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Broadband Excitation of ECR Plasmas

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Overview

1. Problem to be addressed
2. Approach
3. Results
4. Conclusions
5. Future?

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Problem to be Addressed

The energy transferred to the electrons is given by the amplitude of the in-phase rf field integrated over the “width” of the electron-cyclotron resonance zone.

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Problem

The width of the ECR zone is given by the rf bandwidth (Δf) divided by the field gradient (dB).

$$\frac{\Delta f}{\gamma \cdot \nabla B}$$

γ is the cyclotron frequency (~2.79 GHz/kGauss)

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Problem

Given a constant magnetic field profile, which is more efficient:

- Narrow-band rf with higher peak rf power?
- Wide-band rf with lower peak rf power?

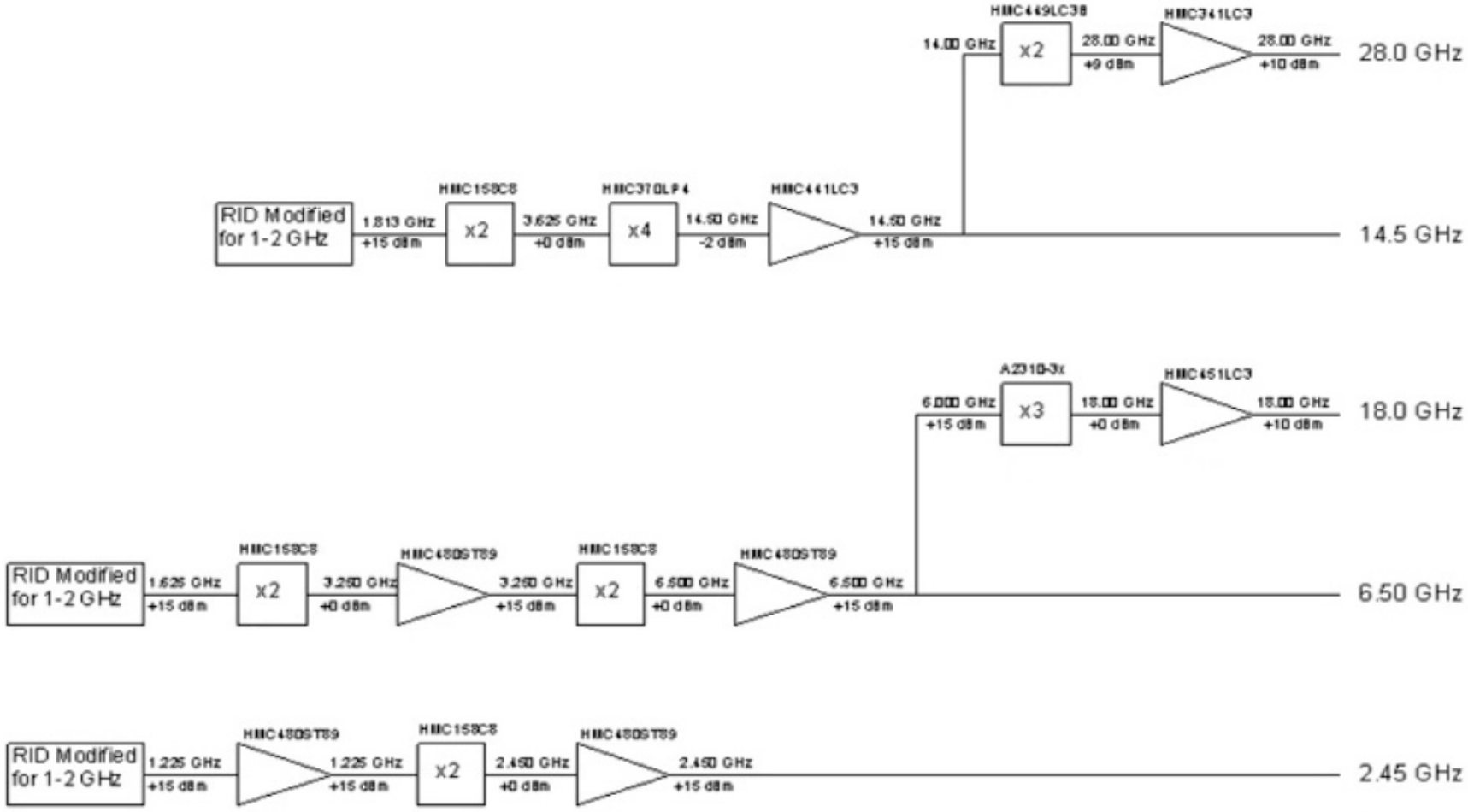
Approach

SSolutions modified a software-defined radio to investigate this question.

- The system was designed to acquire and analyze resonant spectra between 100 and 1000 MHz.
- Modified to produce user-selectable spectra in the 1-2 GHz band.
- These spectra are frequency-multiplied into the common ECR bands.

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Approach



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Approach

Operational Modes:

1. Simultaneous “Comb” Spectrum.
2. Up-Chirp or Down-Chirp.
3. Combination of 1 and 2.

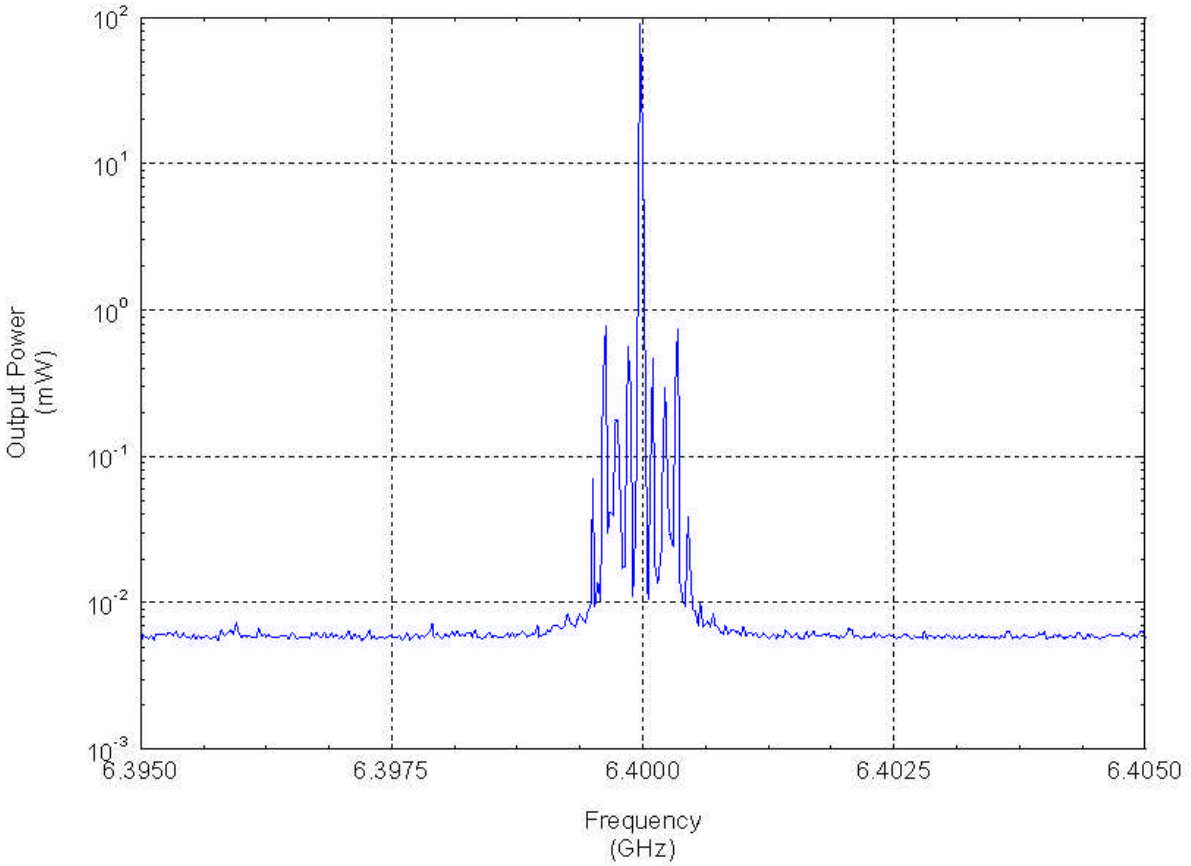
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Approach

Output spectra would not pass FCC requirements (aliased modes and spurious power in sidebands), but are acceptable for ECR applications.

