On the Efficient Modeling of SNOM Tip Configurations in Nano-Optics

Pegah Souzangar

Electromagnetic Fields and Microwave Electronics Lab, ETH Zurich
Seminar of Applied Mathematics, ETH Zurich

A SNOM (scanning Near-field optical microscopy) is a device for sub-wavelength optical imaging of nanometer size samples. The most important part inside a SNOM is a probing device (tip) that couples electromagnetic field distributions emerging from tip and the sample. Since the shape of a tip usually does not change for different samples and the size of the tip is much larger than the sample being imaged, it is worthy to model the tip once with high accuracy, even with high computational cost, and use the model for numerical analysis of different samples and different locations of the tip with respect to the samples in nano-optics. Since the computational cost for the tip modeling occurs only once, this leads to considerable time and memory savings.

In the spirit of a domain decomposition idea, we aim to model the tip with an equivalent non-local impedance type boundary condition that will replace the tip in the computational domain of sample-tip configurations. This is done through the computation of an approximate Dirichlet to Neumann (DtN) map for the boundary of the region encompassing the tip. During numerical simulation, this can be coupled to the space surrounding the sample in order to model the impact of the tip. When computing the DtN matrix resulting from a Finite Element discretization of the tip model, local mesh refinement and mesh grading are indispensable for dealing with the hugely different length scales involved in the tip configuration. Therefore, an hp-finite element method is used.

The obtained DtN impedance matrix is dense and huge, but can be compressed by means of local low-rank approximation (hierarchical matrix format) in order to save memory and accelerate computations. Matrix compression is achieved using the so-called adaptive cross approximation (ACA) implemented in the AHMED library by M. Bebendorf.