Ultra short Pulse Measurement Using High Sensitivity Waveguide Autocorrelator

Mohammad Mehdi Karkhanehchi
Department of Electronics, Faculty of Engineering
Razi University
Taghbostan, Kermanshah
IRAN

*Abstract***:** An AlGaAs optical waveguide has been used as a combined nonlinear mixer and detector, which employ two photon absorption, rather than second harmonic generation in an autocorrelator for measuring the pulse width of 1.3µm wavelength optical pulses. The autocorrelation trace gives the FWHM of a 1.3µm Q-switched semiconductor laser to be approximately 13 ps.

Keywords: Two photon absorption, autocorrelator, semiconductor laser, Q-switching, optical waveguide

1 Introduction

In order to measure the duration of ultra short laser pulses, various autocorrelation techniques have been developed [1, 2]. Measurements have been made by means of second harmonic generation (SHG) [3, 4] and, also, two-photon-induced photoconductivity (TPC) in commercial photodiodes [5, 6]. Using TPC is relativity wavelength insensitive, so that photons of energy between Eg/2 and Eg can be used to obtain an autocorrelation trace, where as a SHG crystal has to be phase match at the appropriate wavelength. Also, due to the increases nonlinear interaction length, using a waveguide geometry for the photodiode increases the sensitivity of the measurement and allows greater opportunity for integration [7]. However, it has the disadvantage that some temporal resolution is lost due to dispersion.

2 Waveguide design and fabrication

A ridge p-i-n waveguide structure which consisted of a $Al_{0.2}Ga_{o.8}As$ waveguide core surrounded by $Al_{0.3}Ga_{0.7}As$ cladding regions, was grown by molecular beam epitaxy (MBE). The upper and lower cladding layer thicknesses were 1µm and 4 µm respectively, both sufficiently thick to ensure only a small optical leakage into the cap and substrate. In order to reduce losses due to free carrier absorption, those parts of the cladding which were expected to have significant overlap with the optical mode were left undoped. This device was designed to measure pulse widths with a wavelength greater than 840 nm. Ridge waveguide 3µm wide, 1 mm long, and separated by about 100µm were fabricated by dry etching; wet etching was then used to mesa between the ribs to isolate individual devices [7]. The reverse breakdown voltage was at least -25 V, and the dark current of the devices at 5V was measured to be -50 pA. It is very important that this dark current is as small as possible in order to increase the autocorrelator's sensitivity.

3 Experiments

The experimental set up for the autocorrelation measurements is shown in Fig. 1.

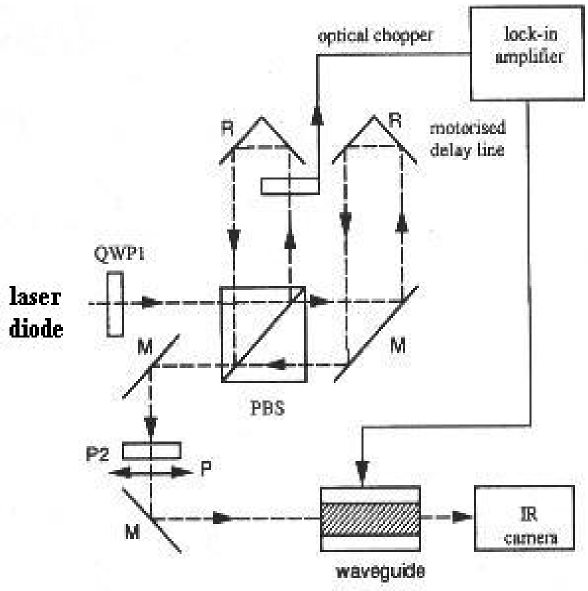

Fig. 1: Experimental set-up
Keys: M: mirror, R: retroreflector, PBS: polarizing beam splitter, QWP: quarter wave plate, P: polarizer