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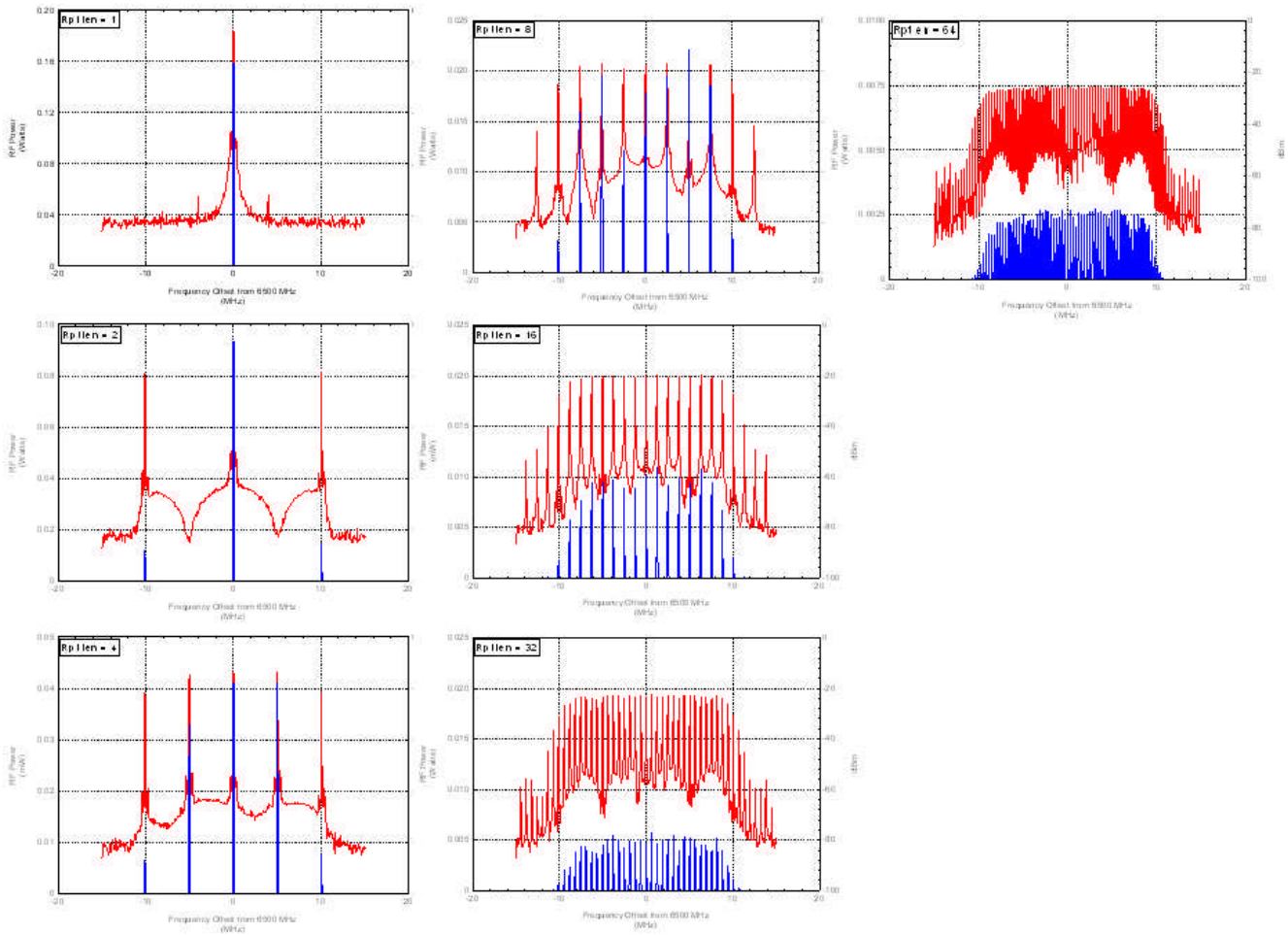
Approach



"Single-mode" spectrum at 6.4 GHz

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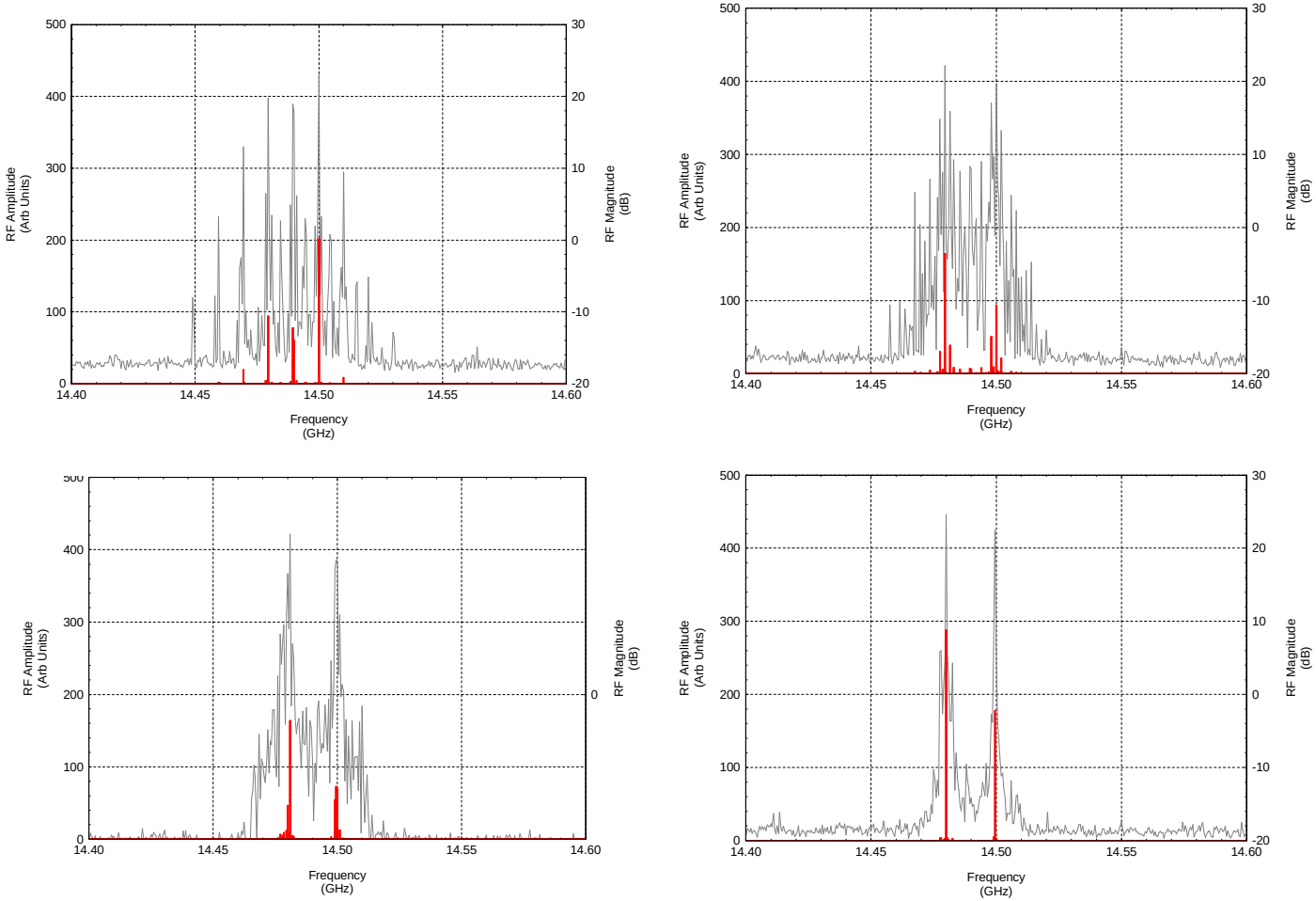
Approach



