Modern technology largely relies on integrated photonics, employing optical signals for efficient, reliable and fast communication means. One of its major challenges is pertinent to the mismatch between large-scale integrated photonics and small-scale electronics. The rapidly developing field of plasmonics promises the generation, processing, transmission, sensing and detection of signals at optical frequencies localized on the sub-wavelengths scale. Enjoying multiple applications in a plethora of fields, including biophotonics and medicine, the most profound impact of plasmonics is related to the information transfer at optical bandwidths. In this approach, optical communication is mediated by surface plasmons, electronic excitations localized at metallic surfaces. These excitations can be turned on and off by external magnetic fields, giving rise to the field of magneto-plasmonics, albeit the sensitivity and operation rates of such devices are far from being sufficient. Naturally, steady external control of these excitations on the ultrafast timescale is highly desirable for the broadband applications. Thus, the ability of optical control of surface plasmon propagation is a key milestone in active photonics is. Yet, direct laser irradiation significantly increases heat losses, which is why other, indirect methods of optical control are required.

In this project, we propose utilizing the achievements of ultrafast spintronics for the active plasmonics. In particular, laser excitation of a ferromagnetic thin film enables injection of spin-polarized electrons into the adjacent metallic layer. Due to the fast (sub-picosecond) relaxation of these highly non-equilibrium electrons, the metal conducts an ultrashort spin current pulse and transiently magnetizes, thus rendering unnecessary the application of external magnetic fields. This magnetization can be utilized for the active modulation of surface plasmons resonances in the metal, being operative on the ultrafast timescale. Importantly, in this approach the plasmons are not subjected to the direct laser irradiation, thus ruling out the heating of the communication devices and associated signal and sensitivity losses.

Within this project, we shall analyze multiple aspects of this electron injection. The project encompasses modeling and experimental optimization of the metallic surface for the most efficient spintronic control over the excitation and propagation of the plasmons. Moreover, we aim at developing a theoretical formalism for the time-resolved plasmonic response, which could be applicable to arbitrary metallic systems and spin current pulses. This formalism is highly promising for the ambitious goal of indirectly engineering plasmon losses at the ultrashort timescale. As an ancillary but important goal, we shall analyze the ultrafast nonlinear-plasmonic response in the presence of spin currents. Successful realization of the objectives declared in the proposal is likely to open a new branch of ultrafast photonics, stimulate extensive interdisciplinary research at the crossroads of plasmonics and spintronics and pave the way towards novel photonic devices and applications.