Optical pulse were generated by a Q-switched diode operating at 1.3µm. the full width half maximum (FWHM) duration of the optical pulses was measured using a conventional SHG autocorrelation to be 12.6 ps (assuming a Gaussian intensity profile). It is noted that for Gaussion pulses, the width of the autocorrelation trace was divided by $\sqrt{2}$ to obtain the true pulse width. The average power incident on the waveguide was 0.6 µW. The quarter wave plate in Fig. 1 made the pulses circularly polarized, thus enabling the polarizing beam-splitter to divide the pulse equally into two orthogonal polarizations. The two orthogonally polarized pulses were recombined after one was delayed with respect to the other by the motorized variable delay line. The beam was the end-fire coupled into a reverse biased p-i-n waveguide, where the corresponding photocurrent was measured by lock-in amplifier and hence the pulse width measured. An infra-red camera was placed at the end of the waveguide to aid alignment and to ensure that the light guided through the waveguide was in zeroth order mode. A piezo-electric translator (PZT) was placed in stationary arm of the autocorrelator to eliminate the coherence spikes.

From the intensity autocorrelation trace shown in Fig. 2, the FWHM of the Q-switched semiconductor laser pulses was calculated to be 13 ps (assuming a Gaussion intensity profile). This result is in close agreement with SHG autocorrelation measurement of the optical pulse of this laser (12.2 ps), the discrepancy being 6% which is within the experimental accuracy (± 10%). Because of high efficiency of the waveguide autocorrelator than the TPC in the waveguide [5, 6], a waveguide autocorrelator is therefore much more suitable for applications where optical power levels are lower, such as for semiconductor lasers.

Also the ratio of the correlation peak to the background was not 2:1 as would be expected theoretically [4], but was only 1.5:1. This is attributed to the effect of single photon absorption on the contrast ratio of the two photon waveguide autocorretor [8]. The peak power level in the waveguide was approximately 50 mW, corresponding to an insertion loss of approximately 20dB. The dispersion in the waveguide was negligible because the dispersion length is much more than the length of the laser pulses.

4 Conclusions

We have used TPA in an AlGaAs waveguide for a high sensitivity autocorrelator suitable for measuring the pulse width of low power 1.3µm wavelength optical pulses. The autocorrelation pulse widths are consistent with that expected from a conventional SHG autocorrelation.

The use of TPA in a semiconductor waveguide was found to be a practical and sensitive alternative to the use of SHG for autocorrelation measurements. Furthermore, the device is sensitive and, being waveguide-based, has the potential both for integration and for simple coupling into a fiber-based interferometer.

5 Acknowledgements

We would like to thank the research department in Razi University for financial support of this work.

References:

[1] H. P. Weber, "Method for pulse width measurement of ultra short light pulses generated by phase-locked lasers using non-linear optics", J. Appl. Phys., Vol. 38, 1967, pp. 2231-2234.

[2] J. A. Armstrong, "Measurement of pico-second laser pulse widths", Appl. Phys. Lett., Vol. 10, 1967, pp. 16-18.

[3]D. Gloge, and R. Roldan, "Investigation of low power laser signals with pico-second resolution", Appl. Phys. Lett., Vol. 14, 1969, pp. 3-4.

[4] E. Mathieu, and J. H. Keller, "Intensity correlation functions of a non-Q-switched laser, measured by second harmonic generation", J. Appl. Phys., Vol. 41, 1970, pp. 1560-1567.

[5] Y. Takagi, T. Kobayashi, K. Yoshihira, and S. Imamura, "Multiple and single shot autocorrelator based on two photon conductivity in semiconductor", Opt. Lett., Vol. 17, 1992, pp. 658-660.

[6]. F. R. Laughton, J. H. Marsh, and A. H. Kean, "Very sensitive two photon absorption GaAs/AlGaAs waveguide detector for an autocorrelator", Electron. Lett., Vol. 28, No. 17, 1992, pp. 1663-1665.

[7] F. R. Laughton, J. H. Marsh, D. A. Barrow, and E. L. Portnoi, "The two photon absorption semiconductor waveguide autocorrelator", IEEE. J. Quantum Electron., Vol. 30, No. 3, 1994, pp. 838-845.