Simultaneous Frequency Spectra

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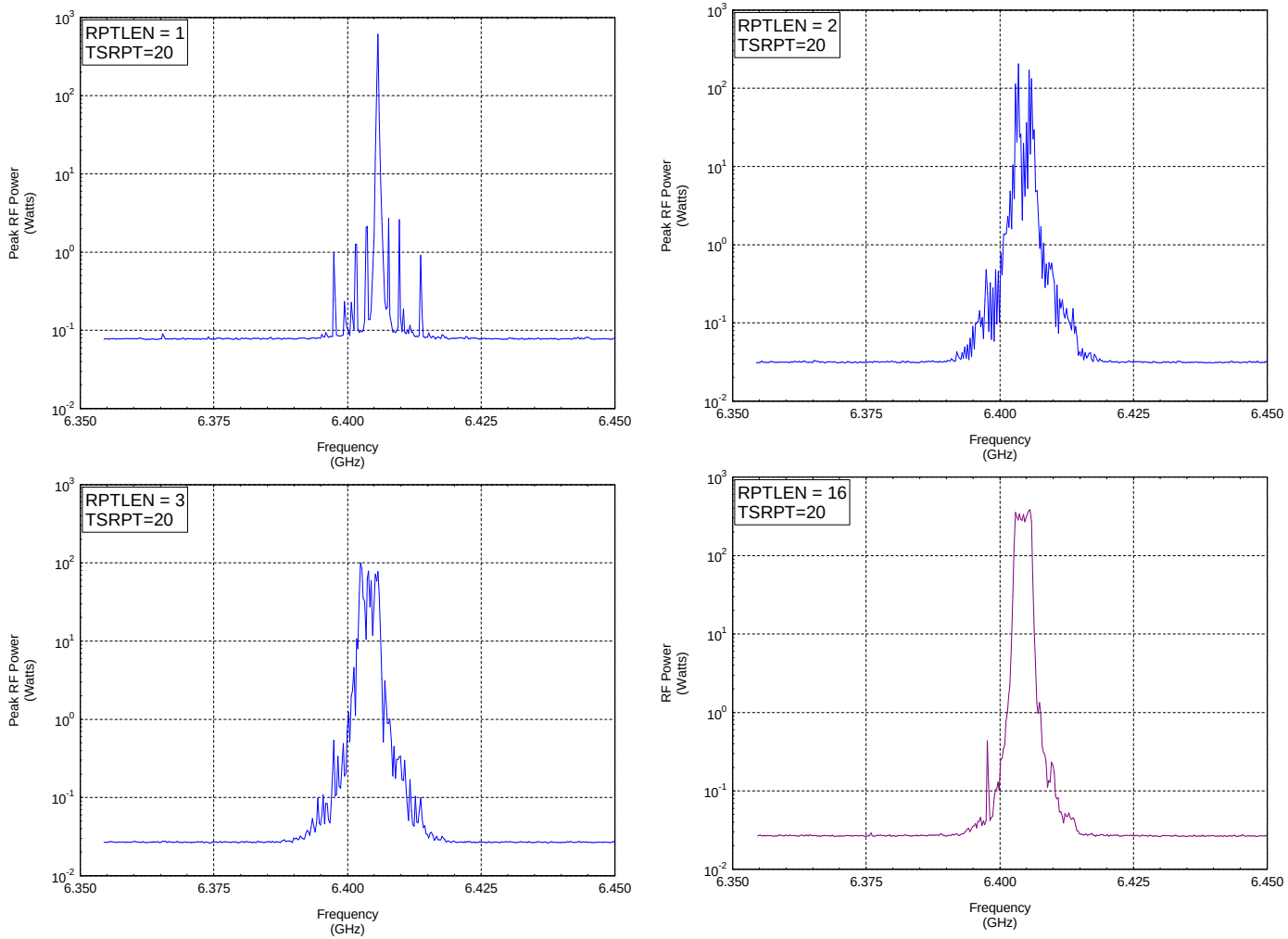
Approach



2-Frequency Chirp Spectrum

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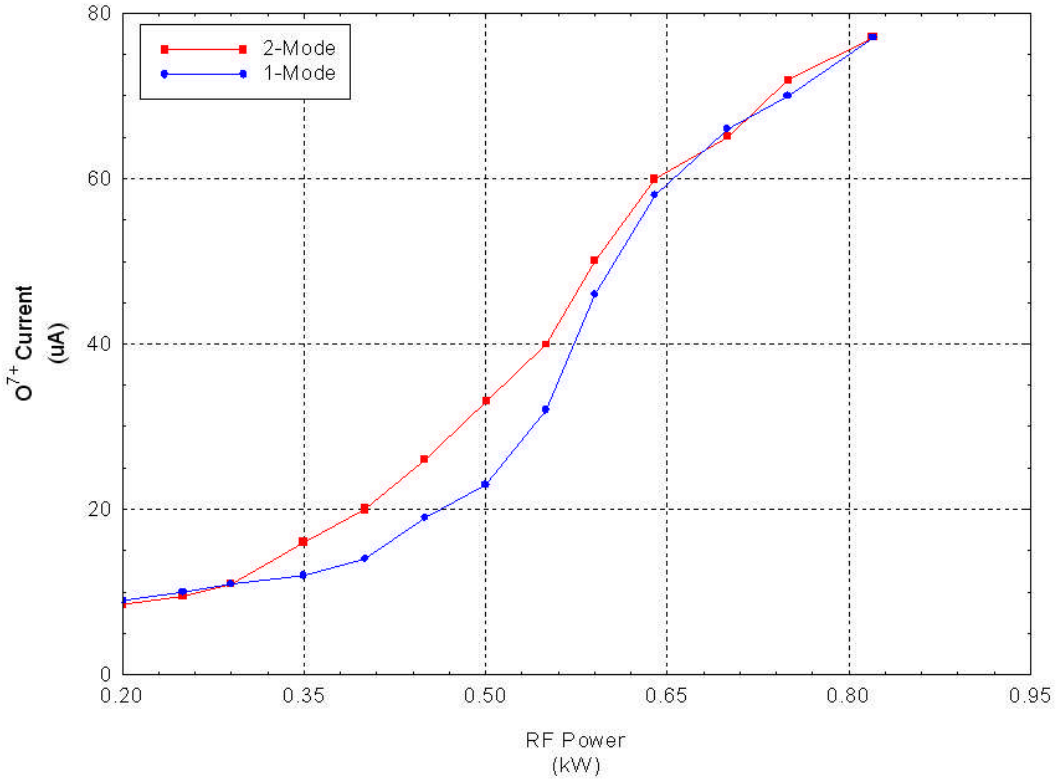
Approach



