Polarization Sensitivity of Quantum Well Infrared Photodetector Coupled to a Metallic Diffraction Grid

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***Abstract*—We study experimentally and numerically the polarization sensitivity of quantum well infrared photodetectors coupled to a diffraction grid. The polarization extinction ratio of such system is determined by two factors: polarization sensitivity of the diffraction grid and the intrinsic polarization sensitivity of the photodetector itself. The combined effect of these factors result in nonmonotonic dependence of the polarization extinction ratio on the parameters of the diffraction grid. By varying the grid parameters, i.e., increasing the height and tuning the grid period, a maximum value for the polarization extinction ratio can be achieved. Both front side and back side illuminations of the photodetector are studied. The strongest polarization sensitivity is achieved under front side illumination.**

***Index Terms*—Infrared detectors, metal grid, polarization sensitive, quantum well (QW).**

I. Introduction

DETECTION of both intensity and polarization information of light can significantly improve the spatial resolution of infrared imaging systems [1]. There are two main directions in the development of polarization sensitive systems. The first one is based on integration of the imaging focal plane array and the polarization element in a nonmonolithic setup. The second one is based on a monolithic design, in which the polarization element is integrated directly into the focal plane array [2], [3]. The second approach, which provides a robust and compact design, is the most promising one. The natural active element of such polarization sensitive systems is a quantum well infrared photodetector (QWIP) [4]. The polarization sensitivity of QWIP is introduced through periodic 1-D corrugation, i.e., diffraction grating, on the top of the QWIP structure [2], [3]. The polarization sensitivity of such corrugated QWIPs has been demonstrated experimentally [2], [3]. Although this system shows polarization sensitivity, the extinction ratio, i.e., the ratio of the QWIP photoresponses for two orthogonal polarizations of the light, is less than 5. To increase this ratio, the polarization sensitivity of the diffraction grating should be improved. Here, we explore the possibility of enhancement of the polarization extinction ratio by introducing a metallic diffraction grating deposited on top of a QWIP. A wire-grid metallic grating becomes an efficient polarizer [5]–[7] if the period of the diffraction grid is less than the wavelength of the incident light, which is the regime studied below. In this case the s-polarized light, defined as the light with electric field parallel to the wires of the grid, is predominantly reflected, while the p-polarized light, defined as the light with electric field perpendicular to the wires, is predominantly transmitted through the diffraction grid.

The coupling of QWIP with metallic diffraction grid has already been discussed in the literature in relation to enhancement of the QWIP sensitivity to the normal incident light [8], where only one polarization of the light has been considered. It is widely known that n-type QWIPs, the most common among QWIPs, are mainly sensitive to the light polarized perpendicular to the quantum well layer [4], [9]. Hence, to obtain sensitivity to normal incident light, optical couplers, such as metallic diffraction grating [2], [8], [10] or corrugated-grating [3], are needed. Depending on the direction of illumination (from front-side or back-side of the QWIP), the metallic diffraction grating can result in two types of coupling between the normal incident light and the intersubband excitations in the quantum wells. Under front-side illumination the light transmitted through the diffraction grating is absorbed by active elements of the QWIP, while under back-side illumination the light reflected from the diffraction grid is absorbed by the quantum wells [11]. Usually the back-side illumination is realized in QWIP focal plane arrays. We would like to emphasize that the polarization properties of the diffraction grid are mostly visible in the light transmitted through the grid. That is, the intensity of the p-polarized light (defined as before) to which QWIPs are sensitive is the strongest in the transmitted light. Below we study both front-side and back-side illuminations and analyze to what extent the polarization properties of the QWIP coupled to the diffraction grating can be controlled by varying the grid parameters.

Although the QWIP's sensitivity to the parallel component of the electric field (with respect to the plane of the quantum well) is small, the existence of such sensitivity is crucial for our analysis of the polarization properties of QWIP + diffraction grid system. To characterize the sensitivity of QWIPs to the

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parallel and perpendicular components of the electric field, we introduce the corresponding absorption coefficients: $\alpha_{||}$ and $\alpha_{\perp}$, respectively. Below we consider the ratio $\alpha_{\perp}/\alpha_{||}$ as a parameter, which is used to fit the experimental results. The ratio $\alpha_{\perp}/\alpha_{||} \sim 10 \cdots 100$ is large and depends on the materials and the QWIP structure [9]. It is determined by the band mixture and possible intrinsic inhomogeneity of the QWIP. Below for a given experimental sample we extract the parameter $\alpha_{\perp}/\alpha_{||}$ from the experiments with the front-side illumination. Then with the known parameter $\alpha_{\perp}/\alpha_{||}$ we perform numerical simulations to study the properties of QWIP with both front and back-sides illuminations.

