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Femtosecond inverse Faraday effect in magnetic ionic liquid [bmim]$FeCl_4$

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The nonthermally photoinduced magnetization in a magnetic ionic liquid 1-butyl-3-methylimidazolium tetrachloroferrate ([bmim]$FeCl_4$) is investigated via the inverse Faraday effect on the subpicosecond time scale at room temperature. The pump beam induced the ellipticity changes of probe beam are revealed to arise from the contributions of both the inverse Faraday effect and the optical Kerr effect. The formation of about 1.8 THz coherent superposition between magnetic sublevels of the Fe^{3+}-ion's ground-state multiplet is observed with a circular pump polarization, which is assigned to the allowed impulsively stimulated Raman scattering in the magnetic ion liquid. © *2011 American Institute of Physics*. [doi:10.1063/1.3574442]

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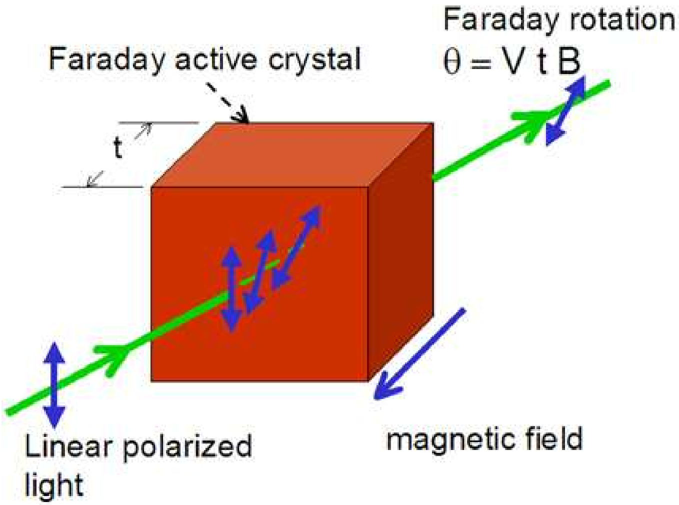
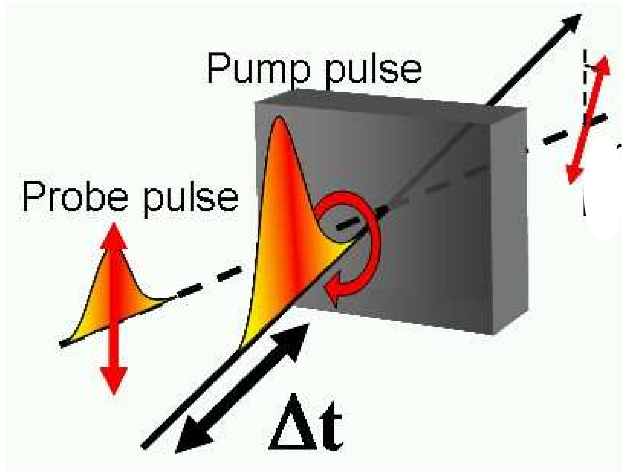
Faraday effect ⇔ Inverse Faraday effect



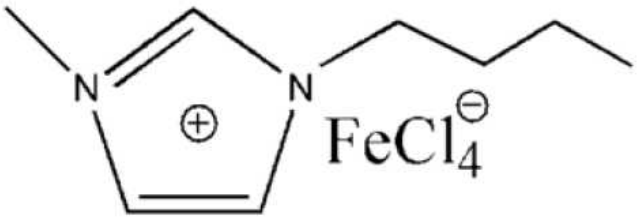


$$\boldsymbol{M}(0) = \chi[\boldsymbol{E}(\omega) \times \boldsymbol{E}^*(\omega)]$$
$$= \chi(|E_+(\omega)|^2 - |E_-(\omega)|^2)e_z$$