Chirp Frequency Spectra

Results

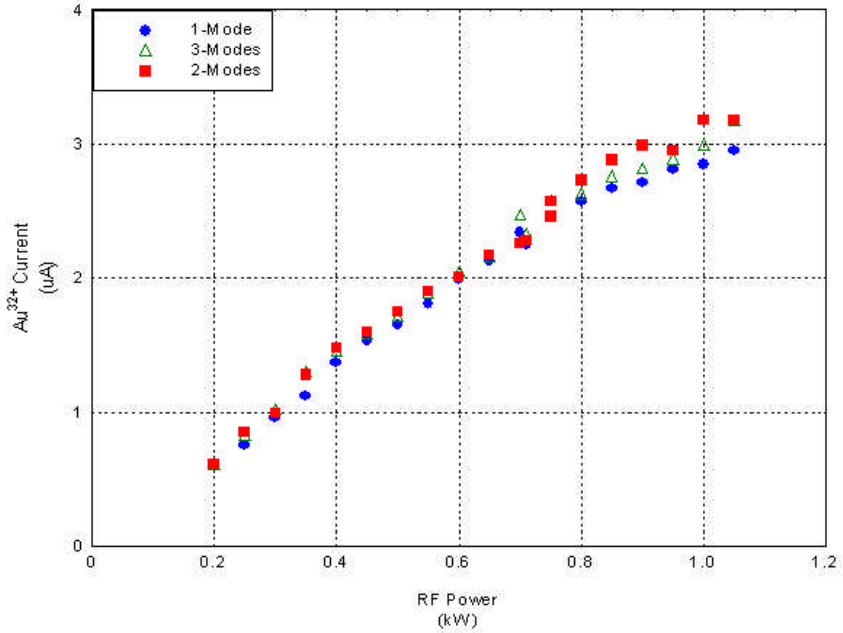
TAMU 14.5 GHz Source



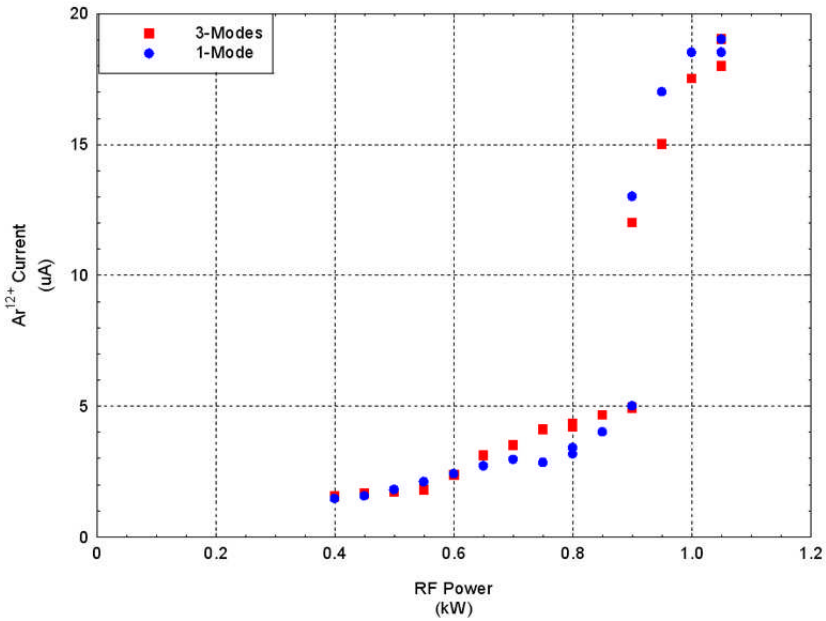
O^{7+}

Results

TAMU 6.4 GHz Source



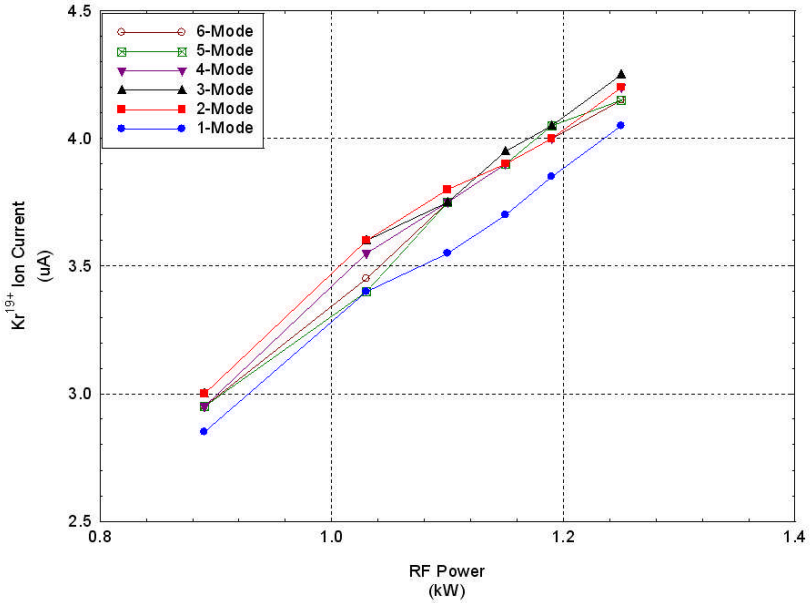
Au^{32+}



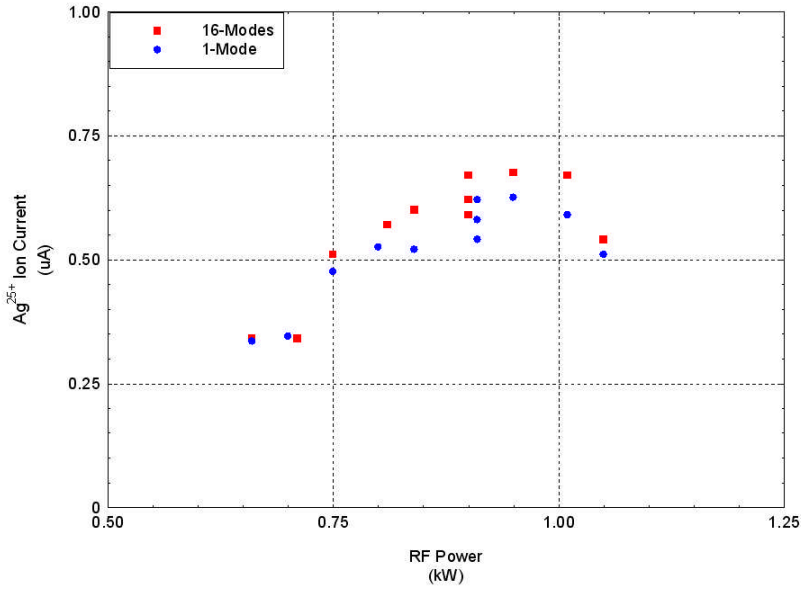
Ar^{12+}

Results

TAMU 14.5 GHz Source



Kr^{19+}

