Supplementary Material: Characteristics and Applications of Current-Driven Magnetic Skyrmion Strings

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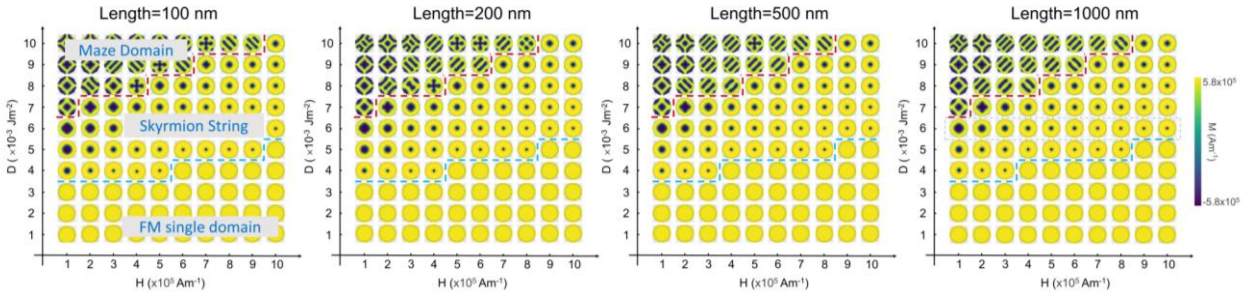


(a) (b) (c) (d)

Fig. S1 Phase diagrams for skyrmion string formation as a function of D and H with lengths of (a) 100 nm, (b) 200 nm, (c) 500 nm, and (d) 1000 nm. We can see that the lower value of D is unfavorable for skyrmion string generation. In the following simulation of skyrmion strings, the external applied magnetic field is set to 5×10^5 Am^{-1}, and DMI constant D is set to 6.0×10^{-3} Jm^{-2}. Although the D value is larger than the usual experimental data, a distinct varying morphology or configuration with a wider range of external field H can be achieved when the D value is set to 6×10^{-3} Jm^{-2} as shown in all four conditions in Fig. S1.

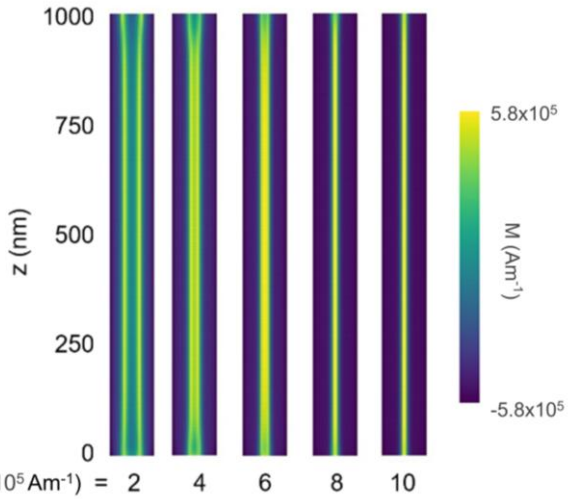


Fig. S2 Cross-section views of skyrmion string with H changing from 2×10^5 Am^{-1} to 10×10^5 Am^{-1}. The 2D skyrmions at different z-axis locations present slightly different profiles.

