ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	Amir Maghoul
Nationality	Iranian
Name of the *Host Organisation*	NTNU
First Name / family name of the *Scientific Coordinator*	Ilangko Balasingham
Period of the fellowship	01/10/2019 to 30/09/2021

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my fellowship, my research mainly focused on the characterization and investigation of the feasibility of photonic communication between nerve cells inside the brain based on available experimental models. Firstly, we worked on a common engineering model of the nerve fiber as a nerve channel to evaluate the feasibility of photonic signal transmission under the demyelination and then calculated the optical signal attenuation in the considered model. We indicated photonic communication across the nerve channel and extracted the results related to the impact of demyelination over optical signal transmission. We proposed a new method based on the injection of nanoparticles surrounding the demyelinated nerve fiber to improve the optical communication inside the nerve fiber. The results arising from the simulation framework demonstrated a significant enhancement in photonic transmission across the demyelinated nerve fiber in the optical range.

In following this approach, we considered a multilayer myelinated axon to investigate the effect of optical communication in more detail. The proposed framework was the first effort to develop a theoretical foundation with numerical simulation based on the experimental data in the literature. In attempting to establish the concept governing the photon transmission across the nerve fiber with multi-layered myelin at the nanoscale, we achieved and compared the optical signal transmission across the multi-layered myelinated axon model. In this approach, the nerve's optical characteristics are extracted by focusing on the reflectance arising from light incidence on the nerve fiber with the dimensional change of the demyelination area to distinguish demyelinated—from myelinated nerves by contrasting the achieved reflectance spectra. We designed a nanostructure configured with silicon dioxide,

graphene sheet, and gold nanoparticles to function as a neurophotonic biochip that enables recognizing myelinated axon damage via surface plasmon resonance wavelength shifts. This device can promote a practical procedure to present the distinction of nanoscale myelinated and demyelinated axons, which can be utilized for neural sensing applications of tiny brain tissues as a neurophotonic needle. In the third approach, I focused on the design of a terahertz fractal-shaped perfect absorber based on graphene that can be used for sensory applications.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

I have provided the list of published papers and submitted manuscripts during this fellowship:

[1]. A. Maghoul, A. Khaleghi, and I. Balasingham, "Engineering Photonic Transmission Inside Brain Nerve Fibers," in IEEE Access, vol. 9, pp. 35399-35410, 2021. (doi: 10.1109/ACCESS.2021.3062299.)

[2]. A. Maghoul, Ali Rostami, Mladen Veletic, Bige Deniz Utluruk, Ilangko Balasingham, "Optical Modeling and Characterization of Demyelinated Nerve Using Graphene-Based Photonic Structure," is revised and resubmitted in IEEE Access. (Nov-2021)

[3] A. Maghoul, A. Rostami, Ilangko Balasingham "Design and Simulation of Terahertz Perfect Absorber with Tunable Absorption Characteristic Using Fractal-Shaped Graphene Layers," Photonics 2021, 8, 375.
https://doi.org/10.3390/photonics8090375.

[4] A. Maghoul, Ilangko Balasingham, "Mathematical Equation of the Potential on the Single Neuron under Plasmonic Scattering of Nanoparticle," is under preparation.

[5]. A. Maghoul, I. Balasingham, "Optical Simulations for Single Neuron Model under Plasmonic Effect of Different Shapes of Noble Nanoparticles" presented in 1th ERCIM FP Community event, Nov 2021. (Poster)

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I participated in the Norwegian Nano Symposium 2019 in Trondheim, Norway. Unfortunately, I couldn't participate in the other conference due to Corona's situation and available restrictions. However, I participated in some virtual courses at the nanoelectronic group and signal processing group at NTNU.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Due to Corona's restrictions and rules, I couldn't have a specific plan for visiting the other institutes physically. However, I had three virtual meetings with two research groups in Simula, Oslo, Norway. I participated in regular weekly meetings of the Computational Physiology group two times in Simula. I also presented a PowerPoint about my research concerning optical modeling of nerve fiber in the Numerical Analysis and Scientific Computing group of Simula.