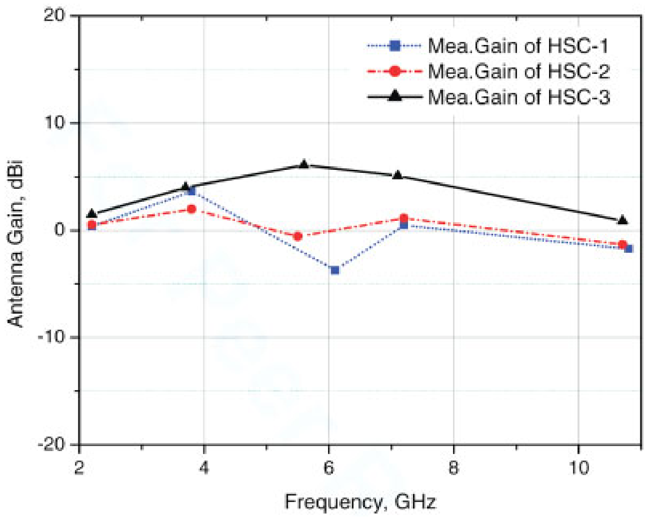


Figure 6 Measured gain of the HSC monopole antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

obtained. From the simulation and experimental results, it considered that the flare angle is a dominant factor for wideband matching. In case of 120° flare angle, almost less than −10 dB matching is observed for the wide frequency bands except for some slight mismatch throughout entire bands.

The first resonant frequency is occurred at near 380 MHz, which is attributable to radial stub mode formed by current distribution on outer peripherals. It seems that the truncated or cutouts effect degrades matching performance near the first resonant frequency. As we can know in Figure 4, the proposed HSC antenna shows better wideband matching performance than log-periodic multiband performance of previous Sierpinski carpet antenna.

Figure 5 shows the radiation patterns of the HSC antennas measured in anechoic chamber at several frequencies. Almost the patterns shows omni directional but some shows directional property. It is considered that several class of different sized cutouts work like many different frequency selective loop radiators adding more freedom for antenna design.

Since each annular sector has a reduction in the scale of one-third, the fundamental resonant frequency triples as the iteration number goes up. An important geometric feature compared with classical Sierpinski carpet is a series of different sized cutouts. The measured gain of the HSC antenna is shown in Figure 6.

We obtained the gain of the HSC antennas: −0.1 ± 0.5 dBi, 1.6 ± 0.3 dBi, and 2.6 ± 3.5 dBi, respectively. Especially, the HSC-2 antenna shows almost flat gain of ±0.3 dBi.

4. CONCLUSION

In this paper, a novel design of the printed HSC antenna is presented. From the simulated and measured results, the microstrip feeding and partial ground methods have been well functioned for wideband impedance matching performance. All of these proposed antennas have provided the return loss of less than −5 dB throughout 1.2–20 GHz frequency band. Especially the HSC antenna with 120° flare angle shows almost −10 dB impedance matching (1.8–20 GHz). We have also obtained the moderate antenna gain of −3.5 to 6 dBi.

REFERENCES

1. P. Tang, Scaling property of the Koch fractal dipole, IEEE Int Symposium Ant Propagat Dig 3 (2000), 150–153.
2. J. Solar, C. Puente, and A. Puerto, A Dual-Band Bidirectional Multilevel Monopole Antenna, Microwave Opt Tech Lett 34 (2002), 445–447.
3. C. Puente, M. Navarro, J. Romeu, and R. Pous, Variations on the fractal Sierpinski antenna flare angle, IEEE Ant Propagat Int Conf, Atlanta, GA (1998), 2340–2343.
4. C.T.P. Song, P.S. Hall, H. Ghafoury-Shiraz, and D. Wake, Fractal stacked monopole with very wide bandwidth, Electron Lett 35 (1999), 945–946.
5. C.T.P. Song, P.S. Hall, H. Ghafoury-Shiraz, and D. Wake, Sierpinski monopole antenna with controlled band spacing and input impedance, Electron Lett 35 (1999), 1036–1037.
6. G.S. Lee, A uniplanar widebnad loop antenna design using an alternate inverted 2D cantor set, Microwave Opt Tech Lett 39 (2003), 437–439.
7. F. Glaser, The universality of the hyperpolar images of the Sierpinski carpet and the Menger sponge, J Interdisciplinary Studies 10 (1997).

