Proposals for M.Sc and Ph.D Research Projects at the Optoelectronic Computing Laboratory of Prof. Agranat

The Research group of Prof. Ronny Agranat at the Department of Applied Physics (https://scholars.huji.ac.il/agranatgroup/home) offers subjects for M.Sc and Ph.D research projects for students who are interested to continue their graduate studies in applied physics, physics, or Material science, including those who are interested in specialization in Nano-Science and Nano-Technology.

Students who will be admitted to the group will receive subsistence fellowships

Research Areas:
1. Nanophotonics inspired by General Relativity.
2. Electroholographic laser systems.
3. Nanophotonic tunnels formd in the proximity of the ferroelectric phase transition.
4. 3D nanophotonic electrooptic structures by sculpting of the crystalline medium during the crystal growth.
5. Multifunctional optoelectronic biosensor based on genetically engineered bacteria.

- The candidates are required to hold a B.Sc in either Physics, Electrical and Computer Engineering, or Exact Sciences.
- **Interested undergraduate students at their senior year** can apply for carrying out a research project of a smaller scale for fulfilling the requirements for an “Amirim Project”, “Third year physics laboratory project”, or “Engineering final project”. These projects will address specific issues and aspects of the offered full-fledged research subjects, and can serve as a platform for those who wish to continue to M.Sc and PhD. Studies upon their graduation.
- The research will be carried out at the Optoelectronic Computing Laboratory.
- Students who will be accepted to carry out their research at the OECL will awarded special scholarships.

Students who are interested in exploring the possibility of working on either of these projects, are invited to meet Prof. Agranat, and explore the possibilities.
For setting up the meeting please write to Prof. Agranat agranat@savion.huji.ac.il

Detailed description of the Research Areas:

1. Nanophotonics inspired by General Relativity
The core of the proposed research is an exploration of a new paradigm in Nanophotonics: **Nanophotonics in Curved Spaces**. The research is in essence an investigation of electromagnetic wave propagation in waveguiding 3D surfaces that emulate the curved spaces in which electromagnetic waves propagate in the vicinity of objects with immense gravitation such as black holes. The waveguiding surfaces are constructed by the Nanoscribe System that enables the fabrication of complex 3D objects with submicron features. (The Nanoscribe System at the Brojde Laboratory of the Hebrew University is the only one of its kind in Israel).
For more details: https://scholars.huji.ac.il/agranatgroup/nanophotonic-structures-3d-curved-spaces
The research is suitable for physics and applied physics students who are interested in the fundamental principles of basic physics, and wish to harness them for constructing miniscule quantum computing and quantum sensing systems. The research activity consists of both design and fabrication of the waveguiding objects, measurements of wave propagation in these objects, and an exploration of the mechanism the governs the wave propagation in these objects by computer simulations.

2. **Solid state laser systems with electroholographic active Q switching and wavelength tunability**
This research project aims at creating an new class of laser systems for the 1-5 mm wavelength range, with active Q switching and electrical wavelength tuning. The implementation of both these features with performance that supersedes the state of the art will be based on the principle of electroholography. In addition, a special methodology for constructing integrated photonic circuits will be developed and employed for constructing the laser systems in waveguiding configurations.
The research is suitable for students of applied physics with flare for inventions who are interested in exporting concepts from the realm of basic research to the arena of viable technology, and explore it potential as the physical chassis for the development of a wide range of applications.
More details about this project can be found in:
https://scholars.huji.ac.il/agranatgroup/electroholographic-active-q-switching-and-wavelength-tunability
Electroholography: https://scholars.huji.ac.il/agranatgroup/electroholography
Refractive Index Engineering: https://scholars.huji.ac.il/agranatgroup/refractive-index-engineering

3. Investigation of nanophotonic tunnels formed around light beams propagating in KLTN and KNTN crystals in the proximity of the ferroelectric phase transition:

The subject matter of this research project are ensembles of nano-dipoles that are formed in KLTN and KNTN crystals at the paraelectric phase upon approaching the ferroelectric Curie temperature. It was shown that ensembles assume, upon approaching the Curie temperature the behavior of dipolar glass forming liquid. Furthermore, it was shown that in photorefractive KLTN these ensembles can be thermally manipulated to form nanophotonic tunnels that surround light beams that traverse through the crystals, which inhibit the diffraction of these beams.

The research will strive to gain a profound understanding of these phenomena, and harness it for creating a technique for constructing programmable complex 3D nanophotonic structures within the volume of the crystals.

For further details about this phenomena:

Nature Photonics 5, (1) pp. 39-42, (2011), and **Nature Photonics 9** (4), pp. 228-232 (April 2015).

The research is suitable for students who wish to do their Ph.D in Applied physics or Physics, who wish to do basic research which combines soft condensed matter physics with nonlinear optics, and those who wish to exploit complex physical phenomena for creating a new class of nanophotonic devices.

4. design, fabrication, and investigation of 3D nanophotonic electrooptic structures by sculpting of the crystalline medium during the crystal growth.

This research consists of three interlaced elements: (i) development of novel technique which enables to create spatial distribution of the composition during the growth of electrooptic crystals, in particular KLTN and KNTN; (ii) Employment of this technique to the construction of 3D nanophotonic structure, and the study of their properties; and (iii) design, fabricate, and evaluate the performance of electrooptic devices which exploit the properties of these structures to implement unique functionalities.

More details can be found in:

http://www.nature.com/ncomms/2016/160224/ncomms10674/full/ncomms10674.html

J. of Non-Cryst. Solids 353, pp. 4405-4410 (2007).

Appl. Phys. Lett. 90, Art. No. 192902 (2007).

Nature Communication 7 Article number: 10674 (2016):

The research is suited in particular to students who are graduates of the "Exact Sciences" program at the Hebrew university, but also to chemistry and physics graduates interested in material science and its employment to the creation of novel nanophotonic and electrooptic devices with unique functionalities.

5. Multifunctional optoelectronic biosensor based on genetically engineered bacteria.

The goal of the project is the development of an optoelectronic biosensor. The core of the sensor is an ensemble of genetically engineered bacteria that respond to the presence of a specific material in their microenvironment by the emission of light generated by a bioluminescence process. The biosensor will be the basic building block of a generic technology for fast deployment upon request a swarm of biosensors that operate outdoors, and can detect a wide range of materials.

For our previous activity in this area see: "Remote detection of buried landmines using a bacterial sensor"

In **Nature Biotechnology 35**, (4) pp. 308-310 (April 2017).

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