Ultrafast tutorial in Ultrafast Magnetism

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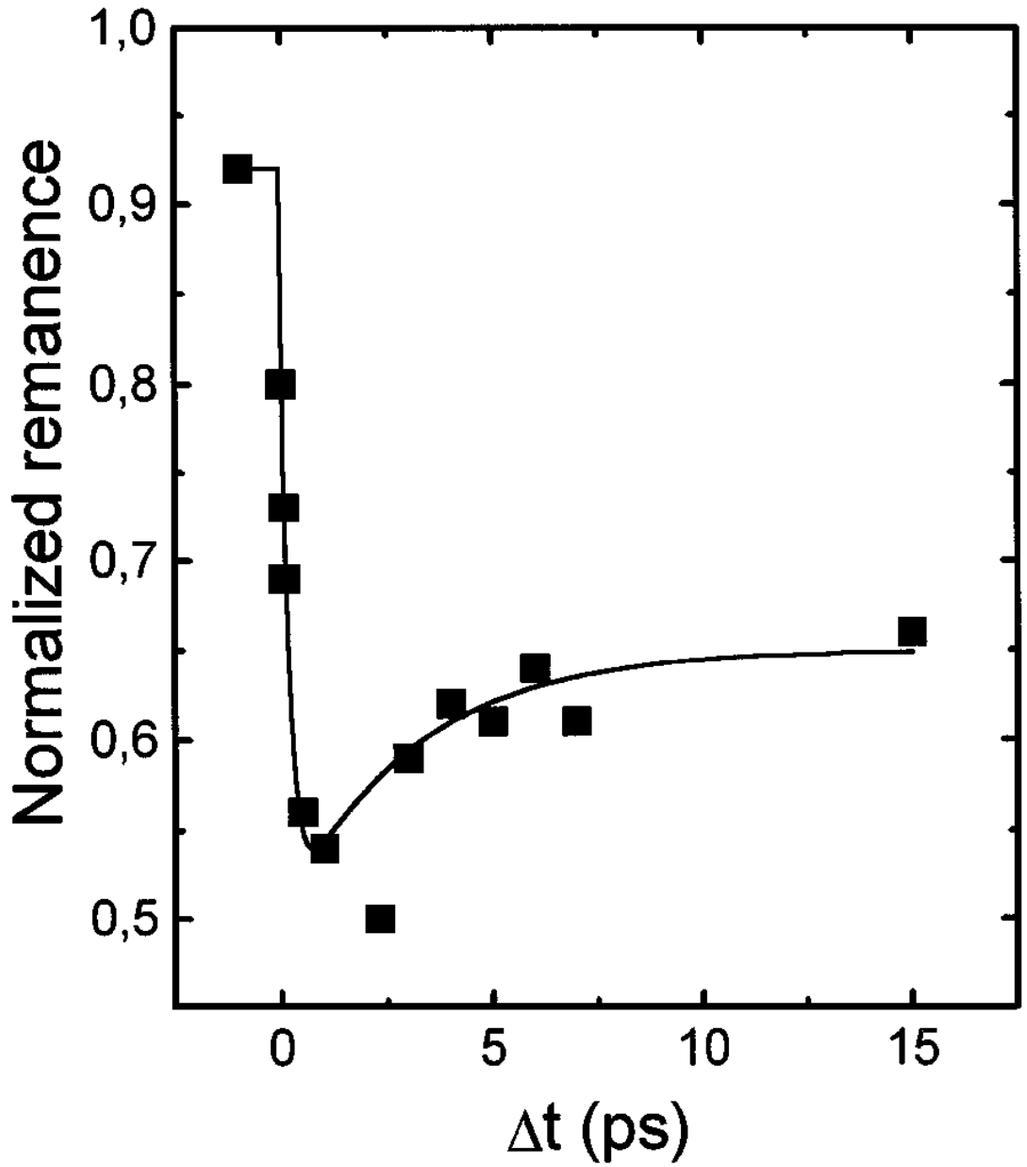
Ultrafast demagnetization in Ni