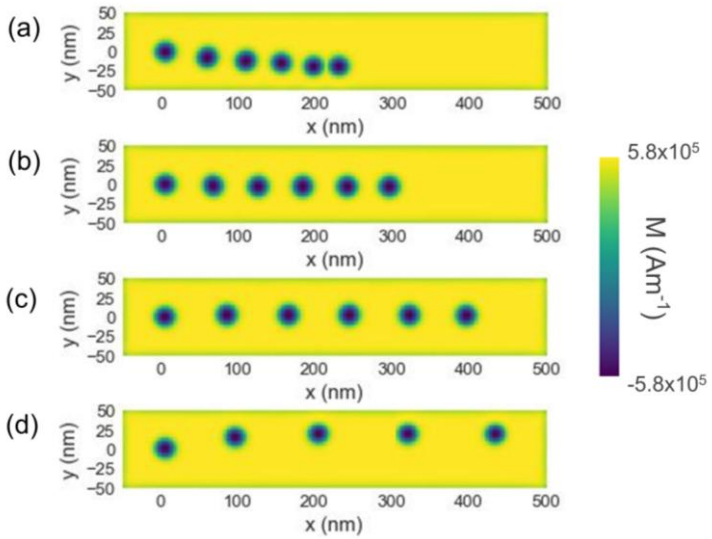
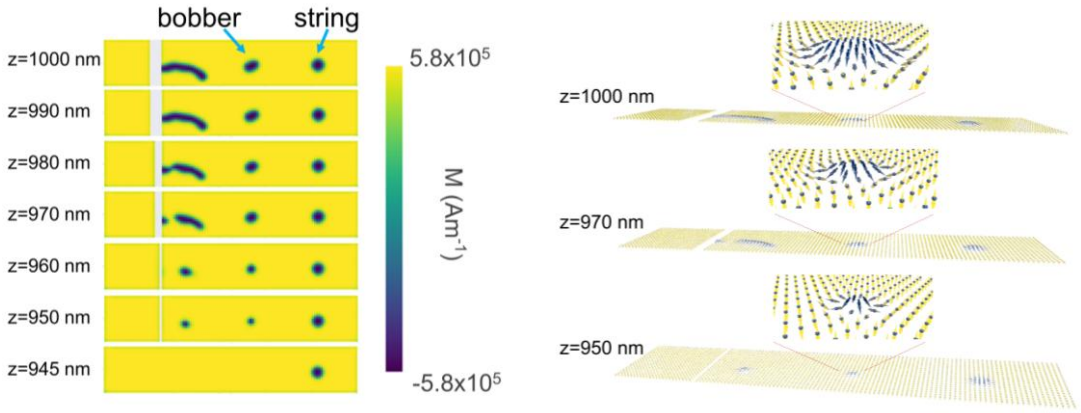


Fig. S3 The moving profiles with ξ of (a) 0.2, (b) 0.3, (c) 0.4 and (d) 0.6 under j=3.84×10^{7} Am^{-2}.



(a) (b)

Fig. S4 (a) Plane views of bobber generation process in driving times of 0.5 ns with j=3.84×10^{8} Am^{-2}. (b) 3D views of the bobber with the magnetic vector field.

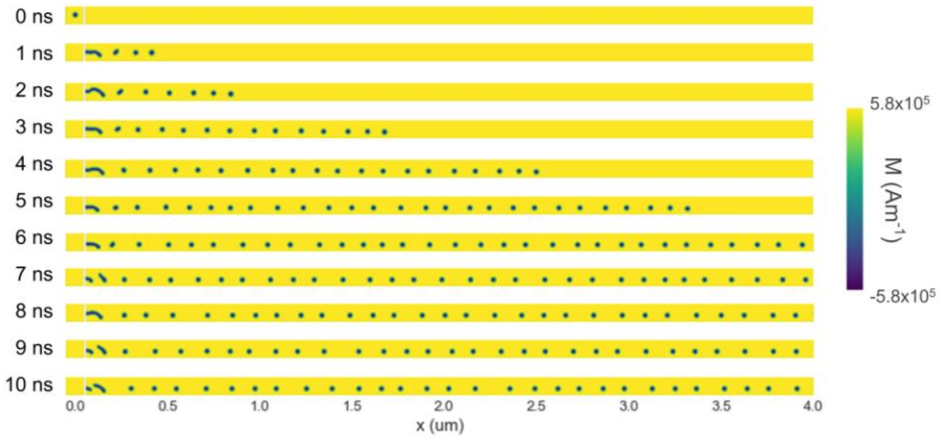
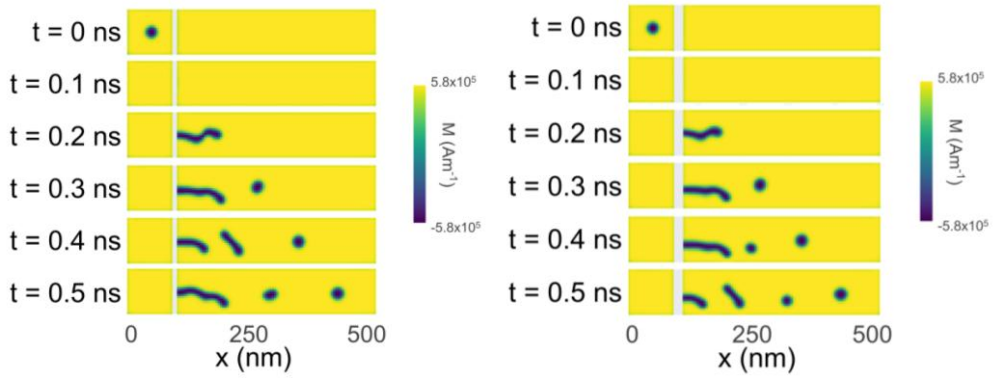
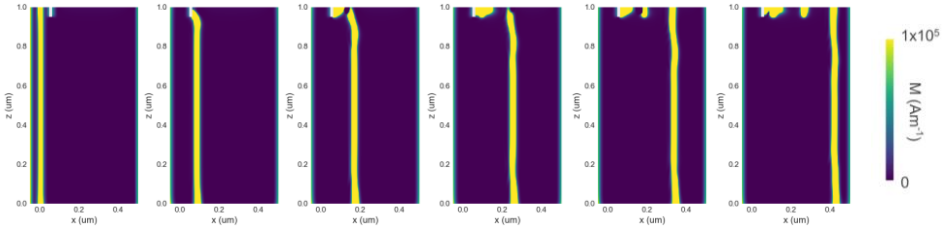


