Nonlinear optical phenomena are a wide family of processes that are elicited when light of very high intensity (of the order of hundreds of GW/cm^2) interacts with matter. The term “nonlinear” comes from the fact that laser light changes the optical behavior of investigated sample. Normally, according to optics of every-day life (which is equated with linear optics), refractive index n and ability of material to absorb light, called extinction coefficient ε are material constants that are specific for given wavelength, but are not dependent on the intensity of incident light. This situation starts to dramatically change when the electric field induced by light becomes comparable with electric fields that constitute matter, modifying properties of given material on the nano-, micro- and macroscale. One of most known and useful nonlinear optical processes is two-photon absorption, which basically is an electronic excitation that would be achieved by one-photon absorption at two-times shorter wavelength. For example, absorption of two photons of 800 nm wavelength should act as the absorption of one photon of 400 nm wavelength.

What is so specific in two-photon absorption? Two-photon absorption is dependent on the square of the laser light intensity. To achieve very high light intensity there should be an efficient source of laser radiation, and the laser light should be focused. Usually, nonlinear optical processes occur in a very small volume, exactly where the laser light intensity is the highest. In this small volume can be triggered various phenomena like photochemical reaction or emission of light. Thus, this localized irradiation can be used for two-photon microfabrication (it is like 3D printing in the microscale), two-photon fluorescence imaging, called also as two-photon microscopy, but also for two-photon photodynamic cancer therapy. The latter process involves laser-induced generation of reactive species that are potentially able to kill cancer cells.

Unfortunately, absorption of two photons simultaneously is very unlikely, in comparison to absorption of one photon, and moreover, is highly dependent on the structure of chemical compound or material. This is why scientists intensively look for new materials which would be better than currently known “nonlinear absorbers”. In fact, nonlinear optical properties were and are currently investigated for organic molecules, polymers but also for other systems such as semiconductor and metallic nanoparticles. Although still are reported better and better nonlinear absorbers, one can notice that it is increasingly harder to design materials with record high two-photon cross sections.

This research proposes to prepare a series of cross-linked conjugated polymers which will have key important feature – they will be aggregated. Why actually macromolecules should nearly touch each other? Aggregation was previously found to enhance the two-photon cross section in small molecule aggregates of e.g. porphiryns but also in large biomolecules. It is not clear what is the precise mechanism of observed two-photon enhancements, and more attention of researchers should be paid to the exploration of this topic. Therefore, herein proposed polymers, can be treated as model materials not only designed to follow traditional design guidelines successful for molecular nonlinear optical absorbers, but also to reveal aggregation effects in order to obtain higher two-photon cross sections than already achieved.

A successful demonstration of enhanced two- and multi-photon absorption properties in cross-linked conjugated polymers would provide a novel approach to rational design of organic macromolecular materials by drawing an attention to the aggregation as a tool, which may be found indispensable for obtaining higher than already reported two-photon cross sections.