We characterize the polarization sensitivity of the system by an extinction ratio, determined through the photoresponse. Namely, the extinction ratio at a given wavelength, λ, is given by the following expression:

$$R = \frac{J_p}{J_s} \tag{1}$$

where J_p and J_s are photoresponses of the grating coupled QWIP at wavelength, λ, for the p-polarized and s-polarized waves, respectively. The diffraction grating, placed on top of the photodetector, has rectangular groove and is schematically shown in Fig. 1(a). The diffraction grating is characterized by its period, d, height, h, and the fill factor, a/d, where a is the width of metal strips. The s and p polarization components of the incident light are also shown in Fig. 1(a). Here only the front-side illumination is shown.

A. QWIP Without Diffraction Grating

For normal incident light, irrespective of the polarization direction, the electric field is always along the quantum well plane, i.e., there is no electric field component perpendicular to the quantum wells. Hence, the photoresponse is always determined by the absorption coefficient $\alpha||$ and it does not depend on the polarization of the incident light. Therefore, the extinction ratio for this case is 1: $R_{\text{QWIP}} = 1$.

B. QWIP With Diffraction Grating

A diffraction grating deposited on the top of a QWIP introduces polarization sensitivity. There are two sources of such sensitivity: (i) the intensity of the light transmitted through the diffraction grating or reflected from the grating depends on the (s or p) polarization of the incident light; (ii) light transmitted through the diffraction grating or reflected from the diffraction grating propagates in different directions and as a result has both parallel and perpendicular polarizations with respect to the plane of the quantum well.

The paper is organized as follows. In Section II we describe a QWIP sample, which was studied experimentally, along with the results. In Section III we describe the numerical approach used to model the system of QWIP coupled to diffraction grating. In Section IV we provide the results of the numerical simulations, emphasizing the extinction ratio of the QWIP+grid system for both front-side and back-side illuminations.

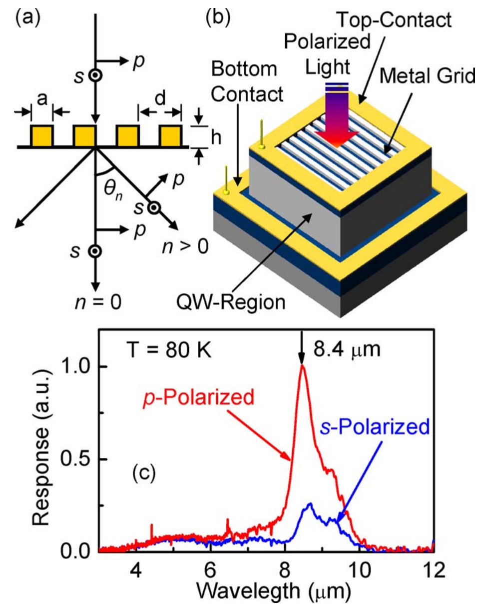

Fig. 1. (a) Schematic diagram of the diffraction grating. Here d is the period of the grid and a is the length of the metallic strip. Only the normal incident light is considered. The propagation of the transmitted waves are characterized by the angle θ_n, where n is the diffraction order. The p- and s-polarization of the incident and transmitted waves are shown. A metal grid having a fill-factor of 0.5 and a period of 2.8 μm was used for experimental verification. (b) Schematic diagram of the QWIP structure with a metal grid. (c) Measured spectral response of the detector at 80 K for s- and p-polarized light under front-side illumination.

