Nanowire-based Photodetector with High Gain

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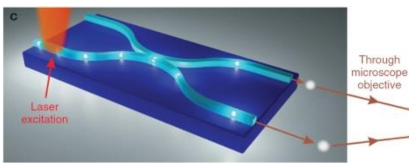
Introduction:

This project aims at measuring the photoconductive gain of semiconductor nanowires of CdSe and ZnO. In recent years, photodetectors based on nanowires with extremely high gain appear excellent sensibility as the best detectors of the market. The origin of this high gain is still not completely known, nor mastered. Therefore, we propose to implement a precise measurement of photoconductive gain by building such a photodetector, which is designed to couple a controlled number of photons with an optical or plasmonic guide and send the photons to the nanowires.

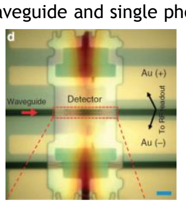
State of the art

Integrated structure:
Single photon source and waveguide



From the article [1] (Jöns and al.)

Waveguide and single photon detector (superconductor device)

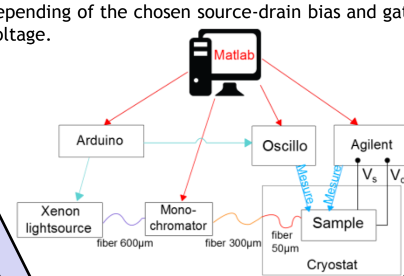


From the article [2] (Najadi and al.)

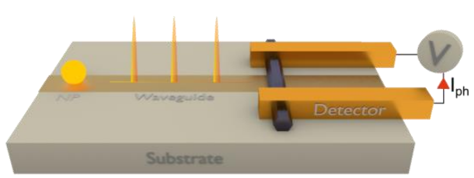
Setup for photocurrent measurement

The setup is designed to have control over the incident wavelength light, the atmosphere and temperature.

Photocurrent measurement can then be performed depending of the chosen source-drain bias and gate voltage.



Our project (Nanogain)



Origin of the gain

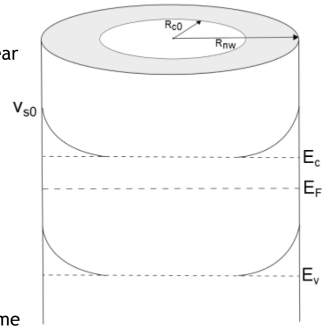
An efficient way to describe the photoconduction sensitivity of a semiconductor is the photoconductive gain, G, which is defined as

$$G = \frac{N_{el}}{N_{ph}} \text{ or } G = \frac{\tau}{\tau_t}$$

the ratio of the number of charge carriers which pass between the photoconductor electrodes per second to the number of photons absorbed per second that create electron-hole pairs.

The lifetime τ depends on radiative and non radiative recombinaison rate. It is strongly constrained by the surface effects

- Space charge region (SCR), near the surface
- The effective conduction area depends on the SCR size



→ Minimize dark current
- Less noise
- Increase sensitivity

→ Carriers are separated
- Increase carrier lifetime
- Higher gain

Side Effect:
- Slow recovery time

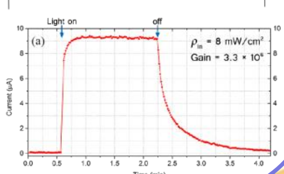
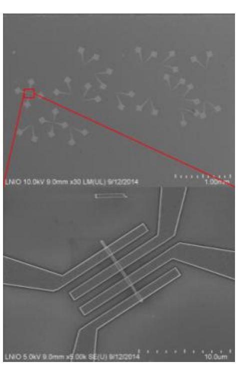
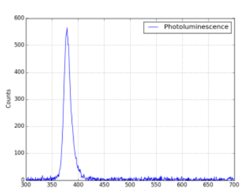


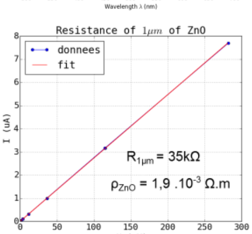
Image from [3]

Single nanowire photodetector (ZnO nw)



SEM images of a 4-point photoconductivity measurement setup on ZnO nanowire





References :
[1] *Jöns and al*, Monolithic on-chip integration of semiconductor waveguides, beamsplitters and single-photon sources, *Applied Physics Letters* **107**, 021101
[2] *Najafi and al*, On-chip detection of non-classical light by scalable integration of single-photon detectors, Nature communications 6, 5873 (2015)
[3] *Wei Geng*, Coupling of Nanostructures for Integrated Nanophotonics Devices, Ph.D Thesis, UTT, 2015

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