Ultrafast MOKE Study of Magnetization Dynamics in an Exchange-Biased IrMn/Co Thin Film

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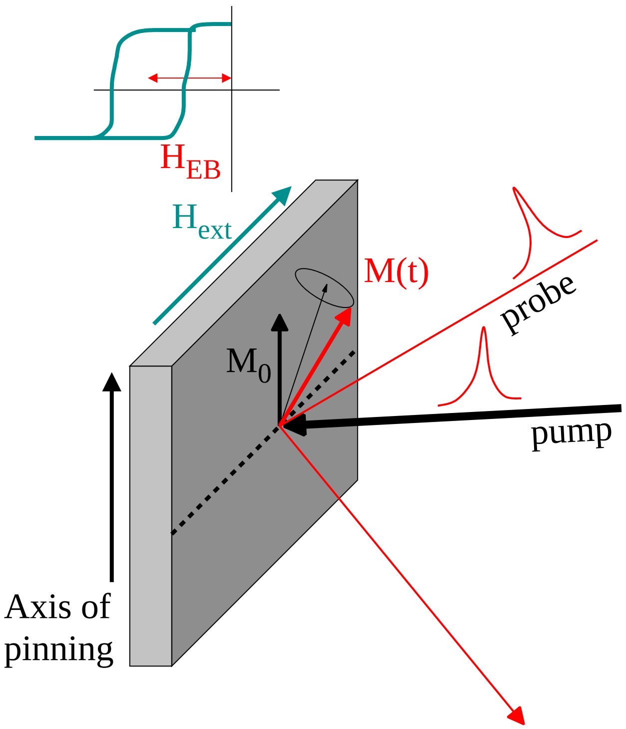
Abstract

We have observed coherent magnetization rotation in exchange biased IrMn/Co by ultrafast pump-probe magneto-optical Kerr effect (MOKE). We are exploring the application of this experiment, first introduced by Ju et. al. [1] to more general exchange biased systems such as this all metal system.

Ultrafast pump-probe MOKE



- M_0 set by exchange biasing (EB).
- Pump beam modifies EB and anisotropy by electron excitation and lattice heating.[1]
- M precesses about a new equilibrium, according to the Landau Lifshitz Gilbert (LLG) equations.
- We detect in-plane magnetization by MOKE.

$$\frac{(1+\alpha^2)}{|\gamma|}\frac{d\vec{M}}{dt} = -(\vec{M}\times\vec{H}_T) - \left(\frac{\alpha}{|M_S|}\right)(\vec{M}\times(\vec{M}\times\vec{H}_T))$$

$$\vec{H}_T = \vec{H}_{\mathrm{ext}} + \vec{H}_{\mathrm{EB}} + \vec{H}_{\mathrm{AN}} + \vec{H}_{\mathrm{DM}}$$

All optical probes

Benefits of an all-optical method:

- Sub micron surface selectivity.[2]
- Analagous to FMR.[2]
- In-situ capability.
- No need for lithographically patterned samples.
- Spectroscopic capability.

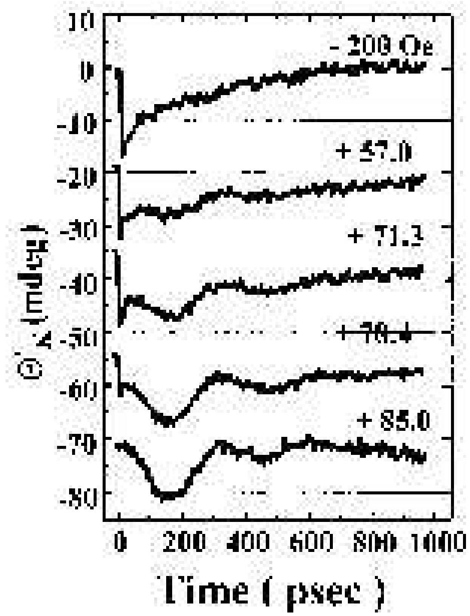
Disadvanatages:

- Not always easy to modify magnetization optically.
- Need to understand how the laser affects the magnetization.