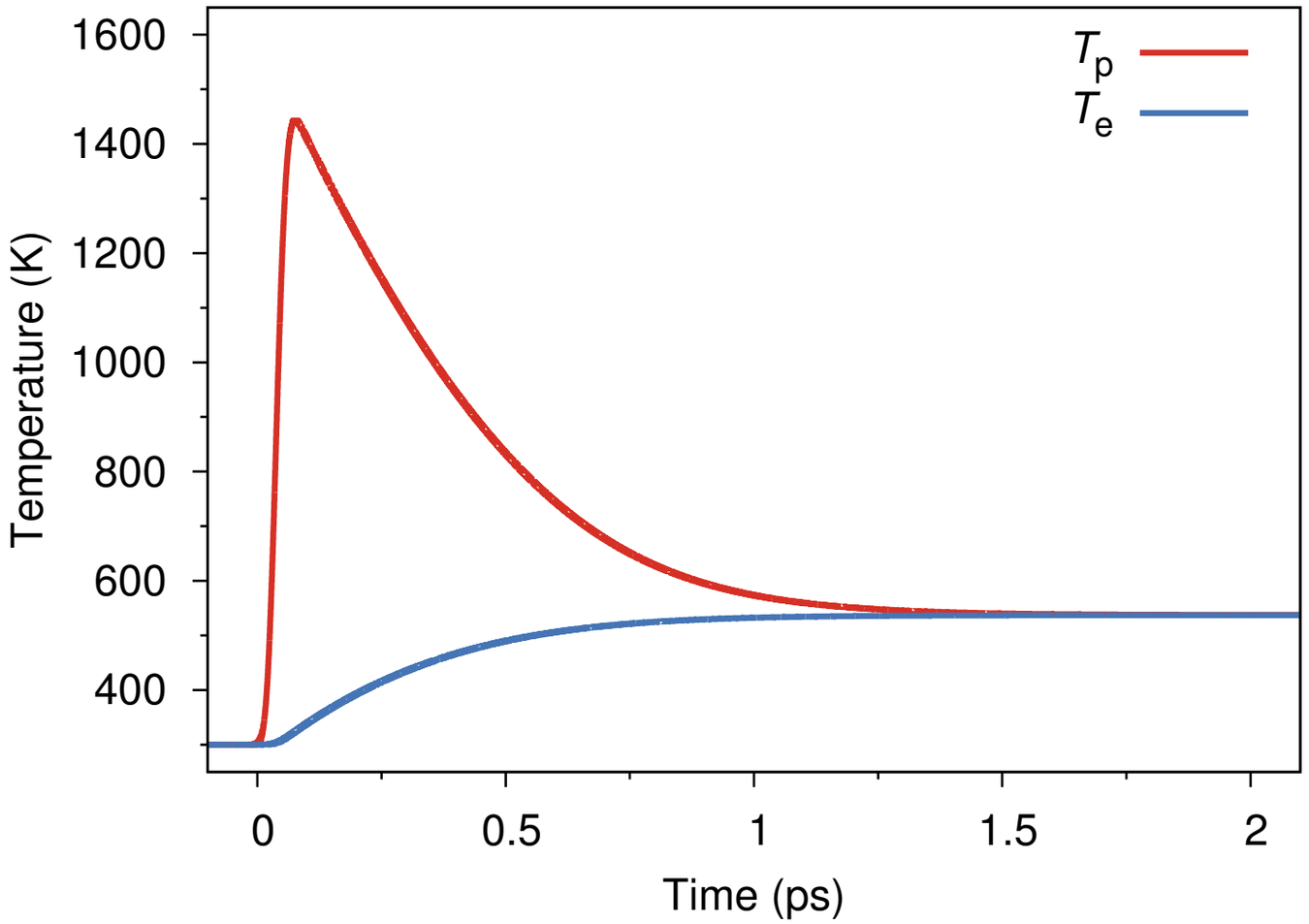


E. Beaurepaire et al, Phys. Rev. Lett. **76** 4250 (1996)

Two temperature model

$$C_e \frac{\partial T_e}{\partial t} = -G(T_e - T_l) + S(t)$$

$$C_l \frac{\partial T_l}{\partial t} = -G(T_l - T_e)$$



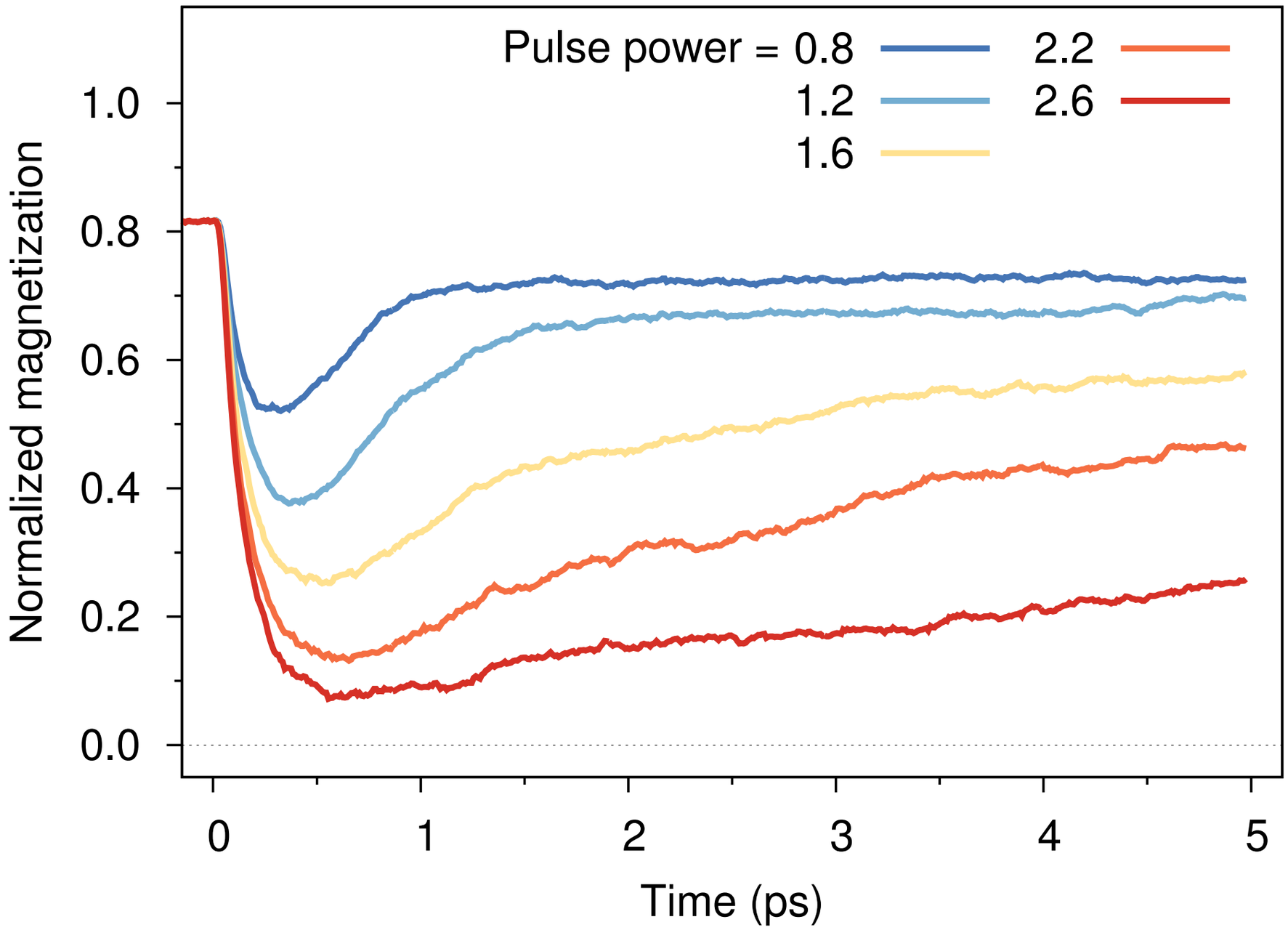
Free electron approximation

$C_e \propto T_e$

Input file for simulated laser pulse

