" Small furan-based donor-acceptor molecules and their photonic properties" *- a popular science summary of the project.*

Small organic compounds called dyes belong to the family of chemical species characterized by relatively simple, cheap and efficient synthesis. Despite their simplicity, they can exhibit many beneficial properties that could be utilized for different purposes. For example, in the case of medicine, dyes are used in photodynamic therapy, angiographic measurements and histopathology for cancer cells labelling etc. They are compatible with wet-processing techniques and thus they can be easily added to plastics or other types of matrices, therefore the resulting material is gaining additional features that it never had before. The scope of materials functionalisation may include simple colouring of the polymers for esthetic purposes, gaining the ability to exhibit the photoluminescence phenomenon or activation of other features, very beneficial for modern photonics such as the ability to generate the second harmonic, two-photon absorption, two-photon excited fluorescence, optical limiting, generation of laser light etc. The utilization of dyes is also very important for photovoltaics where these kinds of compounds are used as sensitizers for increasing of the light to electric energy conversion efficiency. Thanks to the mentioned features, nowadays it is possible to develop cheap and flexible materials for electronics, optoelectronics and photonics, which can be printed, spun or coated using known painting techniques.

One very interesting group of dyes are the family of compounds exhibiting the phenomenon of intramolecular charge-transfer in the excited state, the so-called charge-transfer (CT) molecules. These type of dyes are perfect for lasing purposes, they can be used as indicators of environmental changes and are perfect for nonlinear optical applications. Their chemical structure usually consists of two moieties, the electron-donating (D) and electron-accepting (A) groups conjugated, with a π-electrons rich linker ensuring the charge “conduction” inside the chemical structure. Such a chemical design leads to the delocalization of the electrons within the molecule and this effect is very sensitive to the changes in environmental conditions. This is the reason why CT molecules are so often used as pH, the polarity of different ions presence indicators. The charge-transfer character ensures the ease of molecule polarization under the influence of the electric field of incident light and therefore the nonlinear optical response might be easily achievable. Finally, the appearance of a CT state after excitation of the molecule leads to the formation of the so-called four-level system of energy states which is very beneficial for laser action achieving. The possibility to gain and control the above-mentioned effects depends on the chemical structure of a given compound, and in particular, on the D and A groups that were used for this purpose.

This research project is aiming at the development and characterization of CT compounds substituted with furan-based electron-accepting moieties. This type of substituents with the tricyanofuran (TCF) as a flag-ship, are among the strongest ever-known electron attracting moieties. So far, the non-linear properties and the ability to generate laser light have not been systematically studied for compounds of this type. The author of the project suggests that the use of such strong electron-acceptor groups may hypothetically lead to the development of a novel class of efficient dyes capable to emit two-photon excited infrared laser light. This hypothesis will be validated during the realization of the present project. The potential benefits coming from positive validation of this hypothesis can result in the development of a novel class of dyes that could be very beneficial for non-invasive medical diagnostics and biological imaging since the infrared light can easily penetrate the biological tissue. The cognitive significance of the project will rely on the development of novel types of dyes, elaboration of new synthetic routes and the connection of optical properties of obtained molecules with their chemical structures. The last one will help in the engineering of novel molecules that will exhibit the desired and apriori selected optical features. Moreover, the tested compounds will be designed in such a way that they will exhibit aggregation-induced/enhanced emission (AIE/AIEE). The influence of this phenomenon on laser emission parameters has never been systematically studied before. The author of the project hypothesizes that compounds of this type may exhibit far superior lasing properties over commonly-known commercially available laser dyes.