Magnetization

Magneto-optical susceptibility tensor

Sample



$[bmim]Cl$ +
anhydrous $FeCl_3$ and $FeCl_3.6H_2O$

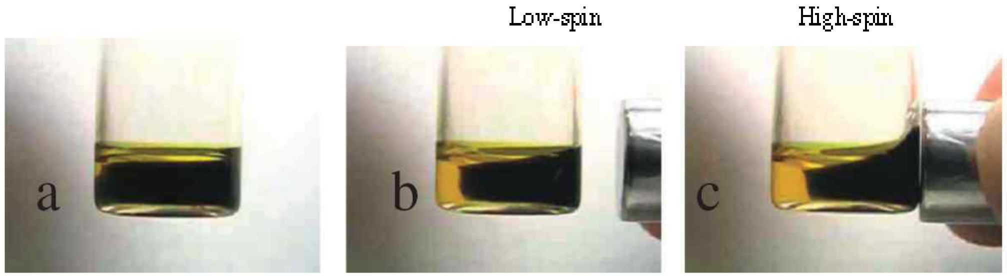
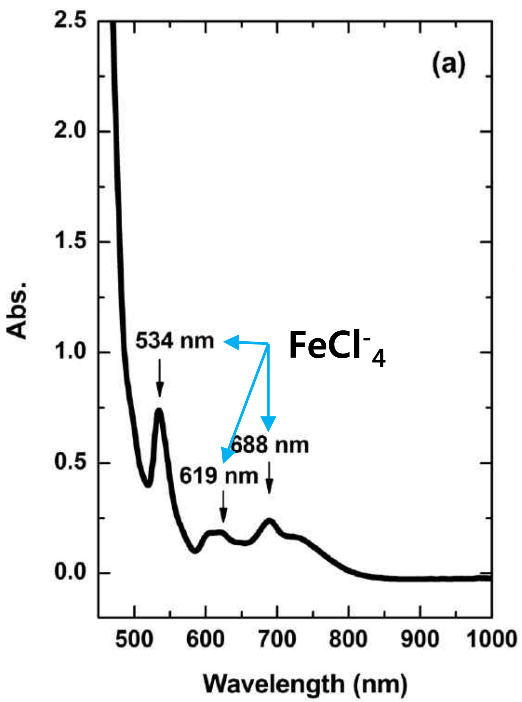
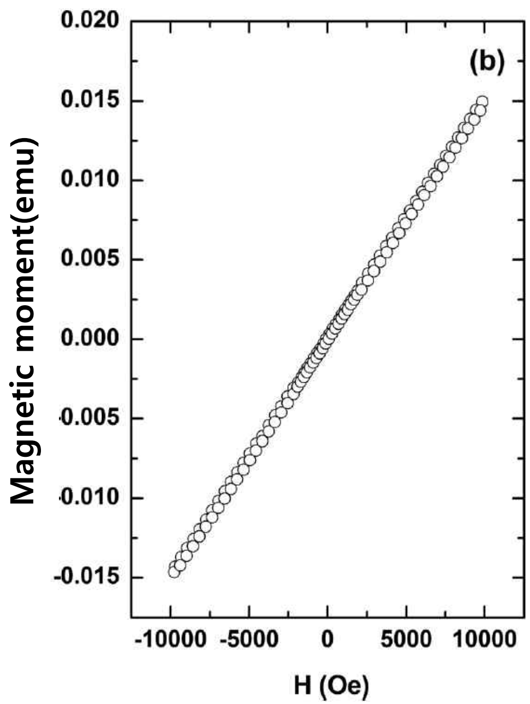


Figure 1. Pictures showing the response of $[bmim]FeCl_4$ (Liquid 2) to a magnet.

Chem. Lett. 33, 1590 (2004).