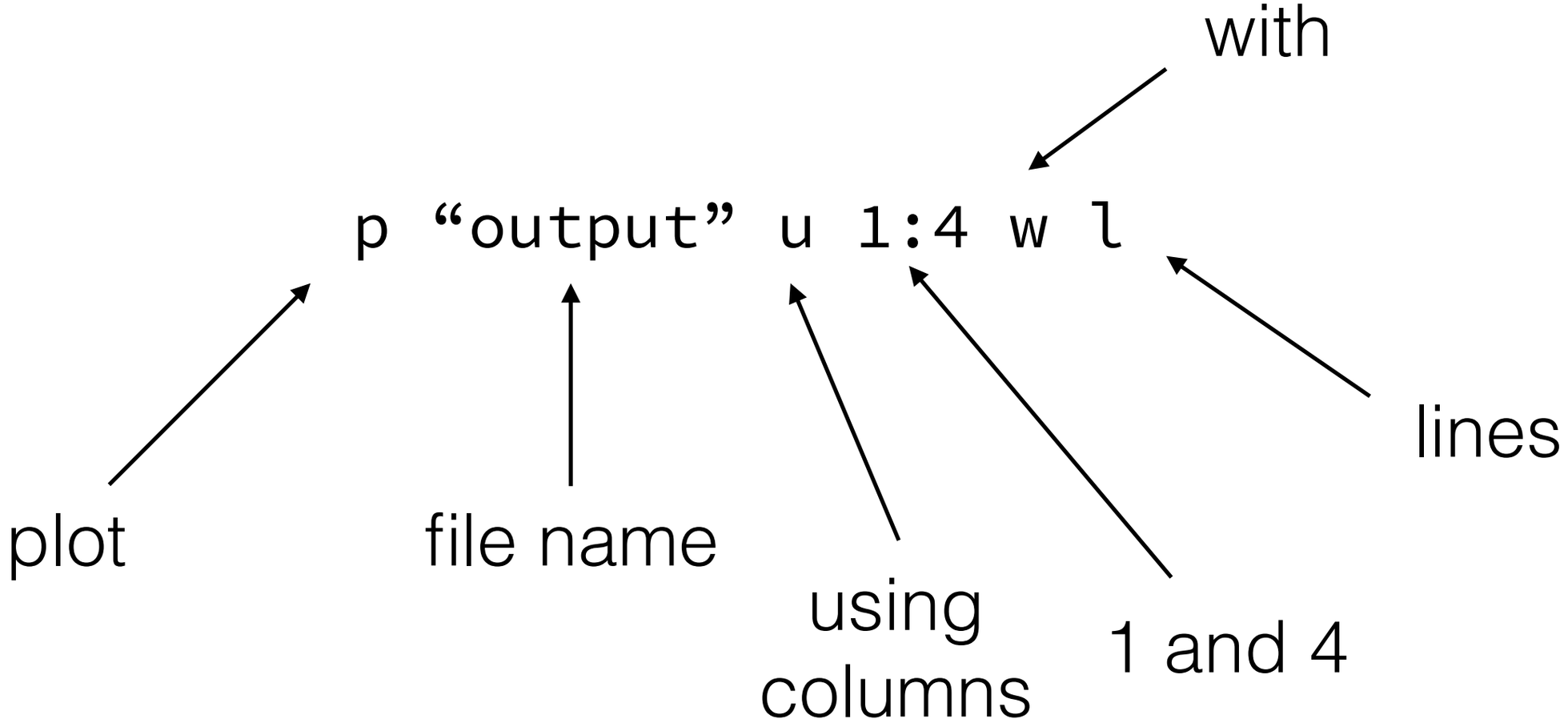
```
sim:equilibration-time-steps=10000
sim:total-time-steps=50000
sim:laser-pulse-power=5.0
sim:laser-pulse-temporal-profile=two-temperature
sim:program=laser-pulse
sim:integrator=llg-heun
sim:time-step=1.0e-16

output:real-time
output:electron-temperature
output:phonon-temperature
output:magnetisation-length
```

