Supplementary Information for “Comparative Study of Femtosecond Laser-Induced Ultrafast Magnetization Dynamics in Soft Ferromagnetic Ultra-thin alloy”

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This supplementary information is formed in 2 part. In the first part, we investigate the dependence of our calculation results noted in the main manuscript to the depth of potential well (V_z). In the second part, we studied the sensitivity of pulse width on the magnetization dynamics.

The code simulates the dynamics of thickness-dependent magnetization calculated based on microscopic three-temperature (M3T) model. First, chemical potential and density of states are calculated for a range of thicknesses of a thin layer. Then, some M3T model parameters such as electron-phonon coupling coefficient, Sommerfeld coefficient and spin-flip ratio that are a function of density of states are calculated. At last, M3T model differential coupled equations are solved to simulate dynamic magnetization, electron temperature and phonon temperature for several thicknesses and several fluences.

I. Effect of the potential well depth (V_z) on the quantum confinement effect of ferromagnetic ultra-thin films

We noted our computation results of quantum confinement effect in figure 2 and 3, using the potential well depth of V_z=10 eV in the main manuscript. In this section of SI script, we show that our result are sensitive to the potential well size. In the Free electron model, V_z occupies a limited amount. We calculated an additional value of V_z=15 eV in detail and compared with the results of V_z=10 eV.

The calculation results for the both potential well depths, V_z=10, and 15 eV in Figures S1-S4, shows that size of V_z effect on the calculations. In the other words, Normalized Fermi energy increases slightly about 2% for three of ferromagnetic ultra-thin films from V_z=10 eV to V_z=15 eV, but the DOS, Sommerfeld coefficient, and electron-phonon coupling coefficient oscillations does not change significantly when V_z changes from 10 eV to 15 eV.

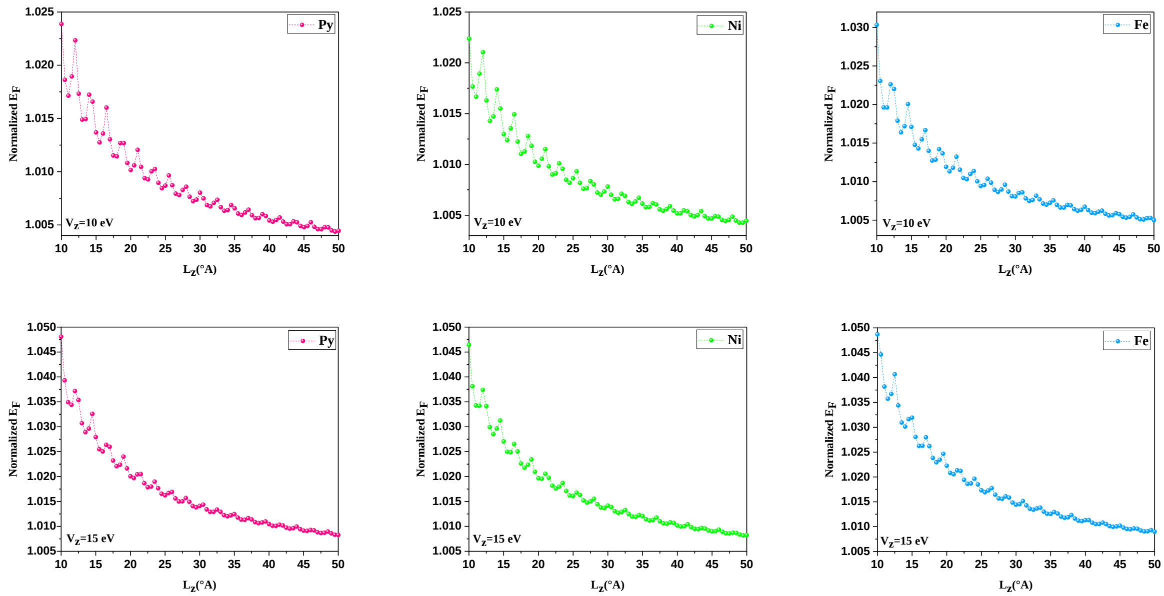

Fig. S1. thickness-dependent Fermi energy of quantum confined Py, Ni, and Fe ferromagnetic ultra-thin film with quantum well depth of V_z=10 eV, and 15 eV.