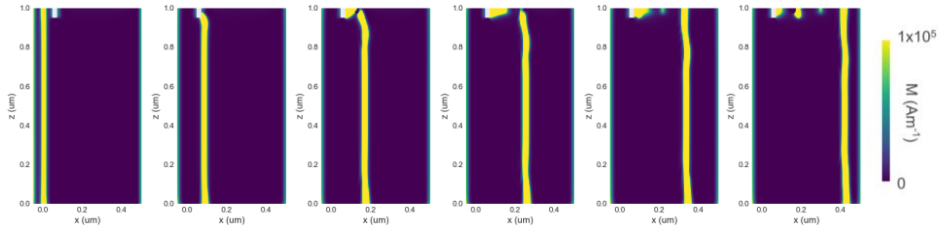
Fig. S5 Surface views of the skyrmion strings and bobbers in driving times of 10 ns with j=3.84×10^{8} Am^{-2} and ξ=α=0.3.



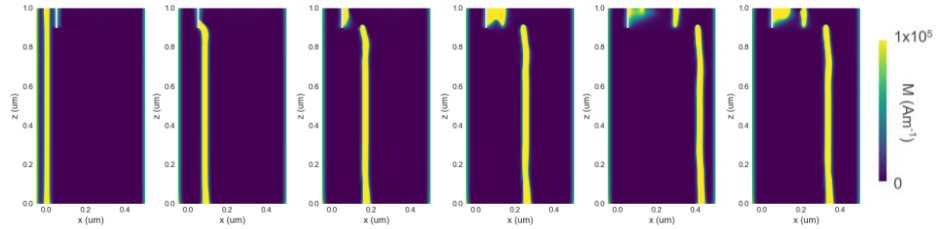
(a) (b)



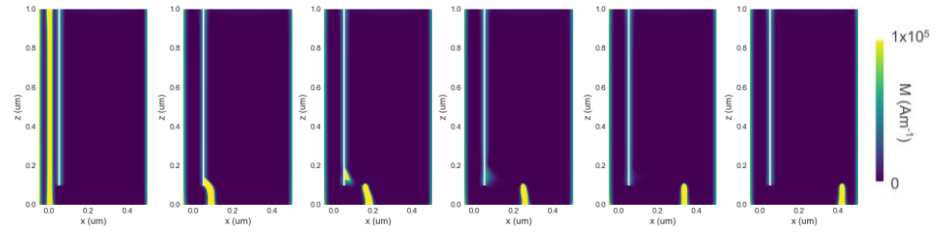
(c)



(d)



(e)



(f)

Fig. S6 Surface views and cross-section views of the skyrmion strings and bobbers in driving times of 0.5 ns with j=3.84×10^8 Am^{-2} for h=50 nm and (a, c) l=10 nm and (b, d) l=20 nm. The bobbers can be generated stably. When l is fixed at 5 nm and h becomes larger (100nm in (e) and 900 nm in (f)), there are no bobbers generated.

