

Quantitative separation of linear and quadratic magneto-optical Kerr effects in ultrathin Fe films



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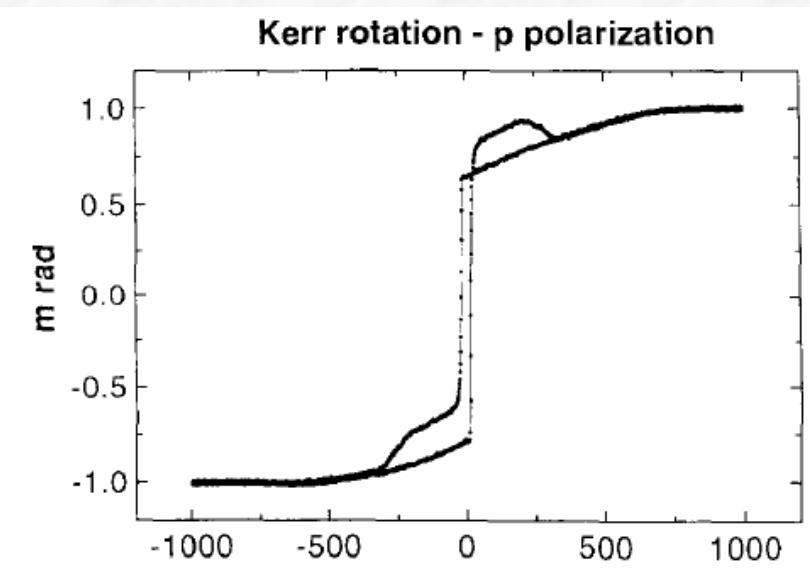
Introduction

Linear Magneto-Optical Kerr Effect(LMOKE)

--Widely used for investigation of thin film magnetism

Quadratic Magneto-Optical Kerr Effect(QMOKE)

--Effects the measurements based on LMOKE



e.g. QMOKE causes asymmetry in hysteresis loops

Composing?

Properties?

How big?

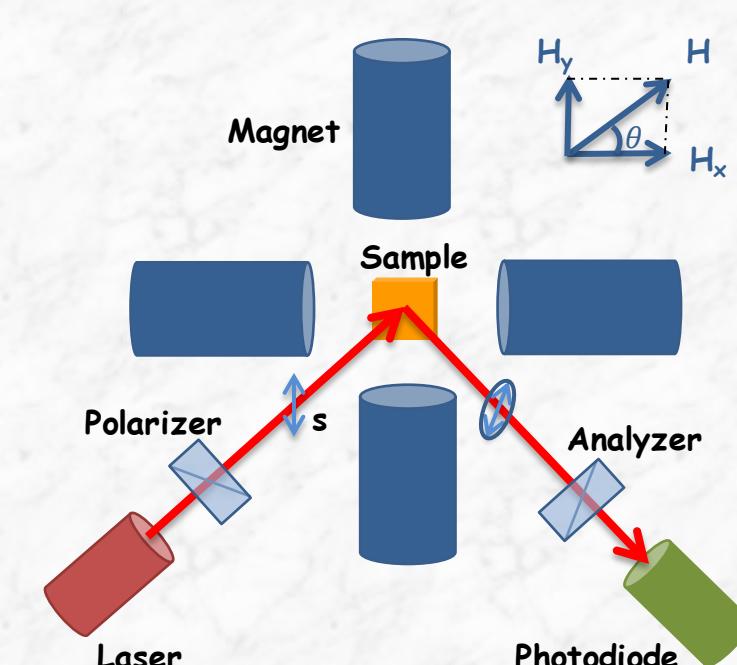
QMOKE

???