Previous studies

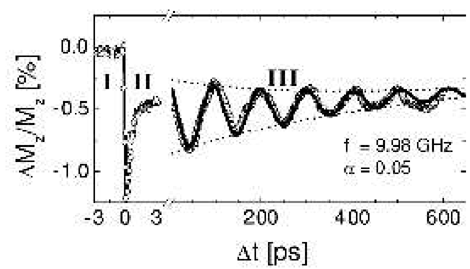
Ju et. al. [1] on NiFe/NiO:

- First demonstration of coherent rotation in an EB system.
- Explained by LLG equations.
- Exploited the optical transparency of NiO to preferentially excite NiO/NiFe interface.



van Kampen et. al. [2] on ferromagnetic Ni and NiFe:

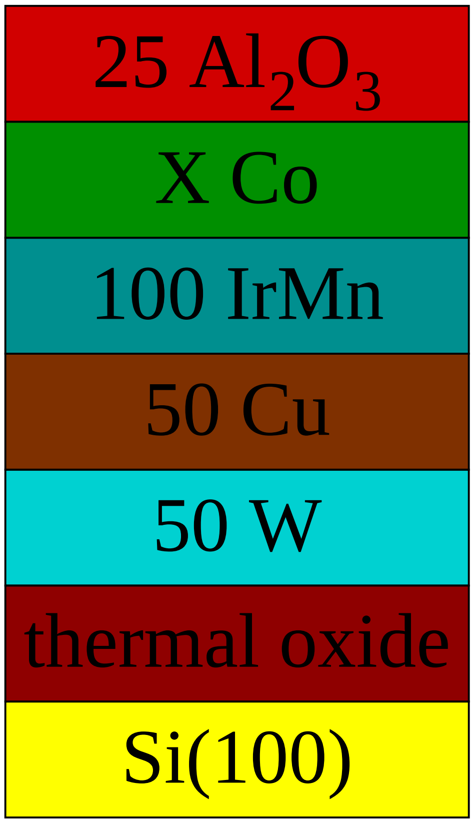
- Showed analogy to FMR.
- Demonstrated locality of technique by measuring a 10 μm element.



Questions we are asking

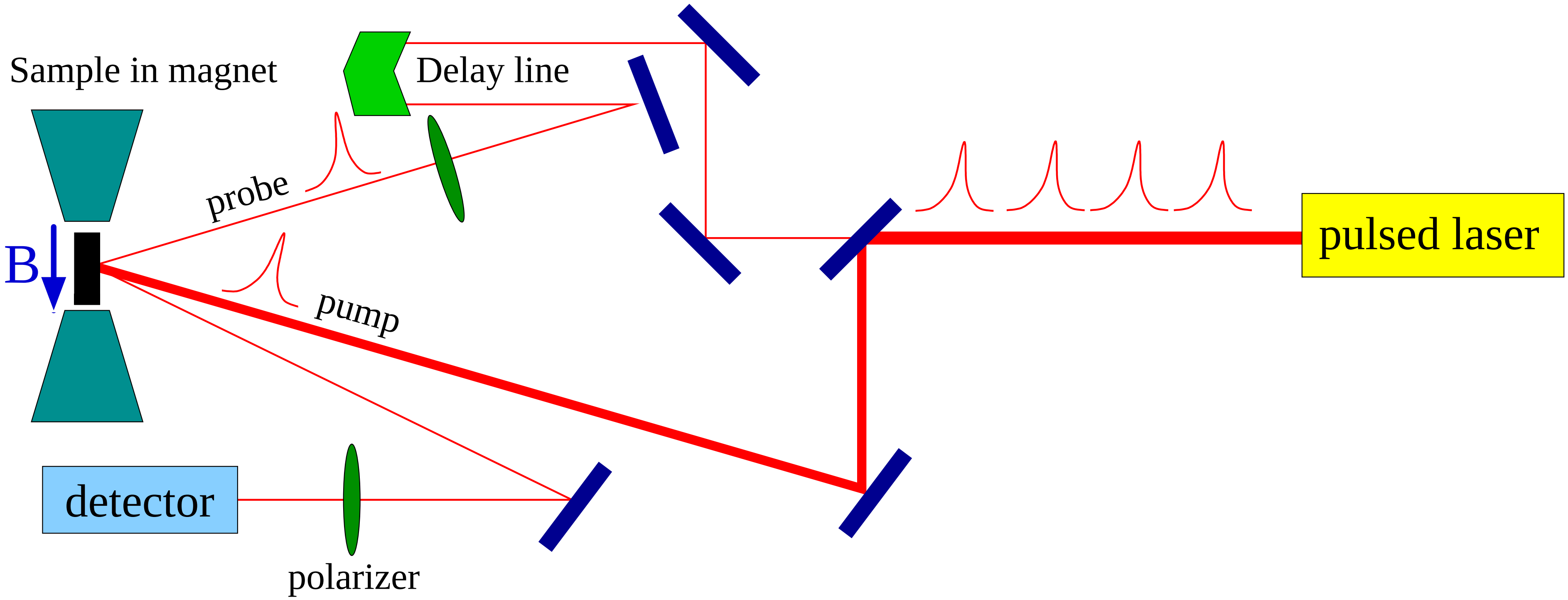
- Can we use this method on a more general exchange biased systems such as IrMn/Co or FeMn/Co?
  - These are used in exchange biased GMR spin valves.
- Can we easily relate the quantities we extract from this technique and compare with FMR?

