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Design and Simulation of Photonic System for Terahertz Signal Generation

Ms.SEETHAL.R[1],Mrs.K.BHUVANESHWARI[2]
[1]*IFET College Of Engineering, UG Scholar*
[2]*IFET College Of Engineering, Professor*

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ABSTRACT

This paper presents a generation of terahertz(THz)signal with photonic system using microringresonator and direct modulated laser. DM laser is given as input to microring resonator. The output signal obtained from the photodetector consists of full-width half maximum(FWHM) is higher when comparing to the MLL. Also the parameters of BER and Q-factors are investigated.Thus the THz signal produced seems to be more efficient. Hence the proposed microwave photonic system generates THz carriers which can be efficiently used for communication between a pico/femto cell base station and the mobile user or between two devices present in the same pico/femto cell or different cells deployed in a macro cell of a 5G environment.

KEYWORDS: Microwave photonics, Microring resonator, THz signal generation, Direct-modulated laser.

I. INTRODUCTION

Microwave photonics (MWP) involves in working with the photonic devices which operates at the microwave frequencies results in finding the solution for the complexities faced by microwave domain. Also the combination of microwaves and photonics provides the solutions to the fiber-radio systems. On comparing with traditional electronics, microwave photonics consists of advantages such as reduction in size, weight and cost, less attenuation and dispersion[1,2].Now,high wireless transmission rates with IEEE 802.16 provides higher carrier frequencies in wireless communication which supports Gb/s data rates[3].

Photonic domain deals with the study of proving that one of the simplest way to generate high data rate signals using photonic devices which has the larger bandwidth[4]. There have been many photonic based techniques are proposed for generating terahertz signals. MWP has a wide applications in satellite communication[5],distributed antenna systems[6],medical imaging[7] and optical signal processing[8].

Due to the compactness, demands for data rates and bandwidth, wide ranged tunability, the microwave photonics satisfies the complexities existing in the 5G technology [9].Microwave Photonics domain acts as a potential candidate to address the challenges of upcoming technologies such as 5G and terahertz systems. To increase the number of connected devices, 5G architecture has many pico and femto cells with base station. The span of frequency band between 0.1 THz and 10 THz in terahertz communication has an application on both fronthaul and backhaul base stations, small area networks for smart homes and offices etc,.[10,11]. Also the THz signals has a speciality to propagate through non-metallic components such as mirrors, plastics etc,.Thus THz imaging finds various applications and the image considered as sparse signal based on the compressive sensing [12].

1.1 Cell Densification in 5G environment

Nearly 75-80% wireless users stays at indoor than spending time at out. Thus 5G has occupied a crucial role to provide the signal with less penetration loss for the indoor users. But, the main challenge in the 5G architecture is network densification. Small cells are proved as potential one on comparing the macro cells to overcome from offload traffic and act as an improved parameter for the cellular coverage and also increases the network capacity[13]. Small cells which are managed by network operatorsare wireless access points operating in a licensed spectrumwith low power consumption. Nearly it supports 64-128 users. It can be deployed in shopping malls, airports which are primarily deployed in residential environments around 4-32 users [14].The various types of macro cells are mentioned as

- Femtocells - Residential and Enterprise
- Picocells – Public areas (airports, shopping malls)
- Micocells–Urban areas

Classification of macro cells in 5G environment is shown in Fig.1.1

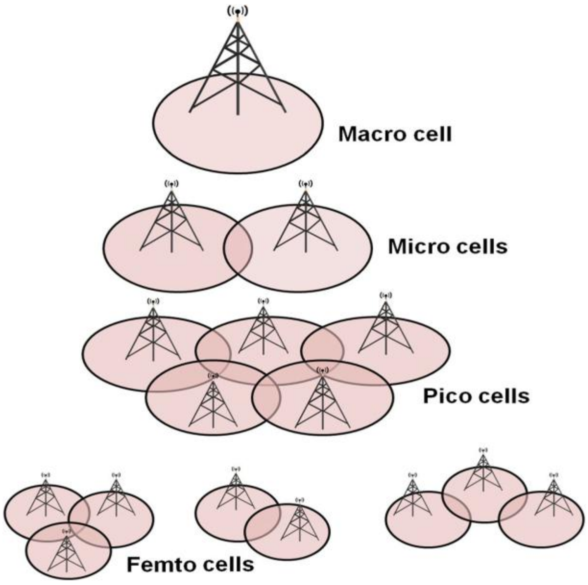

Fig 1.1 Classification of macro cells

5G mobile network has one of the major requirements which are capable to enable gigabit per second throughput along with the larger bandwidth.. Also Small cells founds a wide applications in multimedia such as

High definition television (HDTV), wireless gigabit Ethernet which operates in mmWave about 28,38,71-76 and 81-86 GHZ[15]. Apart from mmWave band, THZ band also involves in the small cell communication which is capable to provide ultra-high-speed data rates upto 10 m coverage [16].Though THz holds a lot of applications, still facing some challenges in photonics. Also THz transmitters are restricted by responsivity and still difficult to reach accurate beam-steering with higher bandwidths.THz transistors are cost evolved in integration considered as challenge in THz communication[17].

