

# Near-field characterization of plasmonic waveguides

Volodymyr Zenin

This Ph.D. thesis is based on a study of metallic nanostructures, capable of guiding information and energy at nearly optical speed and frequency – plasmonic waveguides. The guided electromagnetic wave is a coupled oscillation of electromagnetic field and surface charge density in metal, therefore such wave is confined to the metal-dielectric interface. Conducting electrons in metals are not strongly attached to particular atoms and molecules, so they behave as free charges in plasma, which gave the name for this discipline – “plasmonics”. There are many electromagnetic waveguides around us – for example, copper wires, conducting electric current, or optical fibers, transmitting light over the kilometers-long distance and enabling streaming of large amounts of data through the whole globe. However, each of the mentioned above waveguiding options has its drawbacks: electric circuits can be made tiny (modern facilities allows fabrication with smallest feature size of  $\sim 14$  nm), but they are fundamentally limited in frequency (and correspondingly the speed of data transmission) to  $\sim 1$  GHz = 1 000 000 000 Hz; while the optical circuits are fast (with a frequency of  $\sim 300$  THz = 300 000 GHz), but they are fundamentally limited in size by the diffraction limit (transverse dimensions are restricted by approx. wavelength  $\sim 500$  nm). Therefore the high density of circuit elements and large speed of transmitting information are not achievable at the same time for electric and optical circuits. Plasmonic waves, which have optical frequency and are bound by their inherent nature to the metal-dielectric interface, can thus overcome the abovementioned trade-off. Moreover, the plasmonic waveguides are expected to bridge electric and optical circuits due. Thus the investigation of plasmonic waveguides is of high interest nowadays.

The experimental research of plasmonic waveguides is quite complicated – mostly due to the confinement of electromagnetic field (called also near-field due to the confinement) to the metal interface of nanometer-size waveguides. For such purpose several complicated technics were developed during the last years, but the most straight-forward approach would be to put a tiny probe close to the metal interface and measure the near-field of plasmonic wave. Such approach is called a scanning near-field optical microscopy (SNOM), where the information is gathered by scanning point-by-point a particular line, area or volume. There are two basic modifications of SNOM: fiber SNOM, which uses a sharpened optical fiber as a probe to collect the near-field from each point, and scattering SNOM, where an opaque sharp probe scatters the near-field at each point, which is then detected. Both modifications of SNOM have been used in this project to study plasmonic waveguides and waveguide components. Additionally, theoretical consideration and numerical simulation of some waveguides have been performed.