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The interaction of ultrashort laser pulses and exotic atoms

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Synopsis In this work we present results for the ionization of metastable neon with ultrashort laser pulses. In addition to improving on the accuracy of previous measurements of ion yield, we show comparisons to advanced TDSE based theory. This work presents preliminary experimental evidence of the effects of preparing the target atoms into particular angular momentum projection (m_j) states on the total ionization yield.

The interaction of ultrafast (<6fs) light pulses with matter is a topical field. This stems from the high peak electric field amplitude of such pulses, which is strong enough to cause ionization by tunneling or over-the-barrier ionization. This is the basis of several non-linear effects that are currently being studied [1]

In order to understand these processes it is necessary to understand the underlying principles, in this paper the ionization channels. Metastable ($^3P_2$) neon provides an excellent target for examining the effects of electron configuration the ionization yield, as it allows a clean comparison to ground state neon results. $^3P_2$ neon is also an interesting choice of atom as it has a low ionization energy of 5.1eV, allowing easy access to the above-the-barrier ionization regime.

The ionization yield is predicted by several models. The most basic involves treating the electric field as static and determining the DC tunneling rate - ADK theory [2]. This work also considers adjustments to ADK theory. More advanced treatments are provided by Klaus [3] and Tong [4], who apply approximations to solve the TDSE for $^3P_2$ neon in the laser field.

Experimentally, metastable neon is generated by supersonically expanding neon gas through a 250µm diameter nozzle, while passing a DC discharge through the nozzle. Electron collision promotes 0.01% of the neon atoms to the $^3P_2$ state.

Ultrafast laser light is produced by a commercially available laser system (Femtolasers Femtopower CE Phase Pro), which provides sub 6fs laser pulses centered around 760nm. Optics following the laser system allow the intensity of the laser light in the detection chamber to be varied between 1.5×10^{15}W/cm^2 and 1×10^{13}W/cm^2.

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The detection system is a commercial cold target recoil ion momentum spectroscope (COLTRIMS) supplied by Roentdek. The optical system focuses the laser beam onto the atomic beam, causing ionization. Ions that are produced though the interaction are directed to the ion detector, which utilizes time of flight and position sensitive detection to record the ion yield and momentum of individual ions.

We have taken measurements comparing the ion yield of $^3P_2$ neon to the ground state of neon and compared them to the theoretical ion yield predictions. There is good agreement between these results and theory for low laser intensities. Discrepancies at higher powers are currently under investigation.

We also present preliminary results for the examination of the effects of angular momentum (m_j) dependence though the optical pumping of the target atoms on ion yield. Examination of the base ADK equation [2] indicates an ion yield dependence on the m_j state of the target atom. Relative changes in the atomic m_j states are achieved though optical pumping using the optical transition between the $^3P_2$ and $^3D_3$ states of neon. By pumping this transition with light of a varying polarization ellipticity, the population of the m_j states can be changed.

In conclusion, we will present data on the ionization yield of $^3P_2$ neon as a function of both laser intensity and investigate target atomic states to investigate the effect of the magnetic sublevel dependence on ionization.

References

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