Studying carrier lifetime in InAs/GaAs quantum dot devices by optical pump – terahertz probe measurements

Ivo T. Leite,[a,b,c] Andrei Gorodetsky,[c] Natalia Bazieva,[c] and Edik U. Rafailov[c]

[a] School of Engineering, Physics, and Mathematics, University of Dundee, Dundee DD1 4HN, United Kingdom
[b] Institute for Medical Science and Technology, University of Dundee, Dundee Medipark Dundee DD2 1FD, United Kingdom
[c] Optoelectronics and Biophotonics Group, AIPT, Aston University, Birmingham B4 7ET, United Kingdom

i.t.leite@dundee.ac.uk

www.phoqus.eu/projects_leite

Motivation

- Growing interest in photoconductive antennae based on InAs:GaAs quantum-dots for generation of THz radiation [1,2] which can pumped at high optical intensities [3].

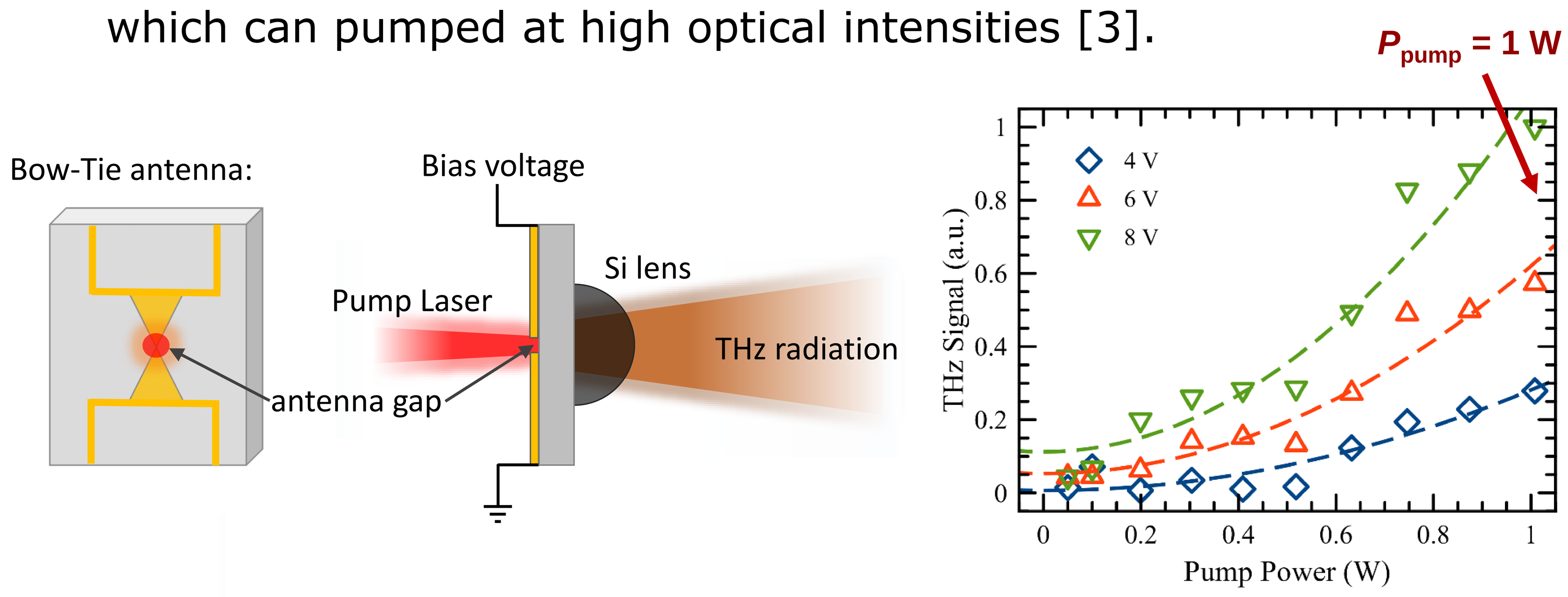

Figure 1 – *(left)* Schematic of a bow-tie microantenna lithographically printed onto a InAs:GaAs quantum dot structure. *(right)* Emitted THz signal as function of the pump power, for varying bias voltages applied to the antenna [3].

