Single Vortex Flow in a Mesoscopic Superconducting Al Disk

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It is known that the collective motion of a vortex lattice in large superconducting films can be controlled by an RF current superimposed on a DC current, evidence of which is provided by voltage steps in current-voltage (I-V) characteristics, analogous to Shapiro step in weak-linked superconductors. However, the dynamical control of a single vortex has not been achieved so far. We report the first evidence of a single-vortex flow in a mesoscopic superconducting disk, which is controlled by RF current with an order of 100 GHz. Clear periodic voltage steps in the I-V characteristics show that when a single vortex inside the disk is driven out of the disk, another vortex enters the disk similarly to two balls colliding in billiards: only one vortex passes through the Al disk at the same time. This single vortex billiard takes place irrespective of the number of vortices confined to the disk. In a large RF power region, the voltage steps become larger than that corresponding to the normal state resistance. The fact shows that the single vortex flow causes a large energy dissipation, which is not explained by conventional theories. The RF power and frequency dependences of the voltage steps are also discussed in terms of the single vortex billiard.