Wavelength conversion of 1.53 micron picosecond pulses in an ion-implanted multiple quantum well all-optical switch

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Abstract:
Wavelength conversion around 1.53 µm in a switching device comprising an InGaAsP/InGaAsP multiple quantum well saturable absorber in a Fabry-Perot cavity is demonstrated. Contrast ratio and recovery time are determined to be 10dB and 4.1ps respectively.

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All-optical wavelength converters can increase the flexibility of wavelength division multiplexed (WDM) networks by allowing such techniques as wavelength routing [1]. This paper describes wavelength conversion using an ultrafast optical switch based on a multiple quantum well (MQW) saturable absorber (SA) integrated within a Fabry-Perot (FP) cavity [2]. The device is designed to be anti-resonant and impedance matched, such that, ideally, its reflectivity is zero under small signal conditions at the operating wavelength. A small change in the absorption of the SA breaks the impedance matching condition, resulting in substantially increased reflectivity.

The device is fabricated from a wafer consisting of a 50 period InGaAsP Q1.6/Q1.1 MQW grown above a 16 period distributed Bragg reflector (DBR) in a single metal-organic vapor phase epitaxy (MOVPE) step. The FP cavity is formed between the DBR and the front air-semiconductor interface. Excitonic absorption bleaching, which is the SA mechanism in the MQW, has a recovery time of a few nanoseconds. To achieve the picosecond recovery times required for state-of-the-art, 40Gbps per channel, optical communication systems the device was implanted with 4MeV nitrogen ions at a density of 10\(^{12}\) ions/cm\(^2\). Lattice damage caused by the transit of the ions through the MQW creates additional recombination centers, hence reducing the recovery time [3]. The implantation energy was such that the ions were deposited below the MQW, in the DBR region.

Wavelength conversion was demonstrated by using the reflectivity change due to excitation by 2ps pulses to modulate CW light. A free space optical arrangement was used to focus 2ps pulses and CW light onto the same 90µm\(^2\) spot on the device, such that the reflected CW light could be independently coupled into optical fiber. This reflected signal was optically amplified and filtered. Wavelength converted pulses were observed using a photodetector and sampling oscilloscope (Figure 1). The observed signal had a maximum contrast ratio of 8.8dB when the wavelength of the CW signal was coincident with the FP anti-resonance (1534nm). The contrast ratio was >6dB over a 3nm range of CW wavelengths.

![Figure 1: Wavelength converted signal observed using a 20GHz bandwidth sampling oscilloscope. A 1534nm, 3mW, CW input is modulated by 1530.8nm, 30pJ pulses.](image-url)

The pulse of Figure 1 is broadened due to the 20GHz bandwidth of the oscilloscope used. The contrast ratio was therefore determined by directly measuring the reflectivity of the device with 2ps pulses (Figure 2) and found to be 10dB. A pump-probe experiment, using 2ps pulses for both the pump and probe signals, was used to determine the
recovery time of the device. From the exponential curve fitted to the measured characteristic of Figure 3, 50% recovery occurs within 4.1ps.

![Figure 2: Saturation characteristic measured with 2ps pulses at 1534nm.](image)

![Figure 3: Pump-probe measurements of reflectivity change made at 1534nm using 2ps, 24pJ, pump pulses, and a pump:probe pulse energy ratio of 50:1. The line is an exponential curve fitted to the decay of the measured data.](image)

This is, to our knowledge, the first report of both all-optical wavelength conversion in an FP SA incorporating an ion-bombarded MQW SA, and fast recovery through ion-bombardment in an InGaAsP/InGaAsP MQW. The measured contrast ratio and recovery time of our device, 10dB and 4.1ps respectively demonstrate its potential for 40Gbps WDM system applications. The device has potential for further applications including soliton control [4] and time division demultiplexing.