Surface plasmon-polaritons (SPP) are collective excitations of the conduction electrons and the electromagnetic field on the surface of such good metals as gold and silver. The wave vector of a SPP diverges near the frequency of surface plasmon resonance, which is located in the visible range. Thus, the use of SPP allows the diffraction limit of the optical field to be shifted down to the nanometer scale: optical energy may be guided by nanometer-scale SPP waveguides, and SPP-based microscopy may potentially be developed, which would allow direct visualization of individual viruses and molecules. In addition, strong concentration of optical energy facilitates nonlinear interactions of surface plasmon-polaritons, which opens new possibilities for making active nanophotonics devices.

Understanding and building novel nanophotonics devices is based on new and interesting physics. Since a SPP exists in a “curved three-dimensional space-time”, which is defined by the shape of the metal sample and the spatial distribution of the dielectric constant near the metal-dielectric interface, the nonlinear optics of surface plasmons may be treated as a quantum field theory in a curved space-time background. For example, a nanohole in a thin metal membrane may be treated as a “wormhole” connecting two “flat” surface plasmon worlds located on the opposite interfaces of the membrane. In another example, a droplet of dielectric on a metal surface behaves as an effective “black hole” for surface plasmons. An effective “Planck length” may be introduced in nonlinear plasmon nanooptics, which defines quantum fluctuations of the refractive index near the metal-dielectric interface, and may be as large as 50 nm. It may also define the large-momentum cutoff of the SPP dispersion law.

This “field-theoretical” approach appears to be rather fruitful in explaining the enhanced nonlinear optical mixing in nanostructured metallic samples.

During my talk I am going to review my experimental and theoretical research in this new and exciting field of optics.