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# A New Design of Intermodulation by Nonlinear Effect Micro-ring Resonator System

N. Pornsuwancharoen[a,*]

[a]*Nano Photonics Research Group, Department of Electrical Engineering*
*Faculty of Industry and Technology, Rajamangala University of Technology Isan*
*Sakon Nakhon Campus, Sakhon 47160,Thailand.*

**Abstract**

This Paper shows an optical intermodulation distortion by the nonlinear effect micro-ring resonator device. The micro-ring resonator system generates a chaotic signal by four waves mixing (FWM) and is cancelled by a multi-ring resonator with filtering signal. The two coherence sources at the approximate wavelength (1,500-1,550 nm) into the micro-ring system generate a new signal center peak by an interference phenomenon. This system can be used to generate the new carrier frequency for a security system. The optical intermodulation distortion system can be selected first, second or center for the carrier of a frequency in application of the THz frequency system.



*Keywords:* Optical intermodulation, Nonlinear effect, Communication

## 1. Introduction

An inter-modulation DWDM [1] terminal multiplexer is the terminal multiplexer actually containing one wavelength converting transponder for each wavelength signal it will carry. The wavelength converting transponders receive the input optical signal, convert that signal into the electrical domain, and retransmit the signal using a 1,550 nm band laser. The terminal MUX also contains an optical multiplexer, which takes the various 1,550 nm band signals and places them onto a single fiber. The terminal multiplexer may or may not also support a local EDFA [2] for power amplification of the multi-wavelength optical signal. The modulation in optical communication on DWDM have more instance, such as the 50-GHz spaced DWDM 60-GHz millimeter-wave radio-over-fiber systems using optical interleaver shown as [3], IP/DWDM networks [4], the DWDM-based optical networks [5], super-DWDM technologies to terrestrial terabit transmission systems [6], the field demonstration of over 1000-channel DWDM transmission with supercontinuum multi-carrier source[7] and the

* Corresponding author.*E-mail address:* jeewuttinun@gmail.com

storage and tunable light source generated by a soliton pulse in a micro ring resonator system for super dense wavelength division multiplexing use [8].

This paper achieves multiplexing of the multi-channel by inter-modulation DWDM with control ring resonator parameter and the pump power for a given input power of 2 W and desired output channel of more than 300 channels.

## 2. Theory and design concepts

The light pulse is input into a ring resonator system with constant Gaussian's field amplitude (E0), which is the combination of terms in attenuation (α) and phase (ϕ0) constants, which results in temporal coherence degradation. Hence, the time dependent input light field (Ein) and L is a propagation distance (waveguide length) as shown in equation (1).

$$E_{in}(t) = E_0 e^{-\alpha L + j\phi_0(t)} \tag{1}$$

The nonlinearity of the optical ring resonator device is of the Kerr type; i.e., the refractive index is given by

$$n = n_0 + n_2 I = n_0 + n_2 (\frac{P}{A_{eff}}) \tag{2}$$

where $I$ and $P$ are the optical intensity and optical power, respectively. The linear and nonlinear refractive indexes are $n_0$ and $n_2$ respectively. $A_{eff}$ is the effective mode core area of the device, which the micro ring and nano ring resonators, the effective mode core areas range from 0.10 to 0.50 $\mu m^2$.

