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An Optical Dipole Antenna by Micro-ring Resonator

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Abstract

The Optical dipole antenna generation signals a high frequency of a micro-ring resonator system. The Gaussian pulse into the micro-ring resonator created the chaotic signal while converting the wavelength domain to the frequency domain for radio broadcasting. The system is designed by varying the micro-ring parameter in the optical dipole model. The high frequency is 100 THz for radiation dipole antenna. This paper shows that the conversion from the pico-second pulse to the frequency domain (THz) can be applied to an optical antenna with the smallest package.

Keywords: optical dipole antenna, ring resonator, broadcasting

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1. Introduction

Optical dipole antennas used in terahertz(THz) frequency in optical communication can be a response demand to increase more and more users in order to increase demands for wireless communication applications such as Optical antennas tuned to pitch [1], Bio-sensing [2], the devices possess collective oscillations of conduction electrons of metals known as plasmon modes[3-5], which increase light coupling from nano-emitters to the nanoantenna [6] or from the nanoantenna to freely propagating light, and vice versa. These intriguing properties implicate great potential for the development of novel optical sensors, solar cells, quantum communication systems [7], and molecular spectroscopy techniques, in particular, for the emission enhancement and directionality control over a broad wavelength range. The optical properties of different types of antennas have been discussed over the last few years [8–18]. Two geometries; i.e., the dipole and the bowtie antennas, appear to combine in a unique way to form a strong hot spot in their gap and the tunability of their resonance. The strong field enhancement of dipole antennas has readily been shown by white light continuum generation [19].

In this paper, we present the use of a new technique for THz carrier generation for optical dipole antenna by micro ring resonator. The dual frequency (THz) signals are generated by using the nonlinear behavior within the

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micro ring system. Finally, the design system can be used to form the micro ring system broadcasting via the optical dipole antenna.

2. Optical antennas

An optical antenna is a device that efficiently couples the energy of free-space radiation to a confined region of subwavelength size. While antennas are widespread in the radiowave and microwave regimes, they are basically unexplored at optical frequencies. Because nanoscale devices need to interface with optical radiation, it is likely that optical antennas will have a broad impact on future technology. The concept of antennas is not new, by any means. They are the enabling technology in cellular phones, satellite communication, and many other devices which use electromagnetic radiation. However, their optical counterpart is basically non-existent in today's technology. Instead, optical radiation is manipulated by redirecting the wavefronts with lenses and mirrors. Consequently, because of the diffraction, it appears that optical fields cannot be localized to dimensions much smaller than the optical wavelength. Optical antennas are a solution to the mismatch between the small dimensions of nanoscale devices and the length scale associated with optical wavelengths. It can be expected that optical antennas will be used for artificially enhancing the absorption cross-section or quantum yield of optoelectronic devices (e.g., solar cells), for efficiently releasing energy from nanoscale devices (e.g. LED lighting), and for boosting the efficiency of biochemical detectors relying on a distinct spectroscopic response (Raman scattering, fluorescence, etc.) [1].

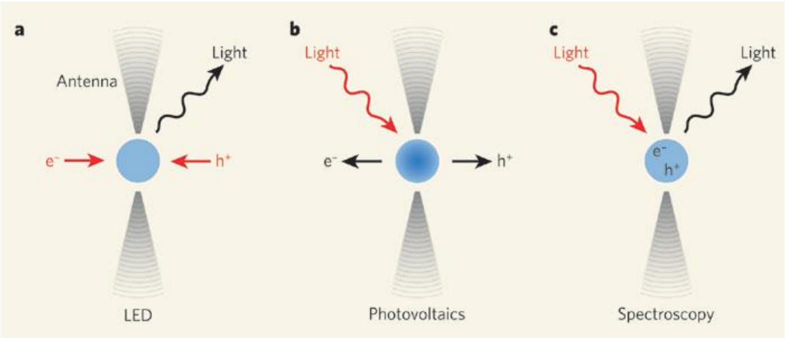

Fig. 1. The gold gap antennas studied by Ghenuche et al. can be used by several applications. a, In a light-emitting diode (LED), charge carriers electrons (e-) and electron holes (h+)—are recombined in a medium (blue) to produce light. b, In photovoltaics, incident light causes separation of the charge carriers. c, In spectroscopy, incident light polarizes the medium of interest, and this polarization gives rise to outgoing radiation. In all three cases, the optical antenna (grey) enhances the efficiency of the input–output conversion process [1]

A light pulse is input into a ring resonator system with constant Gaussian's field amplitude (E_0), which is the combination of terms in attenuation (α) and phase (ϕ_0) constants, which results in temporal coherence degradation. Hence, the time dependent input light field (E_{in}) 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

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

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, where the micro ring and nano ring resonators, the effective mode core areas range from 0.10 to 0.50 μm^2.