II. Experimental Setup and Measurements

A QWIP structure grown by molecular beam epitaxy is schematically shown in Fig. 1(b). From top to bottom, this structure consists of a p-type QW-region (40 periods of 3.1-nm-thick p-GaAs wells in 25-nm-thick $Al_{0.55}Ga_{0.45}As$ barriers), i-GaAs region, and an n-type QW-region (50 periods of 5.4-nm-thick n-GaAs wells in 40-nm-thick $Al_{0.24}Ga_{0.76}As$ barriers). These layers were sandwiched between a highly doped n-type top contact and an n-type bottom contact layers. The p-type QW was designed to detect IR at 5 μm, while the n-type QW was designed for 9 μm. More details on this detector structure can be found in [12]. Square mesa elements were processed by dry etching techniques and the Ohmic contacts were formed by depositing Ti/Pt/Au alloy on the top contact layer and Ni/Ge/Au alloy on the bottom contact layer. A window was opened on the top contact layer [see Fig. 1(b)] for front-illumination. Inside this window, a 1-D grid, having a 50% metal 50% open pattern with a grating period of 2.8 μm, was fabricated by depositing gold on a 15-nm-thick titanium layer. The height of the gold layer is $\sim$ 100 nm, hence, the total grid height (the combined height of titanium and gold) is $\sim$ 115 nm. The optical area of the mesa is 600×600 μm^2. The experimental spectral response of this detector under 15 V bias (applied across top and bottom contacts) is shown in Fig. 1(c). Two peaks were observed at 5 and 8.4 μm due to electronic transitions in p- and n-type QW regions, respectively. It is also clear that the peak at 8.4 μm is sensitive to p-polarized light. From these data we can find that the extinction ratio of the photodetector at $\lambda = 8.4$ μm is about 4.3. It should be noted that different alloys are used for the fabrication of metal grating on *n*- and *p*-type layers, however, based on our theoretical analysis the effects from the alloy on the extinction ratio is not significant.

III. Numerical Model of QWIP Coupled to Diffraction Grid

To find numerically the wave distribution within the multilayer QWIP structure coupled with diffraction grid, we have used the modal expansion approach [13], [14]. Within this approach the light wave within each layer is expanded in terms of the corresponding modes of the layers. The number of modes used in the calculations is determined by the condition of convergence of the results. For the parameters of the diffraction grid considered in the present paper, 15 lowest frequency modes within each layer were enough to guarantee the convergence of the extinction ratio of the grid coupled QWIP. The parameters of the metallic diffraction grid, which correspond to the experimental setup (see Fig. 1), are: the period of the grid $d = 2.8\ \mu$m, the fill factor $a/d = 0.5$, and the height of the grid $h = 115$ nm. The dielectric constant of metal (gold) is taken from [15]. The QWIP is described as a multilayer system [12]. The dielectric constants of p-doped AlGaAs layers were taken from [16].

The light transmitted through the diffraction grating propagates in discrete diffraction directions, which, for a layer i, are characterized by angles $\theta_{i,n}$ [see Fig. 1(a)]:

$$\sin(\theta_{i,n}) = \frac{\frac{n\lambda}{d}}{\varepsilon_i^{1/2}} \tag{2}$$

where $n = 0, \pm 1, \pm 2, \ldots$ is the diffraction order, λ is the wavelength, and ε_i is the dielectric constant of the layer i. The conditions $|\sin(\theta_{i,n})| \leq 1$ and $|\sin(\theta_{i,n})| > 1$ determine the propagating and evanescent waves, respectively.

As explained before, the QWIP has two quantum well regions [12], which result in light absorption at two wavelengths: 5 μm and 8.4 μm. The photoresponse is determined by the light intensity within the corresponding quantum well region.

For s-polarized light the polarization of the transmitted light is parallel to the quantum wells in all diffraction orders [see Fig. 1(a)]. Therefore, the photoresponse for s-polarized light is determined by absorption coefficient $\alpha_{\|}$ and is proportional to the net intensity of the transmitted wave:

$$J_s \propto \sum_i \alpha_{i,||} I_{i,s} \tag{3}$$

where i labels the layers of the QWIP and $I_{i,s}$ is the net light intensity of the s polarized light in the ith layer. Here we take into account that the light is absorbed mainly within the quantum wells, the width of which is small (140 nm for p-type wells and 270 nm for n-type wells in our experimental structure). Therefore, within each absorption layer i, i.e., within each quantum well, the intensity of light can be considered as a constant, I_i. The absorption coefficient in the above expression is nonzero only within the quantum wells.