Sample characteristics



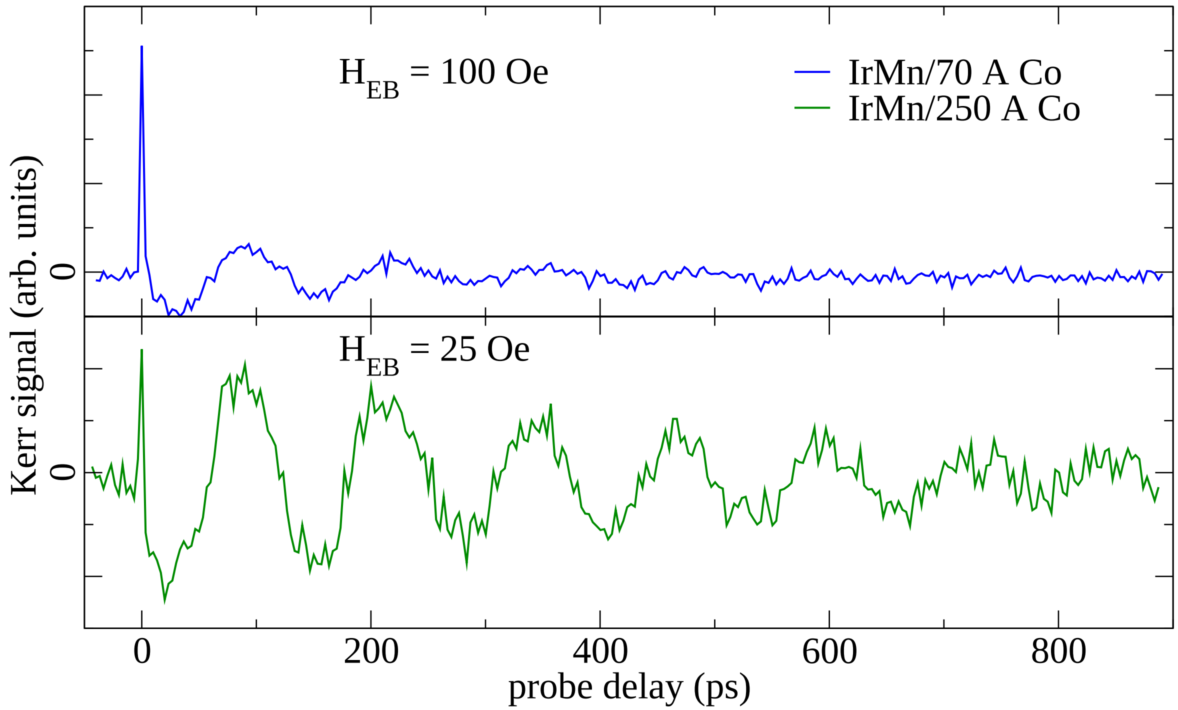
- Samples grown at NIST
- X = 10, 20, 30, 50, 70, 100, 120, 150, 200, 250Å
- Base pressure $\approx 5\times10^{-10}$ Torr. Background Ar pressure was 2 mTorr.
- Field cooled from 250° C to pin the magnetization.
- Exchange bias field H_{EB} linearly dependent with $1/t_{\mathrm{Co}}$.[3]

Ultrafast Pump-Probe MOKE



- Transverse MOKE detected with polarizer-analyzer scheme.
- Spectra-physics amplifi ed Ti:Saph laser.
- 800 nm light of 150 fs pulses at 1 kHz.
- Average pump power $\approx$ 50 mW, probe power $\approx$ 5 mW.
- Spot size $\approx$ 3 mm $\rightarrow$ 0.7 mJ/cm^2 per pulse.