When a Gaussian pulse is input and propagated within a micro ring 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

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

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) represents a roundtrip loss coefficient, $\phi_0 = kLn_0$ is the linear phase shifts, and $\phi_{NL} = kLn_2(P/Ae_{ff})$ is nonlinear phase shifts; $k = 2\pi/\lambda$ is the wave propagation number in a vacuum, where L is a waveguide length and α is linear absorption coefficient, respectively [20].

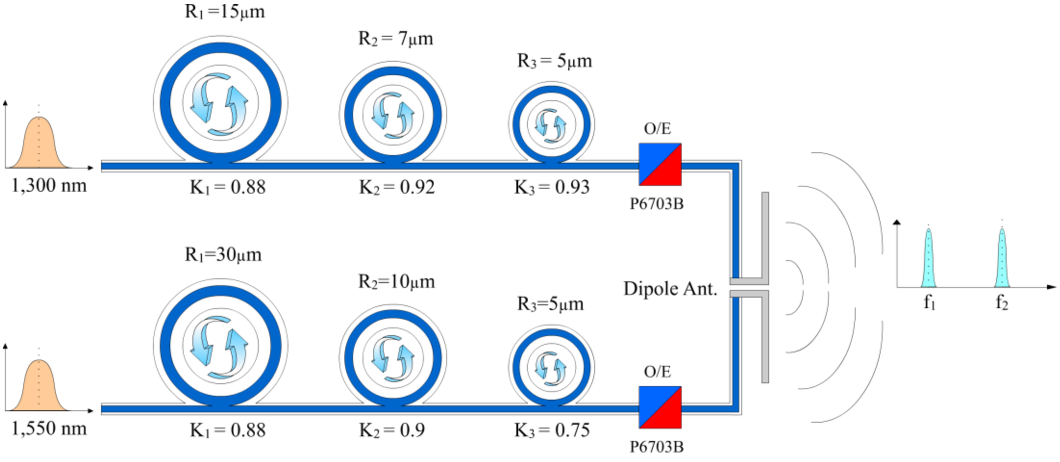

Fig. 2. Sketch schematic diagram of optical antenna system

Fig. 2 shows the system of an optical antenna system which consists of a micro ring resonator system, optical to electrical converter (P6703B product of Tektronix) support 1.2 GHz, which the Tektronix P6700 Series optical-to-electrical (O/E) converters change optical signals into electrical signals for convenient and micro antenna dipole type. We can down convert the THz frequency to GHz frequency by dividing the frequency method shown in Fig. 3. The electrical signal can be converted into the optical antenna system which generates the signal to amplifier circuit for an antenna broadcasting system.