ALL-OPTICAL DIODE IN PHOTOREFRACTIVE CRYSTAL

W. Yuan[1] and B. Wang[1,2]
[1]Electro-Optics Technology Center, Harbin Institute of Technology, Harbin 150001, China
[2]School of Physics and Engineer, Sun Yat-sen University, Guangzhou 510275, China

Received 16 September 2006

ABSTRACT: *In this letter, we present a technique that employs photorefractive crystals for all-optical diode. We theoretically designed a structure using two-pieces of photorefractive crystals, this special crystals set show significantly potentials for applications in unidirectional diffraction beams.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1092–1095, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22360

Key words: *Optical diode; photorefractive capital; grating diffraction; unidirectional diffraction beams*

1. INTRODUCTION

The possibility of achieving anisotropic transmission through a nonlinear device is not only novel and interesting, but also potentially useful in the fields of optical isolation and all-optical processing [1]. Such unidirectional action was demonstrated theoretically in a set of photorefractive crystals, this structure is a spatially nonreciprocal device that allows unidirectional diffraction of beams. Although the parameters used therein were not exact in reality, the preliminary model served the purpose of demonstrating that all-optical diode behavior is possible.

2. THEORY OF GRATING DIFFRACTION

2.1. Diffraction of Two Input Beams at Bragg Conditions

We must know the diffraction characteristics of gratings in photorefractive crystals. Following the coupled-wave analysis of Kogelnik [2], Suppose used the lower intensities, this minimizes the chance that the grating is further optically damaged during readout. When in the process of readout, we obtained the following coupled-wave equations [3]:

$$r'(z) - f(z)s(z) = 0$$

$$s'(z) + f^*(z)r(z) = 0 \tag{1}$$

where $f(z) = i\exp(i\varphi_g)[I_R(z,T)I_S(z,T)]^{1/2}\exp[-i\varphi(z,T)]\Gamma$.

We elect to readout at same frequency as at recording and the readout beams were incident at the angle of recording angle, as shown in Figure 1, we obtained

$$r(z) = N(z,T)\left\{ r(0)\cosh(a) + \left\{ 2\frac{[I_R(0)I_s(0)]^{\frac{1}{2}}}{\sum_0}\exp[-i\varphi(0,T)]s(0) - r(0)\frac{\Delta_0}{2\sum_0}\right\}\sinh(a)\right\} \quad (2)$$

where $N(z,T) = \cosh(\Gamma z\sin(\varphi_g))^{\frac{i\cot(\varphi_g)-1}{2}}$, $a = i\Gamma z\exp(i\varphi_g)/2$, $\Delta_0 = I_S(0) - I_R(0)$,, $\Sigma_0 = I_S(0) + I_R(0)$.

If two beams that satisfy the Bragg condition to be symmetrically incident on grating, we can derive its diffraction intensities. Taking $r(0) = A\exp(i\varphi_1)$ and $s(0) = B\exp(i\phi_2)$ leads to diffraction intensities

$$D_r = r(z)r^*(z) = g(u + v + w) \quad (3)$$

$$g = \frac{1 + m_0}{e^{-k} + m_0 e^k}$$

$$u = \frac{r(0)r^*(0)}{2}\left\{\left[\frac{5}{4} - \frac{m_0}{(1+m_0)^2}\right]\cosh k + \left[\frac{3}{4} + \frac{m_0}{(1+m_0)^2}\right]\cos l - \frac{1-m_0}{1+m_0}\sinh k\right\}$$

$$v = 2AB\frac{{m_0}^{1/2}}{1+m_0}\left\{\left[\frac{1-m_0}{1+m_0}(\cosh k - \cos l) - \sinh(k)\right]\cos\Phi + \sin l\sin\Phi\right\}$$

$$w = \frac{s(0)s^*(0)}{2}\frac{4m_0}{(1+m_0)^2}(\cosh k - \cos l)$$

where $k = \Gamma z\sin(\varphi_g)$, $l = \Gamma z\cos(\varphi_g)$, $\Phi = \varphi(0,T) + \phi_1 - \phi_2$.

