Experience 1 : Quantum Communication

General introduction to the experience

In this section, students should briefly introduce the general context of quantum communication and QKD. They should then delve into the description of the BB84 protocol with polarization coding. Finally, they should list and briefly describe the essential elements of this protocol (sources, detectors, and polarization optics).

Part 1: Implementation of a BB84 demonstration device

- Objective of the experiment

  Provide a short summary of the objectives of this part of the experience

- Setup description and list of components

  Students should list the materials and instruments used in the experiment, as well as provide a description of the overall experimental setup. It is recommended that you include a simple schematic drawing of the setup (no photos of the setup).

- Results:

  - QKD test without Eve

    Here, the data related to the direct key exchange between Alice and Bob will be reported, including: the tables of the bases used and the bits exchanged for both users, the key, and the key comparison with the corresponding QBER measurement.

  - QKD test with Eve

    Here, the data related to the key exchange between Alice and Bob, with the presence of Eve, will be reported, including: the tables of the bases used and the bits exchanged for both users, the key, and the key comparison with the corresponding QBER measurement.

Part 2: Implementation of the OTP protocol

- Objective of the experiment

Provide a short summary of the objectives of this part of the experience.

- Setup description

Students will have to list the software tools used.

- Results:
  - Demonstrative OTP
    students will have to report the procedure for encoding a simple text character using the key generated in part 1 of the experiment.
  - Software for message encoding and decoding
    Students will have to provide their code with detailed comments

Part 3: Characterization of QKD components

- Objective of the experiment

  Provide a short summary of the objectives of this part of the experience.

- Setup description and list of components

  Students should list the materials and instruments used in the experiment, as well as provide a description of the overall experimental setup. It is recommended that you include a simple schematic drawing of the setup (no photos of the setup).

- Results:
  - Half-wave plate characterization
    The graph of the Malus law relating to the half-wave plate to be tested and the data fit must be reported.
  - SPAD characterization
    The measurement of dark counts, dead time and the graph of the efficiency curve of the single-photon detector must be reported.

Notes:

- *The Results sections should not only include data, graphs, and tables, but these must be presented within a text containing their description and discussion.*
- Each figure should have an adequate caption.
- For Part 3, results should be presented with appropriate uncertainty analysis.

Experience 2 : Atomic Spectroscopy

General introduction to the experience

In this section, students should give a concise introduction to the concept of absorption spectroscopy and highlight the main objective of the experimental activity.

Hint: Do not rewrite all the theory of atomic absorption, but focus on the concept and formulas that are actually used in the data analysis.

Part 1: Laser characterization

Provide a short summary of the objectives of this part of the experience (one short paragraph is enough)

Laser current/power characteristic
Find the threshold current extrapolating a linear fit of the linear part of the stimulated emission to "zero intensity". Describe the instrumentation used, analyze and comment the results.

Part 2: Atomic spectroscopy

Recap the objectives of this part of the experience (a short paragraph is enough)

Students should provide a description of the overall experimental setup. It is recommended that you include simple schematic drawings of the setup, optionally together with photos. For drawing the setup, this is a useful open-source library of SVG images: https://www.gwoptics.org/ComponentLibrary/

(remember to acknowledge the author!)

- Results and discussion:
  - *Doppler and sub-Doppler spectroscopy*
    - *Analyze the transmission data (Doppler spectroscopy) to obtain the atomic absorption coefficient.*
    - *Using the data from the Michelson interferometer check the linearity of the laser response to the current ramp.*
    - *Analyze the transmission data obtained with saturation absorption spectroscopy. Find the line centers and use it together with the known frequency separation obtained from the literature to calibrate the x-axis.*
  - *Calculation of the atomic density from the spectra*
    - *From the fit of the Doppler absorption profiles, obtain the atomic density and compare it to the theoretical one at room temperature.*

NOTES:

- Take care of the number of significant digits and to the uncertainty analysis.
- The x-axis of the atomic spectra (i.e. laser frequencies) are more properly visualized using relative frequency differences (in units of GHz), with respect to absolute frequency valueus (THz).

Experience 3 : Cleanroom

General introduction to the experience

In this section, students should briefly introduce the general context of the cleanroom experience concerning the #1, #2 and #3 ones.

Part 1: Materials and Methods - for each of the 3 experience

- Objective of the experiment

  Provide a short summary of the objectives of this part of the experience.

- Setup description and list of components

  Students should list the materials and instruments used in the experiment. Try to get pictures during the experience in such a way that it can be easier to describe them. (example for experience #1: mask aligner instrument, spin, optical microscope and profilometer)

- Process flow description

  Students should describe the process step parameters and try to get motivate them. (example for experience #1: at which rpm was spinned the photoresist?, softbake temperature, exposure and developing parameters?)

Part 2: Results - for each of the 3 experience

- Experience #1 (MICRO):
  - Detailed description of the entire photolithography process – *Motivate the parameters, for example: Why at the indicated velocity? Why is it necessary the soft bake needed?....*
  - Differences between a positive tone process respect to the “image reversal” one
  - Highlight the different between the “nominal” trenches size present in the mask and the final measured size after developing
  - Well correlate the optical microscope acquisitions with the profilometer ones and explain the difference between higher areas and smaller ones

- Experience #2 (NANO):
  - Detailed description of the entire process with parameters indication. Special focus on FIB process in resist reticulation.
  - Differences concerning the smaller size obtained in this case respect to the MICRO-experience➔ consider the wavelength used
  - Connected to the III° experience➔ comment the values for the verticality and and angulation of the obtained structure.

- Experience #3 (Dry etch and SEM imaging):
    - Detailed description of the ICP-DRIE process, reporting and commenting the parameters used. Describe the Pseudo-Bosch process and describe the difference with the Bosch process.
    - Report the Etch rate and selectivity of the process at the Micro and Nano scale
    - Report the Structural differences of the etch process for Micro and Nano scale samples, considering SEM images, considering sidewall profile, angles and underetch.

Notes:

- ➢ *The Results sections should not only include data, graphs, and tables, but these must be presented within a text containing their description and discussion.*
- ➢ Each figure should have an adequate caption.