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Insights into the Nature of the Exotic Fractional Quantum Hall States from Ultra-low Temperature Transport

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It is believed that the $\nu = 5/2$ and 12/5 fractional quantum Hall states (FQHS) in the second Landau level of a two-dimensional electron gas support excitations with non-Abelian braiding statistics. Two outstanding questions concerning the nature of the both the odd and even denominator FQHS of the second Landau level as probed by transport measurements at temperatures as low as 5mK will be addressed. We report the discovery of a new odd denominator FQHS state at $\nu = 2{+}6/13$. The energy gaps of this and other states at $\nu = 2 + 1/3$, 2+2/3, and 2+2/5 reveal a markedly different dependence on the effective magnetic field as compared to that of the corresponding lowest Landau level states at 6/13, 1/3, 2/3, and 2/5. If, in addition, we assume a Landau level-independent effective mass, we find that the 7/3 and 8/3 states are consistent, whereas the 2+2/5 and the 2+6/13 states show a strong deviation from the predictions of the model of free composite fermions. For the even denominator states at $\nu = 5/2$ and 7/2 we extended measurements to the new regime of very low densities and to samples grown in two MBE chambers: one at Princeton and one at Purdue. Comparisons found in the literature of the experimentally measured intrinsic gaps at $\nu = 5/2$ with numerical results are confusing: three methods find a large difference whereas a fourth method finds a good agreement. Our data suggests that the former three methods have deficiencies and therefore cannot be used. Using the fourth and a new method we introduce we find an excellent agreement of the experimental and numerical intrinsic gaps at $\nu = 5/2$. These findings lend a strong support to the Pfaffian description of the $\nu = 5/2$ fractional state. Work done in collaboration with A. Kumar, N. Samkharadze, N. Deng, J. Watson, G. Gardner, M. Manfra, L. Pfeiffer, and K. West. G.A.C. has been supported by the NSF DMR-0907172 and DOE DE-SC0006671 grants.