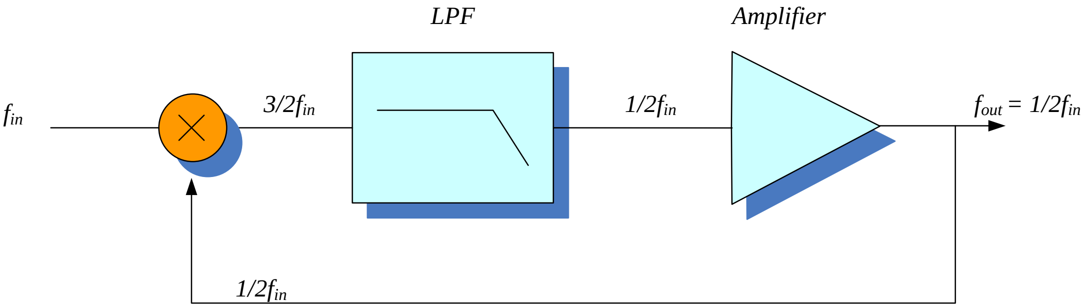

Fig. 3. Show diagram of divider frequency

3. Result

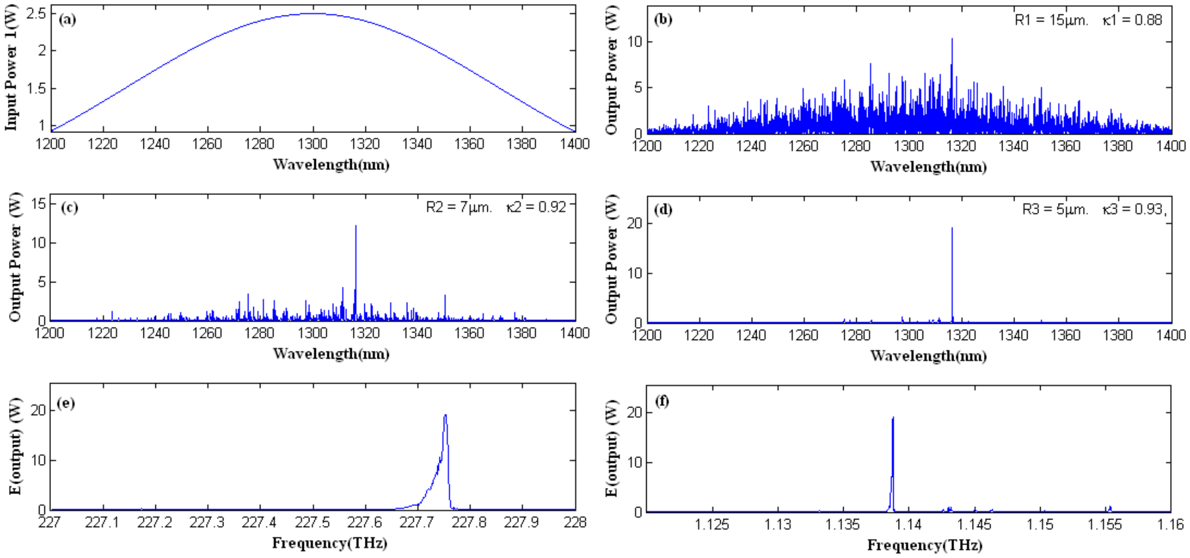

Fig. 4. shows the result of an optical antenna at center wavelength is 1,300 nm. where (a) input signal from Gaussian pulse with a center wavelength of 1300nm 2.5W (b) the large bandwidth signal (c) the filtering and amplifying signal (d) the storage unit (e) is the O/E signal and (f)

The wavelength and frequency domain results are shown in Fig. 4 (a) input signal is a Gaussian pulse 2.5 W and center wavelength of 1300 nm. The result output signals of first ring (R_1) are the chaotic and filtering signals obtained by the second ring (R_2) and the third rings (R_3). The parameters of ring radii are 15μm, 7 μm and 5 μm for R_1-R_3 as shown in Fig.4 (b-d), the single peak is 20 W as shown in Fig. 4(d). The coupling coefficients (κ_1, κ_2, κ_3) of the rings R1-R3 are 0.88, 0.92 and 0.93. The center wavelength is 1.3 μm, where the output signals of O/E converter as shown in Fig.4 (e). We can change the optical signal to Electrical signal by O/E at the frequency between 227.65-227.78 THz, power output is 20W shown in Fig. 4 (f), which have frequency 1.138 THz from output signal by divider frequency method shown in Fig.3. In Fig. 5 (a) input signal is a Gaussian pulse 2.5 W and wavelength of 1,550 nm. The result output signals of first ring (R_1) are the chaotic and filtering signals obtained by the second ring (R_2) and the third rings (R_3). The parameters of ring radii are 30μm, 10 μm and 5 μm for R_1-R_3 as shown in Fig.5 (b-d); the single peak is 50 W as shown in Fig. 5 (d). The coupling coefficients (κ_1, κ_2, κ_3) of the rings are R_1-R_3 0.88, 0.90, and 0.75. The center wavelength is 1.55 μm, with the output signals of O/E converter as shown in Fig.5 (e). We can change the optical signal to Electrical signal by O/E at the frequency between 194 TH; the power output is 50W show in Fig. 5 (f), which have frequency 1.941 THz from output signal by divider frequency method. Fig. 6 shows the result of double frequency broadcasting by antennas system shown in Fig. 6(a) and the output signal of the first ring resonator system (1,300 nm) can be designed by the variable parameter of ring resonator shown in Fig. 6(b) and Fig.6(c) is result of second ring resonator system (1,550 nm), respectively.