Experimental Method

Vector MOKE (longitudinal Magneto-Optic Kerr Effect with Vector Field)

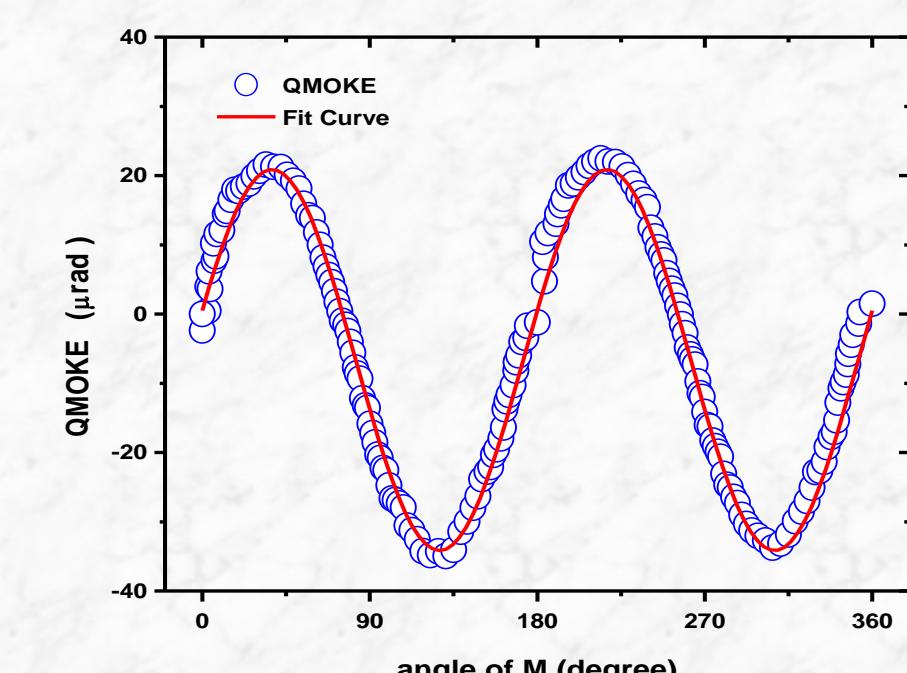
Separation of LMOKE and QMOKE



$$\text{LMOKE}(\bar{H}_{\uparrow\downarrow}) = [\theta(H_{\uparrow\downarrow}) - \theta'(\bar{H}_{\uparrow\downarrow})]/2$$

$$\text{QMOKE}(\bar{H}_{\uparrow\downarrow}) = [\theta(H_{\uparrow\downarrow}) + \theta'(\bar{H}_{\uparrow\downarrow})]/2$$

