Virtual training on Biomedical Nanophotonics

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Abstract: To overcome the negative impact of sanitary restriction in education systems due to the pandemic, we have designed and developed a series of virtual laboratories for remote training on biomedical nanophotonics dedicated to graduate students. © 2021 The Author(s)

1. Introduction

It is well known that COVID-19 pandemic has had a peerless impact worldwide. In terms of the education, several dramatic changes were necessary in order to continue with the formation of students across the world. Many new strategies must be developed and adapted to the 'new normality' due to the limitations and restrictions imposed after COVID. This brings new challenges in terms of pedagogic methods that need to be addressed to ensure the correct preparation of future professionals.

Therefore, we have designed, developed, and adapted a series of videos showing virtual laboratories for specific training on biomedical nanophotonics dedicated to graduate and undergraduate students in areas such as biomedical engineering, physics, chemistry, materials science, and engineering.

The graduate course entitled GBM8810 Nanotechnologie biomédicale has been given in French at Polytechnique Montreal for many years by Professor M. Meunier. This course GBM8810E is now given in English to welcome an international audience. The course aims to give a general overview of the many applications of light-nanomaterials interaction in the medical field. Composed of lectures, assignments, numerical simulations and laboratories, this course allows to acquire notions on both the physical theories governing these phenomena and on their applications in the biomedical field. The course covers many applications, including plasmonic nanoparticle synthesis and functionalization as well as various applications such as imaging, biosensing and hyperthermia for therapy and diagnosis of disease with plasmonic nanoparticles. It is based on extensive research experience acquired over the years in Professor Meunier's group to offer examples at the cutting edge of existing technologies. Recently, different attractive short videos were created in English describing the laboratories showing the main manipulations that must be done on each subject.

2. Materials and methods

Different informatic tools were used in order to simulate the laboratory and help the students to better understand the manipulations that are necessary in a controlled environment such as a chemical hood or biosafety cabinet.

Editing software such as *Movavi video editor* was used to build the interactive videos including quizzes, presentations in PowerPoint and manipulations made by the teaching assistants in the laboratories at Polytechnique Montreal. In terms of the virtual tools, the software Matlab was used for simulation of the plasmonic properties of the nanoparticles. The use of Jupyter Notebook was implemented in the Imaging laboratory for the image processing.

2.1 The virtual laboratories:

In order to broaden the audience for international students, five videos explaining optics and nanophotonics problematics and solutions were developed in English:

- Simulation of optical properties of plasmonic nanoparticles laboratory
- Gold nanoparticles synthesis laboratory
- Functionalization of gold nanoparticles laboratory
- Laser therapy on cells laboratory
- Plasmonic nanoparticles imaging laboratory

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After the first laboratory introducing different simulation tools for a better understanding of plasmonic nanoparticles behavior in aqueous media, the second laboratory covers a complete explanation of the fabrication method of colloidal nanoparticles (NPs). It is worth mentioning that prof. Michel Meunier has a patent for the synthesis of NPs (Patent number: US10239122[1]) and the different software used for the simulation plasmonic materials based on Mie theory were developed by his group using numerical computing platforms such as Matlab [2] (see paper by Wang et al. for more details [3]).

After the characterization of the plasmonic effects, the third video is related to the functionalization of the NPs to be used in biological environments, followed by the two applications of those in cancer cells. The aim of the fourth laboratory is to demonstrate that by using a specific type of NPs with a laser centered at the resonance wavelength, a hyperthermal effect can be used to kill cancer cells. Lastly, the imaging of those NPs and cancer cells is presented in the fifth laboratory explaining the different approaches to visualize nanoparticles taking advantage of their optical properties. Complementary to this last video, the students need to use informatic tools and generate small codes in Python to solve problems related to image processing.

The videos show some manipulations done by teaching assistant in the laboratory making them very interactive, with several short quizzes, ensuring that that the students remain involved. The use of Jupyter Notebook was implemented, allowing the gathering of computer code (Python) and rich text elements in the same document for the imaging laboratory.

3. Results and conclusion

Examples of the structure, organization and implementation of each laboratory can be found in figure 1. All students have access through the virtual platform Moodle to the selected dataset of each laboratory.

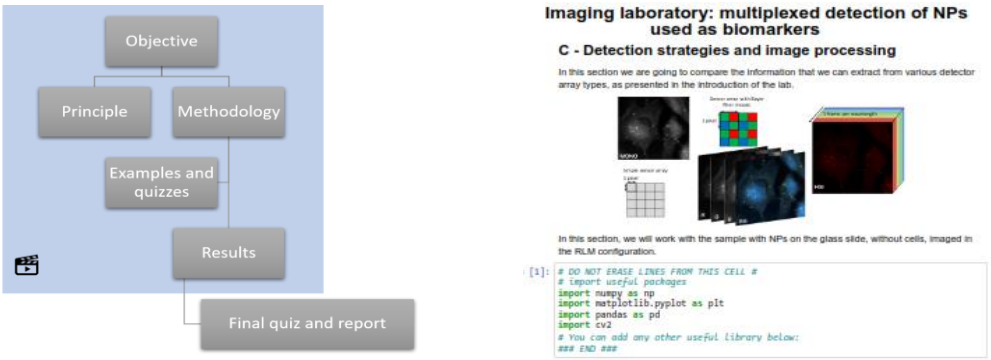

Figure 1. Example of the structure of the virtual laboratories

3.1 The video: includes a complete description of each laboratory including important information related to the principle, methodology and images that students received to complete each virtual laboratory.

3.2 The images: sets of images were taken at different experimental steps.

3.3 Quizzes: after the explanation of the principle and methodology, different quizzes were introduced.

3.4 New tools: The use of Jupyter Notebook was implemented, allowing the gathering of computer code (Python) and rich text elements in the same document for the imaging laboratory.

The 5 virtual laboratories were successfully designed and developed, and students were able to get familiar with all the different topics and experimental features of biomedical nanophotonics. Different attractive short videos were created describing the laboratories showing the main manipulations that must be done on each subject by using open-source platforms and specialized software for remote teaching and learning. By providing different images of the results, the students could analyze and identify the diverse problems to be solved on each proposed topic.

4. References

[1] M. Rioux, David. Meunier, "Alloy nanoparticles, process for their preparation and use thereof," US10239122, 2016.
[2] M. Meunier, "Simulation tools | LP2L." https://lp2l.polymtl.ca/en/outils (accessed Jun. 21, 2021).
[3] L. Wang, M. Hasanzadeh Kafshgari, and M. Meunier, "Optical Properties and Applications of Plasmonic-Metal Nanoparticles," *Advanced Functional Materials*. Wiley-VCH Verlag, 2020, doi: 10.1002/adfm.202005400.