For p-polarized light only the transmitted wave of zeroth order has polarization parallel to the quantum well layers [see Fig. 1(a)], while the higher diffraction order waves have both parallel and perpendicular components. In this case the photoresponse of the QWIP is determined by both coefficients $\alpha_{\|}$ and $\alpha_{\perp}$:

$$\begin{aligned} J_p &\propto \sum_{i,n} (I_{i,p,n}\alpha_{i,||}\cos^2\theta_{i,n} + I_{i,p,n}\alpha_{i,\perp}\sin^2\theta_{i,n}) \\ &= \sum_i \alpha_{i,||} I_{i,p} + \sum_i (\alpha_{i,\perp} - \alpha_{i,||}) \sum_n I_{i,p,n}\sin^2\theta_{i,n} \end{aligned} \tag{4}$$

where $I_{i,p,n}$ is the intensity of the nth diffracted order p polarized wave in the layer i and $I_{i,p}$ is the net light intensity of the p polarized light in the ith layer.

From expressions (1)–(4) we can find that the extinction ratio of QWIP with metallic grid takes the form

$$R_{\text{QWIP+Grid}} = \frac{\sum_i \alpha_{i,||} I_{i,p} + \sum_i (\alpha_{i,\perp} - \alpha_{i,||}) \sum_n I_{i,p,n}\sin^2\theta_{i,n}}{\sum_i \alpha_{i,||} I_{i,s}}. \tag{5}$$

We calculate numerically the wave distribution within the multi-layer QWIP structure with metallic grid and then from expression (5) we obtain the corresponding extinction ratio. Since the absorption of light occurs only in quantum well layers, which are identical, then the ratio of absorption coefficients $\alpha_{i,\perp}$ and $\alpha_{i,||}$ is the same for all layers. We consider this ratio as a parameter, which is tuned to reproduce the experimental extinction ratio of the QWIP shown in Fig. 1.

To study the effects of the parameters of the diffraction grid on the extinction ratio of the QWIP we first find the ratio $\alpha_{i,\perp}/\alpha_{i,||}$ by reproducing numerically the experimental results shown in Fig. 1. In Fig. 2(a) the experimental and numerical results for the extinction are shown. The numerical results were obtained for $\alpha_{i,\perp}/\alpha_{i,||} = 22$. This value is used below to study the properties of the QWIP with diffraction grid. Namely, we study the possibility of tuning the extinction ratio by varying the grid period, d, and the grid height, h. We keep the same fill factor, $a/d = 0.5$, in all calculations below.

In the above expressions we did not take into account the finite size of the sample in the transverse directions. Therefore, we assume that the sample is infinitely large. The finite size of the sample results in additional diffraction effects on the incident light, which can change the photoresponse and the extinction ratio. Since our system is relatively large, i.e., the transverse size of the sample, D, is around 600 μm, the corrections to the extinction ratio of QWIP due to edge effects is small in the parameter ($\mathrm{d/D} \sim 0.00467$). However, the edge effects can be important when the focal plane arrays with small pixel sizes are considered.

IV. Numerical Simulations: Results

A. Front-Side Illumination

In the case of the front-side illumination the incident light transmitted through the diffraction grid is absorbed by the QWIP. Therefore, the polarization properties of the QWIP are determined by the polarization properties of the diffraction grid with respect to the transmitted light. It is well known that if the period of the diffraction grid is less than the wavelength of the incident light then the p-polarized light is predominantly