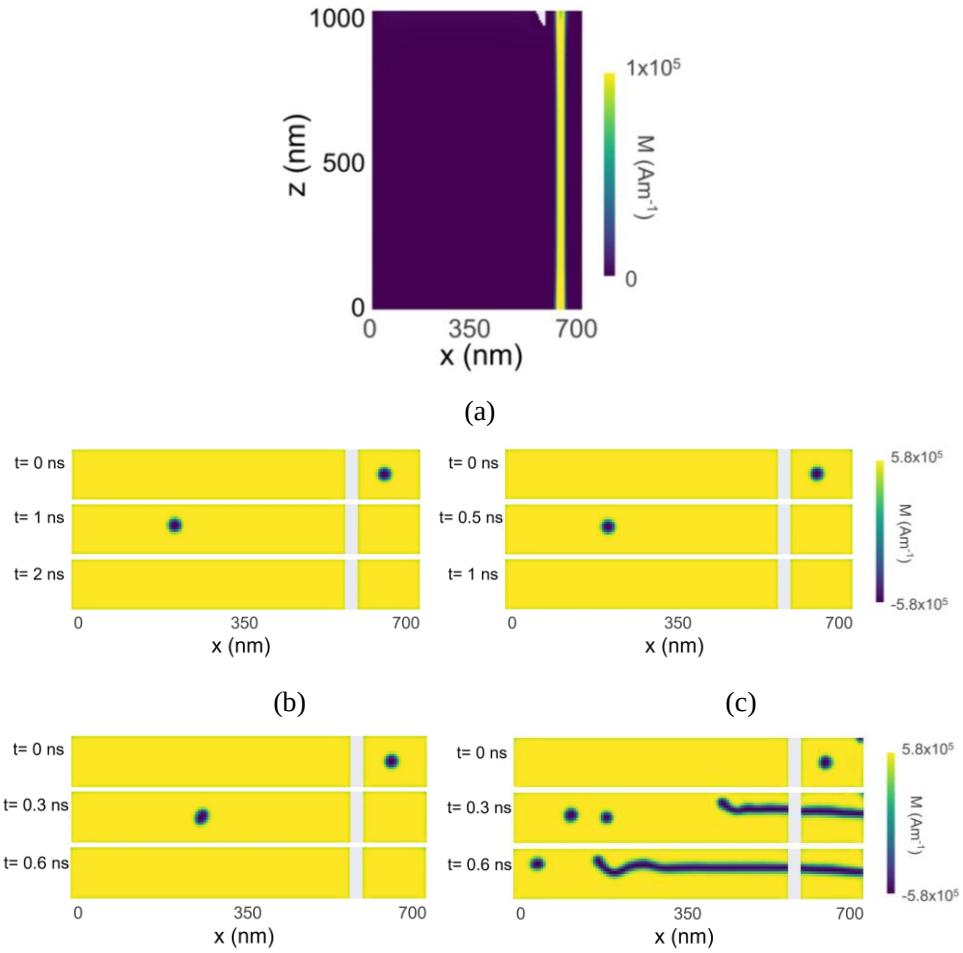
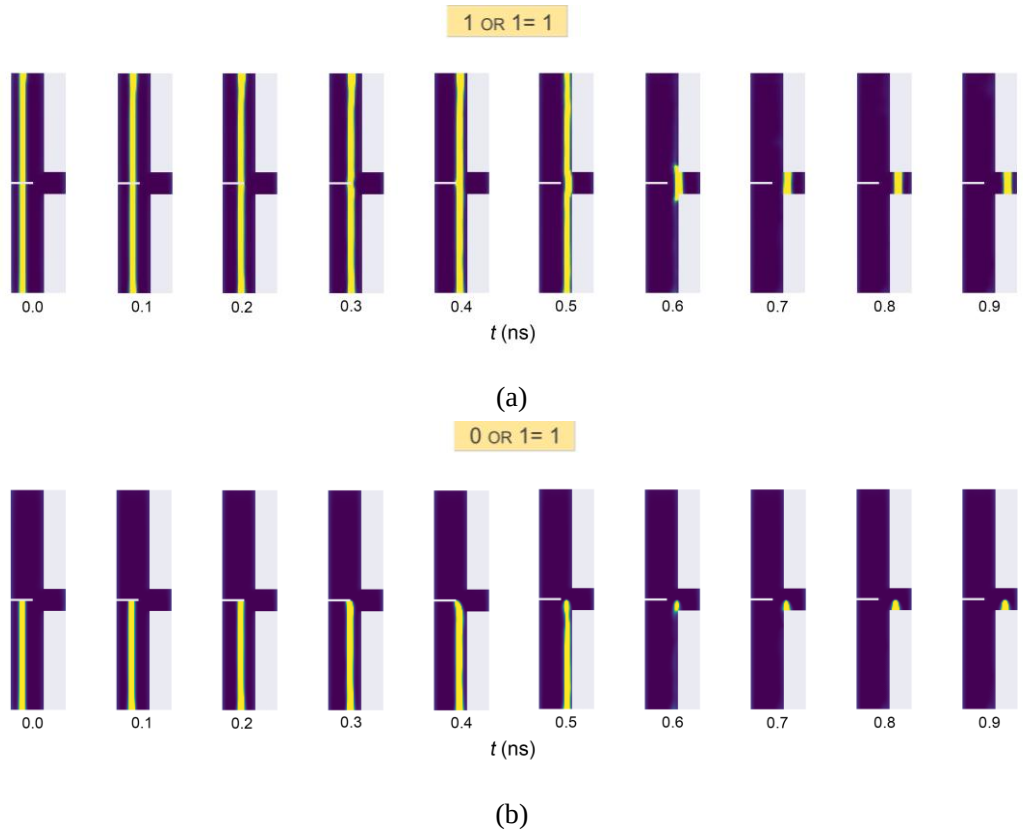