Pump-probe results - IrMn/Co



H_{ext} = 600 Oe

- Initial fast (< 5 ps) decay due to electron excitation and energy transfer to the lattice.
- Osctillations of MOKE signal as a function of pump-probe delay.
- Can be fi t with LLG equations.

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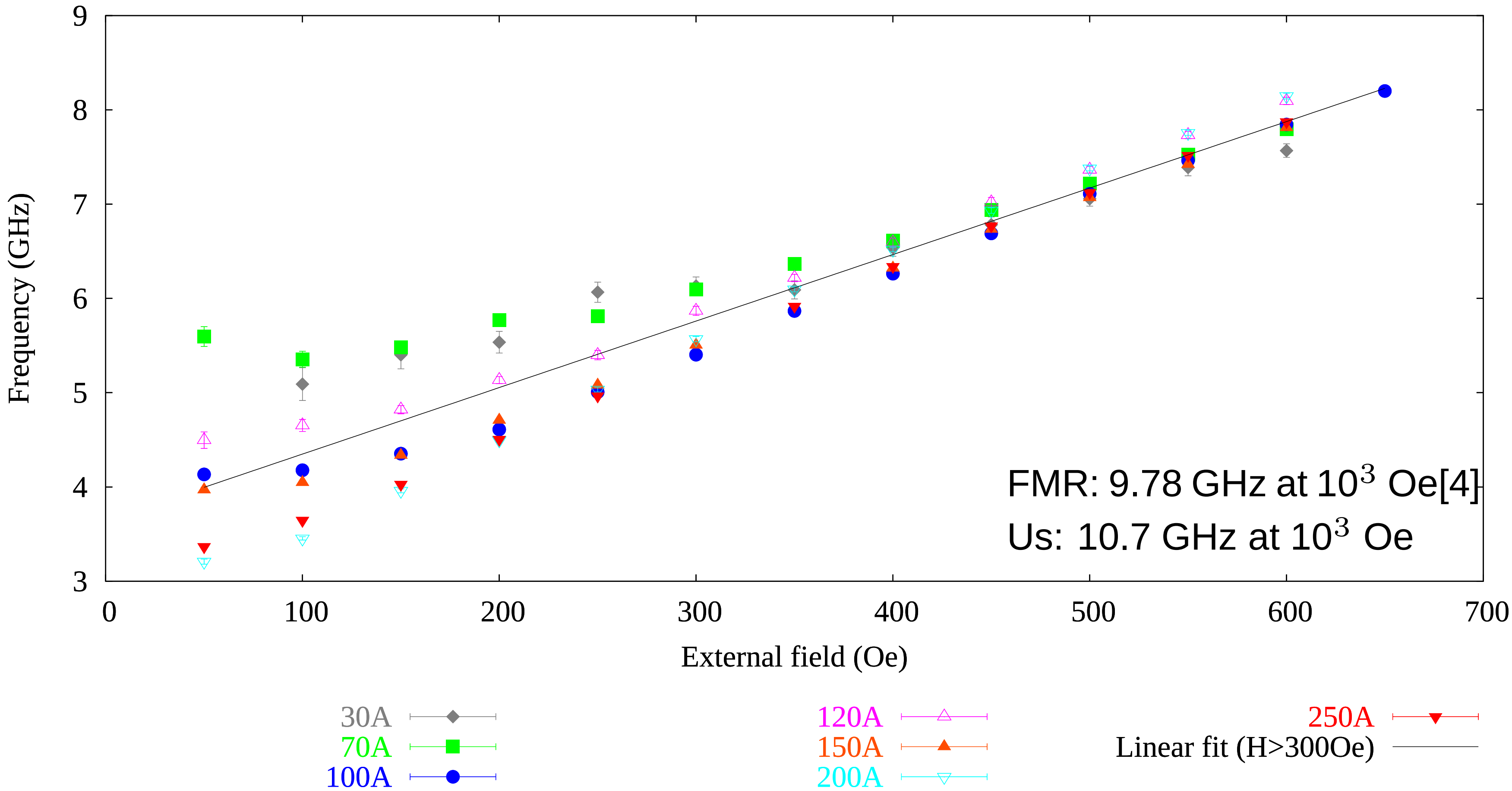
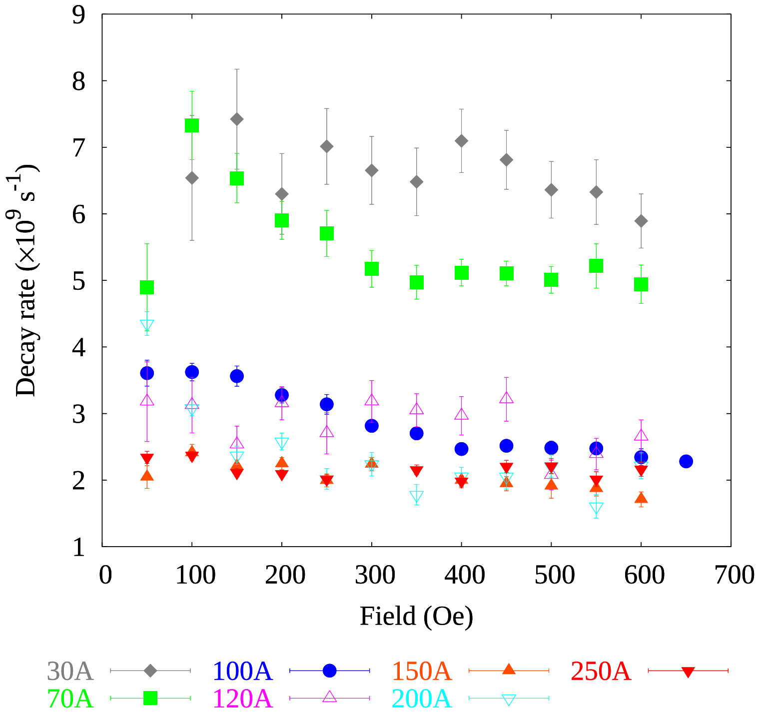
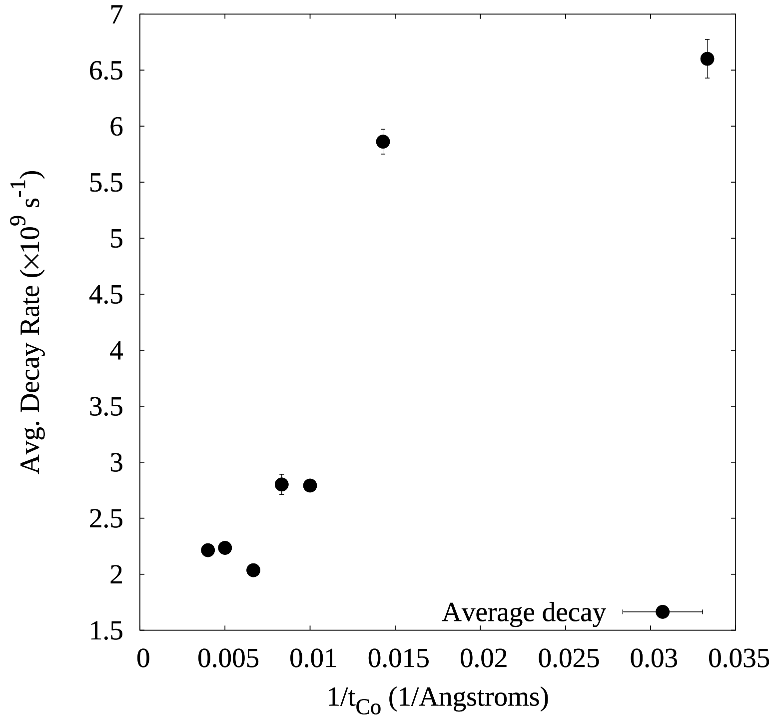
Frequency-Field relation - IrMn/Co



- Data converges at larger external fields.
- Differences in H_{EB} too small to be detected?