Effect of pulse power in Ni

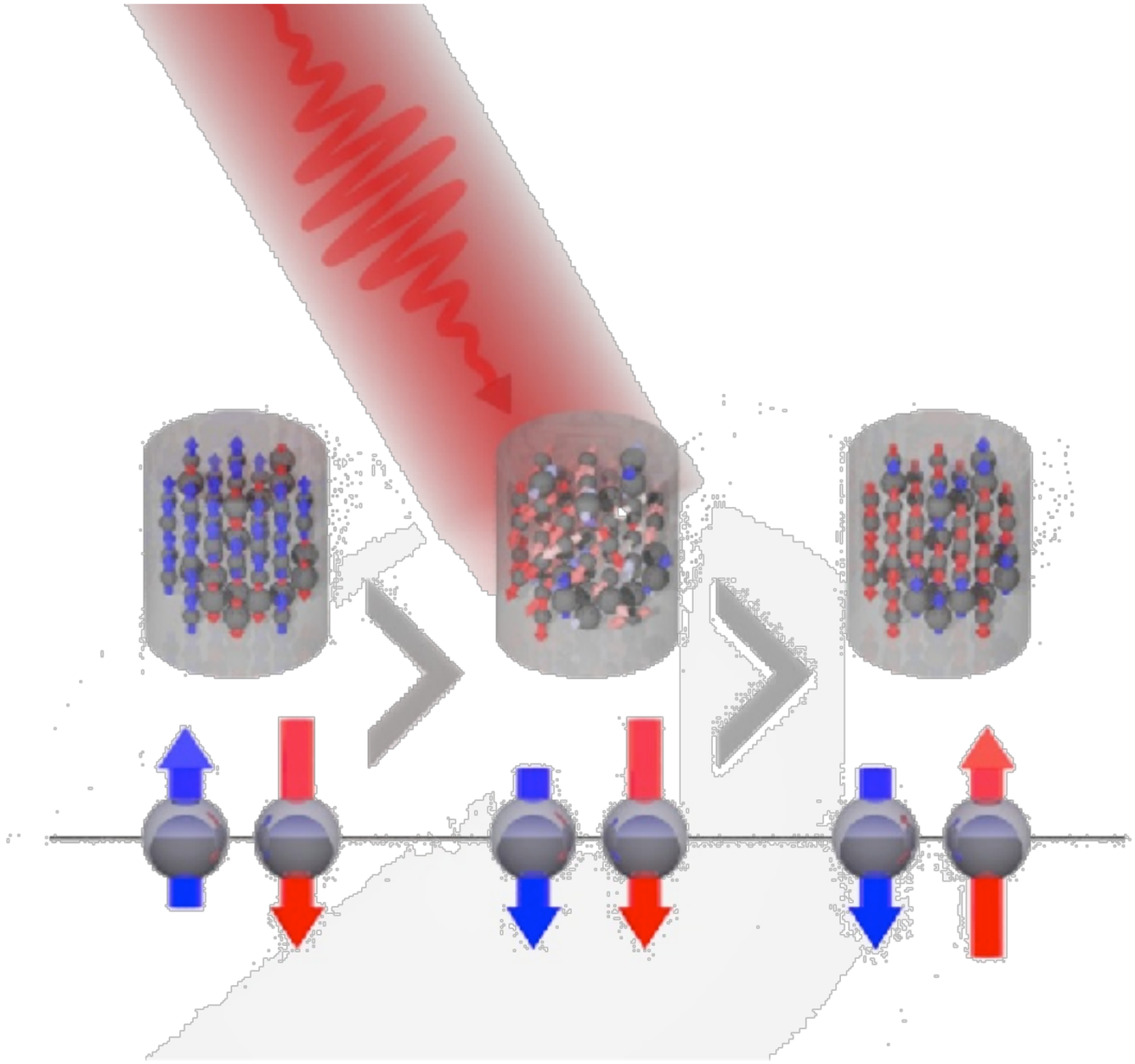


Stronger laser pulses show more demagnetization and slower recovery

Plot |m| vs time with gnuplot