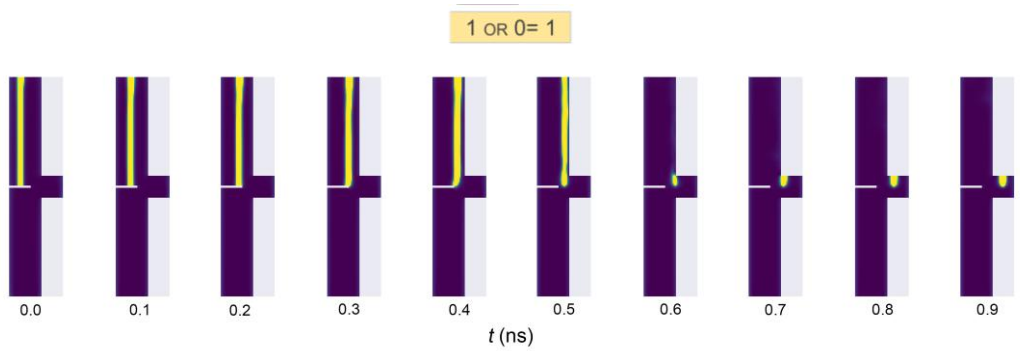
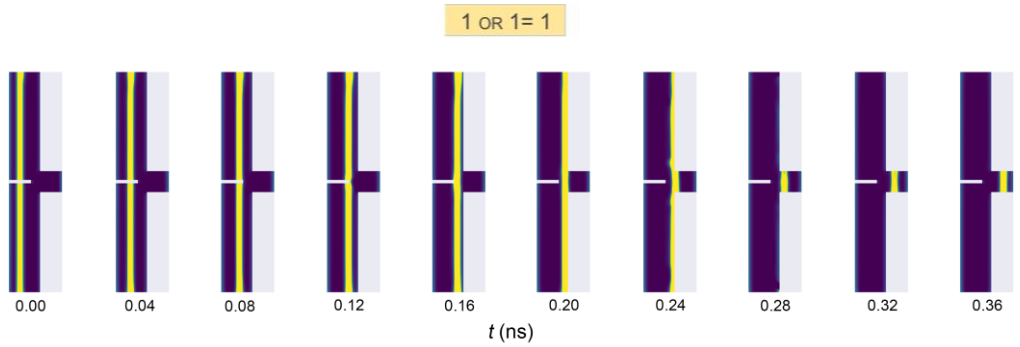