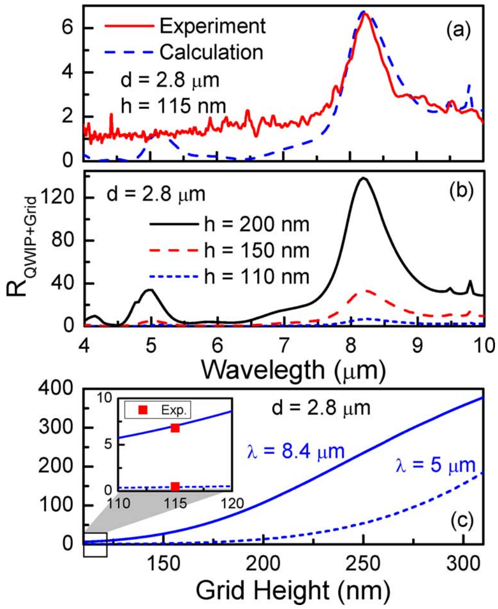

Fig. 2. (a) The extinction ratio of the QWIP coupled with a diffraction grating under front-side illumination. The experimental results, corresponding to the data of Fig. 1(c), are shown by solid line. The numerical results are shown by dotted line. (b) The extinction ratio of the QWIP with diffraction grating is shown as a function of the wavelength of the incident light at different grid heights under front-side illumination. The period of the grid is $d = 2.8$ μm. (c) The extinction ratio of the QWIP is shown as a function of the height of the grid at two different wavelengths. An expanded view (for $h = 110 - 120$ nm) indicating the experimental point (for $h = 110$ nm) is shown in the inset.

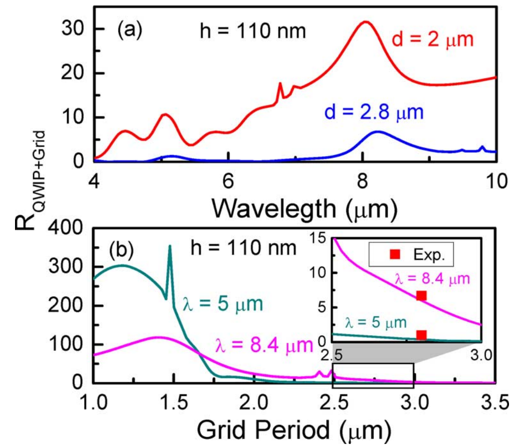

Fig. 3. (a) The extinction ratio of the QWIP coupled with a diffraction grating is shown as a function of the wavelength of the incident light for two different grid periods. The grid height $h = 110$ nm. (b) The extinction ratio is shown as a function of the grid period at two values of the wavelength, $\lambda = 8.4$ μm and $\lambda = 5$ μm. The grid height $h = 110$ nm. An expanded view (for $d = 2.5 - 3.0$ μm) indicating the experimental point (for $d = 2.8$ μm) is shown in the inset. In panels (a) and (b) the QWIP is illuminated from the front side.

transmitted through the diffraction grid. The transmission of the s-polarized light depends on the height of the diffraction grid and become exponentially suppressed with increasing the grid height. Therefore, we should expect that with increasing the grid height, the extinction ratio of the QWIP coupled with the grid increases.

In Fig. 2(b) and (c), the effect of the grid height on the extinction ratio is shown. In Fig. 2(b), the extinction ratio is shown as a function of the incident light wavelength at different grid heights. The grid period, d, is 2.8 μm. We can see that for all wavelengths, with increasing the grid height the extinction ratio increases and it reaches the value of 100 at $h = 200$ nm. The dependence of the extinction ratio on h is monotonic, which is illustrated in Fig. 2(c) at two different wavelengths, $\lambda = 8.4$ μm and $\lambda = 5$ μm. From these data we can conclude that the extinction ratio with diffraction grid can be strongly increased by increasing the grid height.

The dependence of the extinction ratio on the grid period is shown in Fig. 3. In Fig. 3(a), the extinction ratio is shown as the function of the wavelength at two values of the grid period: $d = 2$ μm and $d = 2.8$ μm, and in Fig. 3(b) the extinction ratio is shown as a function of the period of the grid at two values of the wavelength: $\lambda = 8.4$ μm and $\lambda = 5$ μm. These data clearly illustrate that the extinction ratio as a function of the period, d, is non-monotonic and has a broad maximum at some values of the period. The position of the maximum depends on the wavelength. We can also see that the extinction ratio can be strongly enhanced by varying the grid period. For example, by reducing the grid period from 2.8 to 1.5 μm, the extinction ratio at $\lambda = 8.4$ μm increases almost by 20 times. Therefore, by varying the period of the diffraction grid one can achieve large values for the extinction ratio. The sharp maxima clearly visible at $\lambda = 5$ μm ($d \approx 1.5$ μm) and at $\lambda = 8.4$ μm ($d \approx 2.5$ μm) correspond to Rayleigh singularity.

Summarizing, in the case of the front-side illumination the extinction of the QWIP coupled to the diffraction grid can be strongly increased either by increasing the grid height or by tuning the grid period.

