Hyperfine anomaly measurements in Francium

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FrPNC Collaboration

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Overview

- Francium trapping facility
- Francium trapping November 2012
- Hyperfine anomaly
- Isotope Shift
The facility

- Francium trapping facility in ISAC I located beneath TITAN platform
- Magneto-optical trap to cool & collect atoms for further experiments
The facility

- Upper trap chamber, commissioned September 2012
The facility

- Upper trap (before optics)

![Image of laboratory equipment with annotations]

- Glass cell
- Yttrium assembly
- Faraday cup + alpha det.
The facility

- Upper trap (after optics)
Francium trapping

- Trapped isotopes: $^{206}\text{Fr}, ^{207}\text{Fr}, ^{209}\text{Fr}, ^{213}\text{Fr}$

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Standard Deviation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{206}\text{Fr}$</td>
<td>16 s</td>
<td>$\sigma \approx 84.00%$, $\epsilon \approx 16.00%$</td>
</tr>
<tr>
<td>$^{207}\text{Fr}$</td>
<td>14.8 s</td>
<td>$\sigma : 95.00%$, $\epsilon : 5.00%$</td>
</tr>
<tr>
<td>$^{208}\text{Fr}$</td>
<td>59.1 s</td>
<td>$\sigma : 89.00%$, $\epsilon : 11.00%$</td>
</tr>
<tr>
<td>$^{209}\text{Fr}$</td>
<td>50.5 s</td>
<td>$\sigma : 89.00%$, $\epsilon : 11.00%$</td>
</tr>
<tr>
<td>$^{210}\text{Fr}$</td>
<td>3.18 M</td>
<td>$\sigma : 71.00%$, $\epsilon : 29.00%$</td>
</tr>
<tr>
<td>$^{211}\text{Fr}$</td>
<td>3.10 M</td>
<td>$\sigma : 87.00%$, $\epsilon : 13.00%$</td>
</tr>
<tr>
<td>$^{212}\text{Fr}$</td>
<td>20.0 M</td>
<td>$\sigma : 57.00%$, $\epsilon : 43.00%$</td>
</tr>
<tr>
<td>$^{213}\text{Fr}$</td>
<td>34.82 s</td>
<td>$\sigma : 99.44%$, $\epsilon : 0.56%$</td>
</tr>
</tbody>
</table>

- Pulsed trap, cycle based on Y heating
Hyperfine anomaly

- Bohr-Weisskopf effect shifts atomic energy levels due to nuclear magnetization distribution
- Probe transition to $P_{1/2}$ level (no electric quadrupole contribution)

  - isotopes $^{208}\text{Fr}$ to $^{212}\text{Fr}$
  - $^{213}\text{Fr}$ neutron shell closure
  - $^{207}\text{Fr}$ neutron deficient, away from single-particle model?

- Will contribute to better understanding of neutron radius of francium isotopes to be used for eventual parity non-conservation measurements
Hyperfine anomaly

- Trap and repump francium on $7P_{3/2}$ transition
- Probe laser set close to midpoint of hyperfine $7P_{1/2}$ states
- Sidebands on laser through fiber modulator at set frequency
- Sideband frequency swept quickly, reproducibly
Hyperfine anomaly

- 10 ms scans cover \( \approx 140 \) MHz
- Peak separation = 2 \times probe detuning
- Sum of peak frequencies = hyperfine splitting

- Preliminary results
7S\textsubscript{1/2} to 7P\textsubscript{1/2} isotope shift

- Isotope shift caused by change in charge radius (mass difference small for heavy nuclei)

- Relative measurements made with respect to \(^{209}\text{Fr}\)
- Kept laser locked from HFA measurement, change RF sideband frequency

- Trap light chopped \(~10:1\) on/off
- Detailed comparison with known 7S\textsubscript{1/2} to 7P\textsubscript{3/2} (Coc et al. \textit{PLB}, '85) may give info on atomic wavefunction overlap with nucleus
Conclusion and Outlook

▶ In conclusion:
  ▶ $^{206}\text{Fr}$, $^{207}\text{Fr}$, $^{213}\text{Fr}$ splittings measured for $7P_{1/2}$
  ▶ Isotope shifts for same

▶ Next:
  ▶ More analysis: systematics, Rb measurements
  ▶ more $^{206}\text{Fr}$, lighter isotopes, possibly $^{221}\text{Fr}$
  ▶ Working towards parity non-conservation measurement
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