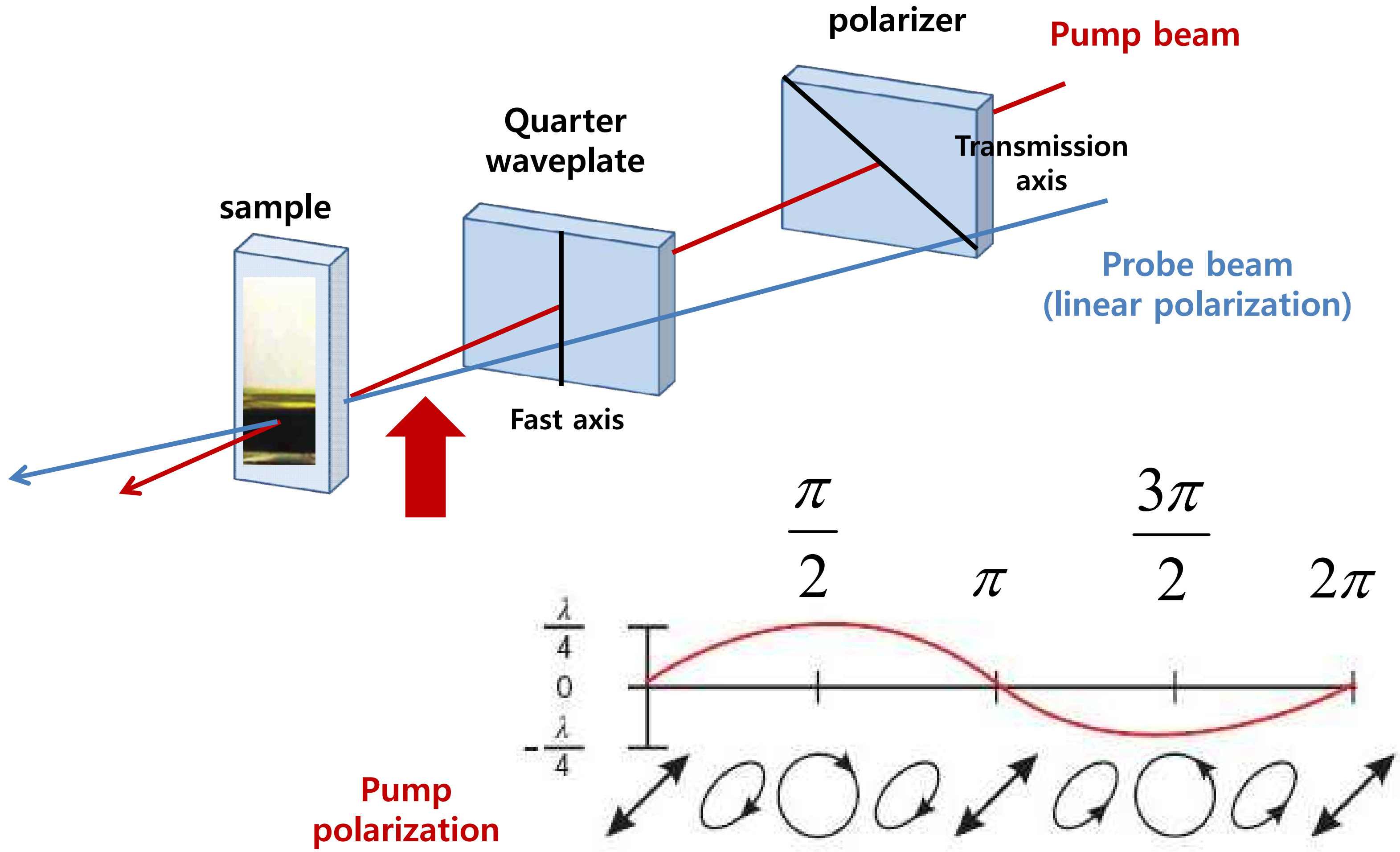
(a)The UV-Vis absorption spectrum of $[bmim]FeCl_4$.