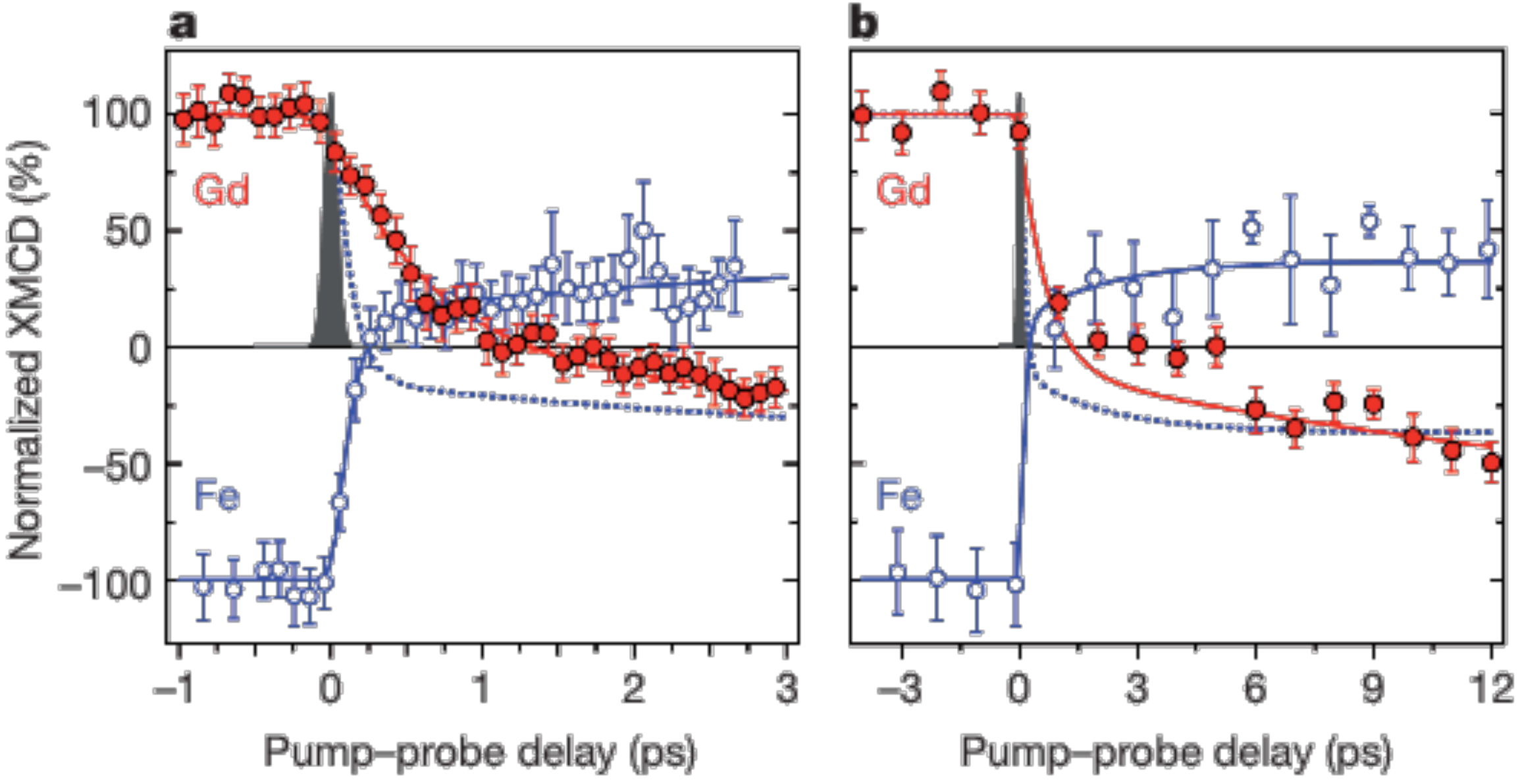


Thermally induced magnetic switching



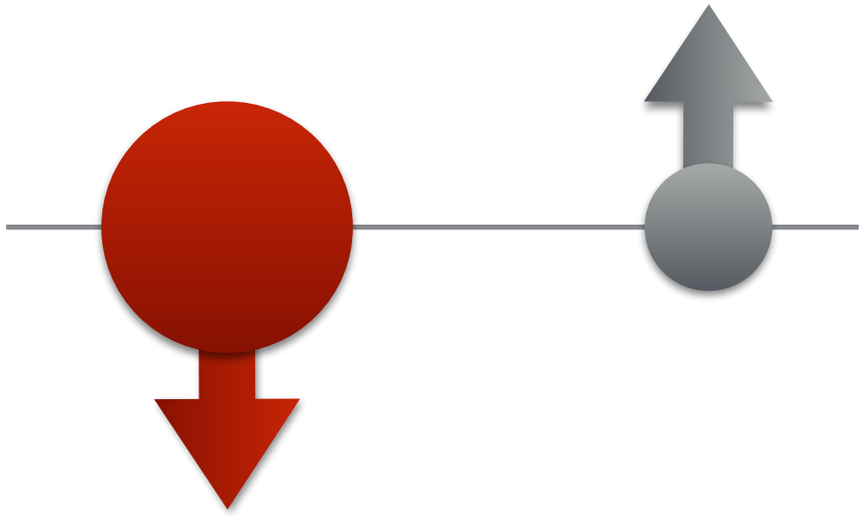
T. Ostler *et al*, Nat. Commun.(2012)

