Microcontrollers as Gate and Delay Generators for Time Resolved Measurements

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Long Electron and Ion Confinement Times are Necessary to Produce Highly Charged Ions

- Electron collision frequency (ionization):
  \[ \nu_{ei} \sim \langle \nu_{ee}^{90} \rangle \approx \frac{n_e e^4 \ln \Lambda}{\epsilon_0 m_e^{1/2} T_e^{3/2}} \approx 10 \text{ kHz} \]

- Ion production rate:
  \[ \frac{\partial n_i}{\partial t} \sim n_e n_{i-1} < \sigma_{i-1 \rightarrow i} E_I v_e > \]

- Criteria for production of highly charged ions:
  \[ n_e \tau_q \geq 5 \times 10^4 T_e^{3/2} e_{opt} \]

Golovanivsky’s Diagram


Kinetic Instabilities Limit Electron Confinement Times and can Suppress Ion Source Performance

Time Resolved Measurements are Necessary to Understand the Unstable Plasma, must be Timed with Instability Events

\[ \frac{B_{\text{min}}}{B_{\text{RF}}} = 0.577 \]

Diagnostics must be triggered by instability
- Microwave Power Burst
- Bremsstrahlung Burst
- Current Variations

Time averaged measurements do not capture complexity seen in time resolved measurements
- \( \frac{B_{\text{min}}}{B_{\text{RF}}} = 0.567 \)
- \( \frac{B_{\text{min}}}{B_{\text{RF}}} = 0.577 \)

Diagnostics must be triggered by instability
- Microwave Power Burst
- Bremsstrahlung Burst
- Current Variations
Arduino Micro-controllers Provide a Cheap and Flexible way to Perform Time Resolved Measurements

**Arduino UNO**
- Mixed Analog and Digital I/O
- 16 MHz Clock speed
- Programmable Delay and TTL Width
- Approximately 0.667 μs Output Delay
- Analog and Digital I/O
- Inexpensive (~$40)
Apparatus Installation and Application
Preliminary Results

\[ \ln I_{\gamma} \sim -\frac{\hbar \omega}{T_s} \]

- \( T_{s,0\text{ms}} = 93 \text{ keV} \pm 27 \text{ keV} \)
- \( T_{s,8\text{ms}} = 94 \text{ keV} \pm 11 \text{ keV} \)
Summary

- Time resolved measurements are necessary in order to better understand instability events and processes within ECR ion source plasmas

- Microcontrollers can be cheap and flexible gate and delay generators
  - Variable delay and gate widths

- Test measurements successful, but the count rate was too low
  - Demonstrated increased photon intensity immediately after instability
  - Larger photon intensity necessary to improve measurement precision
Thank You for Your Attention!

Questions?