Four-Wave Mixing (FWM) Effects within a Micro-Optical Device

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***Abstract*—A PANDA ring conjugate mirror is designed for Phase Conjugate Mirror (PCM) devices with 3D usage. The design of the device parameters and optimum conditions has been improved by the four-wave mixing principle. In the design, a common laser is applied as the input light beam, in which the object beam is the reflected light beam from the throughput port, where the reference beam is the reflected light beam from the drop port of the PANDA ring. The interference of the light between these two beams can form a one pixel image, which is coupled by the two nonlinear side rings. This work has shown improvements in the effect of changing parameters such as the center and side ring radii and the coupling factors between the center and side rings. The purpose of this study was to identify optimal parameter values for the four-wave mixing phenomena leading to high image quality (optimum conditions). From the preliminary results, we have found that the optimum conditions are where the center ring radius is 2 µm and the radii of the side rings are 1.05 µm. The right coupling factor is 0.3 whereas the left coupling factor is 0.7. A PANDA ring conjugate mirror enables the design and fabrication of large area pixels for realistic applications.**

***Index Terms*—3D images, 3D display, four-wave mixing, phase conjugate mirror, micro-optical device**

I. Introduction

There are many methods for 3D imaging displays. One of them is the holography method which uses laser beams and these are built by optical devices. The holographic images are constructed from the result of interference between the light diffracted by the object and the reference which is the coherent background. This method was invented by Dennis Gabor in 1947 [1] and has been continuously developed since then [2]. Many researchers have designed and developed 3D image holography [3]-[6].

Practically, the important devices that are used to construct the 3D images are optical phase conjugation components, which function using the four-wave mixing technique. The device that is used to produce the phase conjugation effect is known as a Phase Conjugate Mirror (PCM), which is the key device for working in holographic applications [7]-[9].

The advantage of micro-optical device is that the nonlinear optical PANDA type can be fabricated a tiny device, which can be used incorporating in various applications such as communication [10], security [11] and medical applications [12], [13].

In the past, holographic 3D images were formed with conjugate mirrors using a PANDA ring circuit [14]. However, there has been no research on the many four-wave mixing behaviors when creating holographic 3D image characters. In the circuit, the object beam and reference beam are formed by reflected signals from the throughput port and drop port of the add-drop filter within the micro device, where the conjugate mirror concept is obtained by the four-wave mixing behavior coupled by the two nonlinear side rings, which can be confirmed that the new type of conjugate mirror can be formed and realized. This paper proposed identifying optimal parameter values for four-wave mixing phenomena leading to high image quality (optimum conditions). These studies can be used to censor the inappropriate images or applied for security encryption systems. Additionally, such a device can also be useful for various applications.

II. Four-Wave Mixing by PANDA Ring Conjugate Mirror

The optical phase conjugation uses a four-wave mixing technique which is an intermodulation phenomenon in nonlinear optics, where light was input and launched into the system, the sandwiched two pumping light beams (waves) in the frequency domain are configured to form the required result, which is shown in Fig. 1.

PANDA ring conjugate mirror was designed in Fig. 2. This made phase conjugate mirror which was proved by the four-wave mixing phenomenon. In principle, the Gaussian pulse signal is sent to the input put of PANDA ring conjugate mirror. Then the signal is divided into two parts. The one part of signal is reflected with throughput

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port and the other part of signal sent into center ring via right ring. Then the signal is divided into two parts. The one part of signal is reflected with drop port and the other part of signal sent into center ring via left ring. The interference of signal within circuit appears to be the Whisper Gallery Mode (WGM) in center ring and the detected signal at output port is four-wave mixing.

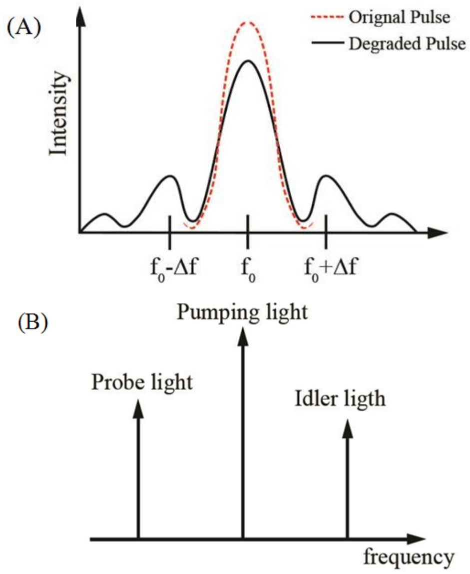


Figure 1. Graphs of (A) the optical signals above the zero-dispersion point, where two side lobes are symmetrically generated, and (B) the four-wave mixing in frequency domain with a channel pumping signal.

