Wavelength-modulated photo-response spectroscopy of GaSb/GaAs quantum ring solar cells

N.R.H. Mandanirina, J.R. Botha, M.C. Wagener

Department of Physics, Nelson Mandela Metropolitan University, Port Elizabeth 6031, South Africa

Nelson Mandela Metropolitan University

for tomorrow

Introduction

❖ GaSb/GaAs quantum ring solar cell has been shown to be an effective means of increasing the photocurrent of the single junction device [1].

❖ The increased photocurrent is typically accompanied by a detrimental decrease in the open-circuit voltage of the solar cell [2-3].

❖ By reducing the operating temperature of the cell or by using a concentrated solar illumination, the decreased of the open-circuit voltage could be restored [3].

❖ In addition to the conventional optical method (photoresponse measurement) [1], a differential measurement has been developed to investigate the optical absorption of the GaSb quantum rings within the solar cell.

Experimental details

❑ GaSb/GaAs solar cells were grown by molecular beam epitaxy.

❑ Modified a conventional photoresponse setup for differential measurements.

❑ Incorporated a flux correction module.

Results and discussion

❖ **Figure 1:** Modification made on the conventional photo-response setup. A wavelength-modulated signal was produced by placing an oscillating slit at the monochromator output. The intensity flux dependence of the light source was removed out by the Flux correction module system.

❖ **Figure 2:** Photocurrent intensity of the GaSb quantum rings of the solar cell. Each phase change (inset plot) on the photocurrent measurement represents a peak on the differential method.