[8] M. M. Karkhanehchi, D. A. Barrow, A. C. Bryce, C. J. Hamilton, and J. H. Marsh, "Influence of single photon absorption on single photon absorption on the performance of the two photon waveguide autocorrelator", IEEE. J.Quantum. Electron., Vol. 33, No. 6, 1997, pp. 933-937.

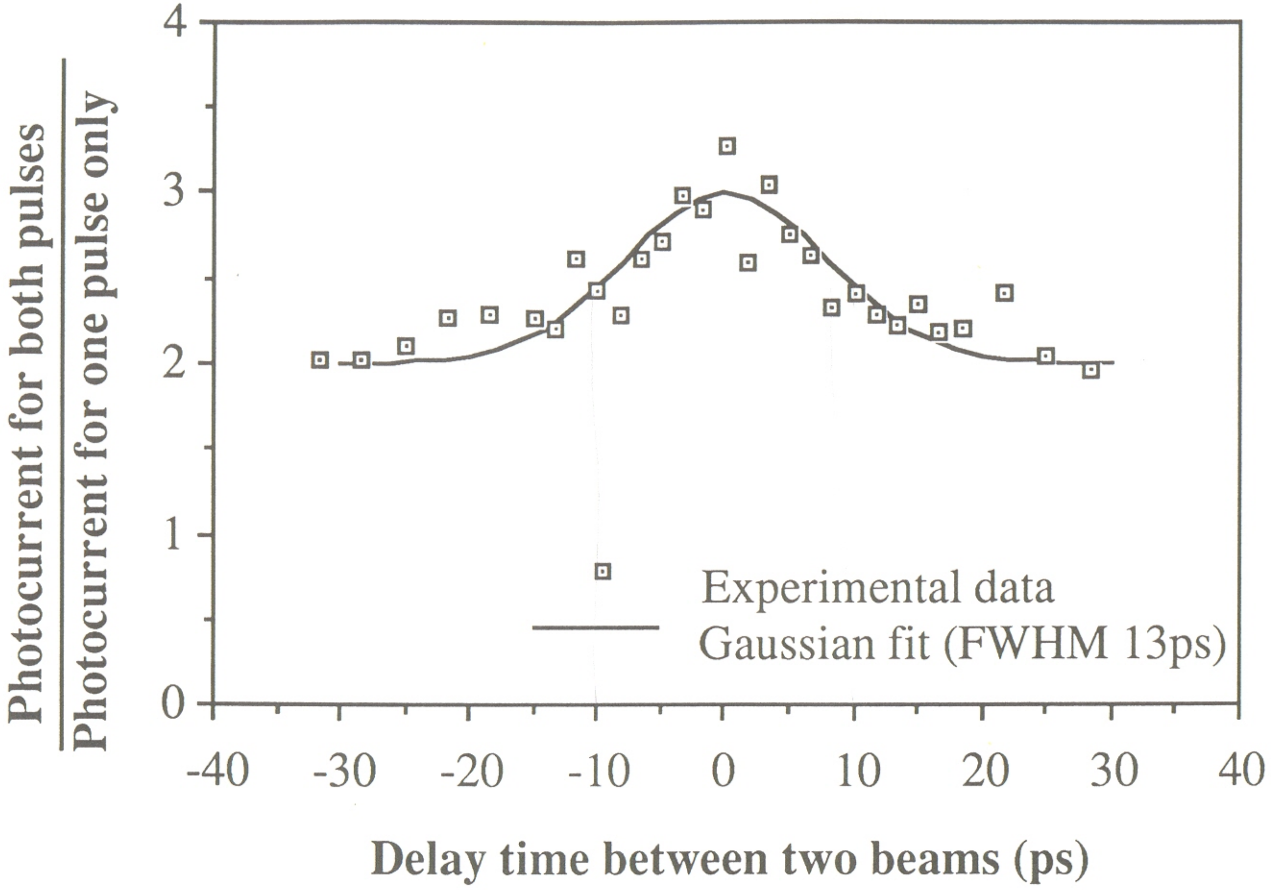

Fig.2 Autocorrelation trace of a 1.3 μm Q-switched semiconductor laser