B. Back-Side Illumination

For back-side illumination, the coupling of the incident light to the QWIP is realized through the reflection of the light from the diffraction grid. The final photoresponse of the grid coupled QWIP is also determined by the multiple reflections at well barrier interfaces [10]. As a result, the dependence of the photoresponse of the QWIP on the parameters of the diffraction grid becomes nonmonotonic and the maximum photoresponse is achieved at some optimal grid parameters [10], resulting in high quantum efficiency. The high quantum efficiency is achieved only for the p-polarized light.

Although the quantum efficiency of QWIPs with back-side illumination can be high, the polarization extinction ratio of such system is expected to be relatively low. This is because the polarization properties of the diffraction grid with respect to p-polarization are mostly pronounced in the transmitted light. Namely, the metallic diffraction grid reflects predominantly s-polarized light, while the p-polarized light is predominantly transmitted through the grid. Therefore, the p-polarized light, which determines the main response of the QWIP, predominantly escapes from the QWIP system with reflective grating compared to the s-polarized light. In this case, the metallic grid alone does not improve the polarization sensitivity of the QWIP and the polarization properties of the system crucially depend on the polarization properties and the geometry of the QWIP itself.

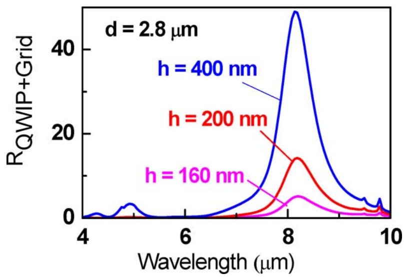

Fig. 4. The extinction ratio of the QWIP coupled with a diffraction grating as a function of the incident light wavelength for different grid heights with $d = 2.8$ μm for back-side illumination.

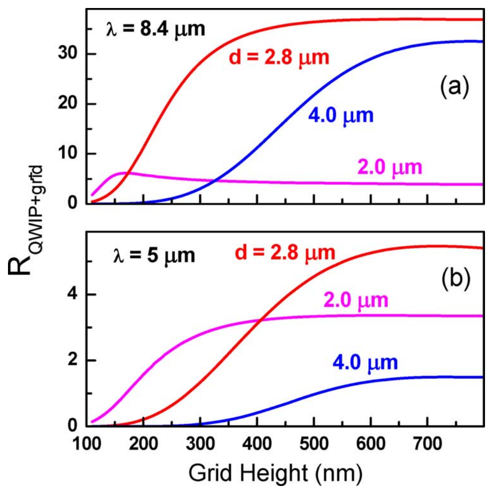

Fig. 5. The extinction ratio of the QWIP coupled with a diffraction grating as a function of the grid height for different grid periods for back-side illumination. The wavelength of the incident light is (a) $\lambda = 8.4$ μm and (b) $\lambda = 5$ μm.

In Figs. 4–6, the extinction ratio of the QWIP with diffraction grid is shown for different grid parameters. The Fig. 4 illustrates the general behavior of the extinction ratio as a function of the incident light wavelength for different grid heights. We can clearly see that the extinction ratio can be enhanced by increasing the grid height, but this enhancement is smaller than the enhancement in the case of front-side illumination. This is what we should expect for the reflective grating, since now there is no polarization advantage of the diffraction grid.

In Fig. 5, the extinction ratio is shown as a function of the grid height at two different wavelengths, $\lambda = 8.4$ μm [Fig. 5(a)] and $\lambda = 5$ μm [Fig. 5(b)]. In all cases the extinction ratio is saturated at large values of the grid height. The saturated values are relatively small and for the present sample are less than 40. This behavior is different from the case of front-side illumination, where the extinction ratio increases with height without saturation and can achieve any large value.