Sublattice magnetization dynamics

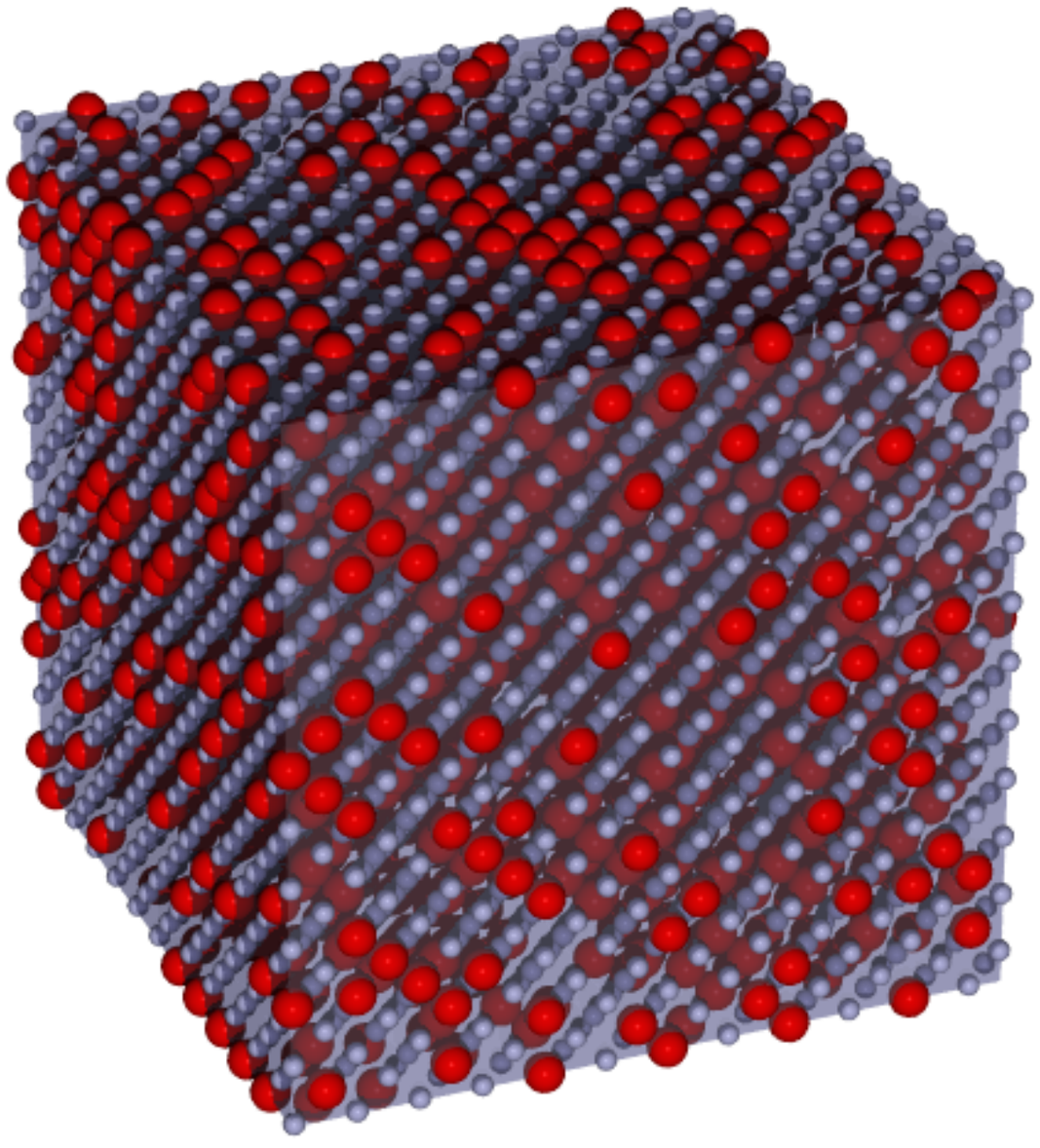


I. Radu *et al*, Nature (2011)

GdFe ferrimagnet



Gd Fe



GdFe.mat

```
#-----------------------------------------------------
# Number of Materials
#-----------------------------------------------------
material:num-materials=2
#-----------------------------------------------------
# Material 1 Fe (TM)
#-----------------------------------------------------
material[1]:material-name=TM
material[1]:damping-constant=0.02
material[1]:exchange-matrix[1]=2.835e-21
material[1]:exchange-matrix[2]=-1.09e-21
material[1]:atomic-spin-moment=1.92 !muB
material[1]:uniaxial-anisotropy-constant=8.07246e-24
material[1]:material-element=Fe
material[1]:minimum-height=0.0
material[1]:maximum-height=1.0
material[1]:alloy-host
material[1]:alloy-fraction[2]=0.25
material[1]:initial-spin-direction=0,0,1
#-----------------------------------------------------
# Material 2 Gd (RE)
#-----------------------------------------------------