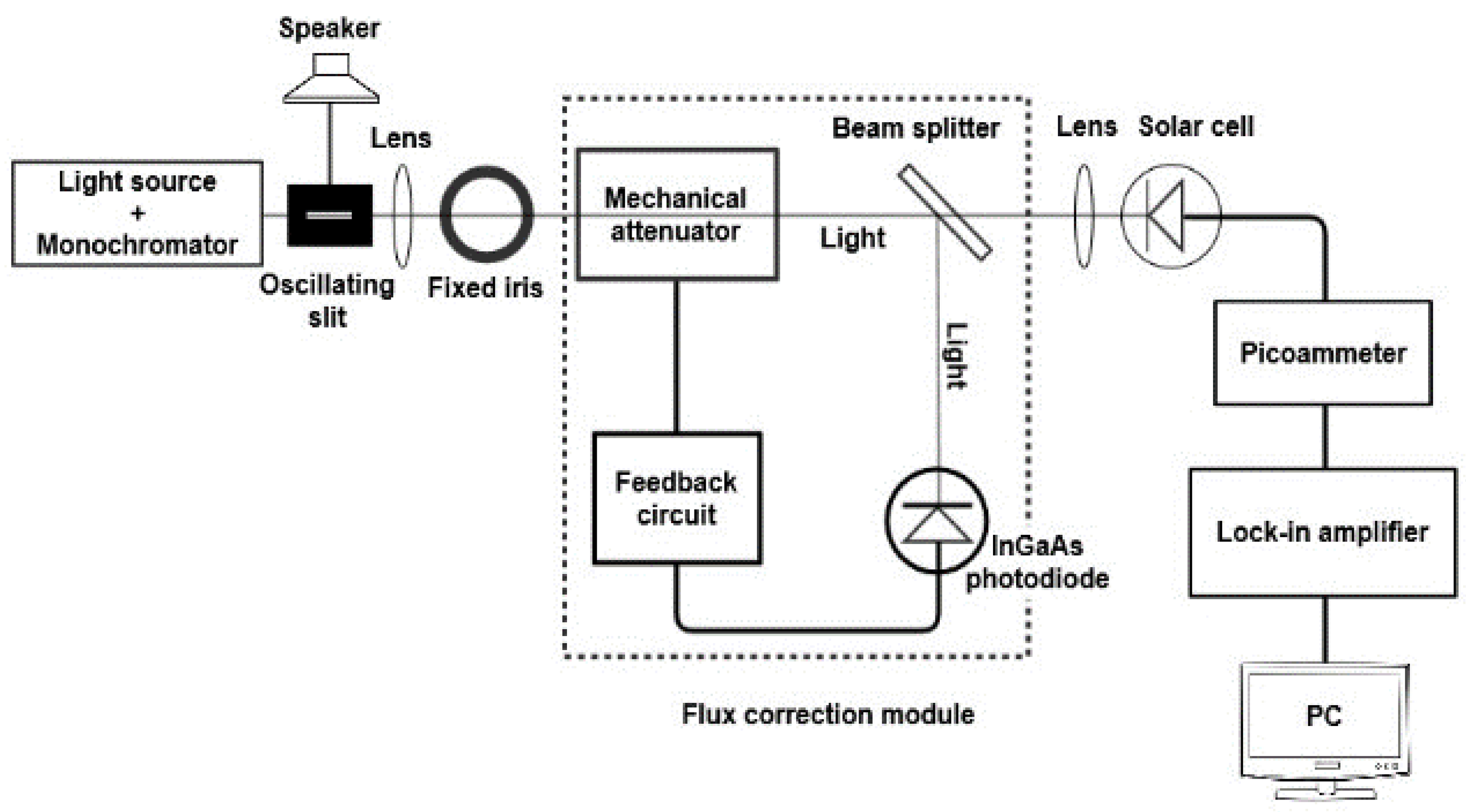

Figure 1: Schematic diagram of the differential measurement setup using feedback response module.

The external quantum efficiency (EQE) is given by:

$$EQE(\lambda) = \frac{1}{q}\frac{J_{ph}(\lambda)}{\phi\,(\lambda)} \qquad (1)$$

where $J_{ph}(\lambda)$ is the photocurrent density and $\phi(\lambda)$the spectral flux density.

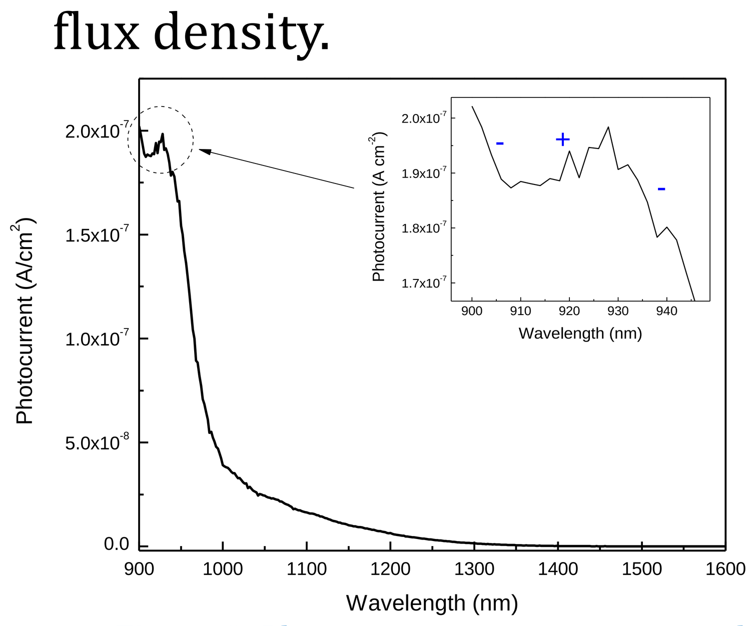

Figure 2: Photocurrent spectrum measured for the GaSb/GaAs quantum ring solar cell. The inset highlights the change in slope near the GaAs band edge.

