Measurement of absolute cooling rates of fullerene ions in an electrostatic storage ring

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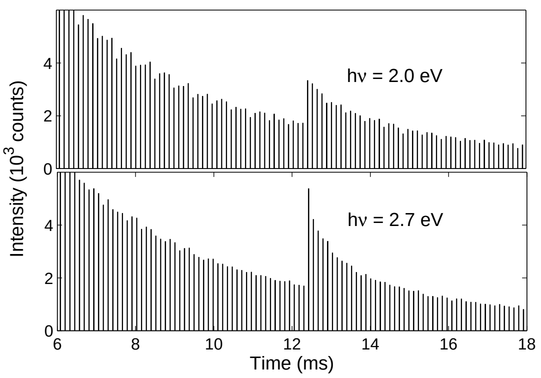
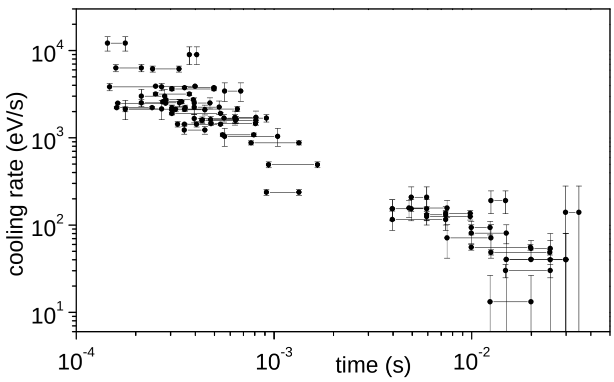
We have developed a novel method to measure absolute cooling rates of ions, based on the non-exponential decay of ensembles of hot molecules, and applied it to C_{60}^-.
The ions were produced in a laser desorption source and stored in an electrostatic storage ring [1]. The spontaneous decay of the ions is well described by a 1/t law for short times [2], while it is quenched by radiative cooling [2] after about 5 ms. One-photon excitation in the energy range of 1.9-2.7 eV induces an enhanced thermionic emission rate. Figure 1 (left) shows examples of the enhanced signal after laser excitation at 12.5 ms after injection. The decay of the enhanced signal is similar to the spontaneous decay, but is shifted backwards in time. The shift depends on the photon energy, as exemplified by the different curvatures of the enhanced signals in figure 1, and can be determined with good precision from the data. Combined with the absolute energy change associated with single photon absorption, the absolute rate of cooling by depletion of the ions can then be experimentally determined [3].
Figure 2 (right) shows the cooling rates extracted from the data. The horizontal bars represent the time interval over which the cooling is averaged. The cooling rate is seen to vary as 1/t, similar to the decay rate, consistent with a broad initial energy distribution. For values of the rate constant around $10^3 s^{-1}$ one obtains from the plot the value $CT^2/\Phi \approx 12000$ K, where C is the heat capacity, T the effective emission temperature and $\Phi = 2.65$ eV is the electron affinity. This value is consistent with the expected values of the heat capacity and the temperature [4].





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