material[2]:material-name=RE
material[2]:damping-constant=0.02
material[2]:exchange-matrix[1]=-1.09e-21
material[2]:exchange-matrix[2]=1.26e-21
material[2]:atomic-spin-moment=7.63 !muB
material[2]:uniaxial-anisotropy-constant=8.07246e-24
material[2]:material-element=Ag
material[2]:minimum-height=0.0
material[2]:maximum-height=0.0
material[2]:initial-spin-direction=0,0,-1
```

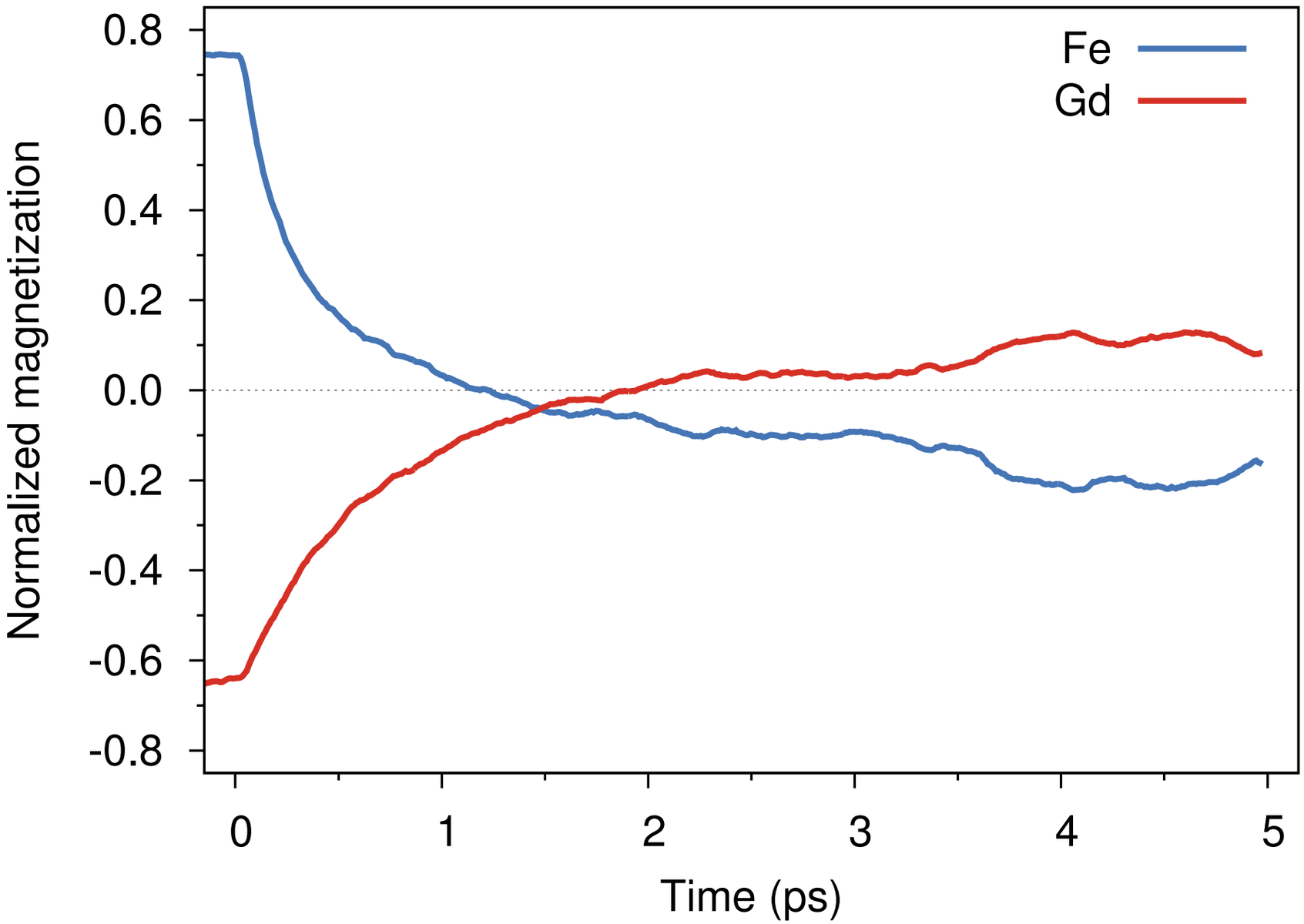
input file

```
sim:equilibration-time-steps=20000
sim:total-time-steps=50000
sim:temperature = 300.0
sim:equilibration-temperature = 300.0
sim:temperature-increment=25
sim:time-steps-increment=10
sim:preconditioning-steps = 200
sim:equilibration-time-steps=1000
sim:total-time-steps=50000

sim:two-temperature-electron-heat-capacity=2.25e2
sim:two-temperature-phonon-heat-capacity=3.1e6
sim:two-temperature-electron-phonon-coupling=2.5e17

sim:laser-pulse-temporal-profile = two-temperature
sim:laser-pulse-time = 50 !fs
sim:laser-pulse-power = 16.70
```

