Photodetachment Spectroscopy of Bound and Quasibound States of the Negative Ion of Lanthanum

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Synopsis The negative ion of lanthanum, La$^-$, has the richest bound state spectrum ever observed for an atomic negative ion [1], and it has been proposed as perhaps the best candidate for laser cooling of a negative ion [2,3]. In the present experiments, La$^-$ is investigated using tunable infrared spectroscopy over the photon energy range 520-920 meV to probe the continuum region above the La neutral atom ground state. The spectrum shows photodetachment thresholds and multiple resonance peaks due to transitions to quasibound excited states of La$^-$, providing useful information about this unique negative ion.

Negative ions are interesting because the extra electron is not bound to the neutral atom by a net Coulomb force, thus their properties depend crucially on short-range polarization and correlation effects. The resulting shallow potential well can typically support only a single bound state. However, an important exception to this general rule is the negative ion of lanthanum. La$^-$ is only the third atomic negative ion shown to possess multiple bound states of opposite parity and it has the richest bound state spectrum observed for a negative ion [1]. A particular dipole-allowed transition between bound states of La$^-$ has been identified as a strong candidate for the first laser-cooling of negative ions [2,3,4]. Clearly, further studies of this unique ion are needed.

In the present study, we have investigated photodetachment of La$^-$ over the photon energy range 520-920 meV. This extends our previous study of the lower energy spectrum [1] to the continuum region near and above the La neutral atom threshold, which is estimated to be 550 meV [5]. A 12 keV beam of La$^-$ ions was perpendicularly intersected by a pulsed tunable OPO laser beam. Relative total photodetachment cross sections were measured by detecting the fast neutral atoms produced by detachment.

Our measurements reveal at least 10 resonance peaks between 600-900 meV, as well as several photodetachment thresholds. An example of the observed structures is shown in Fig. 1, in which a several meV wide resonance lies above an opening threshold at about 820 meV. The data are fit well by a slowly rising Wigner *p*-wave function plus a Lorentzian resonance profile, yielding both the threshold energy and resonance parameters.

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The observed resonance peaks in this energy range are due to excitation of quasibound negative ion resonances that subsequently autodetach. The measured thresholds are due to photodetachment from states of La$^-$ to both the ground and first excited states of La. Our results yield useful information on the structure and photodetachment dynamics of La$^-$ that is important for assessing its potential for laser-cooling applications.

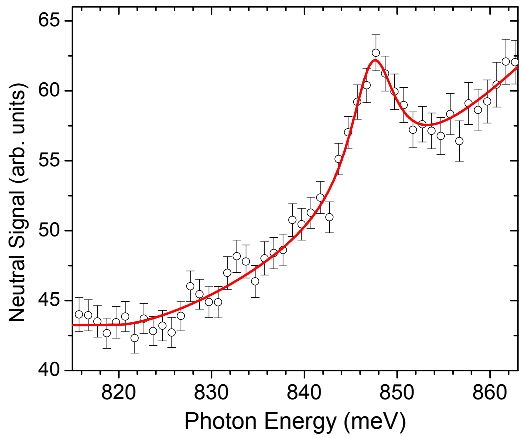

Figure 1. Photodetachment spectrum from La$^-$ showing an excited state threshold and a nearby resonance; the solid line is a fit of a Wigner *p*-wave plus a Lorentzian.

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