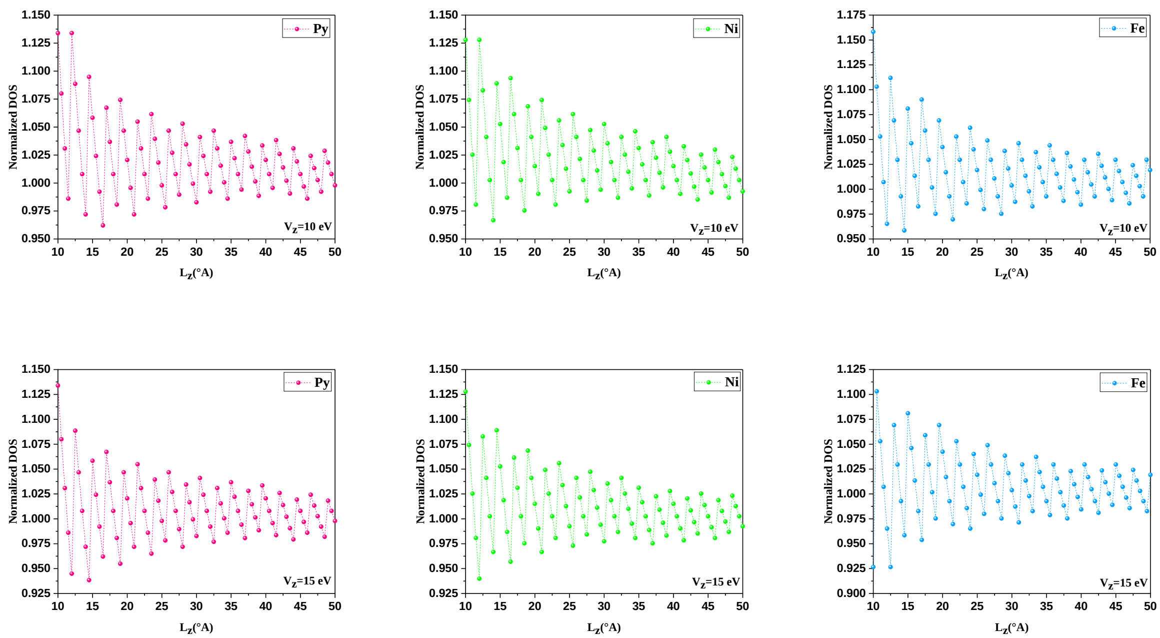

Fig. S2. thickness-dependent electron density of states in Fermi level of quantum confined Py, Ni, and Fe ferromagnetic ultra-thin film with quantum well depth of V_z=10 eV, and 15 eV.