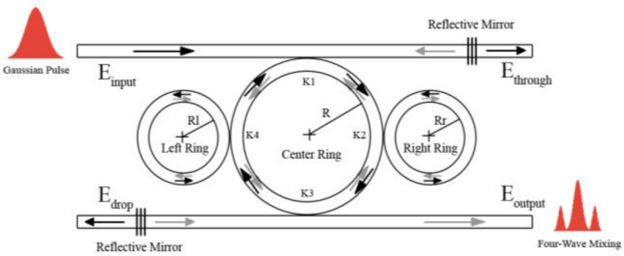


Figure 2. Schematics structure of PANDA ring conjugate mirror.

III. EXPERIMENT AND RESULT

Simulated experiment used programming of MATLAB for PANDA ring conjugate mirror. Used material of waveguide is InGaAsP/InP with reflective index (n) = 3.34 and area (Aeff) = 0.3 µm^2 of core, reflective index (n) = 1 of border on each side by air and loss coefficient (α) = 0.1dB/mm. Adjusted parameters include center ring radius, side ring radii and coupling factor values. The customizing center ring radius was changed between 2.0 µm and 2.4 µm, an increase of 0.1 µm, and then side ring radii is changed between 1.02 µm and 1.06 µm, an increase by 0.01 µm.

Finally, fixation of coupling factor value κ_1 and κ_3 is 0.5. Changed κ_2 values range from 0.1 to 0.9 and κ_4 values range from 0.9 to 0.1 with difference 0.1.

The result of experiment in Fig. 3 shows the result of adjusted center ring radius between 2.0 µm and 2.4 µm. The wavelength was not different and the completed waveform is 2.0 µm. The amplitude left side and right side was not equal but the balance of upper side band and lower band frequencies were obtained. Then Fig. 4 shows the result of adjusted side ring radii between 1.02 µm and 1.06 µm. The wavelength was different. The completed waveform is 1.05 µm. The amplitude and the frequencies was waveform same previous. Then the optimal parameter adjustment of center ring and side ring radii is 2.0 µm and 1.05 µm respectively. Finally, Fig. 5 shows the result of adjusted both coupling factor between center and side ring. The coupling factor between center and right ring was 0.3 µm and the coupling factor between center and left ring was 0.7 µm. The wavelength was not different. The amplitude left side and right side was equal and the balance of upper side band and lower band frequencies was obtained. The result of the optimum condition shows in Fig. 6.

The perfect four-wave mixing is the symmetry of upper side and lower side band frequencies and the symmetry of the side amplitude. The generated 3D imaging display is the perfect 3D image appearance.

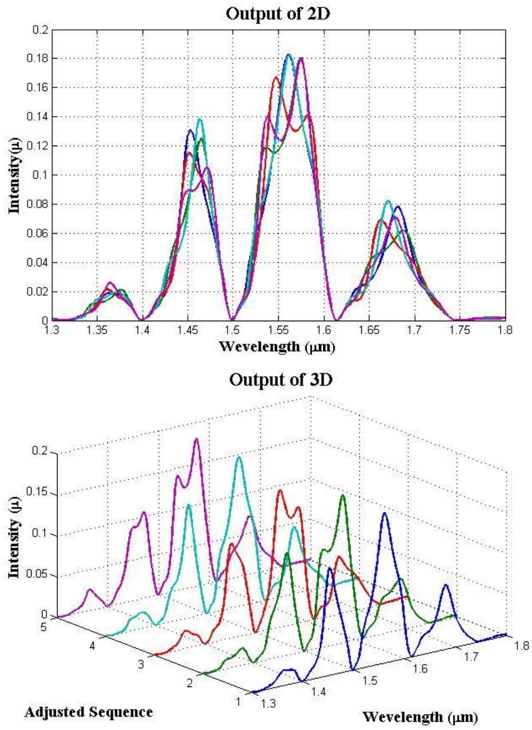
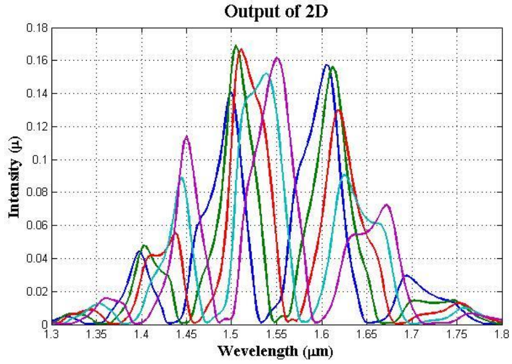


Figure 3. Shows the result of adjusted center ring radius between 2.0 µm and 2.4 µm.