In the simple case, $\Phi = \varphi(0,T) = \phi_1 = \phi_2$ and $m_0 = 1$. It indicated writing grating in crystal used equal writing intensities,

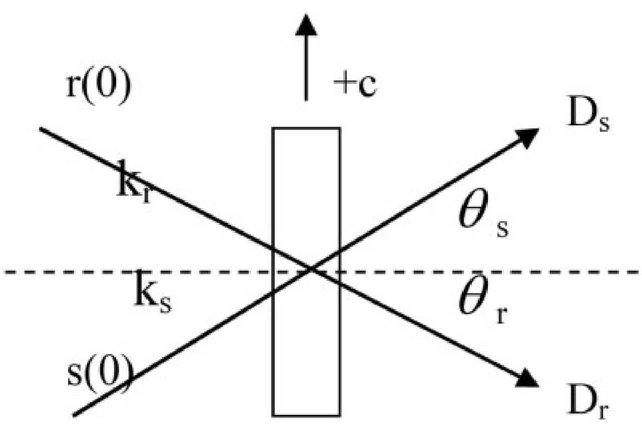


Figure 1 Configuration for the grating writing and readout

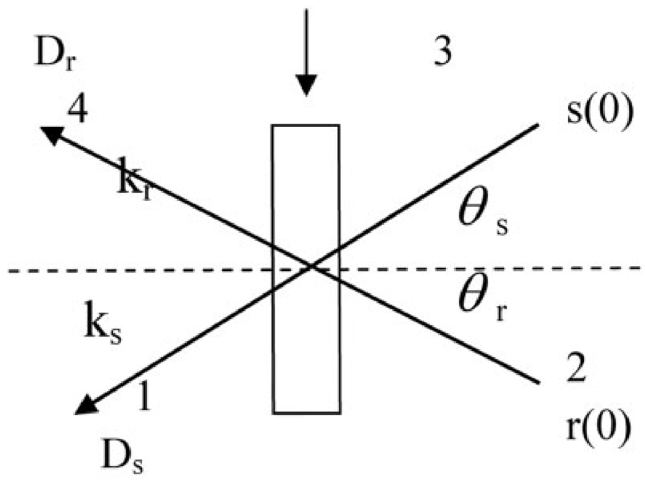


Figure 2 The direction of readout is opposition

and then two beams $r(0)$ and $s(0)$ incident on grating subsequent, we have [4]:

$$D_r = \frac{r^2(0)}{2}\left(1 + \frac{\cos l}{\cosh k}\right) - r(0)s(0)\tanh k + \frac{s^2(0)}{2}\left(1 - \frac{\cos l}{\cosh k}\right) \quad (4)$$

The beams coupled in crystal, so that changed intensities of one beams will lead to changed intensities of the diffraction beams. Suppose $s(0)$ is a variable and Eq. (5) is a quadratic equation, then for the special case $\varphi_g = \pi/2$, Eq. (4) has the character:

$$(r(0)s(0)\tanh k)^2 - 4\frac{r^2(0)}{2}\left(1 + \frac{\cos l}{\cosh k}\right)\frac{s^2(0)}{2}\left(1 - \frac{\cos l}{\cosh k}\right) = 0 \quad (5)$$

This indicated equation has minimal value zero. If the minimal value in readout is met, the relationship of $r(0)$ and $s(0)$ must fit

$$r(0) = \frac{e^k - 1}{e^k + 1}s(0) \quad (6)$$

So, we can change the intensities of D_r by adjusting the intensities of $s(0)$.

Under the same conditions, we similar derived the diffraction intensities of other beams.

$$D_s = s(z)s^*(z) = \frac{s^2(0)}{2}\left(1 + \frac{\cos l}{\cosh k}\right) + s(0)r(0)\tanh k + \frac{r^2(0)}{2}\left(1 - \frac{\cos l}{\cosh k}\right) \quad (7)$$

2.2. Diffraction of Two Input Beams Come from the Opposite Direction

For understanding the diffraction character of grating, we must study writing grating forward and the readout beams come from the opposite directions, as shown in Figure 2.