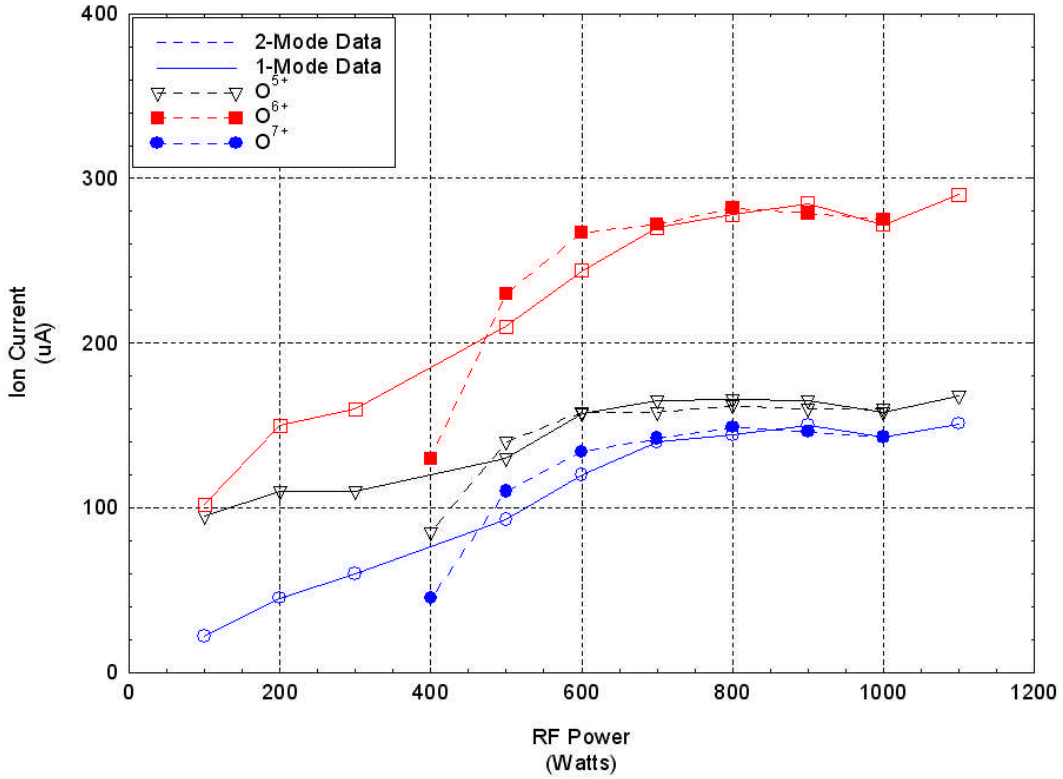


Ag^{25+}

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Results

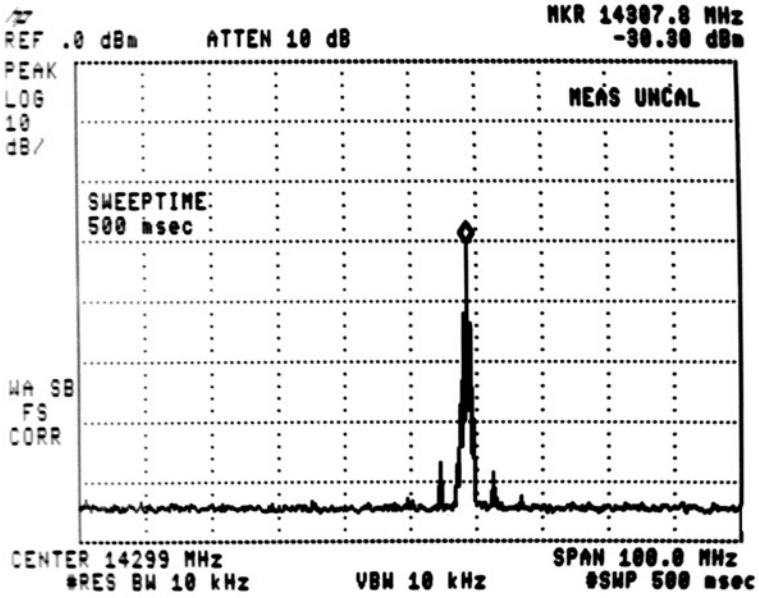
LBNL AECR-U



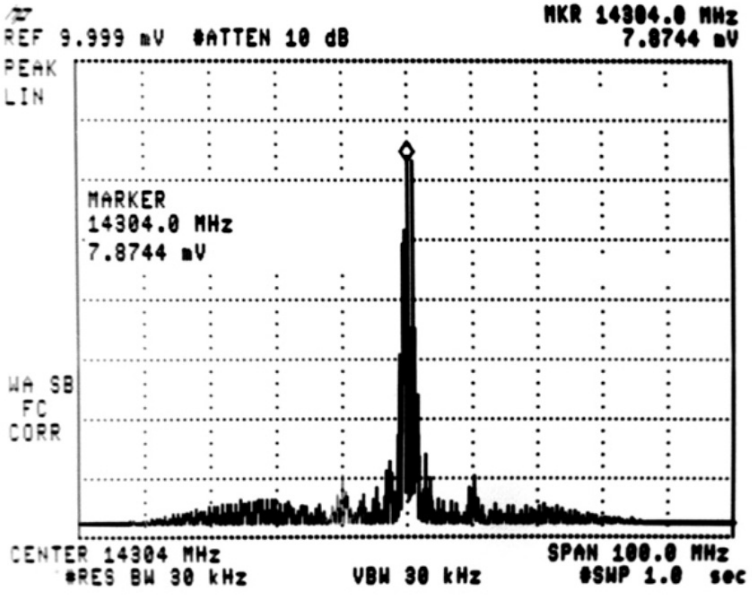
O^{5+} O^{6+} O^{7+}

Tuning?

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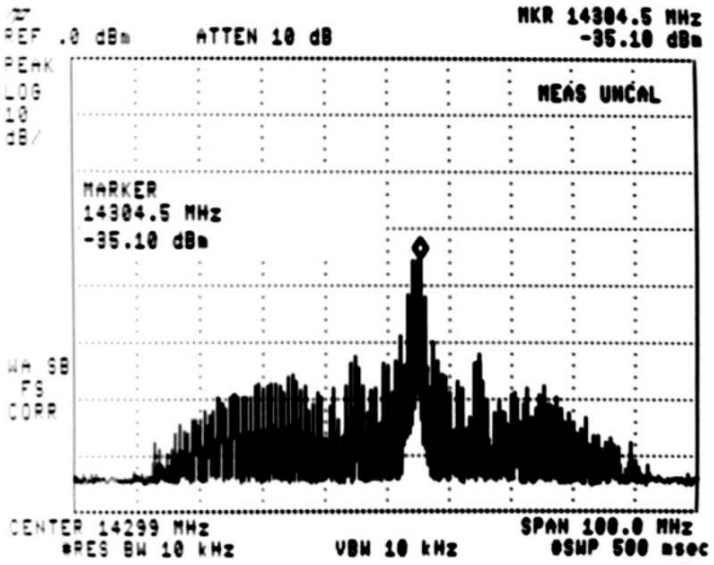
Log Scale



