Inhomogeneous Pseudogap Phenomenon in the BCS-BEC Crossover Regime of a Trapped Superfluid Fermi Gas

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We study single-particle properties of a trapped superfluid Fermi gas in the BCS-BEC crossover region. Including pairing fluctuations within a T-matrix theory, as well as effects of a trap potential within the local density approximation, we self-consistently determine the superfluid order parameter and chemical potential below the superfluid transition temperature $T_{\rm c}$. Using these, we calculate the local density of states (LDOS), local spectral weight, and photoemission spectra. In the crossover region above $T_{\rm c}$, the trap potential leads to inhomogeneous pseudogap phenomena, where the pseudo-gapped LDOS in the trap center and free-fermion-like LDOS around the edge of the gas coexist in the system. At $T = 0$, the single-particle excitations are dominated by inhomogeneous superfluid order parameter. We clarify how the former changes into the latter below $T_{\rm c}$. In the intermediate temperature region, the coexistence of pseudogap and superfluid gap is realized in the sense that, while the pseudogap in the trap center is replaced by the superfluid gap, pairing fluctuations enhance the pseudogap around the edge of the gap. We also determine the pseudogap region in the 3-D phase diagram of a superfluid Fermi gas in terms of temperature, pairing interaction, and spatial position. Our results would be useful for understanding strong-coupling effects in the BCS-BEC crossover regime of a trapped superfluid Fermi gas.