In these conditions, modify the coupled-wave equations [Eq. (1)]

$$f(z) = i\exp(i\varphi_g)[I_R(d-z,T)I_S(d-z,T)]^{1/2}\exp[-i\varphi(d-z,T)]\Gamma$$

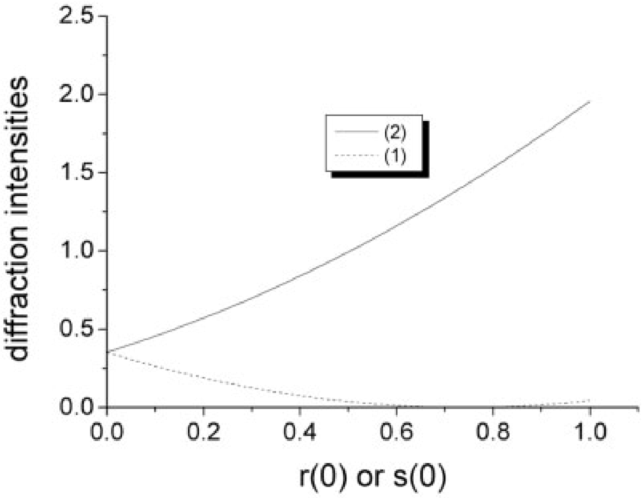


Figure 3 Calculated diffraction intensities of two beams

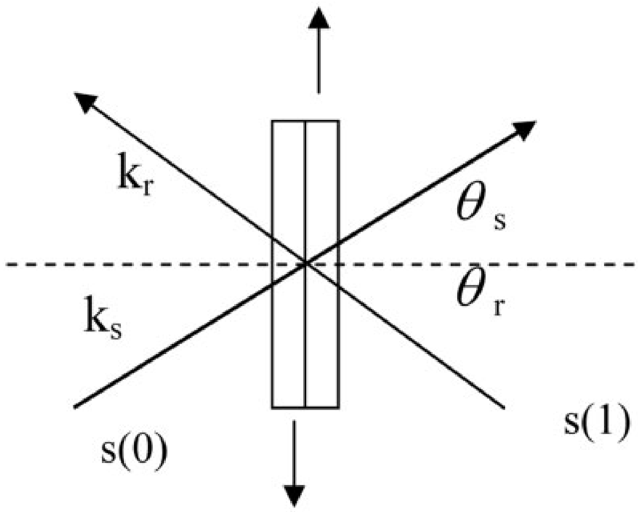


Figure 4 Configurations for two-piece of crystal

which has the solution

$$r(z) = N(z,T)\Bigg\{ r(0)\cosh(a) + \Bigg\{ 2\exp[-2i\varphi_g]\frac{[I_R(d)I_s(d)]^{\frac{1}{2}}}{\sum_0}\exp[-i\varphi(0,T)]s(0) - r(0)\frac{\Delta_0}{2\sum_0}\Bigg\} \times \sinh(a)\Bigg\}$$

$$N(z,T) = \cosh[\Gamma(d-z)\sin\varphi_g]^{\frac{i\cot\varphi_g - 1}{2}} \quad (8)$$

and have the same simplified diffraction intensities:

$$D_r = \frac{r^2(0)}{2}\left(1+\frac{\cos l}{\cosh k}\right) - r(0)s(0)\tanh k + \frac{s^2(0)}{2}\left(1-\frac{\cos l}{\cosh k}\right) \quad (9)$$

Although the writing beams and readout beams are opposite directions, If allows beams that satisfy the Bragg conditions, the diffraction character of grating in both sides fit similar equations.

2.3. Numerical Analysis

We obtain the curves from Eqs. (5) and (8), taking $\Gamma z = 10$. In Curve 1, $s(0) = 1$, where the diffraction intensities changed depending on $r(0)$; in Curve 2, $r(0) = 1$, where the diffraction intensities changed depending on $s(0)$.

Figure 3 shows that the intensities of Curve 1 have the minimal value zero, because of the different direction of optic axis. We have founded the diffraction character of grating in both sides to fit similar equations. It can be said that the minimal value point symmetrically between the two distributed sides. So the two curves can prolong to the negative axis. In the forward direction (Fig. 1), as the intensities of $r(0)$ increase [s(0) fixed], the transmitted intensities fall down first and then increase, but the other transmitted intensities increase straight. So, here we can control the intensities of one beam by the other beam by choosing the direction of optic axis.

