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Thermally activated and coherent charge carrier separation in all-organic solar cells

Rokas Jasiūnas[1], Titas Klepeckas[1], Huotian Zhang[2], Vidmantas Jašinskas[1], Andrius Gelžinis[1], Feng Gao[2] and Vidmantas Gulbinas[1]

1 Center for Physical Sciences and Technology, Sauletekio av.3, Vilnius, 10257, Lithuania

2 Department of Physics Chemistry and Biology (IFM), Linköping University, Linköping SE-58183, Sweden

With the introduction of organic electron acceptors, all-organic photovoltaic devices achieved record efficiencies of almost 20% and aroused the interest of researchers as a promising future photovoltaic technology. Despite the spectacular technological achievements, the new materials raised additional questions about details of solar cell performance that are important for their further development. In particular, one of the long-standing questions, namely the mechanism of charge carrier generation, is still not fully understood. The active material of organic solar cells consists of a blend of donor and acceptor materials. The generation of charge carriers takes place when an electron transfer from the donor to the acceptor takes place under optical excitation of one of the two materials. The generation of charge carriers is a complex phenomenon that involves several steps, from the generation of neutral exciton states to the formation of charge transfer states and their separation against Coulomb attraction. The thermally activated electron motion is considered to be the most important process driving carrier separation. However, the relatively weak temperature dependence of the efficiency of charge carrier generation in some solar cells indicates that another mechanism must also be present.

Here, we have addressed the mechanism of charge carrier generation by studying the ultrafast dynamics of free carrier formation at different temperatures in an efficient all-organic blend PM6:Y6. It was observed that the generation occurs through ultrafast and several picoseconds phases. Surprisingly, the ultrafast phase becomes stronger at low temperatures, while the picosecond component weakens. We attribute the ultrafast phase and its unusual temperature dependence to the coherent propagation of the electron density distribution, which is disturbed and becomes less important at high temperatures.