ION ACCELERATION THROUGH A MAGNETIC BARRIER SINGLE STAGE AND DOUBLE STAGE HALL THRUSTER

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In a Hall thruster, a plasma is formed in a channel between two concentric dielectric cylinders. The anode is placed at one end of the channel and an emitting hot cathode is located outside the channel. In a standard, single stage Hall thruster, neutral atoms are emitted on the anode side and are ionized by electrons emitted from the external cathode. A radial magnetic field, maximum in the exhaust region of the channel, is generated by coils (or magnets) and a magnetic circuit. The presence of this radial magnetic field, perpendicular to the electron current from cathode to anode, leads to a drop of electron conductivity and to the generation of a large axial electric field in the quasineutral plasma of the exhaust region. Ions (which are practically not magnetized) are extracted from the plasma by this electric field. The combination of axial electric field E and radial magnetic field B leads to a large EXB electron drift in the azimuthal direction (closed drift). Efficient operations of a Hall thruster are obtained when the injected gas flow is almost completely ionized by electrons emitted from the external cathode and accelerated by the axial electric field. The gas flow being practically fully ionized in the channel, the gas density in the exhaust region is very small. Because of the small neutral atom density in the exhaust region, electron transport through the magnetic barrier cannot be due to classical, collisional mechanisms.

In a first part of this lecture, we discuss, on the basis of particle simulations, the mechanisms of electron transport across the magnetic barrier, and the possible role of instabilities and turbulence.

In a second part of the lecture we address the question of double stage thruster. In the operation of a single stage thruster described above, the same electric field controls the electron energy (and therefore ionization), and the velocity of the extracted ions. Therefore, it is difficult to control separately the thrust and specific impulse (i.e. the velocity of the extracted ions). Telecommunications satellites will use only electric (plasma) thrusters in a very near future, and the new generation of electric thrusters must be able to operate efficiently for satellite station keeping as well as for orbit transfer. Therefore, there is a need to develop more versatile electric thrusters, able to operate in a large range of thrust and specific impulse (large thruster for orbit transfer, large specific impulse for satellite station keeping). The idea behind the concept of double stage Hall thruster is to use a plasma source (ionization stage, or first stage) upstream of the magnetic barrier, to control ionization separately from ion acceleration (acceleration stage, or second stage). In such double stage thruster, thrust would be controlled in the ionization stage by the power injected in the plasma source, while specific impulse could be adjusted in the acceleration stage, by the applied voltage. Different types of ion sources have been proposed in the literature for the ionization stage. In this lecture, we will describe and compare some of the different attempts at designing double stage Hall thrusters, discuss the concept of ion acceleration through a magnetic barrier in these thrusters, and propose directions for new designs.