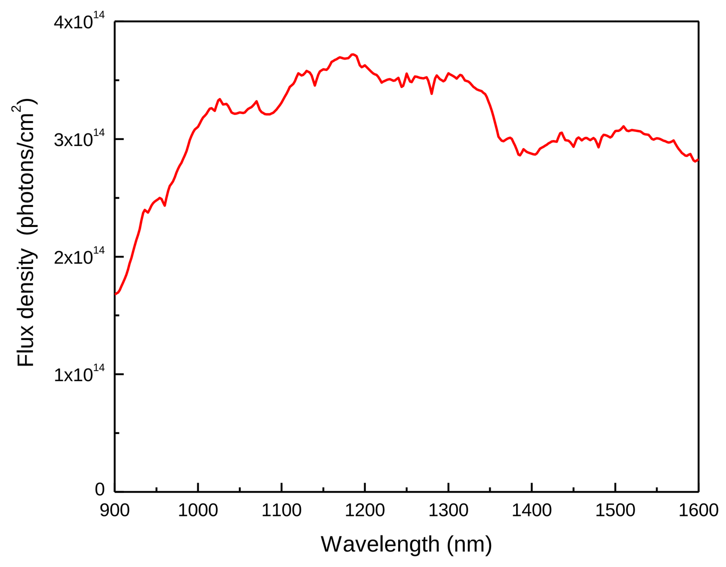

Figure 3: Spectral dependence of the photon flux used for the response measurements.

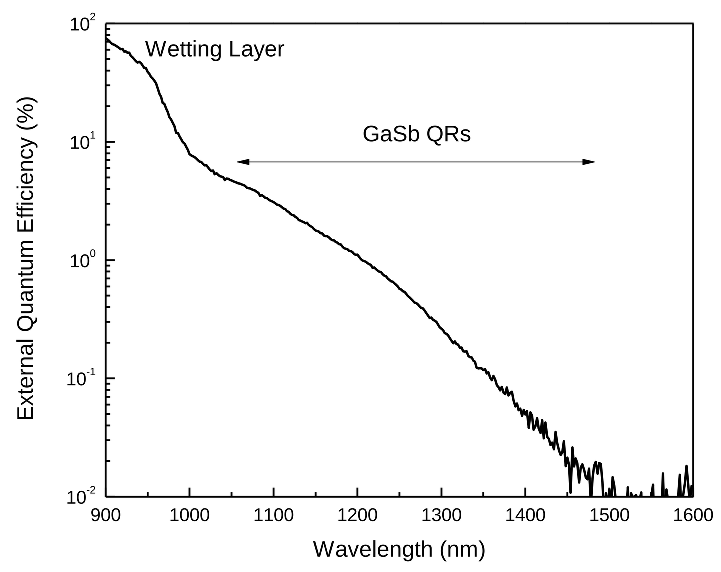

Figure 4: External quantum efficiency spectrum of the GaSb/GaAs quantum ring solar cell

The differential quantum efficiency (QE) of a solar cell device is given by:

$$\frac{dQE(\lambda)}{d\lambda} = \frac{1}{q}\frac{dJ_{ph}(\lambda)}{d\lambda}\frac{1}{\phi(\lambda)} - \frac{1}{q}\frac{d\phi(\lambda)}{d\lambda}\frac{J_{ph}(\lambda)}{\phi^2(\lambda)} \qquad (2)$$

where $J_{ph}(\lambda)$ is the photocurrent density and $\phi(\lambda)$the spectral flux density.