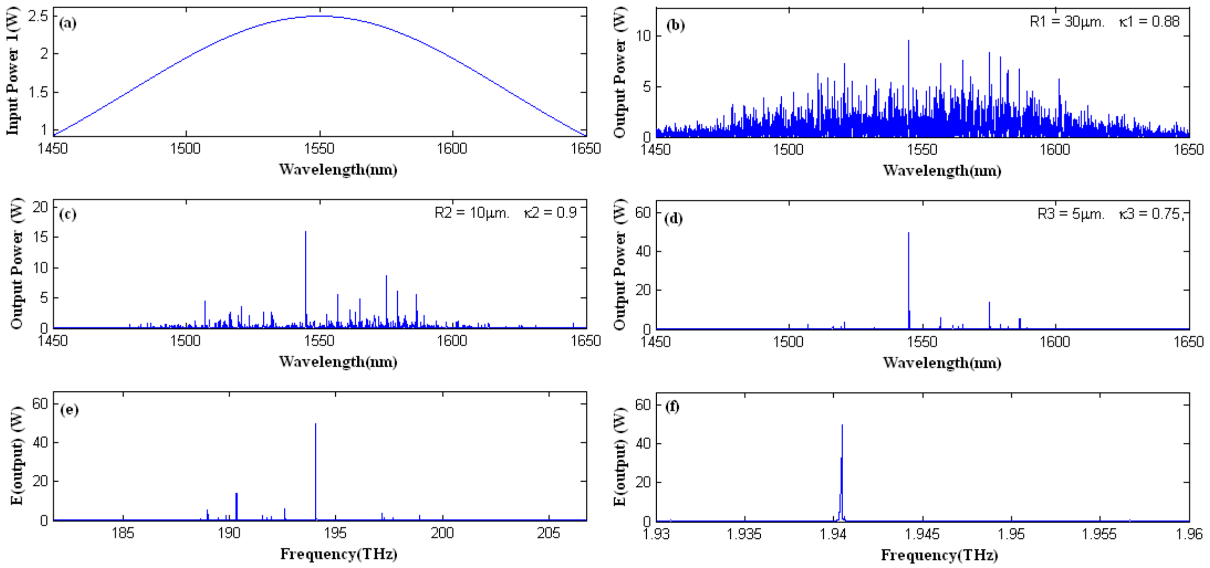

Fig. 5. shows the result of optical antenna at center wavelength is 1,550 nm. with (a) input signal from Gaussian pulse with a center wavelength of 1,550 nm 2.5W (b) the large bandwidth signal (c) the filtering and amplifying signal (d) the storage unit (e) is the O/E signal and (f)

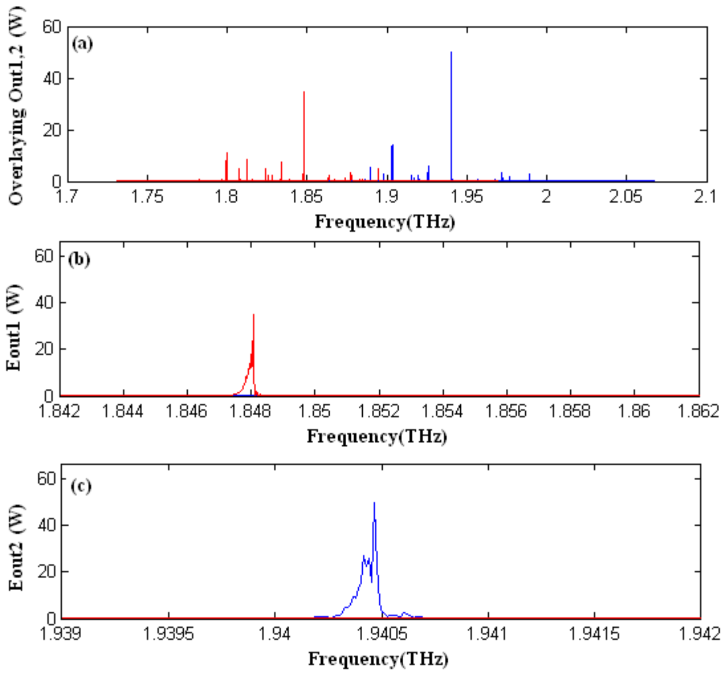

Fig. 6. shows the dual frequency result of optical antenna

4. Conclusion

We have the simulation result of the optical dipole antenna generation signal high frequency by a micro-ring resonator system. We found that the generated output power with the micro-ring resonator created the chaotic signal by converting the wavelength domain to frequency domain for radio broadcasting. Results obtained have shown the conversion from the pico-second pulse to frequency domain (THz), which the high frequencies are 185 THz and 227 THz for radiation dipole antenna. We can use this application for optical antenna within the smallest package.

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