If the two beams according with equation (7), symmetrically incident on the grating on the reverse side, Figure 2 line 2 to 4, because c axis turn around, the grating have the character of that diffraction beams break over in one direction, cut-off in the other direction. The shortcomings are here must have another fixed beams and the ratio of beams intensities must precision.

2.4. Design Structure of Unidirectional Diffraction

Taking $m_0 = 1$, $\varphi_g = \pi/2$, $r(0) = 0$, $s(0) = 0$, we consider the intensities of diffraction and transmission beams. In this situation, the ratio of intensities of two beams is $\frac{\eta}{1-\eta}$; we founded that this is just equal to the Eq. (7). It means where are other same writing grating crystal, if the angle of diffraction beams and optic axis is a blunt angle, the two beams symmetrically incident on the same grating, the transmitted intensities of diffraction beams is zero. Although we can increase the intensities of s(0), but the ratio of two beams intensities is fixed, it determine by the character of material, the transmission of diffraction beams is zero always.

Taking two pieces of crystal, neglect the layer between crystal and boundary. The optic axis direction is opposite, the ratio of writing intensities is 1, $\varphi_g = \pi/2$, the readout beams just like s (0) show in Figure 4. The ratio of transmission and diffraction beams intensities in readout keeping a fixed value, keeping the transmission of diffraction beams is zero if the grating of crystal 2 writes in the equal intensities. Now thinking about the reading beams come from the other side just like s (1) show in Figure 4, for the diffraction efficiency independency of the direction of optic axis, the ratio of two beams intensities is also $\frac{\eta}{1-\eta}$, but here the angle

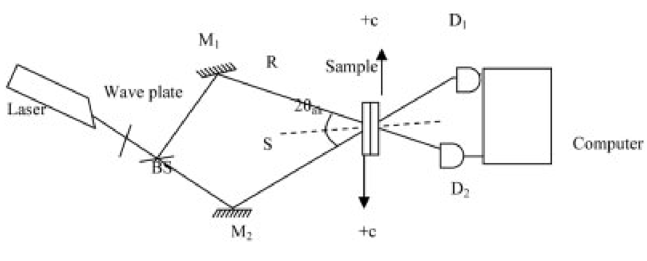
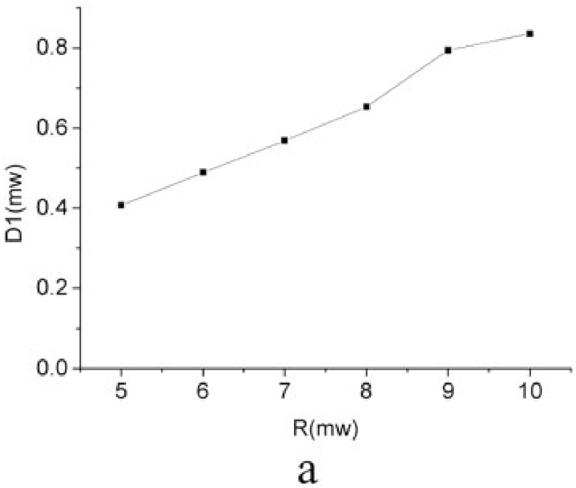


Figure 5 Experimental setup; M1, M2: mirrors; BS1: beam splitters; D1, D2: detectors; R: reference light; S: signal light



