Development of an Experimental Method to Investigate $^3$He-$^3$He Fusion with Inertial Electrostatic Confinement Techniques

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Purpose

Nuclear Physics
• The $^3$He($^3$He,2p)$^4$He fusion reaction is interesting to nuclear physicists because it is poorly characterized at energies less than 200 keV

Solar Physics
• A long proposed resonance in the $^3$He($^3$He,2p)$^4$He fusion cross section could help explain a discrepancy between theoretical predictions and measurements of neutrino emanations from the sun

Fusion Energy
• $^3$He-$^4$He fusion offers the potential of nuclear fusion without nuclear waste
• $^3$He-$^3$He fusion requires high ion energies, which necessitates high cathode voltages and low neutral gas pressure

Inertial Electrostatic Confinement (IEC)
• IEC technology provides a method to achieve high ion currents through recirculation at energies of up to a few hundred keV

IEC Theory
• See poster JP1.104 in this session for details: G.A. Emmert and J.F. Santarius, “Multiple Ion Species Effects in IEC Modeling”
• Model shows little attenuation of ion energy for IEC configuration at low pressure

Simulation Conditions:
- $V_{cathode}=150$ kV
- $I_{cathode}=35$ mA
- $P=30$ mPa
- Cathode trans 0.95

Results
• IEC device has been operated at 150 kV, 60 mA, 30 mPa in $^3$He and $^4$He gasses
• Helicon source allows reliable steady state operation at currents up to 75 mA. Source can operate at up to 3 kW, and as low as 600 W
• Experiments with $^3$He-3He show many more proton counts than those is $^4$He

900 second runs at 130 kV (top pair) and 140 kV (bottom pair), 25 mA—Top in each set:$^3$He, Bottom:$^4$He

Detection System
• Next generation detection system (bottom right) will eliminate counts due to background radiation as well as electronic interference

IEC Experiment
• IEC technology confines ions in an electrostatic potential well
• $^3$He-$^3$He reaction requires high ion energies, which necessitates high cathode voltages and low neutral gas pressure
• Combined system has been operated up to 170 kV, up to 75 mA, and at pressures as low as 3 mPa
• High voltage buffer circuit (shown left) decreases instability, and new insulators (right) enable high voltage connection in plasma

Detection System
• Low noise detection system has allowed low count rates to exceed background noise
• Helicon source technology has enabled high ($\sim$75 mA) currents at low (30 mPa=0.2 mtorr) pressures in an IEC device
• Next generation detection system should eliminate remaining background and allow measurements at lower energy

Summary
• $^3$He-$^3$He reactions detected in an IEC device (see ANS TOFE 2006 paper for details)
• Low noise detection system has allowed low count rates to exceed background noise
• Helicon source technology has enabled high (~75 mA) currents at low (30 mPa=0.2 mtorr) pressures in an IEC device
• Next generation detection system should eliminate remaining background and allow measurements at lower energy