No absorption of photons

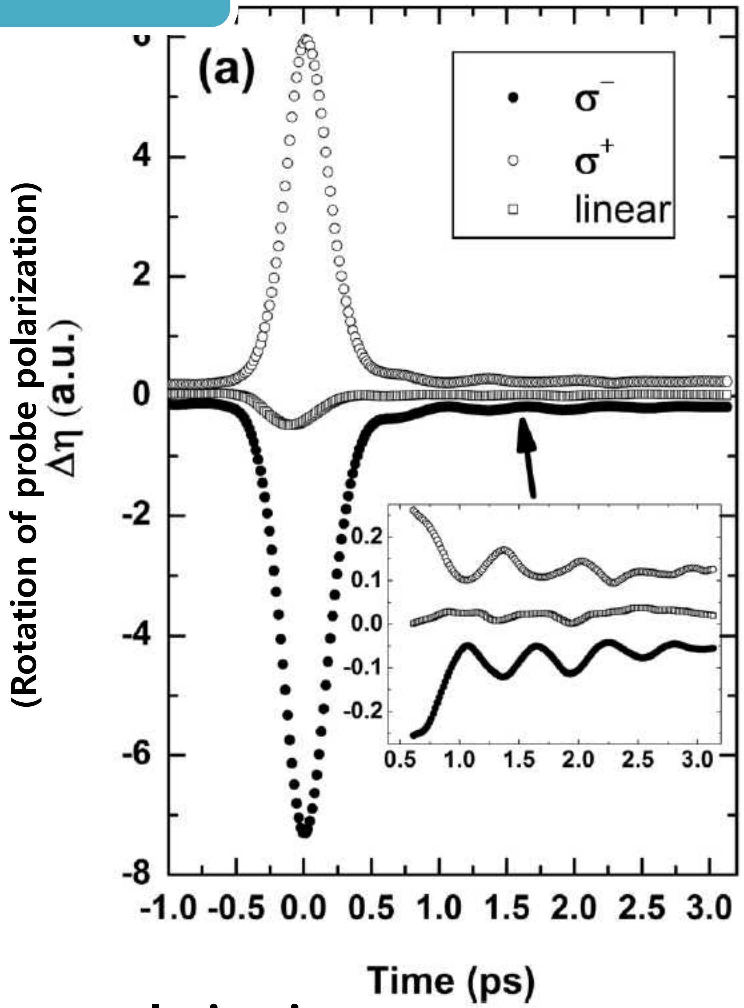
(b)The magnetic field dependence of magnetization response of $[bmim]FeCl_4$ at room temperature.

