SPIN, ELECTRON AND MAGNETIC PROPERTIES OF THE $4f^{n-1}5d$ ELECTRONIC CONFIGURATION OF TRIVALENT RARE EARTH IONS

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Abstract

The interest of investigating the spin, electronic and magnetic properties of the $4f^{n-1}5d$ electronic configuration of the trivalent rare earth ions in wide band gap dielectric hosts is based on current and future optical and magnetic applications. In this communication we investigate the electronic and magnetic properties of the $4f^n$ and $4f^{n-1}5d$ electronic configurations of the trivalent rare earth ions in wide band gap dielectric hosts by exciting crystal samples with laser light at 157nm. Vacuum ultraviolet coherent excitation of the $4f^{n-1}5d$ electronic configuration, will enhance the magnetic moment of the $4f^{n-1}5d$ electronic configuration in comparison to the magnetic moment of the $4f^n$, electronic configuration within the lifetime of the $4f^{n-1}5d$ levels.

In addition the magnetic moment of $^4I_{15/2}$ ground state of the $4f^n$ electronic configuration of the Er^{3+} ions was measured with the VSM method and the crystal indicated paramagnetic response.

Using the VSM method the concentration of different RE ions in crystal elements such as SrF_2 , KY_3F_{10} and CaF_2 was measured in a non-destructive way by measuring the magnetic moment of the ground electronic states of the $4f^n$ electronic configuration of the RE ions. The accuracy of this method is estimated 0.1%.

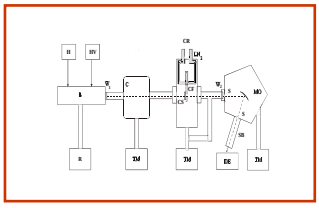
Introduction

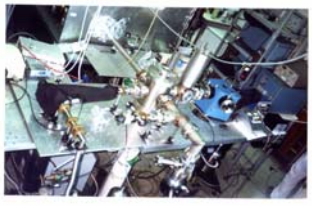
The investigation of the fundamental interactions of the $4f^n$ and $4f^{n-1}5d$ electronic configurations of trivalent rare earth ions in wide band gap fluoride dielectric crystals, not only advances their optical properties in the ultra violet (UV) and vacuum ultraviolet (VUV) spectral regions, but it can as well determine the magnetic properties of the short lived excited electronic states with $4f^{n-1}5d$ mixed electronic configuration which are situated as high as 10 eV above the ground electronic state of the $4f^n$ electronic configuration. This is particularly important for advancing new opto-magnetic applications, were large transient magnetic moments are required such in advanced security systems or in applications related with coherent spin transport in excited electronic states.

Experimental setup

Vibrating Sample Magnitometer
Jozef Stefan Institute, Ljubljana, Slovenia

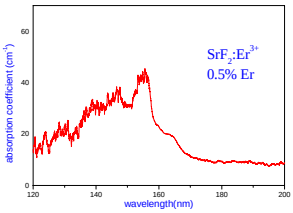
Crystal Growth Facility
National Hellenic Research Foundation Athens Greece



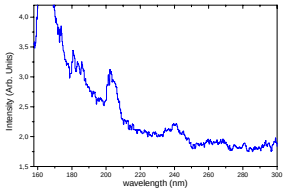


Vacuum ultraviolet absorption spectrometer
H: hydrogen delivery system, HV: high voltage, L: hydrogen lamp, $W_{1,2}$: LiF windows, C: chamber, TM: turbo molecular pump, R: rotary pump, CF: cold finger, CS: samples CR: cryostat , S: slit, SB: solar blind photomultiplier, MO: monochromator, DE: detection electronics

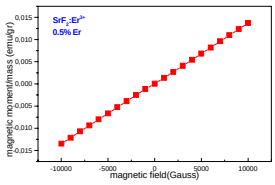
Results



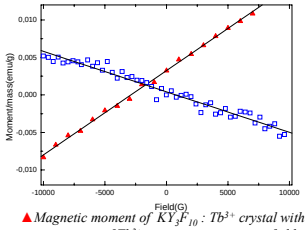
Absorption spectrum of the SrF_2:Er^{3+} crystal in the VUV region of the spectrum. The high value of the absorption coefficient indicates the strong dipole character of the $4f^{11} \rightarrow 4f^{10}5d$ interconfigurational transitions.



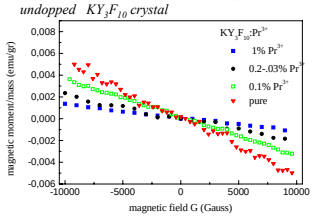
Laser Induced Fluorescence of the Sr_2:Er^{3+} crystal in the VUV region of the spectrum using the F_2 molecular laser at 157nm



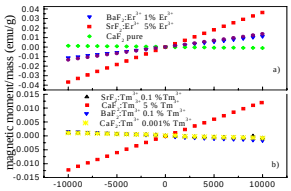
Magnetic moment of the $^4I_{17/2}$ ground electronic state of the $4f^{11}$ electronic configuration of the SrF_2: Er^{3+} crystal measured with the VSM method.



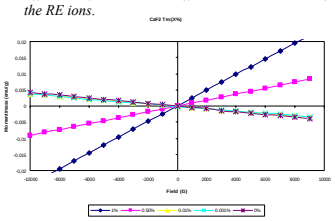
▲*Magnetic moment of KY_3F_{10} : Tb^{3+} crystal with 0.5% concentration of Tb^{3+} ions versus magnetic field.* ■ *undopped KY_3F_{10} crystal*



Magnetic moment of Pr^{3+} ions in KY_3F_{10} crystal host at different concentration



Magnetic moment of Er^3 (a), Tm^{3+} (b) ions in different crystal hosts at different concentrations of the RE ions.



Magnetic moment of Tm^{3+} ions in CaF_2 crystal host at different concentration of the RE ion

Conclusion

- The transient magnetic properties of the $4f^{10}5d$ electronic configuration of the Er^{3+} ions in wide band gap SrF_2 crystals were investigated by exciting the crystal with VUV laser light at 157nm. The crystal indicates a super paramagnetic or ferromagnetic response under VUV excitation.
- In addition the magnetic moment of $^4I_{15/2}$ ground state of the $4f^{11}$ electronic configuration of the Er^{3+} ions was measured with the VSM method and the crystal indicated paramagnetic response.
- Since the efficiency of the laser crystals doped with trivalent rare earth ions depends on the degree of the homogeneous distribution of the concentration of the trivalent rare earth ions over the crystal volume, the method can be used to evaluate the quality of the laser crystals.
- The concentration of the RE ions in different wide band gap crystal hosts was evaluated by measuring the magnetic moment of the RE ions, using the vibrating sample magnetometer (VSM) method, in a non destructive way.

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