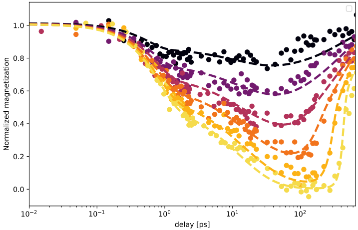
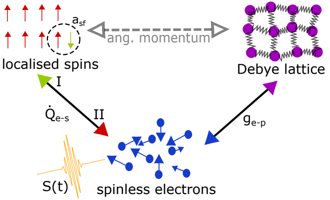
Gadolinium modeling Weinelt et al.

simplified M3TM with uniform heating



$1/R \approx 100$ ps

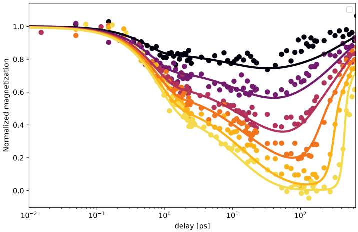


$$C_\mathrm{e}\frac{dT_\mathrm{e}}{dt} = g_{\mathrm{e-p}}(T_\mathrm{p} - T_\mathrm{e}) + S(z,t) + Jm\frac{dm}{dt}$$

$$C_\mathrm{p}\frac{dT_\mathrm{p}}{dt} = -g_{\mathrm{e-p}}(T_\mathrm{p} - T_\mathrm{e}) - \lambda(T_p - T_\mathrm{amb})$$

$$\frac{dm}{dt} = Rm\frac{T_\mathrm{p}}{T_C}\left(1 - \frac{m}{B_{7/2}\left(\frac{Jm}{k_B T_e}\right)}\right)$$

extended M3TM



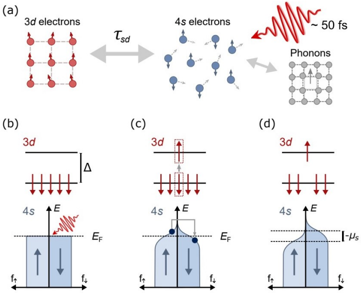
$$\frac{dm}{dt} = -\frac{1}{S}\sum_{ms=-S}^{ms=+S} m_s \frac{df_{m_s}}{dt}$$

$$\frac{df_{m_s}}{dt} = -(W^+_{m_s} + W^-_{m_s})f_{m_s} + W^+_{m_s-1} f_{m_s-1} + W^-_{m_{s+1}} f_{m_{s+1}}$$

$$W^{\pm}_{m_s} = R\frac{Jm}{4Sk_BT_c}\frac{T_p}{T_c}\frac{e^{\mp\frac{Jm}{2Sk_BT_e}}}{\sinh(\frac{Jm}{2Sk_BT_e})}(S(S+1) - m_s(m_s \pm 1))$$

[7] Beens et al., Phys. Rev. B 100, 220409 (2019)

s-d Model (here d-f)



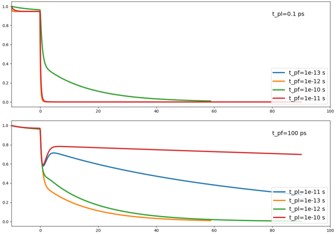
$$W^{\pm}_{m_s} = \frac{1}{\tau_{df}}(\Delta - \mu_s)\frac{e^{\mp\frac{Jm-\mu_s}{2Sk_B T_e}}}{\sinh(\frac{Jm-\mu_s}{2Sk_B T_e})}(S(S+1) - m_s(m_s \pm 1))$$

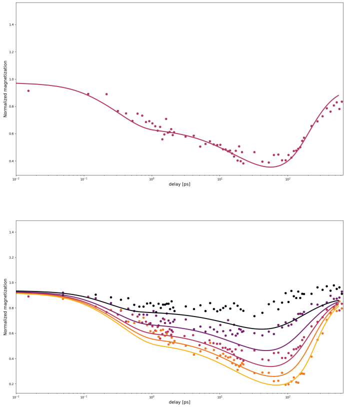
$$\frac{d\mu_s}{dt} = \frac{D_\uparrow + D_\downarrow}{2D_\uparrow D_\downarrow}\frac{dm}{dt} - \frac{\mu_s}{\tau_{pl}}$$

two time scales:

τ_{pf}, τ_{pl}

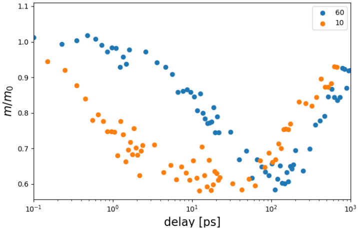
df-fit

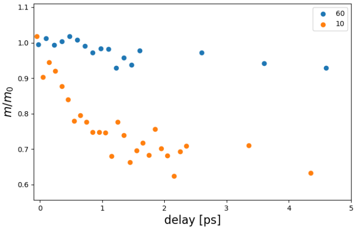




$\tau_{df} \approx 1/R_{\mathrm{M3TM}} \approx 100$ ps
$\tau_{dl} \approx 100$ fs

10nm vs 60 nm Gd





- Gd/W bilayer
- 60nm Gd shows slower demagnetization with same maximum quenching at same fluence and recovery rate
- Martin suspects spin currents at interface to be the limiting factor
- **run simulations with s-d-model with heat/-and spin dissipation**

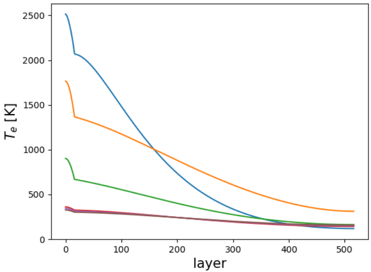
Finite difference method

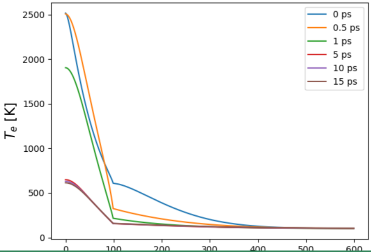
$$\begin{aligned}\nabla(\kappa\nabla T_e^j) &\approx \frac{\kappa_0 \frac{T_e}{T_p}}{dz^2}(T_e^{j+1}+T_e^{j-1}-2T_e^j)\\ &+ \frac{\kappa_0}{4}\left(\frac{T_e^{j+1}}{T_p^{j+1}}-\frac{T_e^{j-1}}{T_p^{j-1}}\right)(T_e^{j+1}-T_e^{j-1})\end{aligned}$$

energy flow conserving interface with transport constant κ_{int}

$$\begin{aligned}\nabla(\kappa\nabla T_e^{Gd_{int}}) &= \frac{\kappa_{int}}{2dz_{Gd}^2}(T_e^{W_{int}}-T_e^{Gd_{int}})\\ &+ \frac{\kappa_{Gd}}{dz_{Gd}^2}(T_e^{Gd_{int-1}}-T_e^{Gd_{int}})\\ &+ \frac{(\kappa_{int}-\kappa_{Gd})}{dz_{Gd}(dz_{Gd}+dz_W)}(T_e^{W_{int}}-T_e^{Gd_{int}})\end{aligned}$$

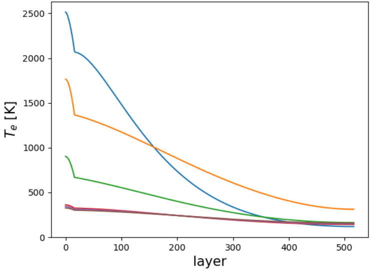
GdW with heat diffusion

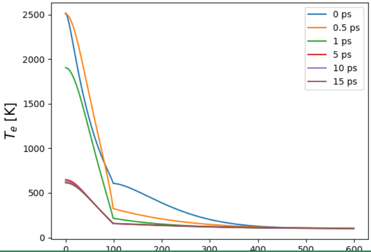


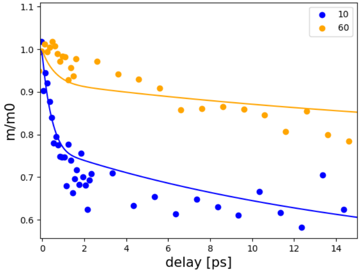


- same pump fluence
- high interface conductivity ($\kappa_{int} \approx 10\kappa_W, 100\kappa_{Gd}$)
- T_e decays slower in 60nm Gd