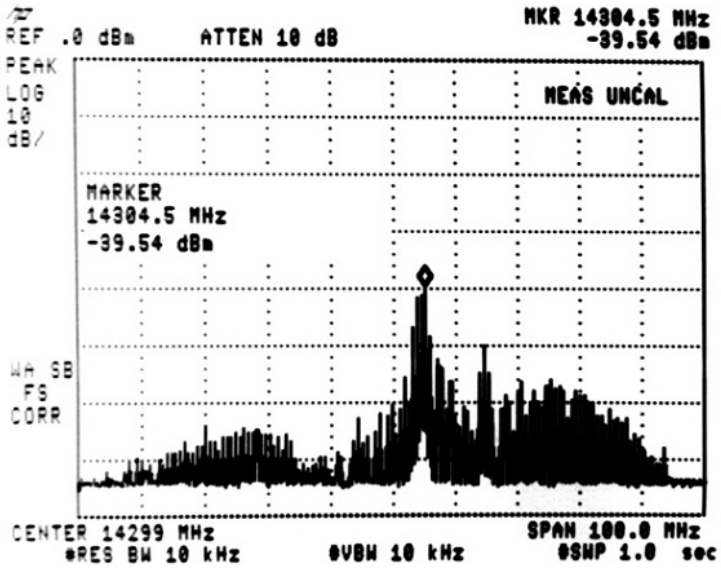
Linear Scale

Tuning?

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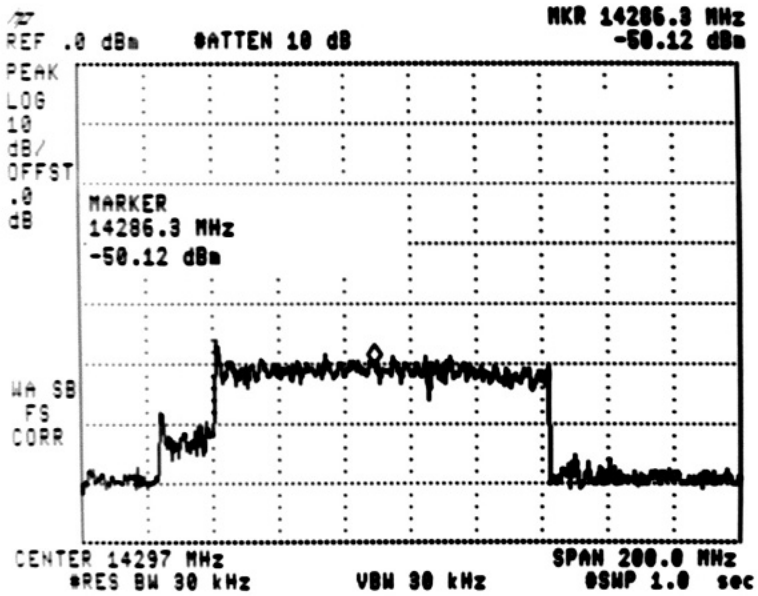
Forward Power



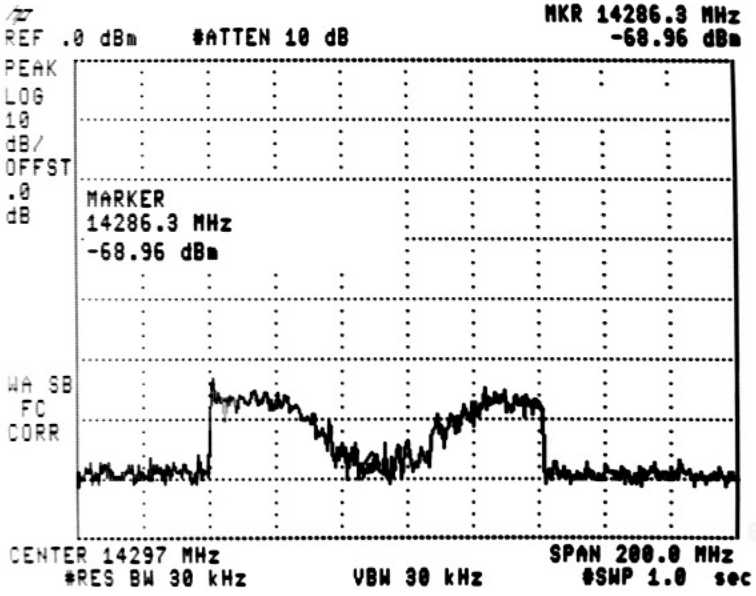
Reflected Power

Tuning?

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Forward Power

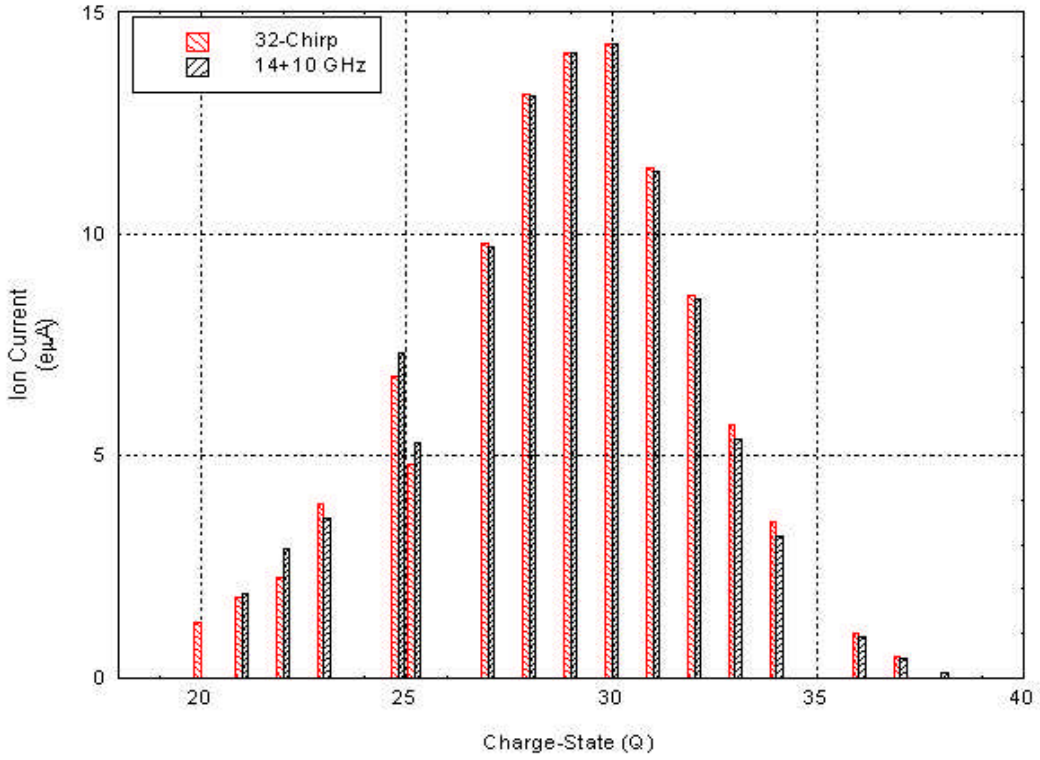


Reflected Power

Results

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2-Frequency Heating (14.5 + 10 GHz)