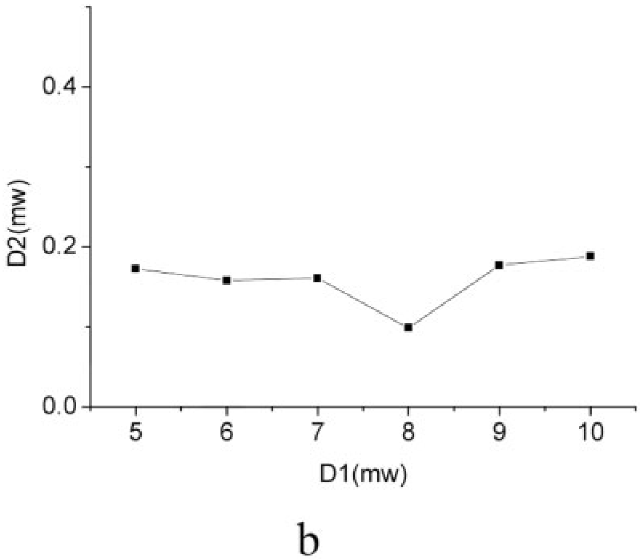


Figure 6 Experiment results

of diffraction beams and c axis compare with the forward direction is reverse, so the intensities of diffraction beams increase in crystal 1, we can calculate the value, taking $r = \frac{e^k - 1}{e^k + 1}s$ into equation (8), obtain $D_s = s^2(0)\tanh^2 k$, it is diffraction intensities of opposite direction.

Diffraction beams of the structure have the unidirectional diffraction character. Neglect the grating is optically damaged during readout, k is stabilization, and so the diffraction and input intensities are linearity proportion.

3. EXPERIMENTAL RESULTS

Figure 5 shows the experimental sketch of measuring the structure that is described above.

Thickness of every piece of crystals is 2 mm; the optic axis direction of two crystals are opposite; the crystals are same Fe: $LiNbO_3$; the polarization of beams is normal to the plane of incidence; after writing grating, shut down the reference beams; we can adjust the wave plate to change the intensities of readout beams; record the intensities D1 and D2, and draw the curve using the recorded D1 and D2 values as shown in Figure 6(b). Next, shut down the signal beams, and by recording the intensities of reference and diffraction beams, draw the curve as shown in Figure 6(a).

The figures show the asymmetry of diffraction of layered lithium niobate, the shape of curve obtained is similar to that obtained theoretically. For the coupling of beams in Crystal 1, the ratio of writing intensities is not 1 in Crystal 2, the intensities of transmission of diffraction beams are not zero. If writing in grating on both sides use ratio of intensities of 1, it will improve the results. There are further experiments to prove the diffraction intensities that readout beams come from the opposite directions.

4. CONCLUSION

From the study of the diffraction beams of grating we have founded the following: (1) The diffraction efficiency is independent of optic axis; (2) Because of the different directions of optic axis, it is determined that the diffraction intensities are different when the two beams are incident on the grating; (3) When the beams come from opposite directions, it fit to the similar equations that described forward. So, it can achieve beams of unidirectional diffraction. We reported it is possible that all-optical diode in two pieces of photorefractive crystals. Unidirectional diffraction was demonstrated theoretically, and experiment proved asymmetry diffraction in one side.

ACKNOWLEDGMENT

This work was supported by the National Natural Science Foundation of China (10572155) and the Key Industrial Project of Guangdong Province (2005A10602002).

REFERENCES

1. M.D. Tocci, M.J. Bloemer, M. Scalora, J.P. Dowling, and C.M. Bowden, Thin-film nonlinear optical diode, Appl Phys Lett 66 (1995), 2324–2326.
2. H. Kogelnik, Coupled wave theory for thick holograms gratings, Bell Syst Tech J 48 (1969), 2909–2947.
3. D.W. Vahey, J Appl Phys 46 (1975), 3510–3515.
4. V.V. Krishnamachari, O. Grothe, H. Deitmar, and C. Denz, Novelty filtering with a photorefractive lithium–niobate crystal, Appl Phys Lett 87 (2005), 071105.

MEANDERING PROBE FED PATCH ANTENNA WITH HIGH GAIN CHARACTERISTIC FOR CIRCULARLY POLARIZED APPLICATION

Hau-Wah Lai and Kwai-Man Luk
Department of Electronic Engineering, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong

Received 21 September 2006

ABSTRACT: *A meandering probe-fed circularly polarized stacked patch antenna with truncated corners is studied. The antenna has a wide 3-dB axial ratio bandwidth of 12%. It exhibits a stable radiation pattern across the axial ratio bandwidth. The antenna has low cross polarization and high gain, which are −14 dB and 10 dBi, respectively.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1095–1098, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22357

Key words: *circularly polarization; wide axial ratio bandwidth; probe feed; high gain*