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Collective Temperature Anisotropy Instabilities in Intense Charged Particle Beams[1]

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Periodic focusing accelerators, transport systems and storage rings have a wide range of applications ranging from basic scientific research in high energy and nuclear physics, to applications such as ion-beam-driven high energy density physics and fusion, and spallation neutron sources. Of particular importance at the high beam currents and charge densities of practical interest, are the effects of the intense self fields produced by the beam space charge and current on determining the detailed equilibrium, stability and transport properties. Charged particle beams confined by external focusing fields represent an example of nonneutral plasma. A characteristic feature of such plasmas is the non-uniformity of the equilibrium density profiles and the nonlinearity of the self fields, which makes detailed analytical investigation very difficult. The development and application of advanced numerical tools such as eigenmode codes [1] and Monte-Carlo particle simulation methods [2] are often the only tractable approach to understand the underlying physics of different instabilities familiar in electrically neutral plasmas which may cause a degradation in beam quality. Two such instabilities are the electrostatic Harris instability [2] and the electromagnetic Weibel instability [1], both driven by a large temperature anisotropy which develops naturally in accelerators. The beam acceleration causes a large reduction in the longitudinal temperature and provides the free energy to drive collective temperature anisotropy instabilities. Such instabilities may lead to an increase in the longitudinal velocity spread, which will make focusing the beam difficult, and may impose a limit on the beam luminosity and the minimum spot size achievable in focusing experiments. This paper reviews recent advances in the theory and simulation of collective instabilities in intense charged particle beams caused by temperature anisotropy. We also describe new simulation tools that have been developed to study these instabilities. The results of the investigations that identify the instability growth rates, levels of saturations, and conditions for quiescent beam propagation will also be discussed.

[1] E.A. Startsev and R.C. Davidson, Phys.Plasmas 10, 4829 (2003).

[2] E.A. Startsev, R.C. Davidson and H. Qin, Phys.Rev. ST Accel. Beams 8,124201 (2005).

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