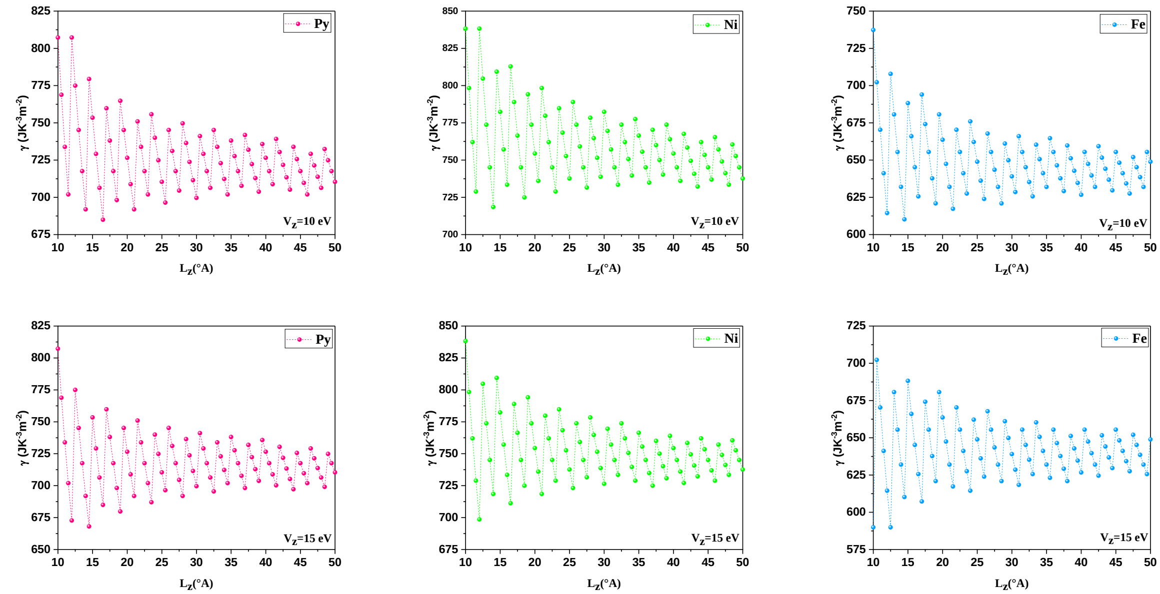

Fig. S3. thickness-dependent Sommerfeld coefficient of quantum confined Py, Ni, and Fe ferromagnetic ultra-thin film with quantum well depth of V_z=10 eV, and 15 eV.

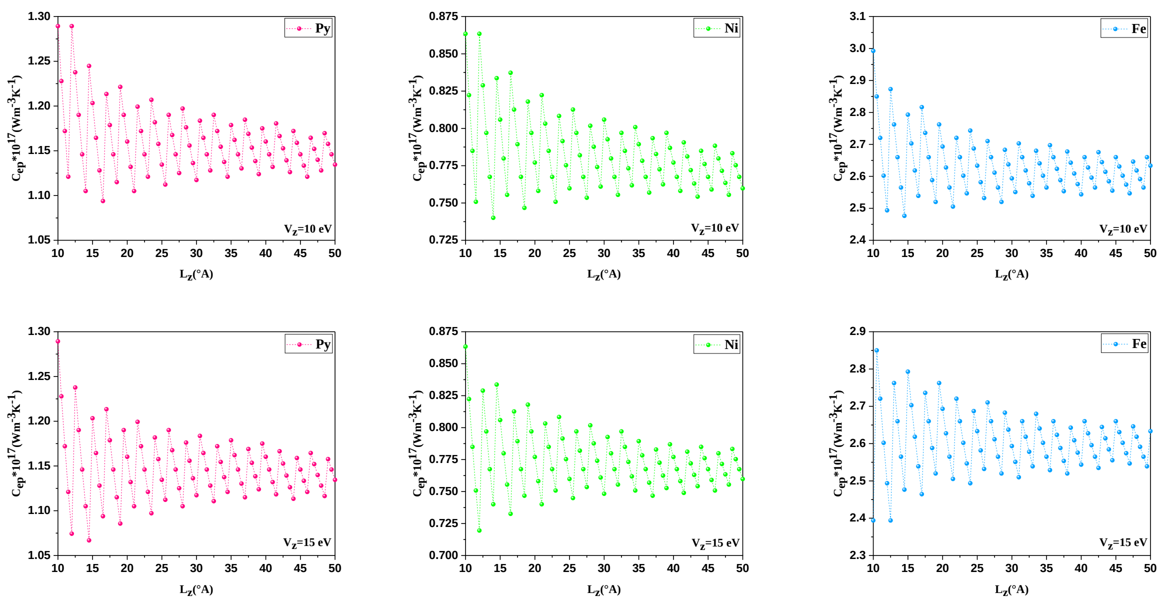

Fig. S4. thickness-dependent coupling coefficient between electron and phonon of quantum confined Py, Ni, and Fe ferromagnetic ultra-thin film with quantum well depth of V_z=10 eV, and 15 eV.