Decay constants - IrMn/Co





- Decays appear to be nearly independent of field strength.
- Generally increasing decay rate with 1/t (similar to H_{EB}), like NiO/NiFe.
- FMR data show little linewidth change comparing exchange biased films to non-biased Co film.[4]

Conclusions

- We have observed coherent rotation in exchange biased IrMn/Co.
- We have observed little dependence in oscillation frequency with Co thickness (We are not sensitive to the small changes in H_{EB} ?).
- General observed trend of increasing damping with 1/t, possibly connected with H_{EB} ?
- It is promising that we can learn about dynamics in general EB systems, with data analagous to FMR.

References

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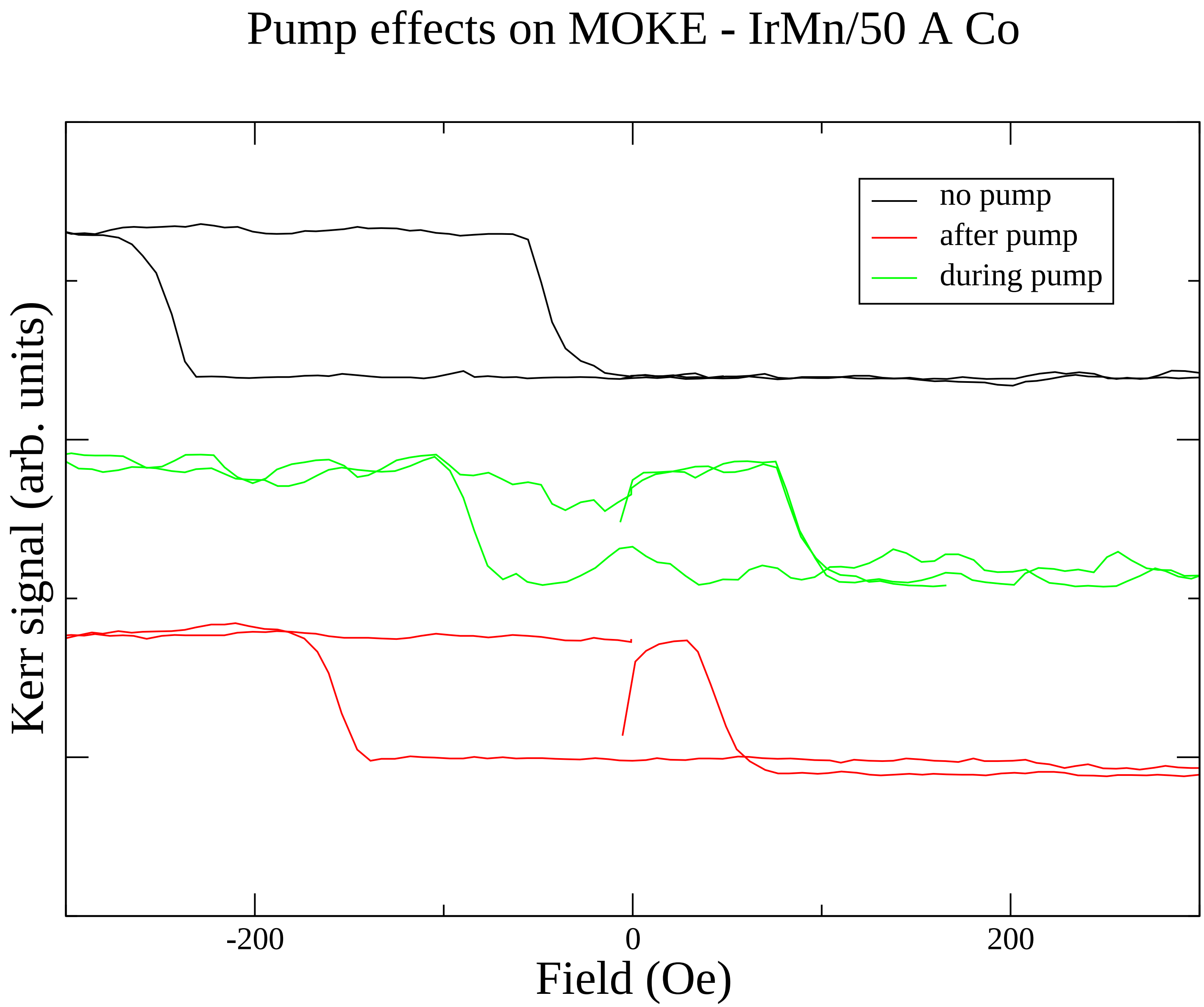
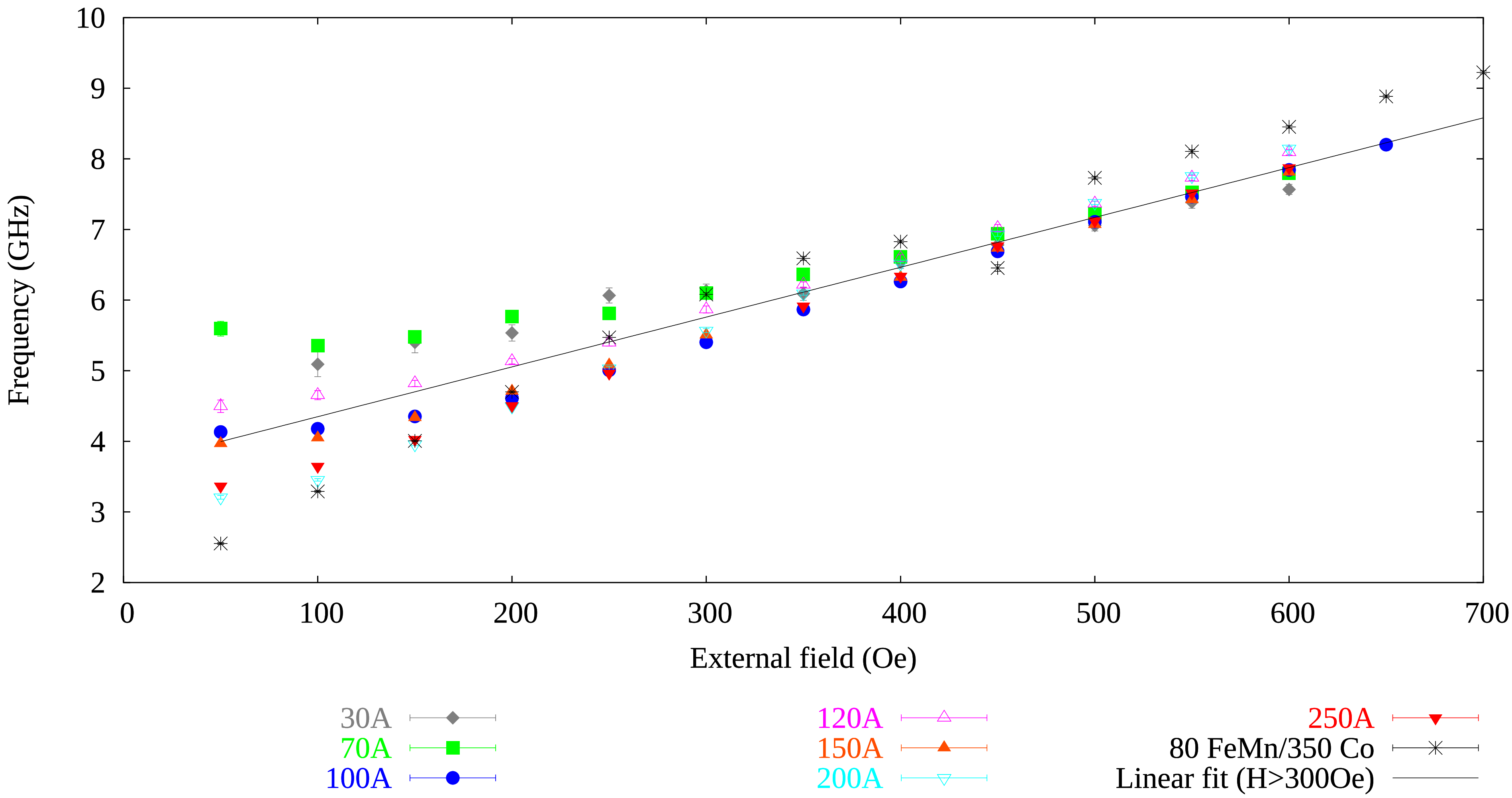
Pump effects of MOKE



Frequency-Field relation - IrMn/Co with FeMn/Co



Decay constants - IrMn/Co with FeMn/Co