Temperature tuning of two-photon absorption microcavity photodetectors for wavelength selective pulse monitoring

J. O'Dowd, W.H. Guo, E. Flood, M. Lynch, A.L. Bradley, J.F. Donegan and L.P. Barry

Temperature tuning of a GaAs two-photon absorption microcavity photodetector with a tuning rate of 0.125 nm per degree is demonstrated. The detector response is shown to be independent of temperature change in the range 10–50°C.

Introduction: Two-photon absorption (TPA) has recently received attention with optical performance monitoring of group velocity dispersion, polarisation mode dispersion and optical signal-to-noise ratio having been demonstrated [1, 2]. TPA is a weak, nonlinear process and as such is inefficient. A number of different detectors have previously been used to overcome the low level of TPA in semiconductors such as silicon APDs and detectors with long absorption lengths [3, 4]. The detector used here is a TPA GaAs/AlAs microcavity which has been previously shown to increase TPA by >10 000 times [5]. These cavities consist of an absorber layer sandwiched between two highly reflective Bragg stacks. The detector intrinsically has a built-in filter with a spectral full-width at half-maximum (FWHM) of less than 1.5 nm. To use one detector to monitor several channels in a wavelength division multiplexed (WDM) system requires these detectors to be tunable. Previously, it has been reported that these cavities can be tuned by 55 nm using angle tuning, thereby allowing one device to cover the entire C-band [6]. Angle tuning, however, will cause the detector response to change, owing to changes in the TPA enhancement factor and the polarisation sensitivity of the photodetector response [6]. In this Letter, we investigate the use of temperature based tuning of the TPA microcavity as a robust, cost-effective means of tuning [7]. As temperature change has been shown to influence other TPA detectors [8] it is necessary to fully understand the temperature dependence of the response of a TPA microcavity. This investigation demonstrates how practical such tuning would be for optical performance monitoring in a telecommunications network.

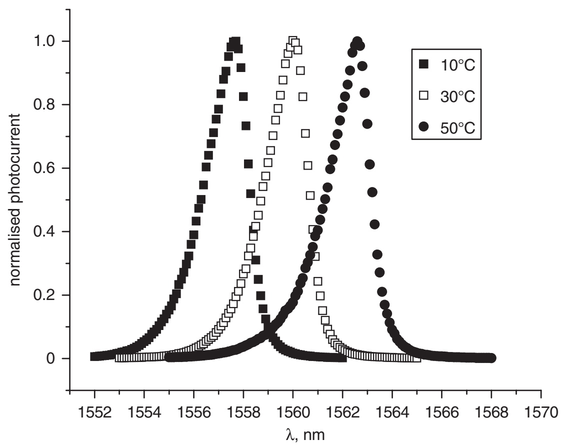

Fig. 1 *Wavelength response of microcavity against temperatures, for three temperatures*

Experiment: The TPA microcavity structure in this study consists of a 1 λ GaAs unintentionally doped absorber region sandwiched between two distributed Bragg reflectors (DBRs). The top DBR through which light is incident consists of 13 p-doped GaAs/AlAs layers while the bottom DBR consists of 23 n-doped AlAs/GaAs layers. The detector is mounted on a copper block which is temperature controlled by a thermoelectric cooler. The accuracy of the temperature stabilisation was within ±0.4°C. The incident signal on the detector is provided by a tunable continuous-wave laser. The laser output is passed through a variable optical attenuator to control the incident power. The signal is then passed through a polarisation controller before being normally incident on the detector. The polarisation of the input signal is set so as to maximise the level of TPA photocurrent. To characterise the shift in resonance position, the wavelength of the input signal is scanned across the resonance while the power onto the device is kept constant at 6 mW, and the photocurrent is recorded as shown in Fig. 1. As can be seen, both the spectral width and shape are independent of temperature in the range 10–50 °C. The change in peak current detected at resonance is ≤6% arising from misalignment owing to thermal expansion of the block on which the detector is mounted. To minimise this misalignment the detector is realigned for each temperature. A linear tuning rate of 0.125 nm per degree is observed as shown in Fig. 2. For a temperature change from 10 to 50°C a tuning range of 5 nm has been achieved. The photocurrent against power has been recorded on resonance at each different temperature, presented in Fig. 3. The power is varied using the variable optical attenuator, while the laser wavelength is kept constant. The photocurrent response of the detector on resonance at different temperatures is seen to remain unchanged (see Fig. 3). Both the TPA and the SPA regimes remain unchanged with no noticeable change in absolute current for a particular power level.

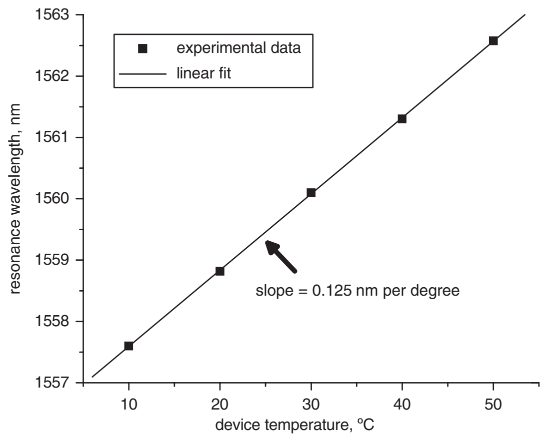

Fig. 2 *Microcavity resonance wavelength against temperature*

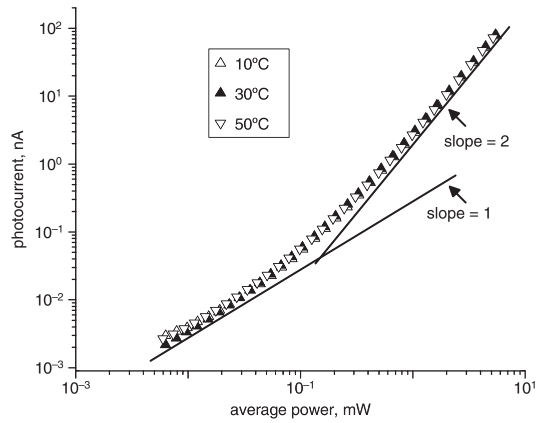

Fig. 3 *Photocurrent against incident power for different temperatures*

Input signal at resonance in each case. Both a slope of 2 and 1, corresponding to two photon and single photon absorption regimes, respectively, are indicated on graph

Conclusion: It has been shown that a TPA microcavity detector can easily be tuned across a 5 nm range by changing the temperature from 10 to 50°C. Furthermore, the detector is shown to be highly stable with varying temperature as only the resonant wavelength of the detector changes. This is unlike silicon APDs, where the response of the detector can be highly temperature sensitive [8]. Using temperature tuning it will be possible to monitor a WDM system across the entire C-band using three or four detectors at fixed angles and then temperature tuning each device to pick out individual channels. While our temperature control circuit allowed only a relatively narrow temperature tuning range over 40°C, lasers in modern networks commonly operate from −40 to 85°C. This increased tuning range would allow the single TPA microcavity device discussed above to be tuned by >15 nm.

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J. O'Dowd, W.H. Guo, E. Flood, M. Lynch, A.L. Bradley and J.F. Donegan (*Semiconductor Photonics Group, School of Physics, and Centre for Telecommunication Value-Chain Driven Research (CTVR), Trinity College, Dublin 2, Ireland*)

E-mail: jodowd@tcd.ie

L.P. Barry (*RINCE, School of Electronics Engineering, Dublin City University, Dublin 9, Ireland*)

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