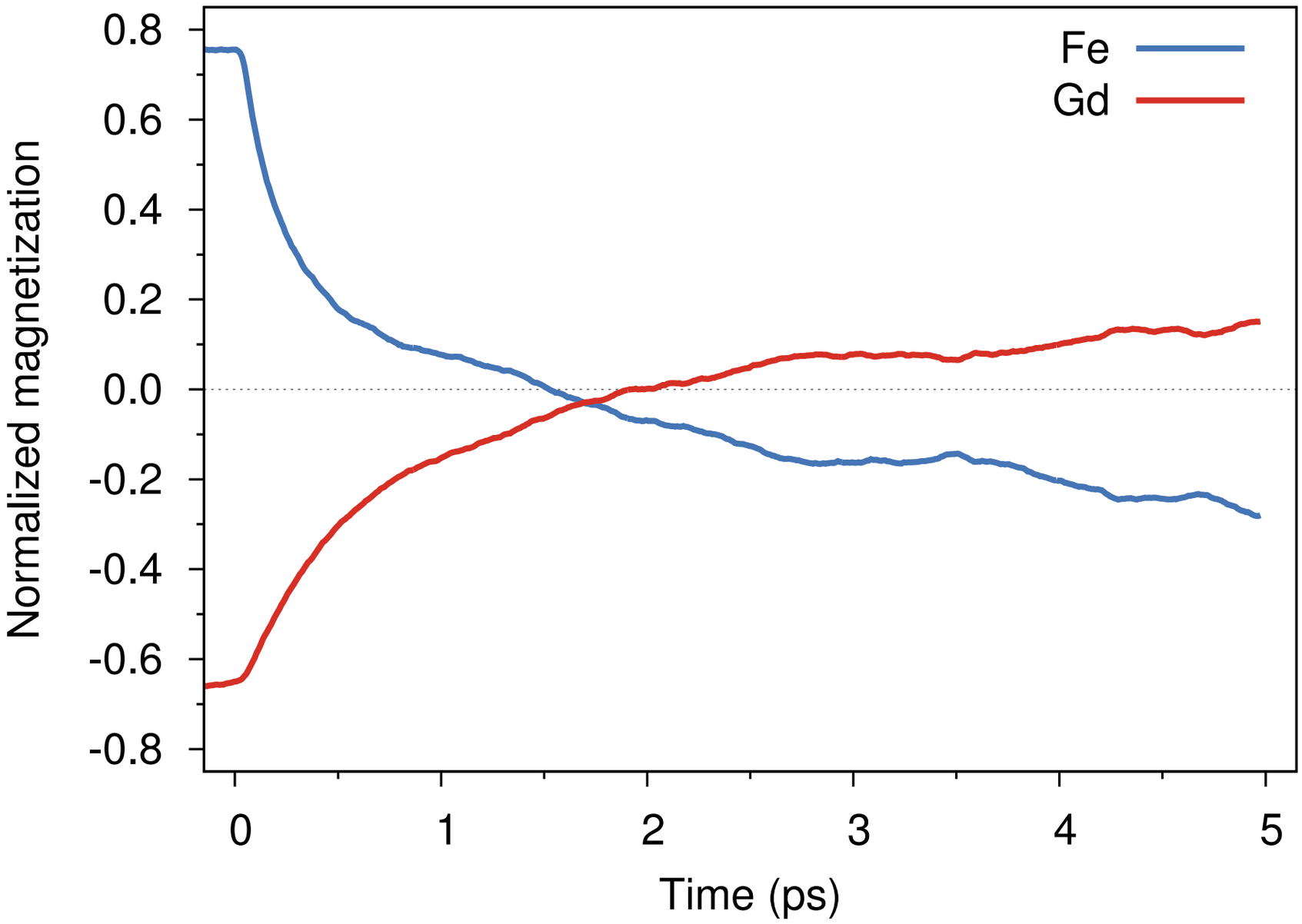
input file (pt2)

```
sim:integrator=llg-heun
sim:time-step=1.0e-16

output:real-time
output:electron-temperature
output:phonon-temperature
output:material-magnetisation
```

Calculated magnetization dynamics



Dynamics for 7nm^3 GdFe



Summary

Simulated Curie temperature and demagnetization dynamics in Ni

Simulated TIMS in GdFe

Many different types of simulations possible (materials, alloys, multilayers…)

VAMPIRE

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