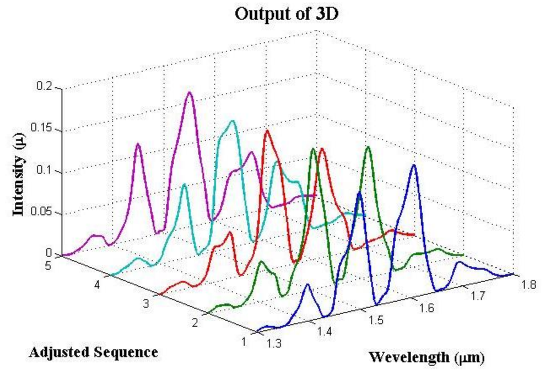


Figure 4. Shows the result of adjusted side ring radii between 1.02 μm and 1.06 μm.

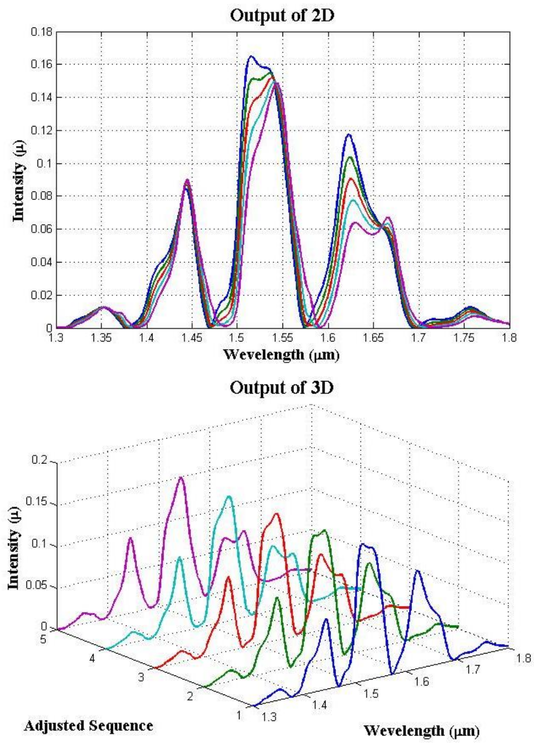


Figure 5. Shows the result of adjusted both coupling factor between center and side ring.

IV. CONCLUSION

The PANDA ring conjugate mirror was developed from a PANDA ring circuit and made 3D imaging display. These were proved by the four-wave mixing phenomenon which is the key of a device concept. The experiment of the 3D imaging display to adjust parameter of PANDA ring conjugate mirror found that the optimum conditions are that the center ring radius is 2 μm and side rings are 1.05 μm. The right coupling factor is 0.3 whereas the left coupling factor is 0.7. The optimum of the four-wave mixing can be generated 3D images clearly and can be useful for 3D image display and high density image resolution. The next work, generated 3D images will research the high-resolution, the mosaic and the transmission to different positions.

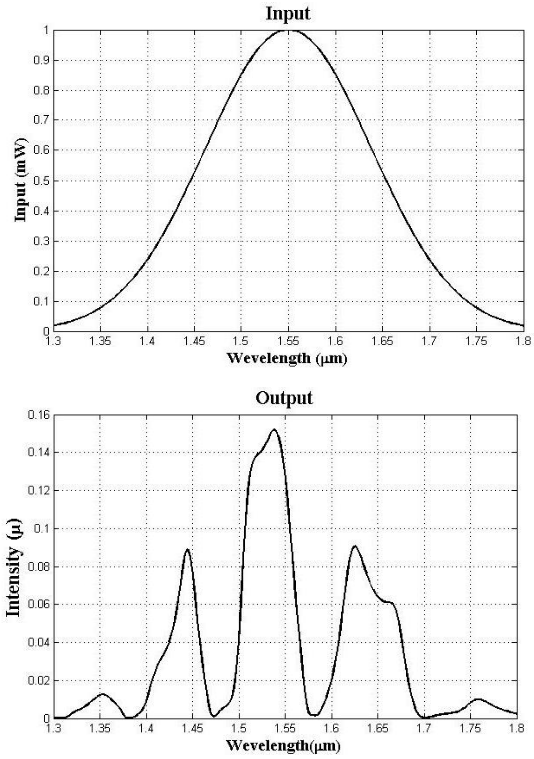


Figure 6. Shows the result of the optimum condition.

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