1.2 Overview

In this paper, THz signal generation using photonic system based on the add-drop microring resonator and direct-modulated laser. DML acts as input source to the MRR. The THz signal carrier generated based on the frequency comb generated at the output of the microring resonator. An algorithm finite difference time domain (FDTD) finds a way of this THz generation system using commercial device modeling tool. Both the optical and electrical filter monitors the generation of THz signal.

DML acts a high speed transmitter as about 40 Gbps. It is a small sized laser and involves low power consumption and which is attractive for short-reach application[18,19]**.** The various High-speed direct modulations are:

- 25-Gbps operation up to 100ºC
- 25-Gbps operation at 50ºC for 4 lasers on LAN-WDM grid
- 40-Gbps operation up to 85ºC
- 40-Gbps transmission over 10-km SMF up to 70ºC

DMLs are promising for future high speed data transmission[20].

Microring resonator (MRR) acts as an important building block of integrated photonics and has many applications in widespread fields [21,22].It consists of two input and output ports namely input and add port then through port and drop port respectively.

Asilicon-on-insulator microring resonator forms an integral part of an optical temperature sensor based on integrated optoelectronic oscillator [23]. A tunable microring resonator-based THz source which generates THz waves about 0.5-10 THz [24]. This generation of THz signal based on the frequency comb generated by the microring resonator.

II. RELATED WORK

Mode-locked laser (MLL) is an input to microring resonator. It is set as an optical source to generate bell-shaped optical signals.The wavelength of MLL is adjusted to the resonance wavelength of the MRR which is 1555.33 nm.The input power is set as 0.5 W. Fig.2.1 shows the block schematic of photonic system for THz signal generation using MLL.

In this case, THz signal carrier generated consists of electrical power of received signal is -72.60 dBm and full-width half maximum (FWHM) is 0.053 ns [25].

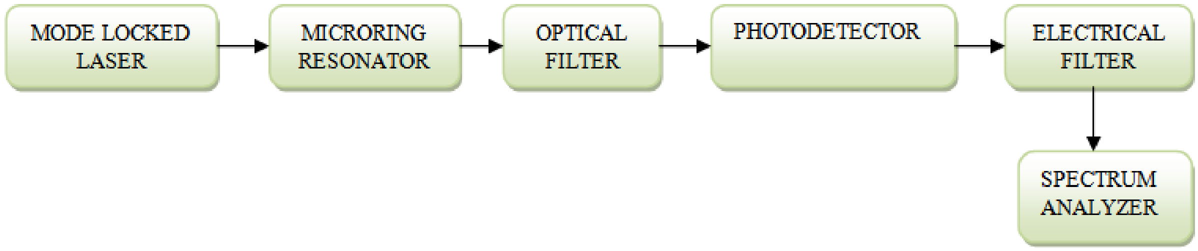

Fig 2.1 Block schematic of photonic system for THz signal generation using MLL

III. PROPOSED APPROACH

In this proposed method, DM laser is an input to MRR.The generated combo lines from MRR are filtered using optical filter. Photodetector is connected at the end of the optical filter. The various noises such as shot noise, dark noise, relative intensity noises which affects the quality of output signal from photodetector can be filtered using electrical filter. Then the spectrum of generated THz signal displayed using the spectrum analyzer.BER tester is added to check the efficient parameters such as BER and Q-factor. Block schematic representation of photonic system for THz signal generation using DM laser is shown in the Fig 3.1

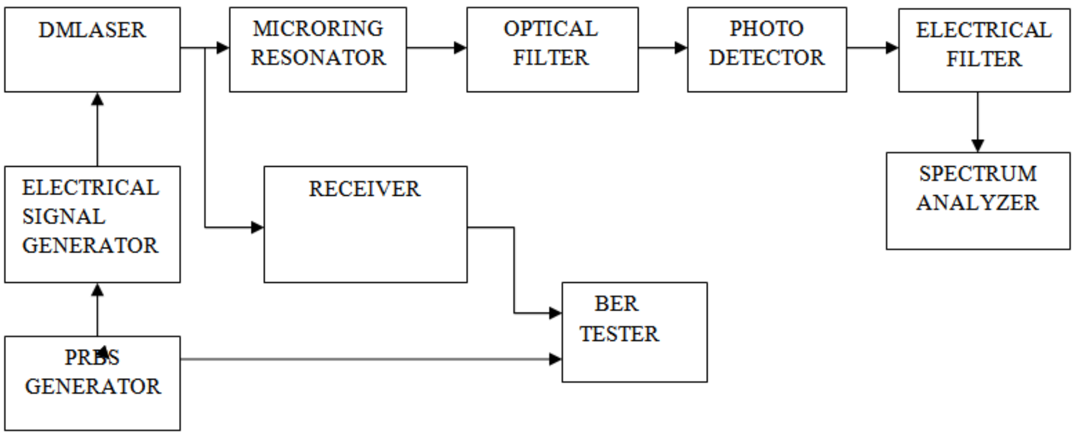

Fig.3.1.Block schematic of photonic system for THz signal generation sing DM laser

3.1 Simulation and Result analysis

RSoftoptsim tool is used for the simulation of fig.3.1.In the optical communication system,RSoftoptsim provides an advanced and accurate simulation of designs.

