

# Wavelength monitor based on two single quantum well absorbers in a standing wave

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The recent growth in wavelength division multiplexing has increased the need for integrated wavelength monitors and wavelength-sensitive detectors. Various devices have been proposed (see, e.g., references in [1]), including Fabry-Perot resonator devices.<sup>[2]</sup> A class of devices based on thin absorbers in standing waves was proposed<sup>[1]</sup> and one such device,<sup>[3]</sup> a detector capable of rejecting a specific wavelength, was demonstrated. Chen et al.<sup>[4]</sup> also used two adjacent MSM detectors with different finger spacings to create a novel wavelength monitor. Here we demonstrate a novel standing wave device that contains two, thin-absorber photodetectors at different points in the standing wave. Our device can function as either a multiple wavelength detector or a wavelength monitor. It is a surface-normal device that could be readily integrated with silicon electronics, for example by solder bonding.

The device structure is shown in Figure 1. The incident light beam is reflected by a distributed Bragg reflector (DBR) and a standing wave is created in the device. (Note that this device is deliberately not a Fabry-Perot resonator;<sup>[2]</sup> the top surface is antireflection coated.) The thin absorbers sample this wave. Figure 1 shows an extreme case where one absorber is placed at a null while the other is at a peak. The peaks and nulls of the standing wave shift position as the wavelength changes. If the absorber lies at a null there will be little or no absorption. Conversely, if the absorber is at a peak the absorption will be strong. Thus, as the wavelength of the light is

varied the absorption at any absorber varies periodically.

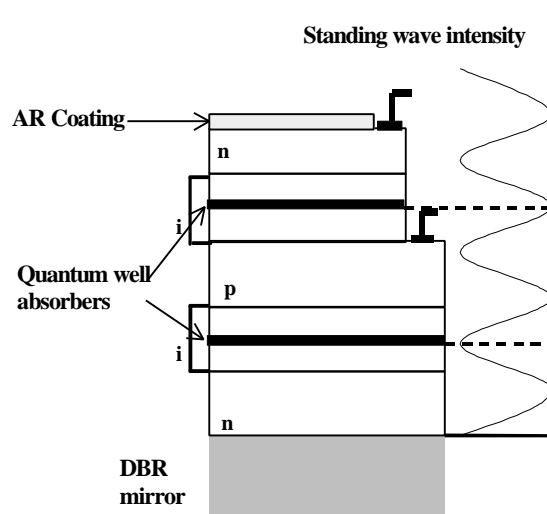


Figure1 –Device Design

It is convenient to use quantum wells as the thin absorbers since they are only  $\sim 1/25$  wavelength thick (though in this device we are not attempting to exploit any quantum effects in these layers).

With two absorbers there is now the flexibility to make a device that can detect two wavelengths simultaneously and separately. At a wavelength where the node lies at the bottom quantum well absorber, the bottom diode detects nothing, and similarly at another wavelength where the node lies at the top quantum well absorber, the top diode detects nothing. The two signals can also be combined in an  $“(A-B)/(A+B)”$  fashion (where A

and B are the signals from the two photodiodes) to make a wavelength monitor that is power-independent, and we demonstrate this operation here.

The device is an *n-i-p-i-n* structure grown by MBE. The DBR mirror stack is *n*-doped with a concentration of  $10^{18} \text{ cm}^{-3}$  and consists of 15.5 pairs of  $\text{Al}_{0.11}\text{Ga}_{0.89}\text{As}/\text{AlAs}$ . The absorbers are single  $95\text{\AA}$  GaAs/AlGaAs quantum wells. Each quantum well is placed in the intrinsic region of a *p-i-n* diode in order to collect the photocurrent that is generated from the absorption of light. The sample was grown on an *n+* substrate. There are metal contacts to the *p* and the top *n* region. The bottom *n* region is backside contacted. In addition to the quantum well each *i* region consists of transparent superlattice, which acts as a suitable substrate for growing a single quantum well and  $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$  region. The nominal thickness for both *i* regions is  $0.41\mu\text{m}$ . During growth of the bottom *n* and superlattice region the wafer was not rotated, thus across the wafer there is a variable thickness between the mirror and the first absorber. Both *n* regions are doped at  $10^{18} \text{ cm}^{-3}$  and the bottom thickness is  $1.5 \mu\text{m}$  and the top thickness is  $0.32 \mu\text{m}$ . The *p* region is doped at  $5 \times 10^{18} \text{ cm}^{-3}$  and has a thickness of  $0.35 \mu\text{m}$ . The absorber that is closer to the mirror has a null located at  $820 \text{ nm}$  and a peak at  $790 \text{ nm}$ . The one that is further from the mirror has a null located at  $821 \text{ nm}$  and a peak located at  $835 \text{ nm}$ . An optimized design would have the two nulls separated by the wavelength region of interest.

The diodes were reverse biased, we measured the photocurrent from the two diodes simultaneously, recording a differential photocurrent signal that is the difference signal (“A-B”) normalized by the sum (“A+B”). The results are shown in Figure 2. The device is a sensitive wavelength monitor over the region from  $818\text{--}825 \text{ nm}$ . In this region the differential photocurrent is relatively linear leading to a simple readout of wavelength. In this particular sample, the photocurrent from the lower photodiode was relatively weak; we tentatively attribute this weakness to a relatively high impurity concentration in the intrinsic region that may have inhibited the depletion of the quantum well absorber under reverse bias. Consequently

the signal from the bottom diode was normalized to obtain the curve shown. Work with re-designed devices is continuing.

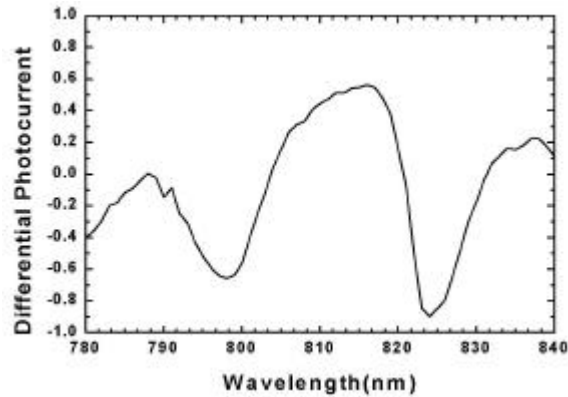


Figure 2-Differential Photocurrent Spectrum

In conclusion we have demonstrated a novel device that can be operated as either a two-wavelength photodetector or a wavelength monitor. The linear output of the wavelength monitor may be convenient for feedback applications to stabilize the wavelength of diode lasers.

This work was supported by grant number MDA972-98-1-0002 from DARPA and a subaward from the University of New Mexico. HLK was funded by an NSF graduate fellowship and a Lucent Technologies GRPW grant.

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[4] E. Chen, S. Y. Chou, "Wavelength Detector using a pair of Metal-Semiconductor-Metal photodetectors" Electron. Lett. **32** 1510-1511 (1996)