Separation of M_L^2 and $M_L M_T$ of QMOKE

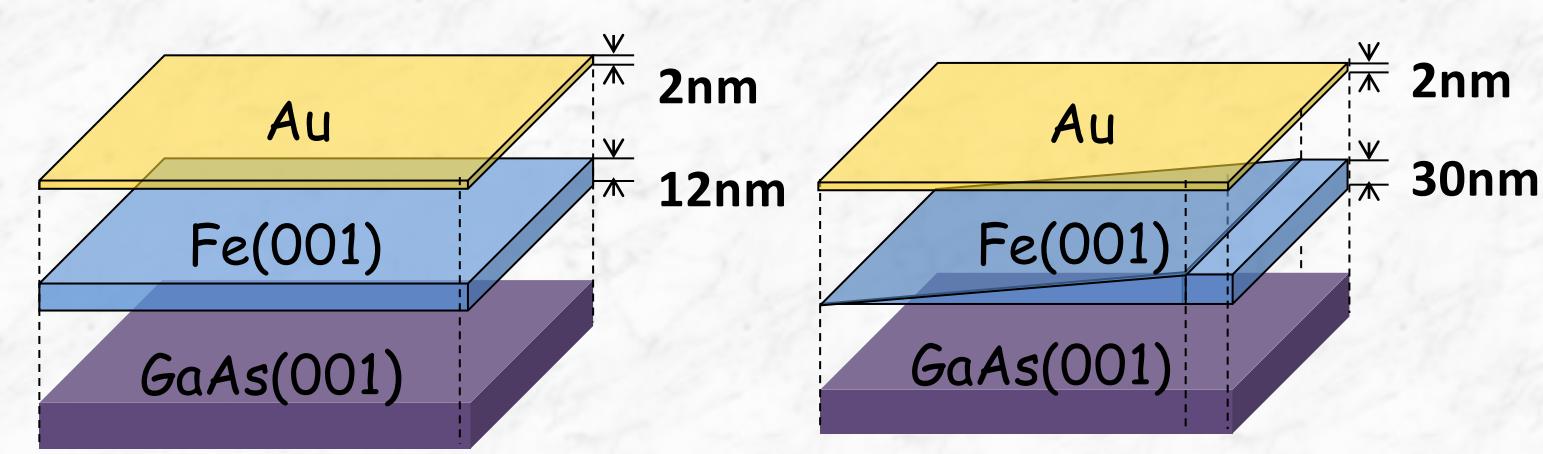


Fitting Equation:

