We report on our efforts to construct a single-ion-qubit sensor capable of Heisenberg limited detection of external fields that can be efficiently coupled to the ion qubit. Based on a single-ion iterative phase estimation algorithm (IPEA), a quadratic enhancement in quantum phase estimation precision is achieved when compared to standard shot-noise limited measurement protocols without using any entanglement. This approach also has the advantage that it does not require an understanding of the quantum Fourier transform, and it is readily related to more conventional approaches for measuring phases. The bit-by-bit estimation of an unknown phase only requires standard quantum information processing (QIP) protocols in addition to the use of single-ion rotations that are each of a relative phase that is conditioned on all previous classical outcomes in the measurement sequence. Successful implementation of the IPEA will demonstrate a working quantum circuit with relatively immediate and useful applications in basic science, remote sensing, and clock synchronization. We also describe the potential application of novel ion trap architectures previously introduced to the problems of this experiment as well as other single- and multi-qubit quantum enhanced metrology experiments. While these architectures were initially conceived in the context of large-scale QIP and quantum simulation, we face similar technical challenges in developing deployable ion trap based quantum sensors. This provides further impetus for developing relevant enabling technologies with both long- and short-term applications.

The Iterative Phase Estimation Algorithm (IPEA)...

A total of 6 iterations for 7 bits of precision, where t = run 3 from Table A.

- Reuse the internal state.
- Prepare and perform 8 rotations, respectively.
- Map the internal state in a two-to-one method and retain.

Expected performance...

- We expect modest gains initially with precisions at the current level.
- The ultimate precision allowed with the present apparatus remains to be seen.
- Currently considering designs for a miniaturized version of the IPEA sensor for magnetic field sensing applications. Expect to use more robust microwave-based control and manipulation methods (see below) and a resulting increase in ultimately achievable precision.

Using the IPEA in an example ...

- Feedback “cancels out” less sig. bits of more sig. bits obtained with higher accuracy.

Summary of Open- and Closed-loop Performance of the Lasers for metrology

<table>
<thead>
<tr>
<th>Laser</th>
<th>α = 0.00</th>
<th>α = 0.05</th>
<th>α = 0.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term drift</td>
<td>52 kHz/day</td>
<td>75 kHz/day</td>
<td>75 kHz/day</td>
</tr>
<tr>
<td>Short-term nonlinear drift</td>
<td>&lt; 6 kHz</td>
<td>&lt; 6 kHz</td>
<td>&lt; 6 kHz</td>
</tr>
<tr>
<td>Offset</td>
<td>0.20</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>0.35</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.05</td>
<td>0.10</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>0.20</td>
<td>0.25</td>
<td>0.30</td>
<td>0.35</td>
</tr>
</tbody>
</table>

The high precision isotope shift measurement on the qubit transition ...

- Seoul of laser A
- ΔM = 570.261(4) MHz
- Also to appear in Phys. Rev. A

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