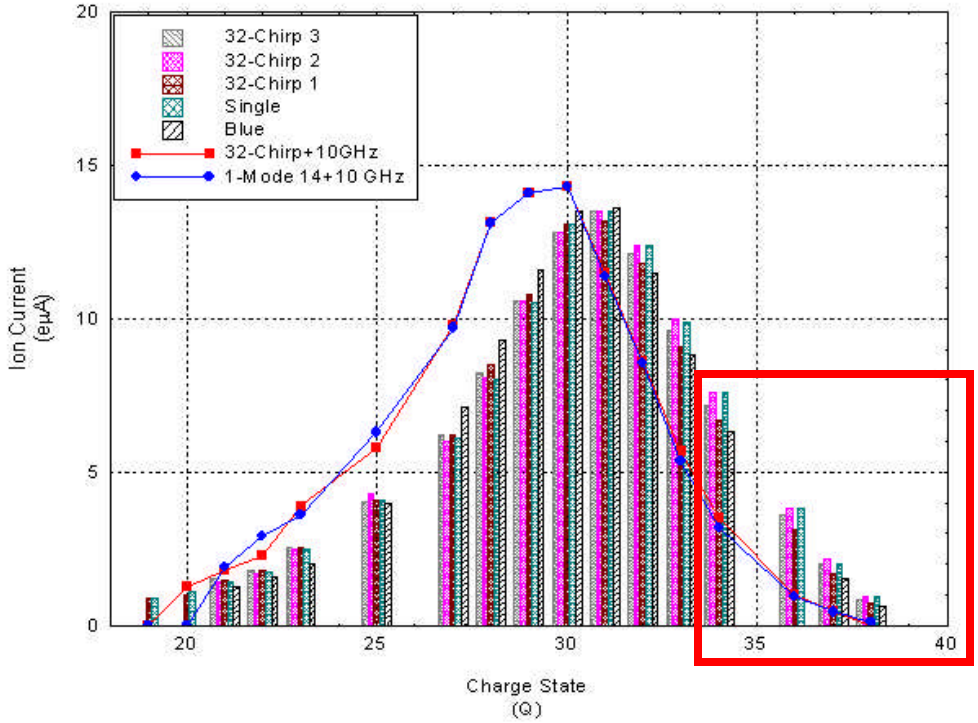


^{209}Bi

Results

LBNL AECR-U

2-Frequency Heating (14.5 + 10 GHz)

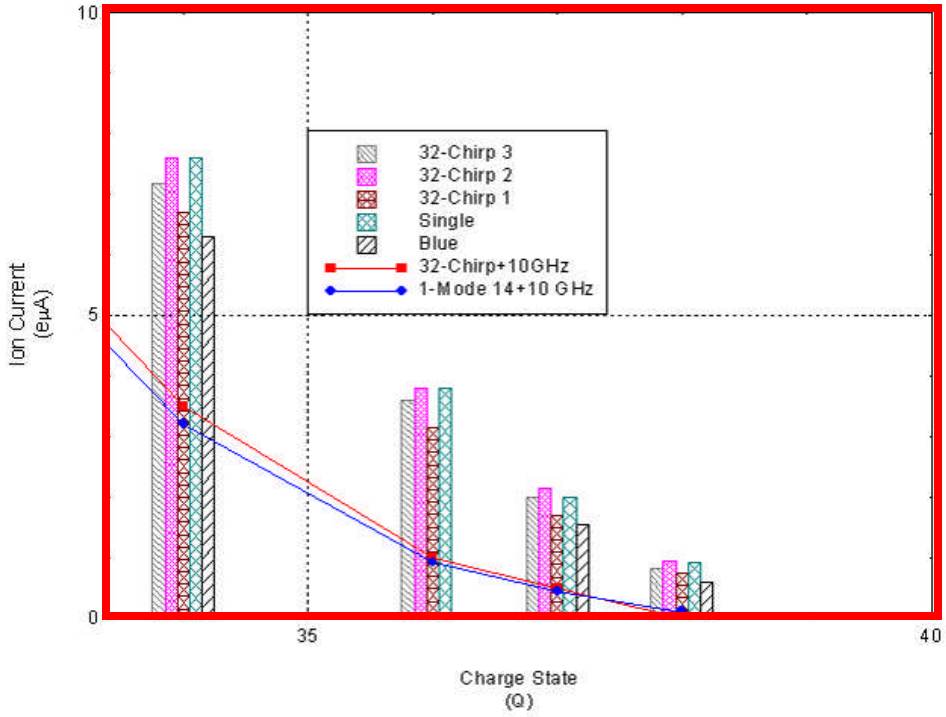


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Results

LBNL AECR-U

2-Frequency Heating (14.5 + 10 GHz)

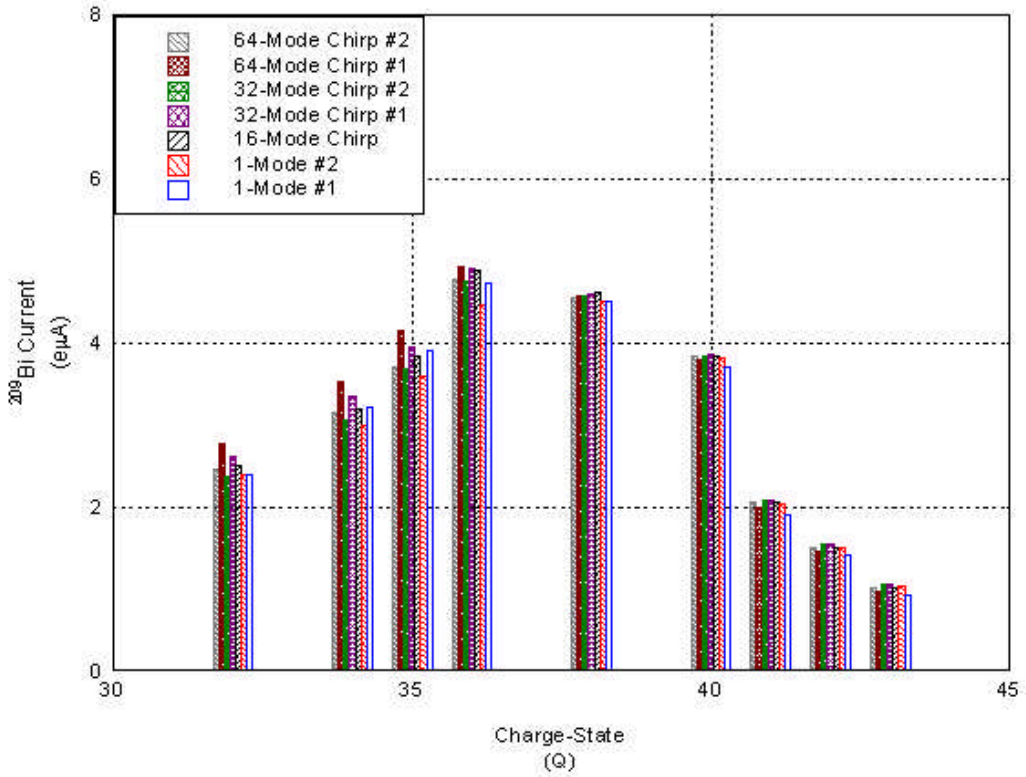


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Results

LBNL AECR-U

2-Frequency Heating (14.5 + 10 GHz)

