Modeling of the extraction of a focused ion beam from an inductively coupled plasma source.

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Ion beam trimming (IBT) is a special case of ion beam etching (IBE), used to locally modify or correct the surface of substrates or optics with a focused ion beam, e. g. for the utilization in augmented reality devices, MEMS or telescope mirrors. As different applications require various ion beam characteristics such as beam widths matching the respective length scale of the topography error, the ion source and its operation conditions have to be adjusted accordingly. If an appropriate simulation model of an ion source would be available it would simplify the development and accelerate experimental examinations, by predicting the ion beam properties in advance without building up several prototypes.

Subject of this work is, to simulate an ion source, especially regarding its operation conditions and beam properties. In a first stage, a positive Ar-ion beam is studied, extracted from an inductively coupled plasma (ICP) through a three-grid multi-aperture system. Therefore, we have applied, two simulation approaches.

First, the trajectory code named IBSimu [1] was used. The influence of the plasma on the ion trajectories is described through a plasma sheath/meniscus approximation. Modeling the complete extraction system, results in a simulated ion beam, whose qualitative properties are in agreement with the experiment. Therefore, the approach is suitable for the examination of basic trends of the ion beam, depending on different operation conditions. However, some compromises in the physical description of the model are made, e. g. an rather simple approximation of the space charge compensation.

To overcome limitations of the first approach and describe the interaction of the ion extraction with the ICP physically coherent, the coupled particle-in-cell (PIC) and direct-simulation monte-carlo (DSMC) code PICLas [2] is used. Physical properties of the real system are described more adequate by regarding several particle species and their interactions. The electrons within the model are described not only kinetically, but rather by using the Boltzmann relation. Together with the exploitation of the source's symmetry, the computing time could be reduced from several days to some hours. By varying input parameters like the plasma density or potential, the resulting simulated ion beam, can show similar qualitative and quantitative behaviour, as observed in the experiment. Now a first prediction of the plasma characteristics of the source is possible, as they are not yet experimentally examined. Both approaches offer different advantages in their description of the ion source and should be combined for the prediction, analysis and optimization of the ion beam properties.

[1] T. Kalvas et al., Review of Scientific Instruments 81, 02B703 (2010)

[2] P. Ortwein et al., 2017 IEEE International Conference on Plasma Science (ICOPS), pp. 1-1 (2017)