Paramagnetic

Experimental Setup

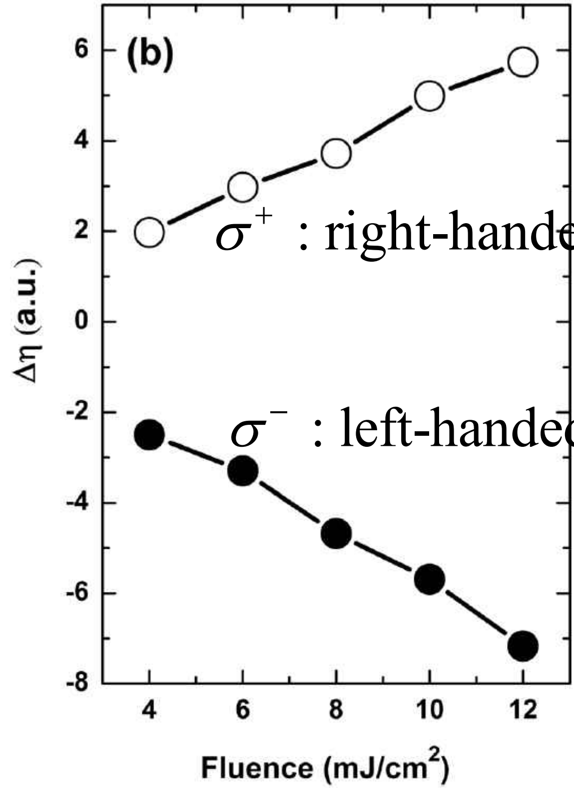


Results



Pump polarization

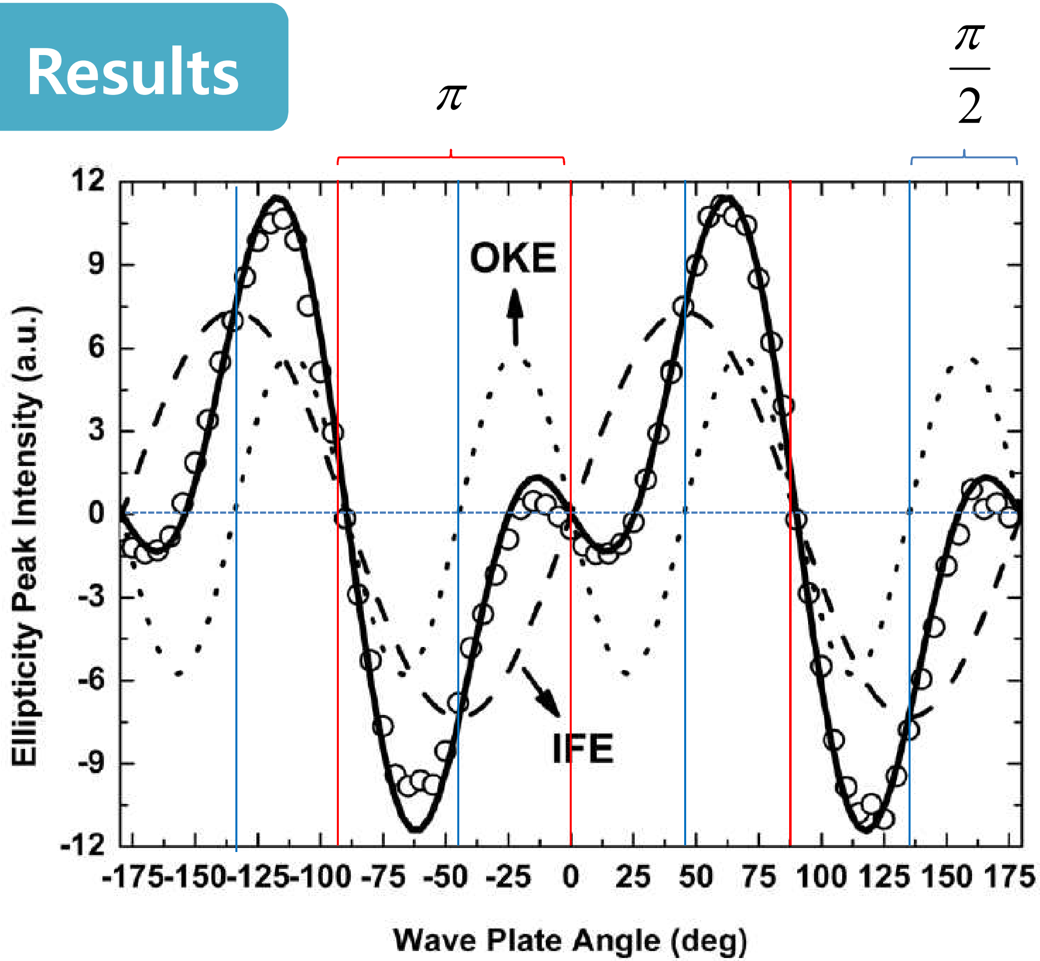
- σ^+ : right-handed circularly
- σ^- : left-handed circularly
- linear



(a) Transient ellipticity changes in $[bmim]FeCl_4$

(b) Faraday ellipticity changes at zero delay time ~ the fluence of the pump

Results



The variation of the peak intensity of the Faraday ellipticity changes at zero time delay with the angle of the wave plate (φ).

Solid curve : fit to eq.(2).

Dashed curve : IFE

Dotted curve : OKE

Faraday ellipticity

$$\eta = -32\pi^2 I_p / c\left|1+n^2\right|\left(\underbrace{A\sin 4\varphi}_{\text{OKE}} + \underbrace{B\sin 2\varphi}_{\text{IFE}}\right)$$

$$A = 1/2\,\mathrm{Im}\left[\left(\chi_{xxyy}+\chi_{xyyx}\right)/n\left(1-n^2\right)\right]$$

$$B = \mathrm{Re}\left[\left(\chi_{xxyy}-\chi_{xyyx}\right)/n\left(1-n^2\right)\right]$$

J. Appl. Phys. 95, 7441 (2004).

Summary

- The opto-magnetic response of [bmim]FeCl4 is investigated by the pump-probe technique.
- The polarization dependence of Faraday ellipticity measurement is employed to isolate the IFE and OKE contributions around zero time delay.