The extinction ratio as a function of the period of the grid is shown in Fig. 6. The dependence of the extinction ratio on the period is nonmonotonic and has a broad maximum. The position of the maximum depends on the height of the grid. This dependence is more pronounced for the wavelength $\lambda = 8.4$ μm [see Fig. 6(a)]. At $h = 110$ nm the maximum is around $d = 1.5$ μm, while at larger values of h the maximum is shifted to

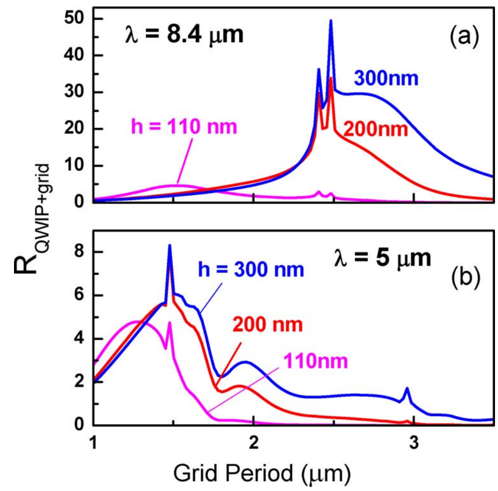

Fig. 6. The extinction ratio of the QWIP coupled with a diffraction grating as a function of the grid period for different grid heights for back-side illumination. The wavelength of the incident light is (a) $\lambda = 8.4$ μm and (b) $\lambda = 5$ μm.

$d \approx 2.8$ μm. Compared to the front-side illumination, the enhancement of the extinction ratio at the maximum is relatively small even at large values of the grid height (for example, at $h = 300$ nm).

Since the polarization properties of the QWIP coupled to the reflective diffraction grid is determined mainly by the properties of the QWIP, the extinction ratio strongly depends on the structure of the QWIP. This is because the final response of the QWIP depends both on the reflection from the grid and on the distribution of the light within the well regions, which is determined by the light reflections at the interfaces in the structure. Hence, by tuning the parameters of the QWIP structure, e.g., by varying the layer thickness, one can effectively change the extinction ratio. To illustrate the sensitivity of the polarization properties of a QWIP coupled to a reflective diffraction grid, we perform the calculations for a modified QWIP structure. Namely, we assumed that the QWIP consists of the following layers: a 15-nm-thick GaAs layer, a 150-nm-thick AlGaAs layer, 50 periods of 5.4-nm-thick GaAs/40-nm-thick AlGaAs *n*-type quantum wells, and a 200-nm-thick GaAs layer. This structure is similar to the QWIP design discussed above without *p*-type wells responsible for the response at 5 μm. Therefore, the modified structure is sensitive to 8.4 μm light only. The extinction ratio of the modified QWIP at 8.4 μm is shown in Fig. 7 as a function of the grid period and grid height. A strong enhancement of the extinction ratio compared to the original design is clearly visible. Now the maximum extinction ratio is more than 150. This value is achieved at a grid height of 100 nm and a grid period of 1.2 μm. These data illustrate that the extinction ratio of a QWIP coupled to a reflective diffraction grid can be strongly enhanced by tuning the grid parameters as well as the parameters of the QWIP structure.

In summary, under the back-side illumination, the extinction ratio of the grid coupled QWIP increases with increasing the grid height reaching the saturated values at $h \sim 300$–400 nm. The extinction ratio can be also increased by tuning the diffraction grid period and the structure of the QWIP.

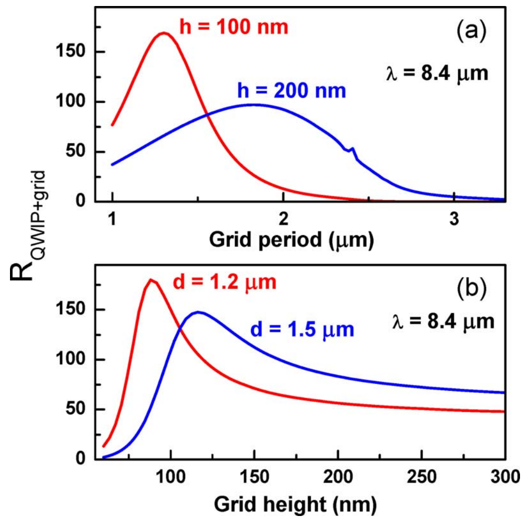

Fig. 7. The extinction ratio of a modified QWIP design coupled with diffraction grating as a function of (a) the grid period and (b) the grid height for back side illumination.