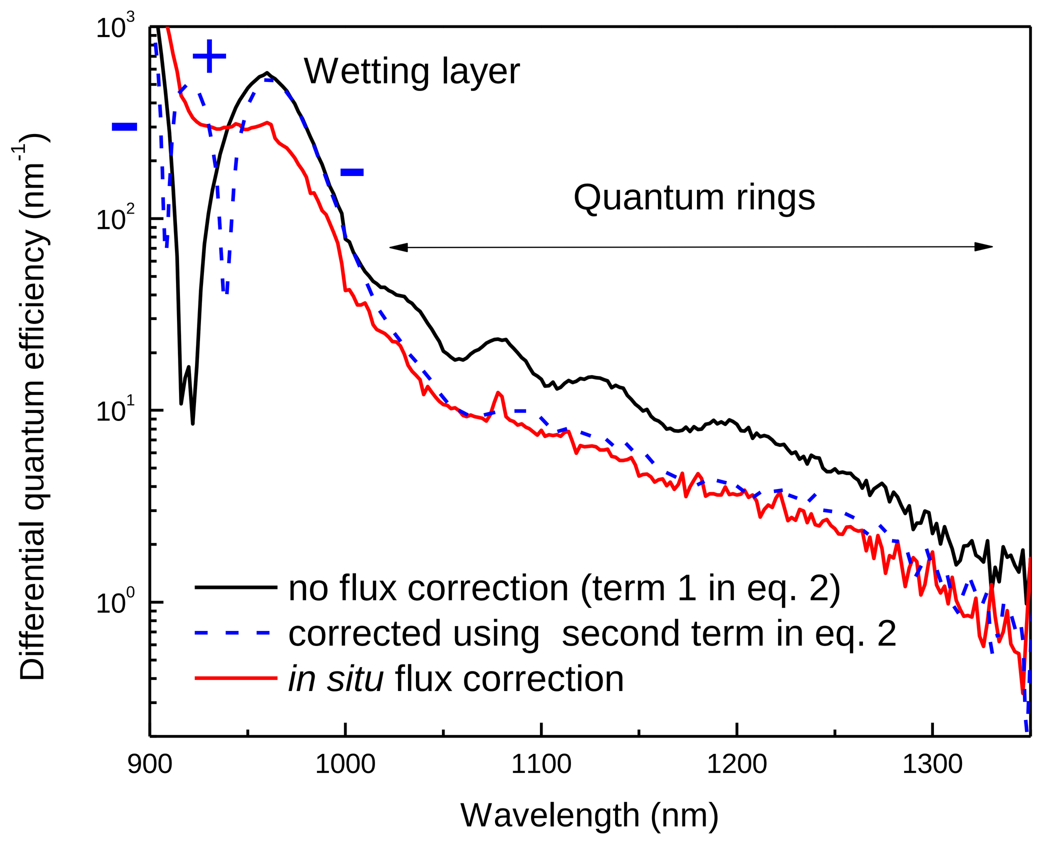

Figure 5: Differential photocurrent spectrum of the GaSb/GaAs quantum ring solar cells, with and without in situ flux correction. The +/- signs represent the phase of the signal.

Results and discussion

❖ **Figure 3:** Variation of the photon flux density of the light source, which needs to be normalized during the wavelength dependence measurement.

❖ **Figure 4:** EQE shows the contribution of the QRs within the intermediate band of the solar cell. The peak on the WL part of the J_{ph} is not visible on the EQE spectra.

❖ **Figure 5:** Correlation between eq. 2 and the flux correction module; i.e. by using the flux correction module, the second term of the right hand side of eq. 2 becomes negligible.

Conclusions

➢ In addition to the flux intensity dependence of the excitation source, the phase change also needs to be considered for the wavelength-modulated spectroscopy method.

➢ The differential measurement is greatly simplified and potential anomalies was prevented by the means of the flux correction module.

➢ The future work consists of the investigation of the optical absorption of the quantum rings at low temperatures.

References

1- P. J. Carrington, M. C. Wagener, J. R. Botha, A. M. Sanchez, and A. Krier, *Appl. Phys. Lett.* **101**, 231101 (2012).

2- A. Marti, E. Antolín, E. Cánovas, N. López, P. G. Linares, A. Luque, C. R. Stanley, and C. D. Farmer, *Thin Solid Films.* **516**, 6716 (2008).

3- J. Hwang, A. J. Martin, J. M. Millunchick, and J. D. Phillips; *J. Appl. Phys.* **111,** 074514 (2012).

Acknowledgements

This work is based upon research supported by the SA Research Chairs Initiative of the Department of Science and Technology and the National Research Foundation, South Africa, as well as by the Nelson Mandela Metropolitan University. The solar cell devices were supplied by A. Krier from Lancaster University.