. Taillaert, B. Luyssaert, P. Bienstman, D. Van Thourhout, and R. Baets, IEEE Photon. Technol. Lett. 16(5), 1328–1330 (2004).

[140] I. Christiaens, Vertically Coupled Microring Resonators Fabricated with Wafer Bonding, PhD Thesis, Ghent University,Belgium (2005).

[141] D. G. Rabus, (2007), *Integrated Ring Resonators: The compendium*. Springer-Verlag Berline Heidelberg

[142] John E Heebner, Philip Chak, Suresh Pereira, John E Sipe, and Robert W Boyd. Distributed and localized feedback in microresonator sequences for linear and nonlinear optics. JOSA B, 21(10):1818{1832, 2004}.

[143] Sang-Yeon Cho and Richard Soref. Apodized scissors for filtering and switching. Optics Express, 16(23):19078{19090, 2008.

[144] A. Taflove and S. C. Hagness, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*, 3rd ed. Norwood, MA: Artech House, 2005

[145] M. Fujii, M. Tahara, I. Sakagami, W. Freude, and P. Russer, "Highorder FDTD and auxiliary differential equation formulation of optical pulse propagation in 2-D Kerr and Raman nonlinear dispersive media," *IEEE J. Quantum Electron.*, vol. 40, no. 2, pp. 175–182, Feb. 2004.

[146] S. Adachi, P. Capper, S. Kasap and A. Willoughby (2009). Properties of Semiconductor Alloys: Group-IV, III-V and II-VI Semiconductors (Wiley & Sons, West Sussex United Kingdom).