- The spectra emitted by InAs:GaAs quantum-dot based photoconductive antennae becomes broader with increasing pump intensity [4].

Quantum-dot structures

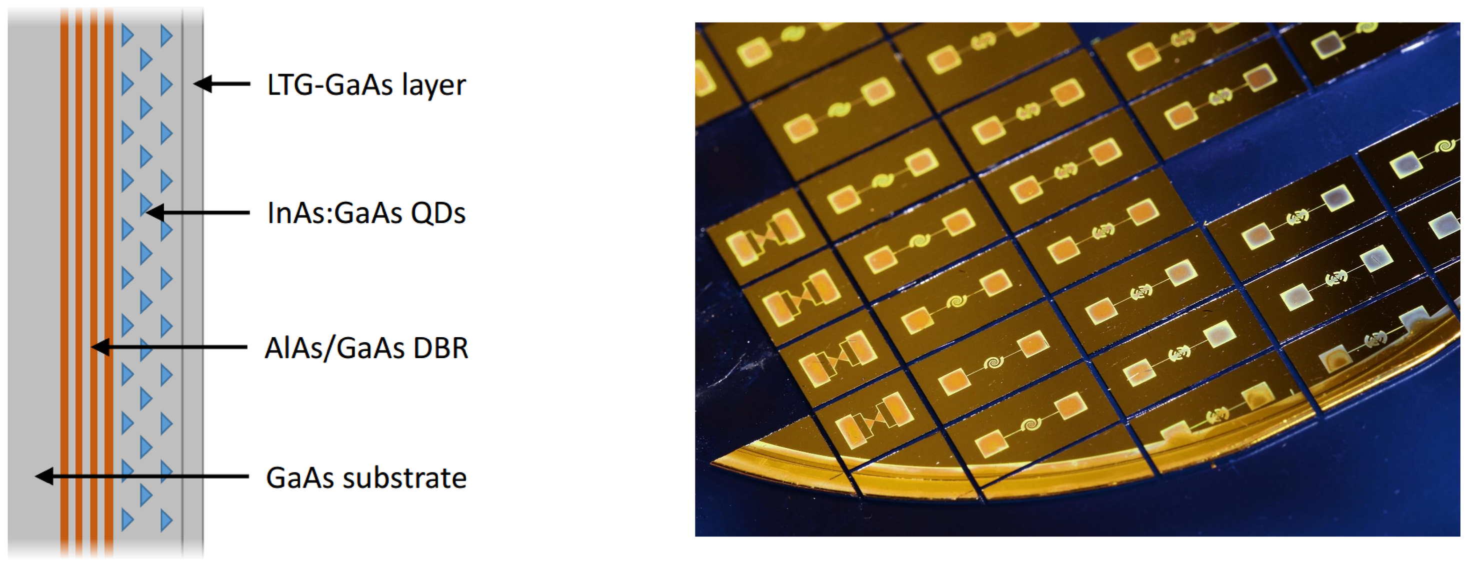

Figure 2 – *(left)* Schematic of the InAs:GaAs quantum-dot (QD) structure grown by molecular beam epitaxy on top of a GaAs wafer. The structure includes a AlAs/GaAs distributed Bragg reflector (DBR) designed for the 1200-1300 nm wavelength region, not used in this work. *(right)* Photograph of microantenna structures printed on a InAs:GaAs quantum dot wafer.