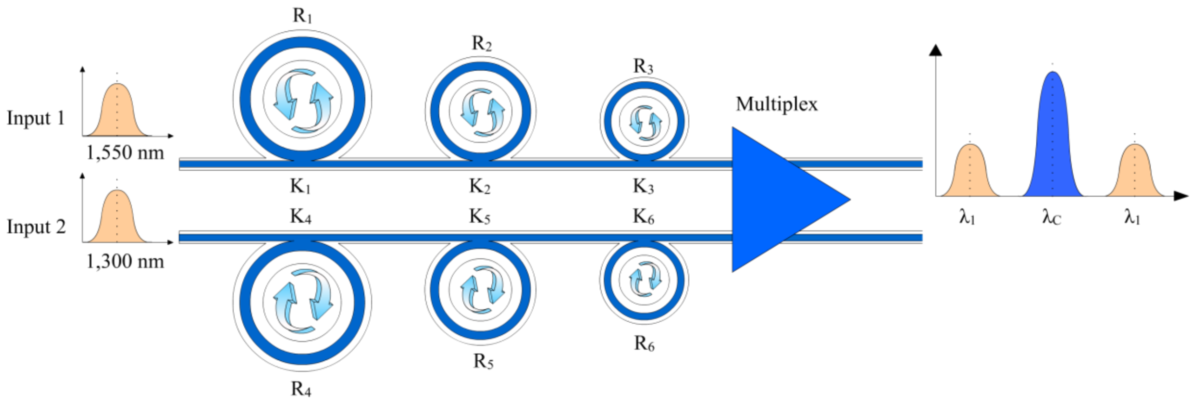


Fig. 1. show the schematic diagram of intermodulation by microring resonator system

Fig. 1 shows the inter-modulation DWDM from 2 Gussian inputs into the micro ring resonator system. The multiplexer mixes the output signal of micro ring resonator system. The input signal must be different from the wavelength center. When a Gaussian pulse is input and propagated within a microring resonator, the resonant output is formed, thus, the normalized output of the light field is the ratio between the output and input fields ($E_{out}(t)$ and $E_{in}(t)$) in each roundtrip, which can be expressed as

$$\left|\frac{E_{out}(t)}{E_{in}(t)}\right|^2 = (1-\gamma)\left[1 - \frac{(1-(1-\gamma)x^2)\kappa}{(1-x\sqrt{1-\gamma}\sqrt{1-\kappa})^2 + 4x\sqrt{1-\gamma}\sqrt{1-\kappa}\sin^2(\frac{\phi}{2})}\right] \tag{3}$$

$$\left|\frac{E_{out}(t)}{E_{in}(t)}\right|^2 = (1-\gamma)\left[1-\frac{(1-(1-\gamma)x^2)\kappa}{(1-x\sqrt{1-\gamma}\sqrt{1-\kappa})^2+4x\sqrt{1-\gamma}\sqrt{1-\kappa}\sin^2(\frac{\phi}{2})}\right]\times(1-\gamma_2)\left[1-\frac{(1-(1-\gamma_2)x_2^2)\kappa_2}{(1-x_2\sqrt{1-\gamma_2}\sqrt{1-\kappa_2})^2+4x_2\sqrt{1-\gamma_2}\sqrt{1-\kappa_2}\sin^2(\frac{\phi_2}{2})}\right] \quad (4)$$

Equation (3) indicates that a ring resonator in this particular case is very similar to a Fabry-Perot cavity, which has an input and output mirror with a field reflectivity (1-$\kappa$), and a fully reflecting mirror. κ is the coupling coefficient, and χ = exp(-αL/2) representing a roundtrip loss coefficient, $\phi_0 = kLn_0$ is the linear phase shifts, and $\phi_{NL} = kLn_2(P/A_{eff})$ is nonlinear phase shifts, $k = 2\pi/\lambda$ is the wave propagation number in a vacuum, where L is a waveguide length and $\alpha$ is linear absorption coefficient, respectively. In this work, the iterative method is introduced to obtain the results as shown in equation (4), similarly, the output field is connected and input into the other ring resonators.

The inter-modulation Dense wavelength division multiplexing (iDWDM) refers originally to optical signals multiplexed within the 1,550 nm band so as to leverage the capabilities (and cost) of erbium doped fiber amplifiers (EDFAs), which are effective for wavelengths between approximately 1,525–1,565 nm (C band), or 1570–1610 nm (L band). EDFAs [2] were originally developed to replace SONET/SDH optical-electrical-optical (OEO) regenerators, which they have made practically obsolete. EDFAs can amplify any optical signal in their operating range, regardless of the modulated bit rate. In terms of multi-wavelength signals, so long as the EDFA has enough pump energy available to it, it can amplify as many optical signals as can be multiplexed into its amplification band (though signal densities are limited by choice of modulation format). EDFAs therefore allow a single-channel optical link to be upgraded in bit rate by replacing only equipment at the ends of the link, while retaining the existing EDFA or series of EDFAs through a long haul route. Furthermore, single-wavelength links using EDFAs can similarly be upgraded to WDM links at reasonable cost. The EDFAs cost is thus leveraged across as many channels as can be multiplexed into the 1,550 nm band [2].