Fig. S7 (a) The simulation scheme when the biased driving current is reversed. The current is (b) -1.92×10^{8} Am^{-2}, (c) -3.84×10^{8} Am^{-2}, (d) -5.76×10^{8} Am^{-2} and (e) -7.68×10^{8} Am^{-2} respectively. No generated stable bobbers can be detected when the driving current moves from right to left with any current density.

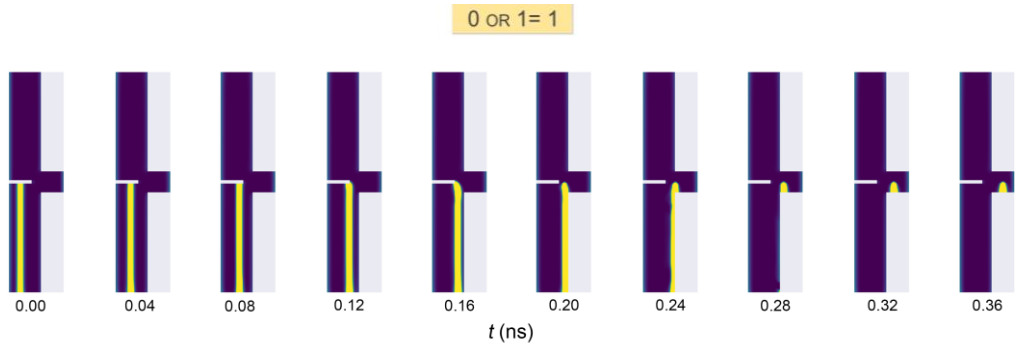




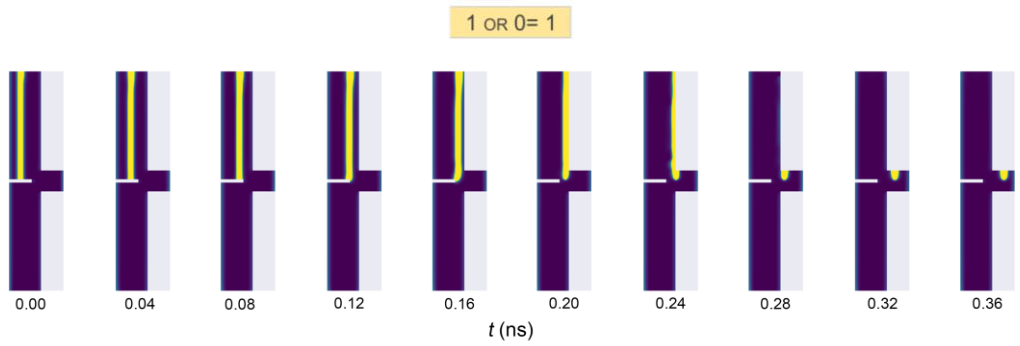
(c)



(d)



(e)



(f)

Fig. S8 OR gate realized through current-driven skyrmion strings with j of 7.68×10^{7} Am^{-2} and 1.92×10^{8} Am^{-2}, respectively.

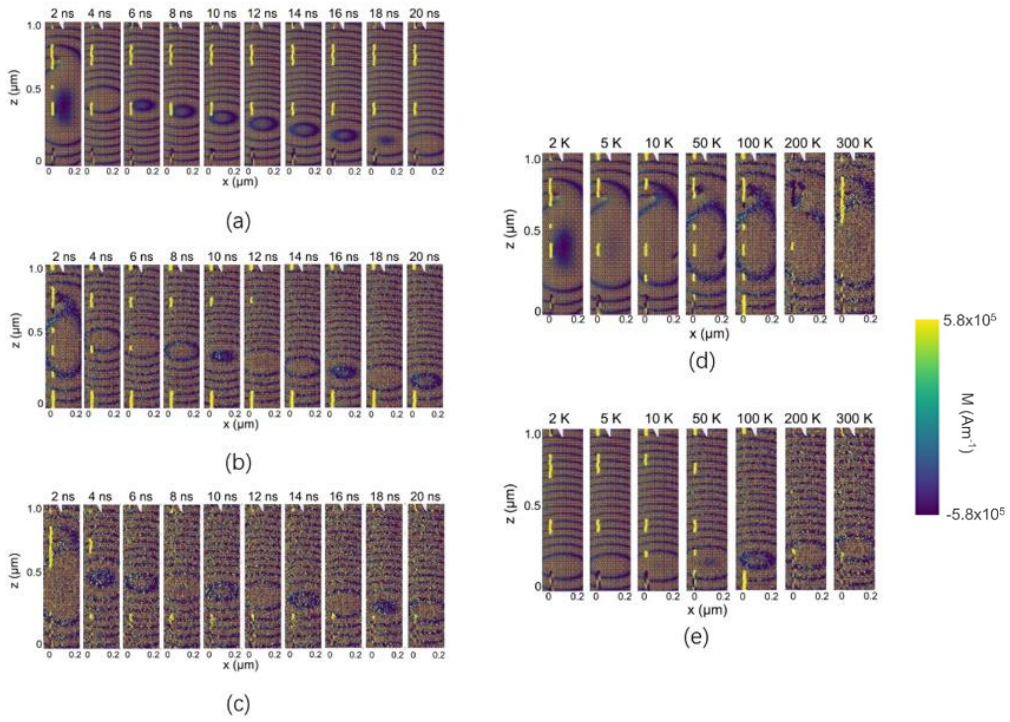


Fig. S9 Cross-section views of skyrmion strings in 20 ns at temperature (a) T=2 K, (b) T=100 K, and (c) T=300 K. Cross-section views of skyrmion strings at temperatures ranging from 2 K to 300 K at simulation time (d) t= 0 ns and (e) t= 20 ns.