大振幅電磁波ビームの強度空間勾配による宇宙プラズマ擾乱に関する計算機実験

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Computer experiments on space plasmas perturbation caused by a spatial gradient of intense EM beam intensity

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In SPS(Space Solar Power System), electric power generated with solar cells installed on the satellite is transferred to the ground by intense microwave beam. In the energy transfer to the ground with microwave beam, we need to consider the interactions between the microwave beam and the ionospheric plasmas.

In our study, we particularly focus on the plasma perturbation and its associated field perturbations by Ponderomotive force which is one of the nonlinear interactions caused by the spatial gradient of the electric field intensity. We performed computer experiments with electromagnetic PIC (Particle-In-cell) model prior to the real experiments in the ionosphere and real SPS, and analyze the effects on the energy transfer by SPS of the Ponderomotive force.

From the simulation results, we find out the basic process of plasma perturbation by Ponderomotive force. When the electromagnetic (EM) beam propagates in the plasma, Ponderomotive force moves electrons out of the beam and ions are left at first because the Ponderomotive force on ions is much smaller than that on electrons. Therefore a charge-separation electric field is created and the electric force by this charge-separation field moves ions out of the beam. This process continues until Ponderomotive force, the electric force, and the pressure-gradient force on electrons or ions are balanced. After all, the plasma density inside the beam becomes smaller than outside at the steady state. From the fluid equations at the steady state and by approximating that electron and ion density is almost equal, we derive the approximate density variation by Ponderomotive force and estimate the density variation with parameters of SPS. With these plasma perturbations, electro-static ion waves which propagate radially to the EM beam are enhanced.

The plasma perturbation mentioned above is caused by the EM beam which has a much stronger intensity and a lower frequency than those of SPS. In the computer experiments with parameters of SPS, we can’t observe the plasma perturbation and associated field perturbations by Ponderomotive force. Although we can’t observe the plasma perturbation and associated field perturbations by Ponderomotive force in the computer experiments with parameters of SPS, we believe that it is important to evaluate the threshold value of the microwave beam intensity of SPS for this nonlinear density perturbation. In this aspect, the nonlinear analysis with PIC simulations is very useful.