## 3. Results

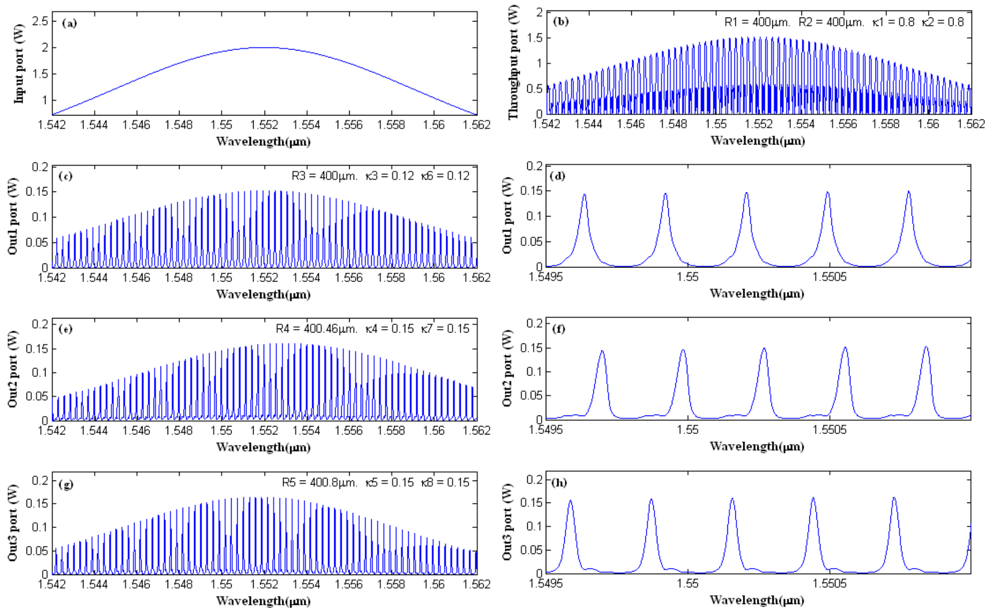


Fig. 2. shows the result of microring system for Gaussian input at centre wavelength 1.550 µm

Fig. 2 shows the result of multi-channel for DWDM and the input Gussain pulse shown in Fig. 2(a) to generate by nonlinear effect from material microring device is AlGaAs/InP. From Fig. 2, the Gaussian pulse with center wavelength ($\lambda_0$) at 1.552 µm, bandwidth of 20 nm (~3.5 THz), peak power at 2 W is input into the network system as shown in Fig. 2(a). The large bandwidth signals can be seen at the throughput port, output1 port, output2 port and output3 port of the network system as shown in Fig. 2(b) to 2(h) respectively. The suitable ring parameters are used as above; for instance, ring radii $R_1$ = 400 µm, $R_2$ = 400 µm, $R_3$ = 400 µm, $R_4$ = 400.46 µm and $R_5$ = 400.80 µm. The selected parameters of the system are fixed to $n$ = 3.47, α = 0.5 dBmm$^{-1}$, γ = 0.1. The coupling coefficient; $\kappa$ of the ring resonator are ranged from 0.12 to 0.80. The maximum output power obtained is about 0.15 W. Furthermore, the non-dispersive wavelength (1.552 µm) can be extended and used with the existed public network installation which is available for high capacity and long distance communication link.