$$\text{QMOKE signal} = A_1 \sin^2 \theta_M + A_2 \sin \theta_M \cos \theta_M$$

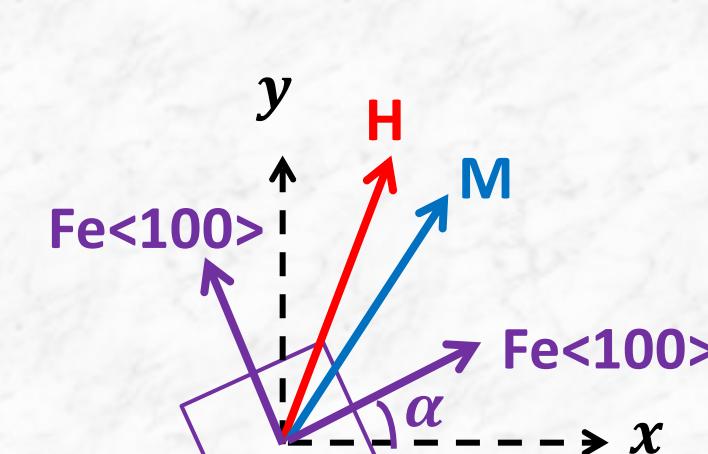
Anisotropy of Quadratic MOKE

Sample Growth

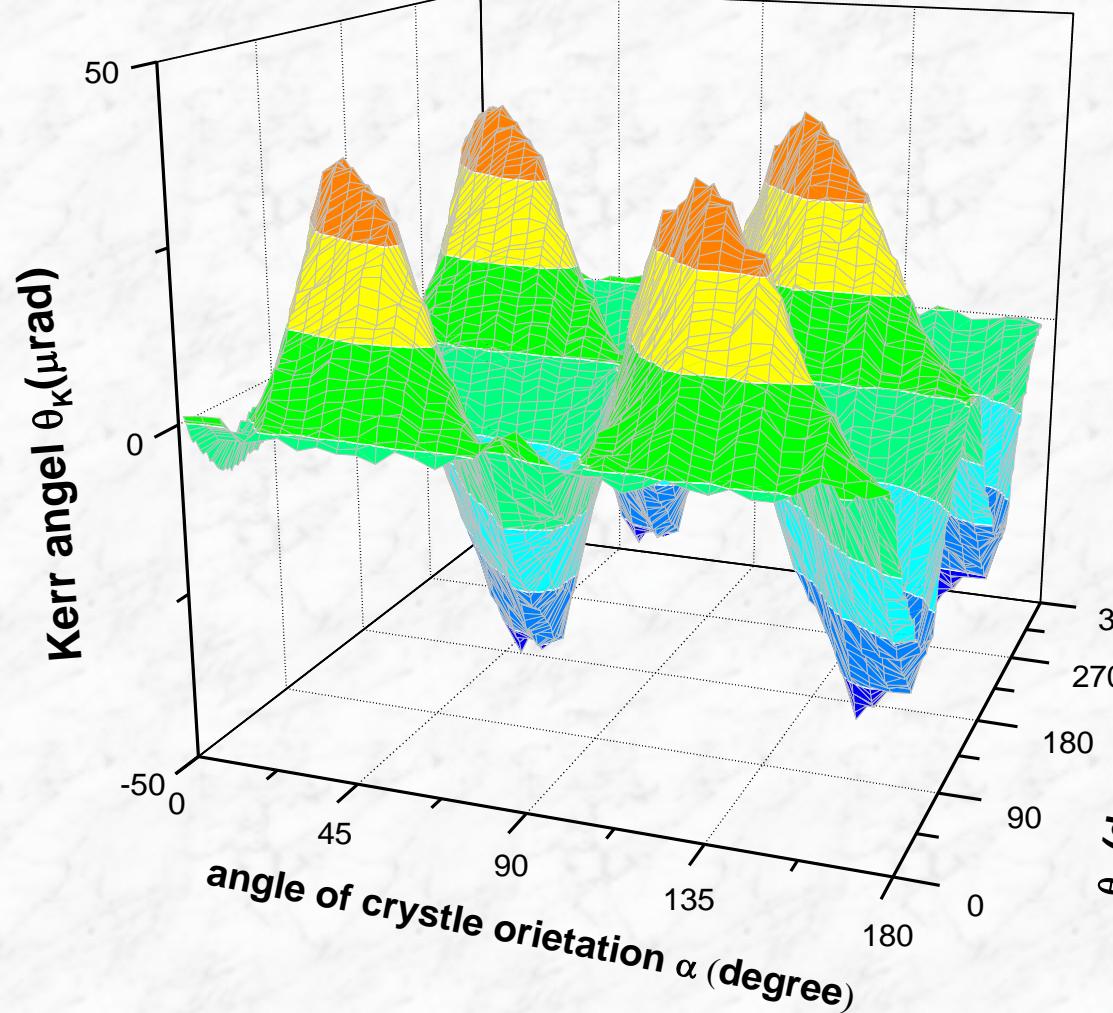


The epitaxial relationship: $\text{Fe} <100> // \text{GaAs} <100>$

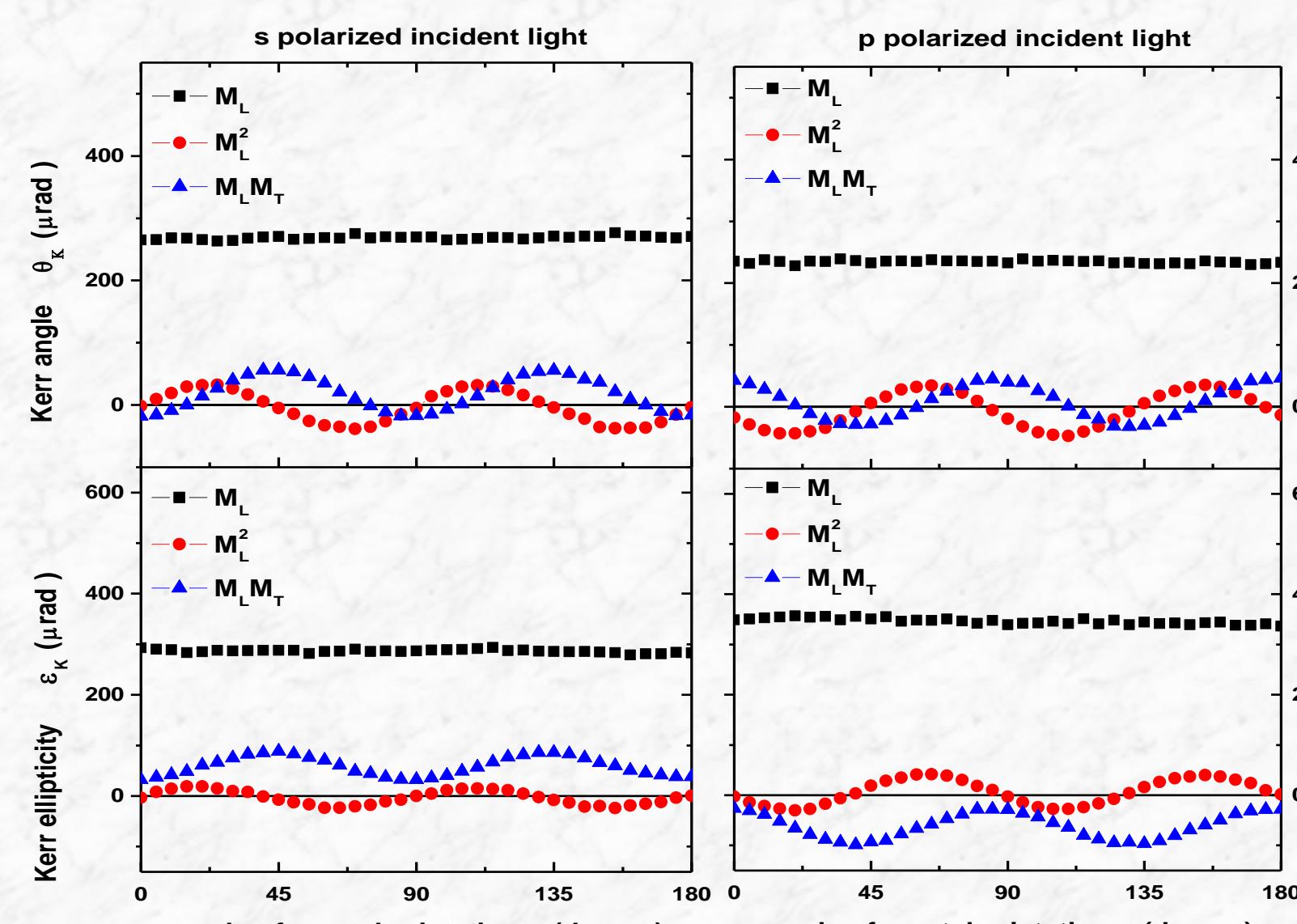
Measurement geometry



QMOKE 2D mapping



QMOKE fitting data



Theoretic Formulas

Permittivity tensor

$$\epsilon_{ij} = \epsilon_0 + K_{ijk}M_k + G_{ijkl}M_kM_l \quad \Rightarrow \quad \tilde{\epsilon} = \begin{pmatrix} \epsilon_0 + G_{11}M_T^2 + G_{12}M_L^2 & 2G_{44}M_T M_L & -KM_L \\ 2G_{44}M_T M_L & \epsilon_0 + G_{12}M_T^2 + G_{11}M_L^2 & KM_T \\ KM_L & -KM_T & \epsilon_0 + G_{12}(M_T^2 + M_L^2) \end{pmatrix}$$

