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Limitation of the ECRIS Performance by Kinetic Plasma Instabilities

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Electron cyclotron resonance ion source plasmas are prone to kinetic instabilities due to the anisotropy of their electron energy distribution. The instabilities are associated with strong microwave emission and periodic bursts of energetic electrons escaping the magnetic confinement. The experimental setup used for detecting the instabilities is described. It is shown that the repetition rate of the periodic instabilities increases with increasing magnetic field strength and microwave power and decreases with increasing neutral gas pressure, the magnetic field strength being the most critical parameter. The effect of the ion source parameters on the growth and damping rates of the instabilities are discussed qualitatively. The instabilities explain the periodic ms-scale oscillation of the extracted beam current observed with several high performance ECRISs and restrict the parameter space available for the optimization of extracted beam currents of highly charged ions. Experiments with the JYFL 14 GHz ECRIS have demonstrated that due to the instabilities the optimum B_{\min} -field is less than $0.8B_{\text{ECR}}$, which is the value suggested by the semiempirical scaling laws guiding the design of modern ECRISs. Finally, the effect of the instabilities on the energy spread of the extracted ion beams is described and possible methods to mitigate their effect on ECRIS performance are discussed.