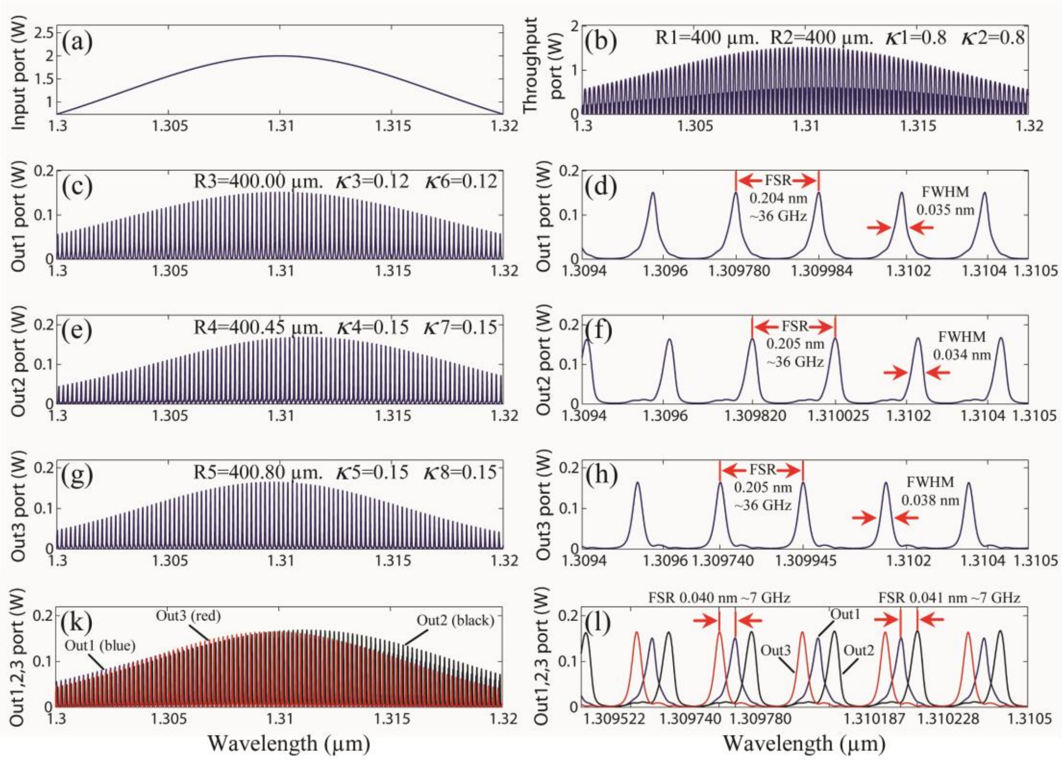


Fig. 3. Simulation results for Gaussian input at center wavelength 1.310 µm

From Fig. 3, the Gaussian pulse with center wavelength ($\lambda_0$) at 1.310 µm, bandwidth of 20 nm (~3.5 THz), peak power at 2 W is input into the network system as shown in Fig. 3(a). The large bandwidth signals can be seen at the throughput port, output1 port, output2 port and output3 port of the network system as shown in Fig. 3(b) to 3(h) respectively. The suitable ring parameters are used in the same way as above; for instance, ring radii $R_1$ = 400 µm, $R_2$ = 400 µm, $R_3$ = 400 µm, $R_4$ = 400.45 µm and $R_5$ = 400.80 µm. The selected parameters of the system are fixed to $n$ = 3.47, α = 0.5 dBmm$^{-1}$, γ = 0.The coupling coefficient; $\kappa$ of the ring resonator are ranged from 0.12 to 0.80. Considering the overlaying of the three output signals (from output1, output2 and output3 ports) as shown in Fig. 3(k) and 3(l), we will find that the system can be equivalent to inter-modulation DWDM multiplexing with about 0.040 nm of FSR (~7 GHz), $90\times3$ = 270 channels, which is merely 20 nm of input signal bandwidth. The maximum output power obtained is about 0.15 W. Furthermore, the non-dispersive wavelength (1.310 µm) can be extended and used with the existed public network installation which is available for high capacity of more than 300 channels and long distance communication link.

## 4. Conclusions

We have presented the use of mirroring system to generate Gussain pulses 2 input signal into multiplexer for design inter-modulation DWDM. From the obtained results, the FSR and intensity power of 0.205 nm and 0.15 W, with a center wavelength of 1,550 nm, can be achieved. In optical communications, any technique by which two or more optical signals having different wavelengths may be simultaneously transmitted in the same direction over one waveguide, and then be separated by wavelength at the distant end. In application, the use of iDWDM can be employed to obtain the multi-wavelength inter-modulation of microring resonator, which may be available for high capacity packet switching. In the near future, we will be used to a iDWDM of optical communication more than in present.

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