II. Sensitivity of the femtosecond laser pulse width on the magnetization dynamics of the ferromagnetic ultra-thin films

Figure S5-S6 show the behavior of the magnetization dynamics and ratio of electron and phonon temperature to Curie temperature for each specific pulse width. According to the quantity of pulse width τ_0 in equation $P_{pump}(t) = \frac{(\frac{F_0}{d.\tau_0})}{\sqrt{2\pi}} exp\left(\frac{-1}{2}\left(\frac{t}{\tau_0}\right)^2\right)$, the larger the pulse width value, the thin film absorbs smaller energy. In addition, the time of magnetization quenching and electron and phonon temperature equilibration increases. Furthermore, for pulses with pulse width of 250 fs, and 500 fs, the absorbed energy is small such that the magnetization quenching of Fe does not recover back and remains constant. In addition, as the pulse width increases, its de-magnetization ratio decreases. Electron temperature becomes lower with increasing pulse width, which is caused by smaller energy absorption by the layers. Using a laser pulse with a high width is not suitable because we need a high fluence for re-magnetization, which is not desirable in practice.

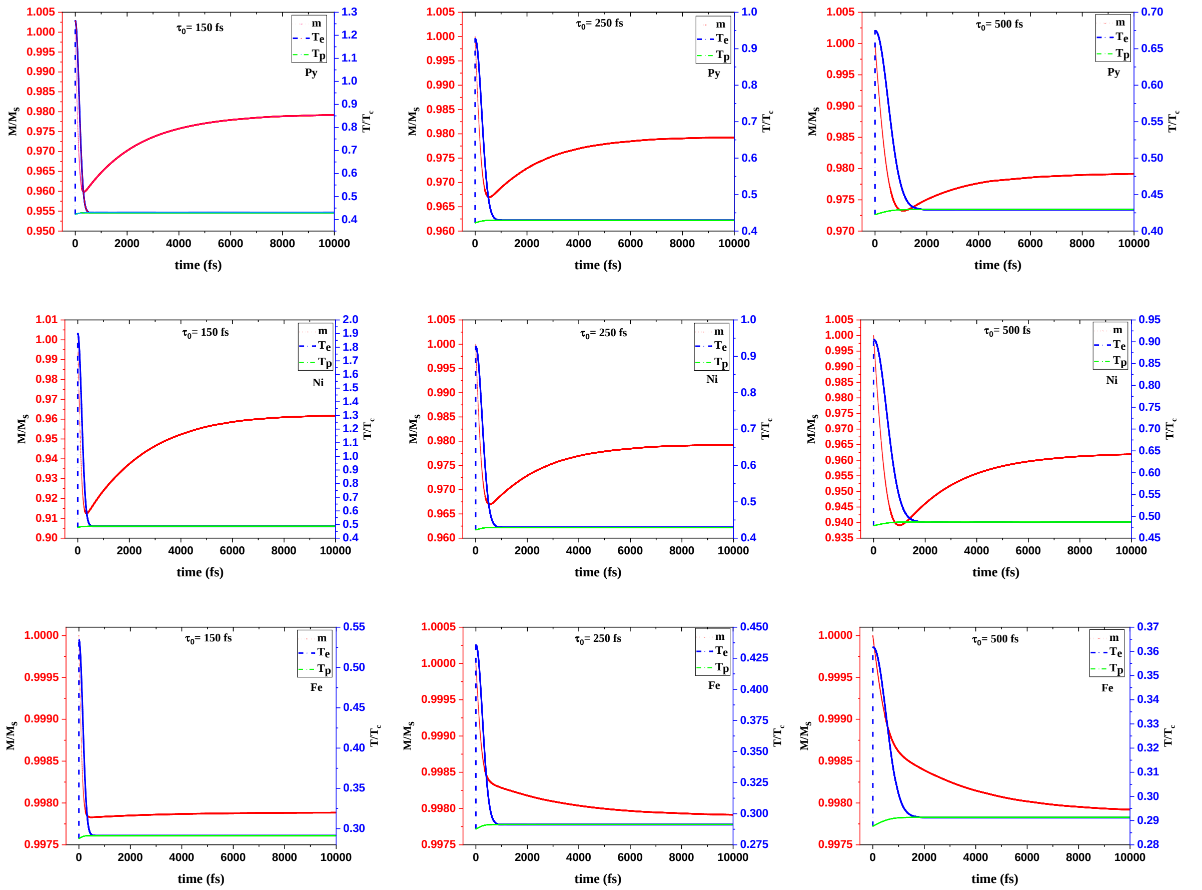

Fig. S5. Magnetization dynamics of 50 °A Py, Ni, and Fe quantum confined ferromagnetic ultrathin films under 20 mJ/cm^2 laser pulse fluence of 150 fs, 250 fs, and 500 fs pulse width.