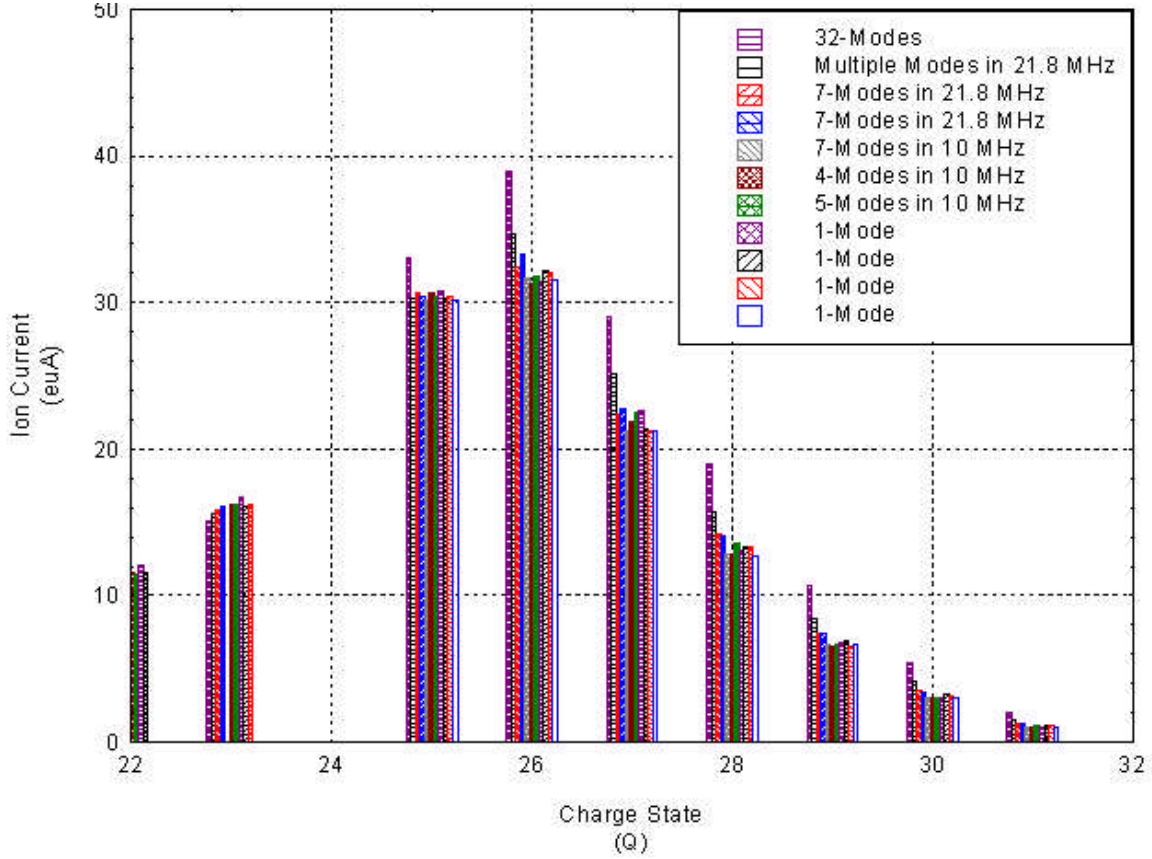


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Results

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Xe

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Conclusions

- Significant improvement in ion current when operating at lower rf power levels.
- Modest improvement in the highest charge-states under certain circumstances.
- Improved operational stability.

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Conclusions

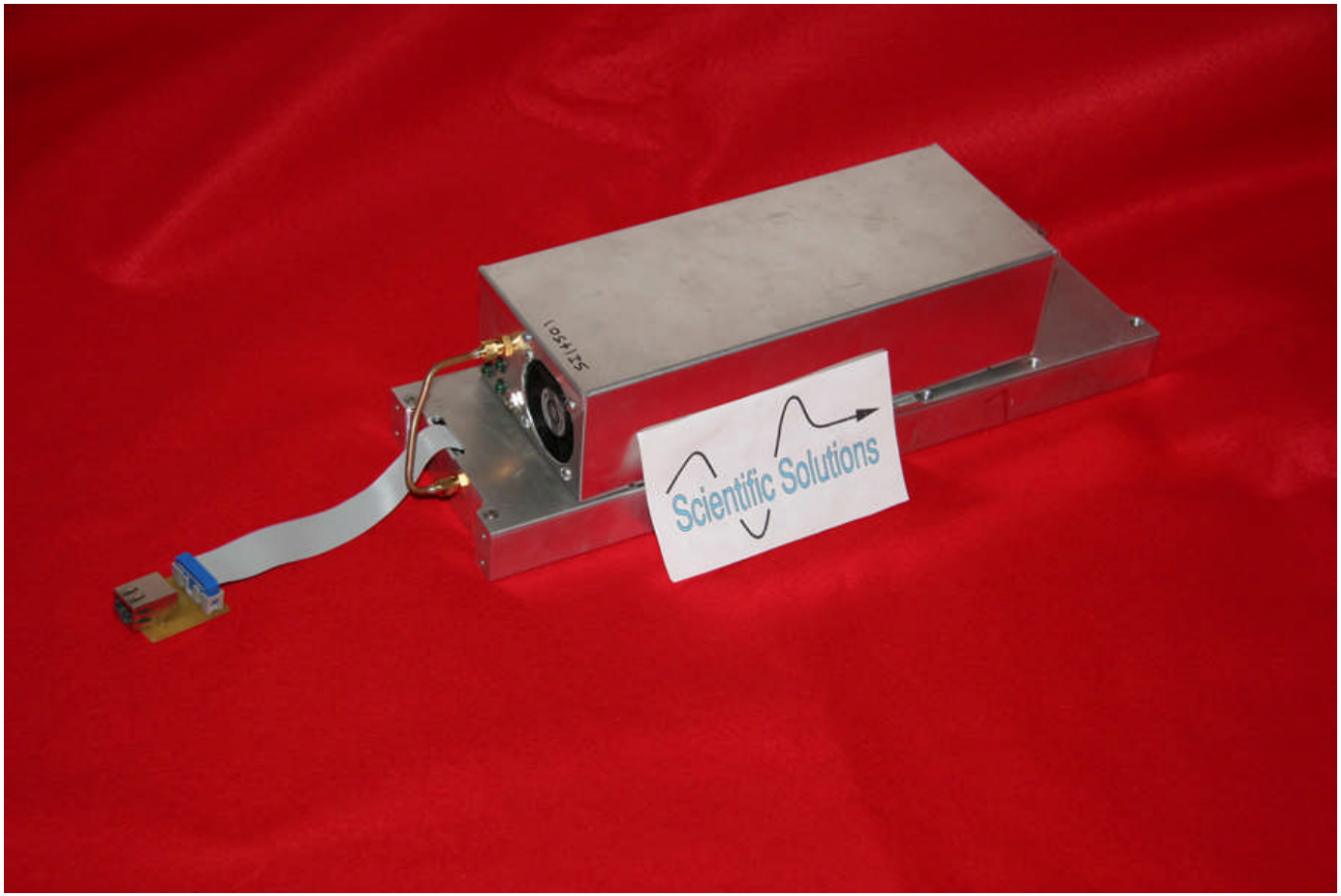
Clearly more testing is needed.

Conclusions

US DoE supported this project under contract Number DE-FG02-04ER84166.

Units can be made available for further testing at DoE-funded facilities.

Conclusions



14.5 GHz RID