Reply to "Comment on 'Frustrated magnetization in Co nanowires: Competition between crystal anisotropy and demagnetization energy' "

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In contrast to our analytic model neither of the two magnetic structure simulations by Lebecki and Donahue [preceding Comment, Phys. Rev. B **82**, 096401 (2010)] for Co nanowires agrees with the experimental results of Liu *et al.* [Adv. Funct. Mater. **18**, 1573 (2008)]. Simulations with the same OOMMF software by Vila *et al.* [Phys. Rev. B **79**, 172410 (2009)] for equivalent Co nanowires yield quite a different structure that shows opposite magnetic poles at the ends and periodic north and south poles on the sides of the wire in agreement with the experimental results.

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In our original paper[1] we made two approximations in order to obtain a model for the magnetization in a Co nanowire which could be solved exactly: (1) the thin wire approximation and (2) a sinusoidal modulation along the length of the wire of the angle the magnetization makes with the wire axis. We showed that this state has a lower energy than any state with constant magnetization for the material parameters and wire thickness that we used. Furthermore, its magnetic structure agreed qualitatively with the experimental results of Liu *et al.*[2] In the meantime this initial approach was improved by Erickson and Mills (EM) (Ref. 3) and by Vila *et al.*[4] EM found an exact numerical solution for the magnetization angle while retaining the thin wire approximation. Vila performed a simulation for equivalent Co nanowires [using the same OOMMF software as Lebecki and Donahue[5] (LD)].

Based on their simulation LD state in their comment that our thin wire approximation does not hold for the range of wire thicknesses that we were studying. Although we do not disagree with this conclusion, we would like to criticize their work for two reasons: (1) their results do not agree with the experimental features that we were trying to explain and (2) they should have compared their results with the improved work of EM and Vila rather than our initial approach in order to justify their conclusions.

LD simulated the spin lattice and observed two different structures, which they call the z-vortex and the y-vortex structures. In contrast to our simple solution these structures do not agree with the experimental results of Liu *et al.* This group observed consistently two properties: (a) opposite poles at the two ends of all the wires and (b) quasiperiodic modulation of north and south poles along the sides of all the wires. Both of the structures of LD fail to show these combined properties: (1) Their z vortices have opposite poles at the two ends of the wire but do not have the quasiperiodic north and south poles on the sides of the wire. (2) Their y vortices have the quasiperiodic north and south poles on the sides of the wire but they do not have poles at the ends of the wire.

LD point out that other groups did not always observe quasiperiodic modulation along the sides of the wire. This may be due to pinning centers that hinder the formation of this complex structure. If the pinning forces exceed a critical value then they block its formation.

LD state that their results are consistent with the simulations by Vila. However, the lowest magnetic state obtained by Vila is quite different from LDs and does show both properties: (a) opposite poles at the two ends of the wire and (b) quasiperiodic modulation of north and south poles on the sides of the wire. This is quite remarkable since these authors used the same software as LD. Vila's simulation yields a better match to the experimental data by Liu *et al.* that we were attempting to explain while agreeing with the conclusion that one has to go beyond the thin wire approximation for these wire thicknesses.

Therefore further work is needed to understand the energy difference between the LD and Vila simulations and to compare the simulation results with the EM model. In particular, it is important to show that for thinner wires the simulation results eventually agree with the EM results when the thin wire approximation does become valid. Nevertheless we consider the LD work an interesting contribution that will surely stimulate further research.

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