VUV spectroscopy of lanthanide ions: joining fun(damental) science and application

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For almost 100 years the sharp line spectra of the lanthanide ions have been studied [1]. Triggered by the application of the efficient visible luminescence of lanthanides in lamps and displays the energy level structure up to 40 000 cm^{-1} and transition probabilities for transitions within the $4f^n$ configuration of the lanthanides have been extensively studied and are well understood. Until recently only a limited number of publications has been involved with the high energy levels of the lanthanides in the vacuum ultraviolet region (including $4f^n$-$4f^n$, $4f^n$-$4f^{n-1}5d$ and charge transfer transitions). In the past decade knowledge on the high energy levels has become of great interest in view of the need of luminescent materials for high energy excitation (e.g. in mercury free fluorescent tubes, plasma display panels, VUV detectors in wafer steppers, tunable VUV lasers and scintillators).

For the intraconfigurational $4f^n$ transitions high resolution spectra of lanthanides incorporated in very pure fluoride crystals have been recorded at the DESY synchrotron in Hamburg and many previously unknown energy levels within the $4f^n$ configuration have been observed. Based on these measurements and energy level calculations the Dieke diagram of lanthanides has now been extended from 40 000 to 70 000 cm^{-1} [2] and the possibility for efficient quantum cutting through downconversion was discovered which offers new prospects for the development of photon doubling materials [3].

Contrary to the situation for energy levels within the $4f^n$ configuration, energy level calculations for $4f^{n-1}5d$ levels are scarce and have not been able to explain the observed fine structure in the $4f^n$-$4f^{n-1}5d$ (f-d) excitation spectra. Systematic research on the fine structure observed in the f-d excitation spectra of almost all lanthanides in three host lattices provided the basis for the development of a theoretical model which reproduces the experimentally observed energy level structure remarkably well [4]. Understanding of the fd spectra of lanthanide ions is important for the development of new VUV phosphors and tunable VUV lasers.

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