The Parameters used in simulation of photonic system for THz signal generation are mentioned in below table 3.1

PARAMETER	VALUE
DM laser power	0.5 W
DM laser wavelength	1555.33 nm
Radius of MRR	20 µm
Quantum efficiency of photodetector	0.8
Electrical filter type	Lowpass Bessel
Electrical filter bandwidth	10 GHz
Opticalfilter bandwidth	1 nm

Direct-Modulated (DM) laser is used as an optical source. The wave length adjusted for the laser to the resonant wave length to MRR is about 1555.33 nm. The input power of DM laser is 0.5

W. The output of DM laser is connected with input port of MRR. The output of MRR from the drop port is fed into the optical filter, which consists of bandwidth about 1 nm. After filtering out the required optical frequency components, it is given to the photodetector to obtain the THz signal in electrical domain. The ouput power of signal from an electrical filter is about -32.41 dB.The spectrum of electrical signal obtained at the output of photodetector is shown in Fig 3.2.The FWHM of THz carrier is obtained as 0.072 ns.

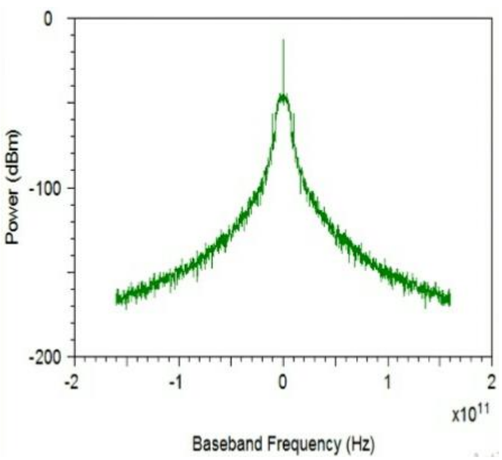

Fig 3.2 Output signal of electrical filter

3.2 Mathematical analysis

At resonance, cavity consists of a signal with round trip phase shift is termed as 2π.When wavelength of receiving signal considered as not a multiple of optical path length of round trip, such resonator known to be OFF resonance.The resonance condition is expressed as

$n_{eff}L = m\lambda_{res}$

where n_{eff} is the effective refractive index of waveguide, L is the circumference of ring resonator, r is the ring radius, m is the integer of azimuthal mode number and λ_{res} is the resonant wavelength of microring resonator.

IV. PERFORMANCE ANALYSIS

(a) BER Analysis

BER is the ultimate criterion used to quantify the quality of an optical transmission and is related to the error probability. The error probability is definedas the probability of incorrect identification of a bit by the decision circuit of the receiver. The BER of output signal obtained is shown in Fig 3.3.

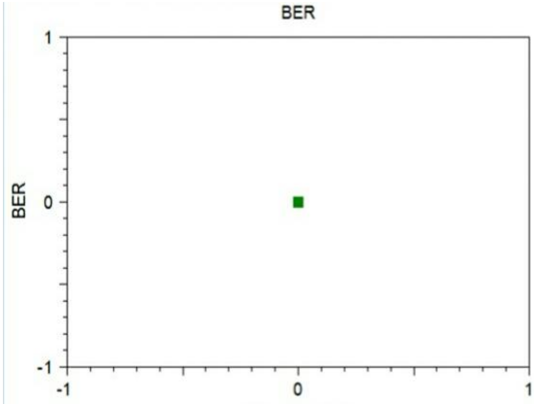

Fig 3.3 BER Analysis

(c) Q-factor Analysis

The quality of the signal can be measured using the value of Q. The higher value of Q represents the reduction in the loss of signal.

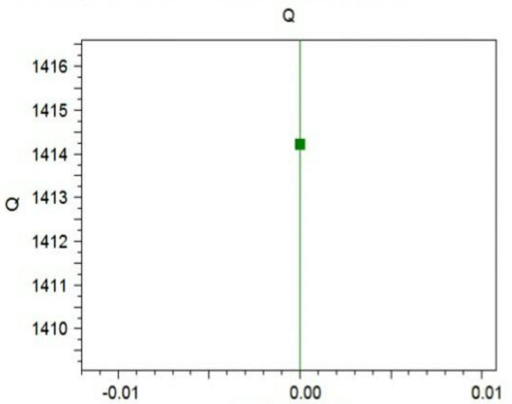

Fig 3.4 Q-Factor analysis

V. CONCLUSION

As a result, an efficient way to generate THz signal using photonic system using DM laser than MLL is implemented. The resultant THz carrier consists of the FWHM is about 0.072 ns which leads to achieve better signal to noise ratio. Also the BER and Q-factor is discussed for the spectrum to prove the efficiency of the output signal. Thus the proposed microwave photonic system generates THz carriers which can be efficiently used for communication between a pico/femto cell base station and the mobile user or between two devices present in the same pico/femto cell or different cells deployed in a macro cell of a 5G environment.

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Email id: ijaem.paper@gmail.com