Experiment

- Optical pump – terahertz probe measurements to record the transmitted THz signal for varying time delay between pump and probe, and for different optical pump intensities:

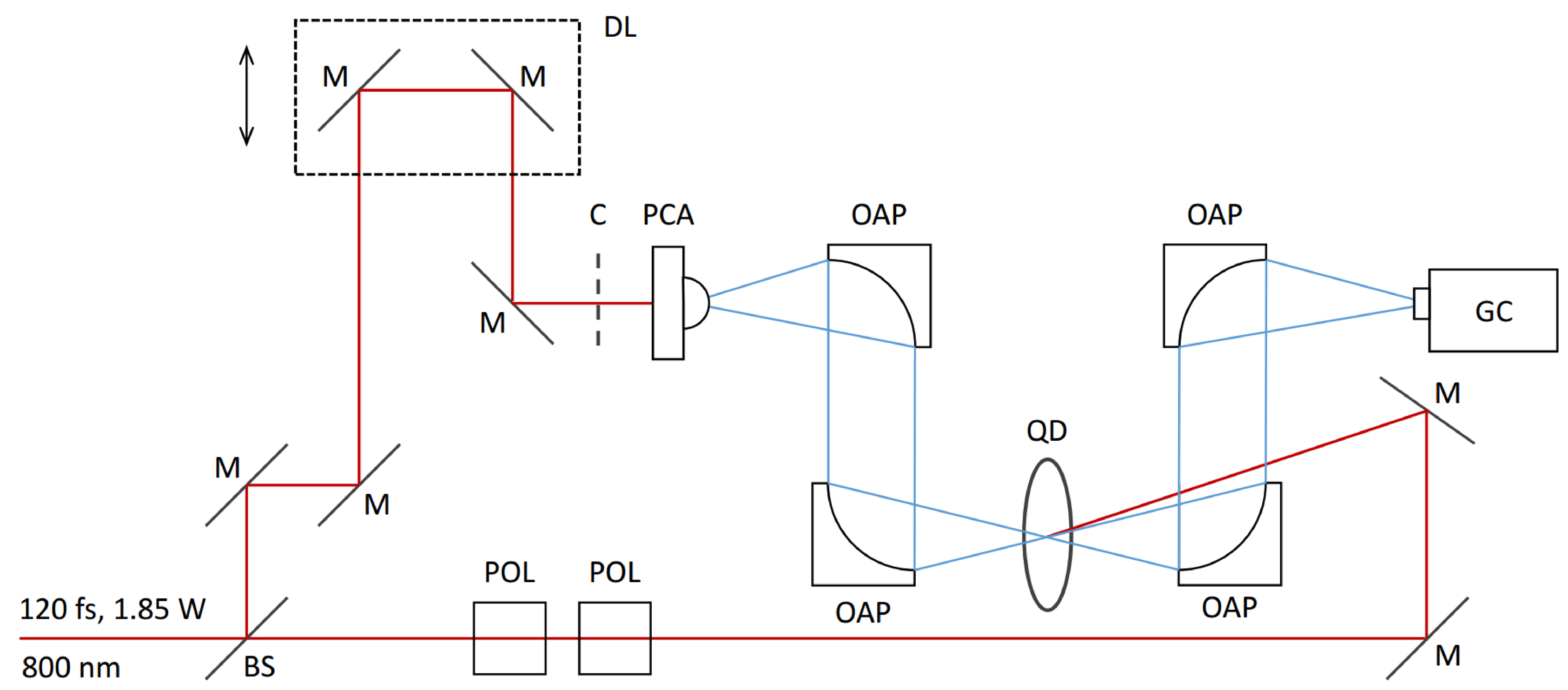

Figure 3 – Experimental layout used in the optical pump – terahertz probe transmission measurements: BS – Beam splitter; POL – Glan-Taylor polarisers; OAP – bare gold off-axis parabolic mirrors; PCA – commercial LT-GaAs THz photoconductive antenna; QD – quantum-dot structure under study; GC – Golay cell detector; DL – delay line; C – mechanical chopper; M – protected silver mirrors. The optical source is a femtosecond Ti:sapphire laser.

Results

- The photo-induced carrier lifetime of the InAs:GaAs structures can be estimated by fitting exponential curves to the time variation of the THz transmission.

