Title: Imaging the ultrafast coherent control of a skyrmion crystal

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Abstract: Exotic magnetic textures emerging from the subtle interplay between thermodynamic and topological fluctuation have attracted intense interest due to their potential applications in spintronic devices. Recent advances in electron microscopy have enabled the imaging of random photo-generated individual skyrmions. However, their deterministic and dynamical manipulation is hampered by the chaotic nature of such fluctuations and the intrinsically irreversible switching between different minima in the magnetic energy landscape. Here, we demonstrate a method to coherently control the rotation of a skyrmion crystal by discrete amounts at speeds which are more than six orders of magnitude faster than previously observed. By employing circularly polarized femtosecond laser pulses with an energy below the bandgap of the Mott insulator Cu_2OSeO_3, we excite a collective magnon mode via the inverse Faraday effect. This triggers coherent magnetic oscillations that directly control the rotation of a skyrmion crystal imaged by cryo-Lorentz Transmission Electron Microscopy. The manipulation of topological order via ultrafast laser pulses shown here can be used to engineer fast spin-based logical devices.