cubic crystal structure

Complex Kerr amplitude

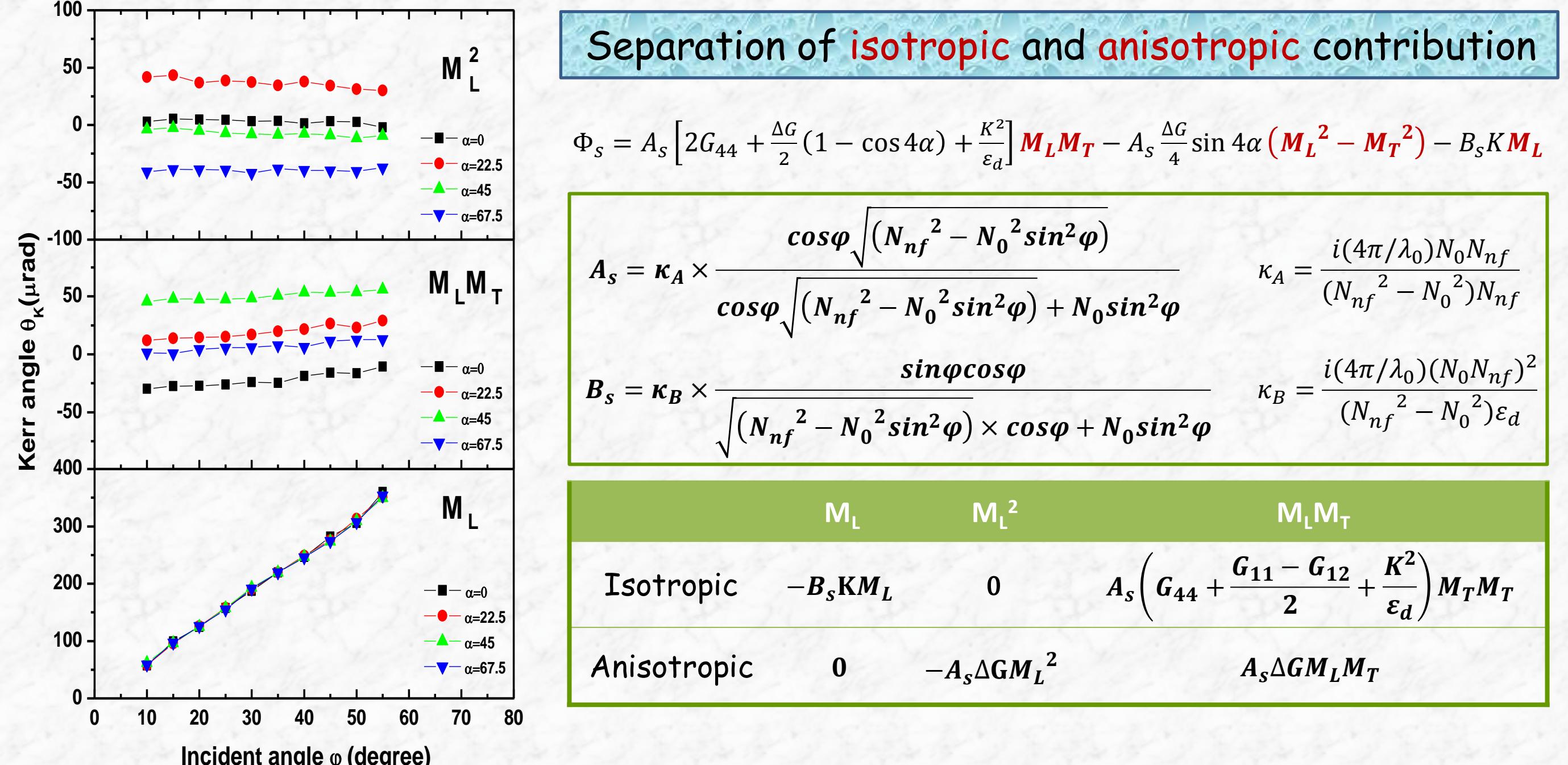
$$\Phi_s = -r_{ps}/r_{ss} = A_s \left(\epsilon_{yx} - \frac{\epsilon_{yx}\epsilon_{zx}}{\epsilon_d} \right) + B_s \epsilon_{zx}$$

$$\Phi_p = r_{sp}/r_{pp} = -A_p \left(\epsilon_{xy} - \frac{\epsilon_{xz}\epsilon_{zy}}{\epsilon_d} \right) + B_p \epsilon_{xz}$$

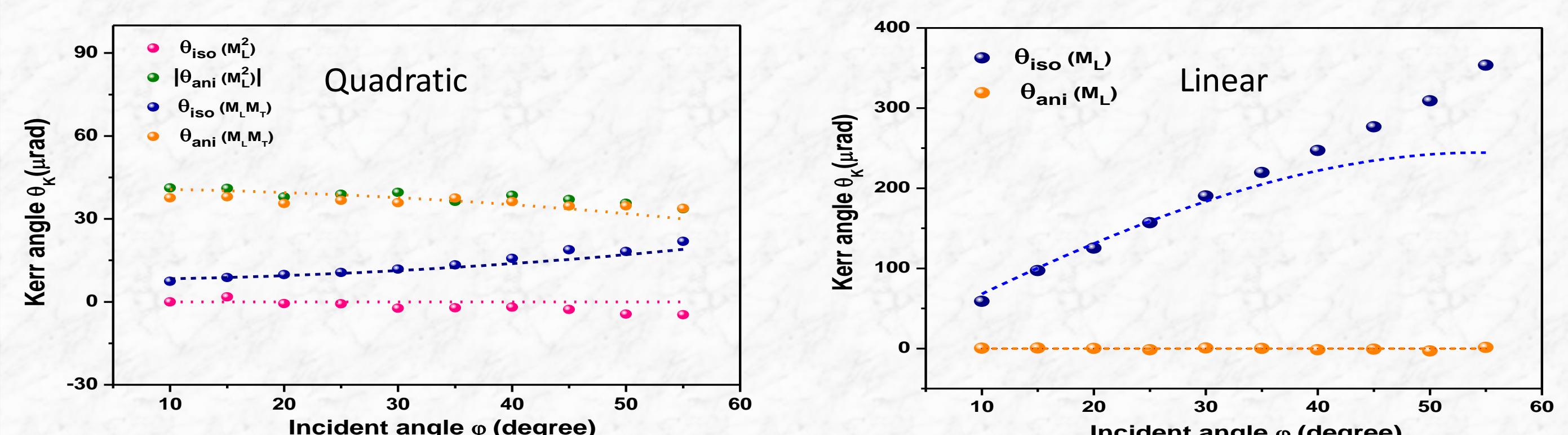
MO anisotropy parameter $\Delta G = G_{11} - G_{12} - 2G_{44}$