GdW with heat diffusion

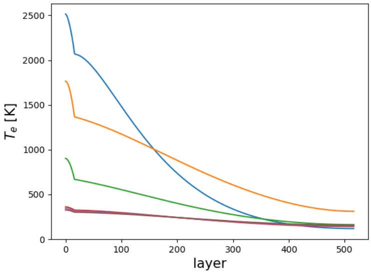


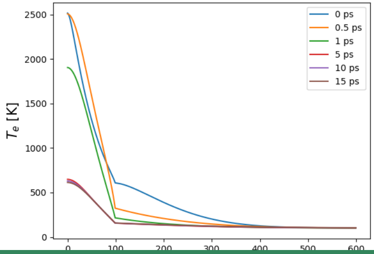


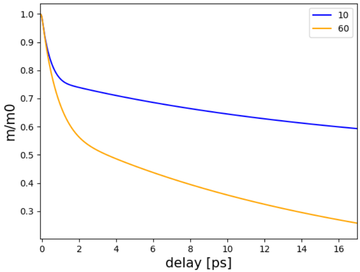


- 5nm penetration depth of XMCD probe
- 60nm simulation shows less demagnetization due to **low temperatures** in the bulk

GdW with heat diffusion





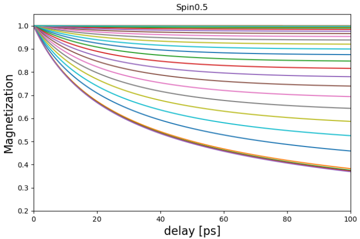


- only regarding first 5 nm of Gd in XMCD signal: magnetization in 60nm more strongly quenched

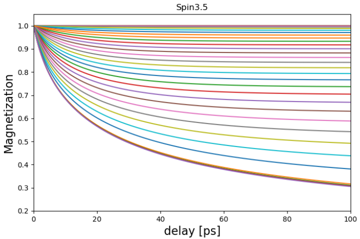
LLB and M3TM: relaxation times for different spin qunatum numbers

relaxation plots

$S = 1/2$



$S = 7/2$



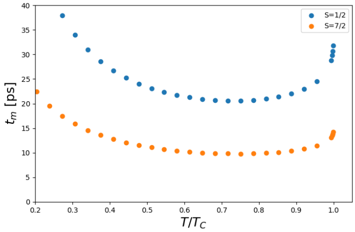
- initial temperature varied between 0.1 K and 292.9 K
- both equilibrium magnetization and 'slopes' differ
- $J(S = 7/2) > J(S = (1/2)$, thus faster relaxation with $S = 7/2$

τ_m definition

in the M3TM often referred

$$\tau_m = \Delta m / \dot{m}(t = 0)$$

- Define $\Delta m = 1 - m_\infty$
- $m_\infty = m_e = B_s(Jm_e/k_B Te)$
- $\dot{m}(t = 0)$ slope between first to data points
- τ_m is the intersection of the linear graph and m_∞)
- diverges for $T \to 0$ due to $\dot{m} \to 0$
- diverges rises $T \to T_C$ due to $\frac{dm_e}{d_T}(T \to T_c)$



fitting of M3TM with analytical function?

LLB: $\frac{dm}{dt} = \frac{m_e \gamma \alpha_\parallel}{2\chi_\parallel} m \left(1 - \frac{m^2}{m_e^2}\right) = 1/\tau_m \; m\left(1 - \frac{m^2}{m_e^2}\right)$

$$\begin{aligned}
\Rightarrow \int dt &= \int dm \; \tau_m \frac{1}{m(1 - \frac{m^2}{m_e^2})} \\
&= \int dm \; \tau_m \frac{1}{m(1 - \frac{m}{m_e})(1 + \frac{m}{m_e})} \\
&= \int dm \; \tau_m \left(\frac{1}{m} + \frac{1}{2m_e(1 - \frac{m}{m_e})} - \frac{1}{2m_e(1 + \frac{m}{m_e})} \right) \\
t(m)/\tau_m &= \left(\ln(m) + \frac{1}{2} \ln\left(\frac{1 - \frac{m}{m_e}}{1 + \frac{m}{m_e}} \right) \right) \\
\exp\left(-\frac{t - t_0}{\tau_m}\right) + m_0 &= \left[m^2 \frac{1 - \frac{m}{me}}{1 + \frac{m}{me}} \right]^{-1/2}
\end{aligned}$$