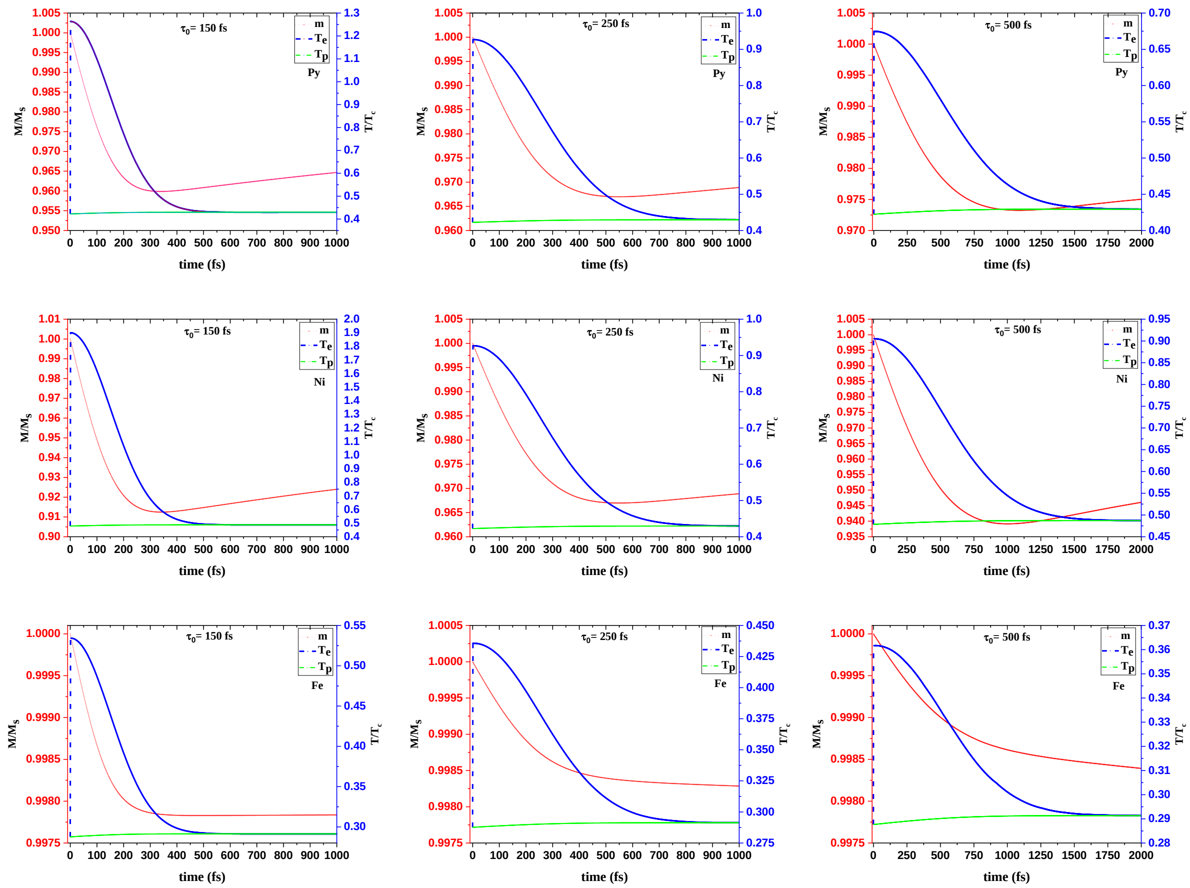

Fig. S6. The zoomed-in version of the Fig. S5.