Using the standard deviation of the points shown in Fig. 7 as an estimate of the uncertainty we assign a 40 kHz uncertainty to the A constant due to possible magnetic fields.

For an analysis of the shifts due to collisions, the pressure of the Cs vapor was changed by heating the vapor cell as described above. Data were taken at temperatures of 297, 318.6, and 345.5 K, corresponding to Cs vapor pressures of 0.15, 1.2, and 11 mPa. As described above, we determine the center-of-gravity frequency with a fixed hyperfine A constant for each pressure. We see no indication of any variation of the data with the Cs vapor pressure (Fig. 7). The standard deviation of the frequencies extracted at the different temperatures is 31 kHz, which we take as the uncertainty in the center-of-gravity frequency due to temperature or pressure effects. For the hyperfine A constant, the scatter in the data taken at different temperatures gives a standard deviation of 18 kHz, which we adopt as the uncertainty.

The final systematic considered was possible error due to imperfect alignment of the counter-propagating laser beams. The effect of misalignment of the two beams is to broaden and shift the peaks through a first-order Doppler shift. As can be seen from Eq. (2), the position of the peaks depends on the difference in the magnitude and direction of the two vectors $\vec{k}_1$ and $\vec{k}_2$ as well as the velocity class excited. Additional first-order Doppler shifts come into play if the wavefronts of $\vec{k}_1$ and $\vec{k}_2$ are not precisely counter-propagating, which can result from divergence of the counter-propagating beams and mismatch of the spatial modes. For a spectrum that contains many peaks coming from many different velocity classes the shift due to the misalignment largely averages out. This effect was investigated theoretically by modifying the program to include the effect of misalignment of the two beams. This was done by changing the $\vec{k}_2 \cdot \vec{v}$ term in Eq. (2) to include an additional perpendicular velocity component. For the 8S state three spectra were calculated with different angles of misalignment. Analysis of the calculated spectrum and an estimate of the maximum possible misalignment of the beams gives a conservative limit on possible effects from angular misalignment of 22 kHz for the center-of-gravity frequency and 20 kHz for the hyperfine A constant. If we attribute the scatter in the experimental results to angular misalignment, we conclude that for all the spectra, the effective angular deviation due to either misalignment or to divergence and mode mismatch of the beams is less than 0.04 radians. We note that for the calculated data the misalignment of the counter-propagating laser beams leads to no significant shift in the extracted frequency, it does lead to a larger spread of the data and an increased value of χ^2, as observed. This additional spread of the data beyond what is expected from the statistical noise is taken into account by conservatively increasing the uncertainties to achieve the expected χ^2, as described in Section IV A.

In addition, the effect of misalignment was investigated experimentally on the $6S_{1/2} \rightarrow 6P_{1/2} \rightarrow 7D_{3/2}$ transition.

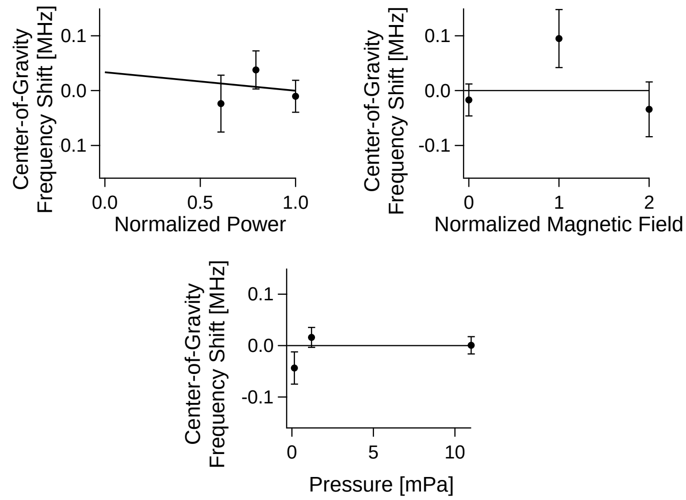

FIG. 7: The dependence of the center-of-gravity frequencies for the $6S_{1/2} \rightarrow 6P_{3/2} \rightarrow 8S_{1/2}$ state on the power (upper left), the magnetic field (upper right), and the Cs vapor pressure (bottom). The straight line for the power dependence is a weighted linear fit to the data. The vertical axis has been offset and centered so that the nominal operating point is at zero for the power-dependence plot. The magnetic field and pressure data are shown scattered about the weighted mean of the data. The horizontal axis for the power dependence is plotted as a function of the fraction of the maximum power. The horizontal axis for the magnetic field dependence is plotted as a function of the residual magnetic field, $\approx 50\,\mu T$.

The study of this transition confirmed that while the individual peaks do shift, there was no shift in the mean value of the transition frequency, within the uncertainty of our measurement.

The non-zero second-order Doppler shift $(v/c)^2\,\nu_0$ is about 300 Hz for this transition and is negligible compared to the other uncertainties.

Table I summarizes the corrections and associated uncertainties on the extracted center-of-gravity and hyperfine A constants. We see no evidence for any shift that is larger than the uncertainty associated with evaluating the effect. As our final value we take the mean of the $8S_{1/2}$ frequencies determined from the $6P_{1/2}$ and $6P_{3/2}$ intermediate states, weighted by their respective statistical uncertainties, and apply the corrections and systematic uncertainties (propagated in quadrature) listed in Table I. We find final values for the center-of-gravity frequency and hyperfine A constant of $8S_{1/2}$ state of

$$\nu_{6S_{1/2}:8S_{1/2}} = 729\,009\,798.86(19)\,\text{MHz}$$
$$A_{8S_{1/2}} = 219.14(11)\,\text{MHz}.$$

These results are in good agreement with previous measurements of the $8S_{1/2}$ state, summarized in Table II.