A laboratory experiment to demonstrate magnetospheric cyclotron maser mechanisms

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Electrons precipitating into the Earth's polar magnetosphere experience adiabatically increasing levels of magnetic field and conservation of the magnetic moment results in conversion of momentum orientated along the magnetic flux to rotational motion. This leads to the formation of a horseshoe shaped distribution in electron velocity space with regions where $dn/dv_{\perp}$ is positive. Such distributions have been observed in the auroral magnetosphere and have been shown to be unstable to emission of radiation in the X-mode at the cyclotron frequency. Satellites have observed radiation with such properties being emitted from regions of depleted background plasma density in the auroral magnetosphere, where it is referred to as Auroral Kilometric Radiation (AKR). The dominant emission frequency is around 300kHz with an efficiency of conversion from the auroral electron precipitation energy to wave field energy of up to 1%. Theoretical analysis shows that the parameters of the instability are scaled to the cyclotron frequency, which opens the possibility of reproducing important aspects of this process in a controlled laboratory experiment by increasing the magnetic flux density to provide a cyclotron frequency in the microwave band. This paper will present results obtained from such an experiment, demonstrating that there is sufficient free energy in such electron distributions to explain the magnetospheric observations. Electrons injected into the experiment using a specially designed electron gun were subjected to a controlled magnetic compression of up to a factor of 30. The electrons were brought into resonance with near cut-off TE modes of a cylindrical waveguide at either 4.42 or 11.7GHz as these modes have similar polarization and propagation properties to the X-mode. The experiment confirmed that the radiation was emitted at the cyclotron frequency and measured the radiation output mode. The conversion efficiency from beam power to wave power varied between 0.5 and 2% in a manner consistent with measurements of the electron distribution in velocity space. The experimental results are therefore in close agreement with the observations from the magnetosphere and also correlate well with the predictions of PiC code simulations which will also be presented.