Incident angle dependent Quadratic MOKE

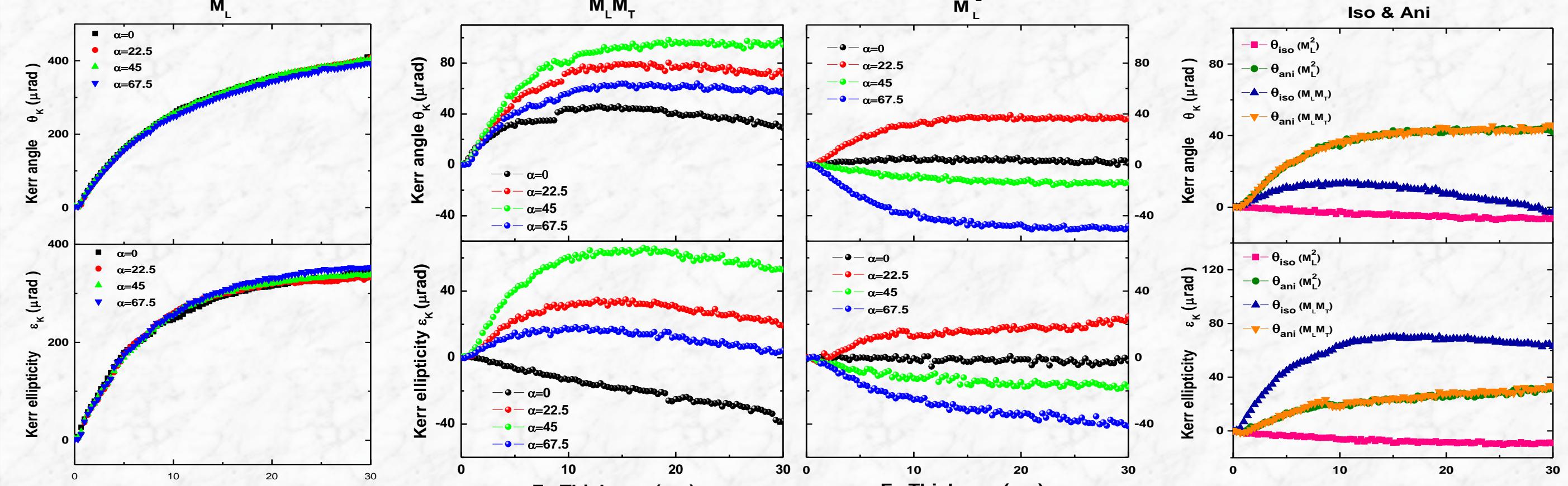
Separation of isotropic and anisotropic contribution



Comparison between theoretical and experimental data



Thickness dependent Quadratic MOKE



Theoretic formula can be obtained using 4×4 Transfer Matrix Method

Conclusion

- The linear Kerr contribution is isotropic with the sample orientation, but the quadratic Kerr contribution, which is as large as one fourth of linear contribution, is anisotropic with the crystalline geometry
- The linear and quadratic Kerr contributions show very different thickness dependence, and the experimental data of incident angle dependence of QMOKE shows good agreement with theoretic calculations.