Linear and nonlinear optical properties of AIE fluorophores for potential utilization in laser medical diagnostics

The cancer treatment issue is currently one of the most important concerning the mortality of the human population in developed countries. For example, according to the Polish National Cancer Registry, these diseases are the second most common cause of death among Poles, right after cardiovascular diseases. Thus, they are responsible for almost ¼ of all deaths in Poland. The way to deal with this problem is, of course, to develop new treatment protocols. However, proper medical diagnosis is also very important because most cancers can be successfully treated when they are properly diagnosed at the early stage of the disease.

Current diagnostics, in addition to that based on "chemical" detection of relevant markers, are based mainly on histopathological examination. In such a situation, the altered tissue is resected, and its morphology is evaluated by a histopathologist using microscopic techniques to determine the type of changes and the stage of disease evolution. This type of examination requires a lot of experience from the person performing it, is time-consuming, and, unfortunately, prone to so-called human error. Therefore, the development of new, faster, and more reliable diagnostic methods is of particular importance.

One of the methods, developed by Prof. Vardeny, is based on the use of random lasing phenomenon to detect cancerous changes in tissue. A random laser is a specific type of laser that achieves light amplification in a disordered medium. The so-called feedback for the laser action in such conditions is realized through multiple light scattering. As a consequence, the performance of the laser and its emission characteristics are strongly dependent on the nature of the disorder generating the feedback. As it is commonly known, cancer cells differ in their morphology from healthy cells; thus, they will scatter light in an entirely different way. Those differences can be detected in laser emission characteristics, which is the fundament of the diagnostic method developed by Prof. Vardeny. Previous attempts have used so-called laser dyes for tissue staining, which often poorly penetrate biological matter and degrade rapidly when exposed to emission excitation light. AIEgens often lack these limitations.

AIEgens - the dyes that exhibit so-called aggregation-induced emission (AIE stands for Aggregation-Induced Emission) are known for their ability to aggregate at specific sites in biological tissue. They are often used to stain various types of cellular organelles, but also cells undergoing cancer mutations. Moreover, aggregation can enhance the fluorescence and the possibility of nonlinear optical effects occurrence (such as two-photon excited fluorescence), as well as decrease the photodegradation processes. In addition, many of the AIE compounds can emit laser light, which can be significantly enhanced by the aggregation process. Therefore, AIEgens seems to be perfectly suited to the development of such laser-based cancer diagnostics techniques as proposed by Prof. Vardeny.

Within the framework of the present scientific project, the authors would like to focus on the use of AIEgens for laser diagnosis of cancer diseases. It is planned to test various types of AIEgens for their ability to stain biological tissues, including different healthy and tumor-lesioned lines of cells, and to test their ability to generate laser light upon one and two-photon excitation. During the research, changes in laser emission parameters upon the cancerous cells' presence will be investigated, and the whole technique will be evaluated according to its utility in tumor diagnosis.

Additionally, next to laser emission studies, morphological ones will be carried out as well. They will be conducted to determine how the dyes can bind to various types of cell organelles. The results of these studies can be very important for the elaboration of novel cell labeling protocols for bio-imaging used in medicine and biotechnology.

Finally, research will be conducted according to obtaining two-photon excited fluorescence, which may find application in the development of high-resolution bio-imaging methods or two-photon excited laser action for cancer diagnostics or deep-tissue photodynamic therapy.