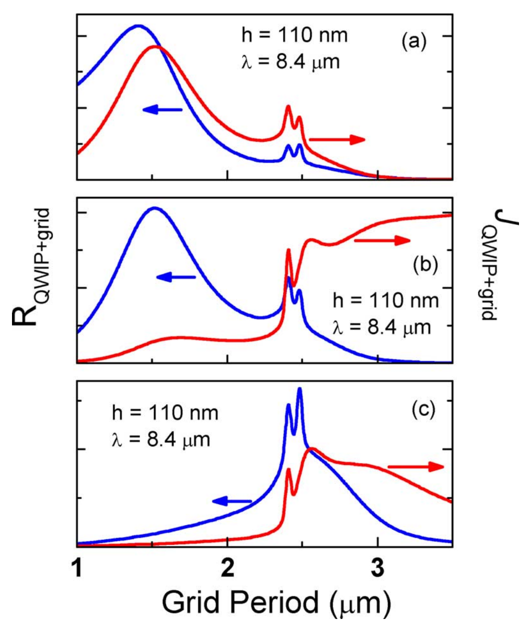

Fig. 8. The extinction ratio ($\mathrm{R_{QWIP+grid}}$) and the p-polarization photoresponse ($\mathrm{J_{QWIP+grids}}$) of the QWIP coupled with a diffraction grid as a function of the grid period for the front-side (a) and the back-side (b),(c) illuminations at a wavelength of 8.4 μm. The values of the grid height are 110 nm (a),(b) and 200 nm (c). The extinction ratio and the photoresponse are shown in arbitrary units.

V. Polarization Extinction Ratio and Responsivity

In the above analysis we discussed only the extinction ratio of a QWIP coupled to a diffraction grid. By tuning the grid parameter, it is possible to achieve the maximum extinction ratio at a given wavelength. In practical applications, not only the extinction ratio should have the large value but also the photoresponse itself should be maximal. In Fig. 8, we compare the variation of the extinction ratio and the photoresponse for p-polarized light as a function of the grid period at 8.4 μm for the grid coupled QWIP structure, which was experimentally tested and discussed before in Section II. In general, there is no direct correlation between the extinction ratio and the photoresponse. Both the extinction ratio and the photoresponse intensity have local maxima as the functions of the grid period, but the maxima do not coincide [see Fig. 8(b)]. At the same time it is possible to tune the grid parameters, e.g., by changing the grid height, so that the maxima are realized at almost the same value of the grid period. This is clearly seen in Fig. 8(c), where at a grid height of 200 nm, both the extinction ratio and the photoresponse have maximum values at grid period $\sim$ 2.5 μm. Therefore, we can conclude that the parameters of the diffraction grid can be tuned so that the QWIP system has large values of both the extinction ratio and the photoresponse intensity.

VI. Conclusion

The polarization sensitivity, i.e., extinction ratio, of a QWIP coupled to a metallic grid is determined by the properties of the diffraction grid as the polarizer and an intrinsic polarization sensitivity of QWIP itself. The intensity of the light transmitted through or reflected from the diffraction grid depends on the polarization of the light, i.e., s and p polarizations relative to the grid pattern, while the absorption in the QWIP depends on the polarization of the light relative to the plane of the quantum wells. The polarization of the s-polarized light is always parallel to the quantum well, while the s-polarized light has both perpendicular and parallel components depending on the direction of propagation of the wave within the well region. The combination of all these factors results in a strong dependence of the extinction ratio on the parameters of the diffraction grid. By varying the grid period and the height, one can maximize the polarization sensitivity.

The actual values of the extinction ratio of the QWIP strongly depend on the direction of illumination. In the case of the front-side illumination the extinction ratio of the QWIP coupled to the diffraction grid monotonically increases with increasing the grid height and can be large, $R_{\mathrm{QWIP+Grid}} \sim 200$, already at small values of the grid height, $h \sim 250$ nm. For back-side illumination, the extinction ratio is saturated with increasing the grid height and is much smaller than the extinction ratio in the case of the front-side illumination. Namely, for a sample studied in the present paper the extinction ratio of the QWIP with the back-side illumination does not exceed 50 for all values of the grid parameters and the wavelengths of the incident light. However, it was found that the extinction ratio shows a strong dependency for the layer structure of the QWIP with back-side illumination. Finally, by optimizing the parameters of the QWIP structure, one can achieve a maximum extinction ratio, while obtaining a maximum photoresponse at the same time, under either front-side or back-side illumination configurations.

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