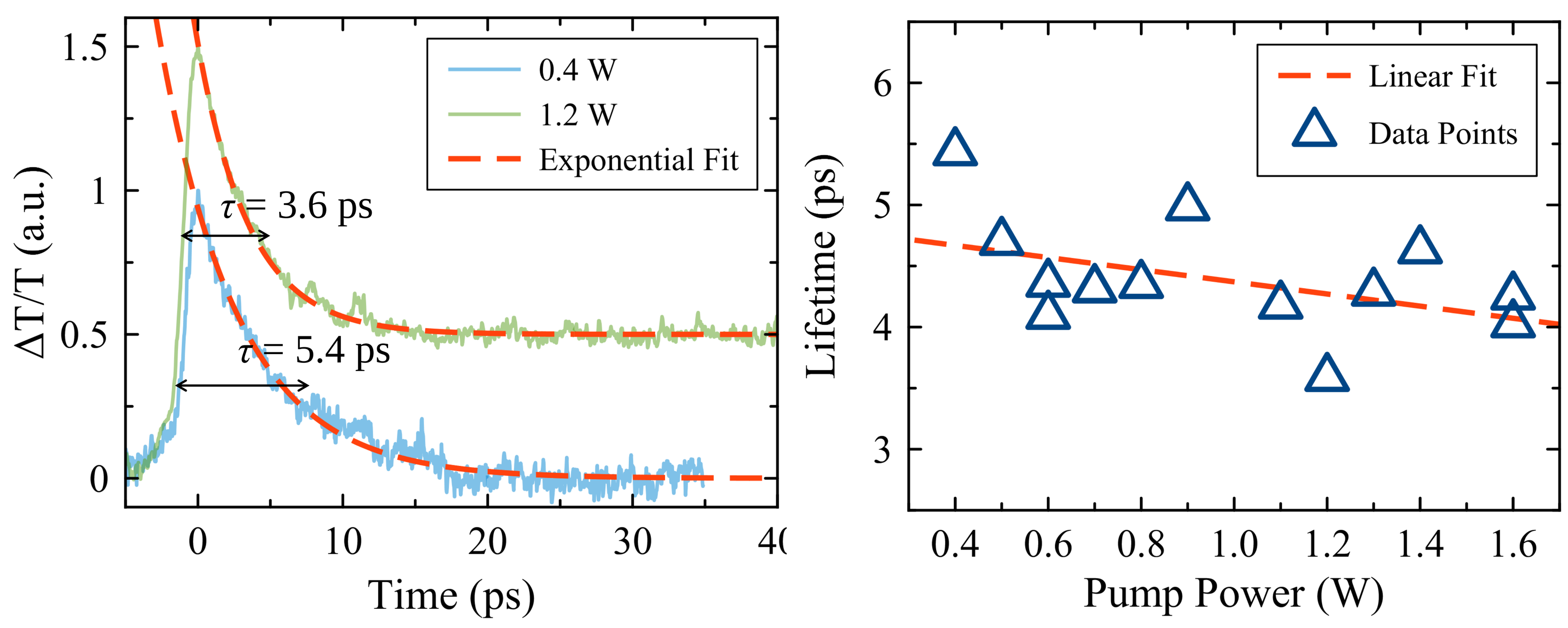

Figure 4 – *(left)* Relative variation in THz transmission due to the generation of excess carriers in the QD wafer induced by the optical pump beam. An offset was added to the upper curve to allow for better visualization. *(right)* Photo-induced carrier lifetimes extracted from the exponential fittings, as function of the optical pump power.

- The photo-induced carrier lifetime the InAs:GaAs quantum-dot structures is observed to decrease significantly under higher optical pump intensities, in accordance with previous results reported in similar structures [5].

Conclusions

- These preliminary results indicate that the physical origin behind the observed spectral broadening in the emission of QD-based photoconductive transmitters with increasing pump power may be the lifetime shortening of the photocarriers.
- This seems to confirm the hypothesis that under higher pumping intensities the carriers undergo non-radiative relaxation through QD excited states rather than through slower ground states.

References

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Acknowledgments

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