# Superfluid phases of $^3$He in a periodic confined geometry[†]

J. J. Wiman and J. A. Sauls

Department of Physics and Astronomy, Northwestern University, USA

It has long been known that confinement of superfluid $^3$He on length scales comparable to the superfluid coherence length $\xi_0$ can stabilize phases not seen in the bulk. Recently, experimental systems with such restricted geometries have emerged that are periodic, or nearly periodic, opening up new possibilities for the study of complex phases in periodic confined geometries.[1] We report theoretical and computational results on the phases and phase diagram of superfluid $^3$He confined by a two-dimensional periodic array of square boundaries ("posts") with diffusive boundary scattering and translational invariance in the third dimension. Our computational domain is a square region of side length $l$, with periodic exterior boundary conditions and a square interior boundary of side length $d < l$ with diffusive boundary conditions. The interior boundary reduces the normal-state $SO(3)$ orbital symmetry to the point group $D_{4h}$. We describe the allowed symmetry classes for the superfluid phases in this geometry. We present results for the phase diagram obtained by numerically minimizing the free energy in Ginzburg-Landau theory formulated with a general $3 \times 3$ complex $^3$He order parameter. For $6 \leq l/\xi_0 \leq 20$, and weak-coupling values of the material parameters, we find a transition ($T_{c_1}$) from the normal state to a periodic polar phase, for all post dimensions $d$ at which a superfluid transition occurs. For the smaller post dimensions a second transition onsets at a lower temperature, $T_{c_2}$, to a periodic distorted B phase. There is a critical post dimension above which only the periodic polar phase is stable.

1. N. Zhelev *et al.*, Nanofabricated cells for confined $^3$He. APS March Meeting 2013, abstract Z22.003.

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