Panel 2: Vibrational Mode Analysis and Coupling Dynamics
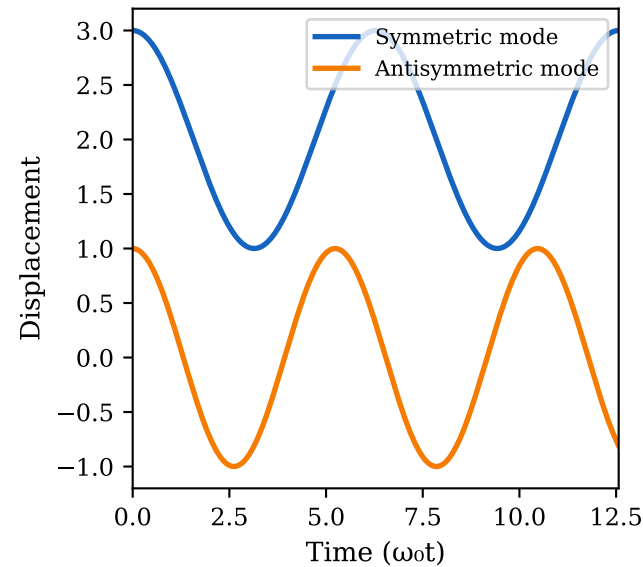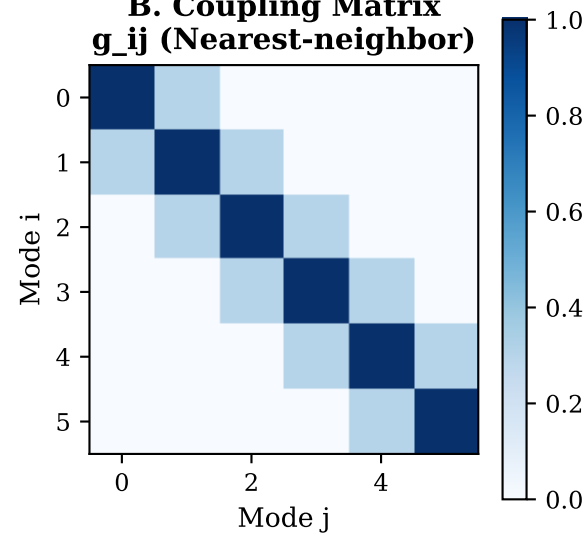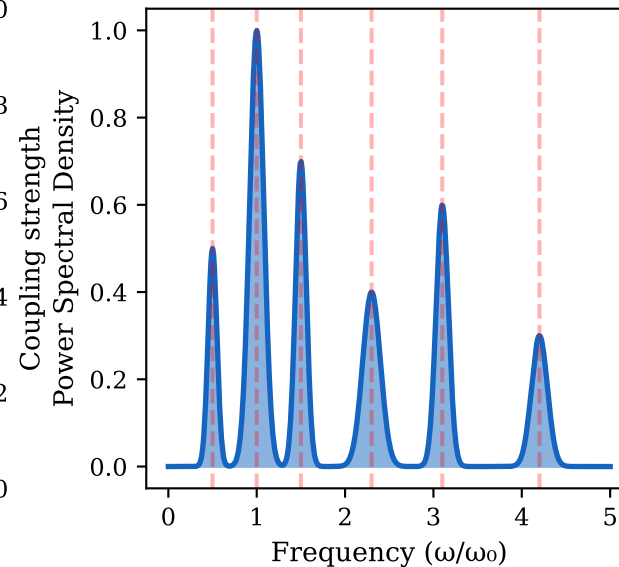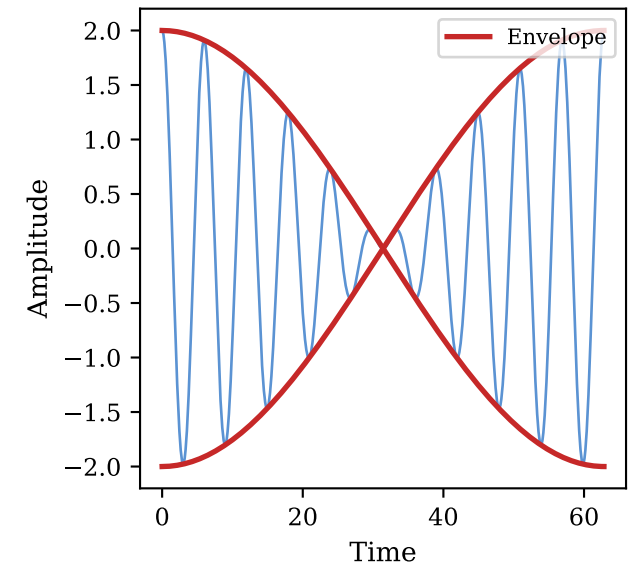
A. Normal Modes (Coupled Oscillators)

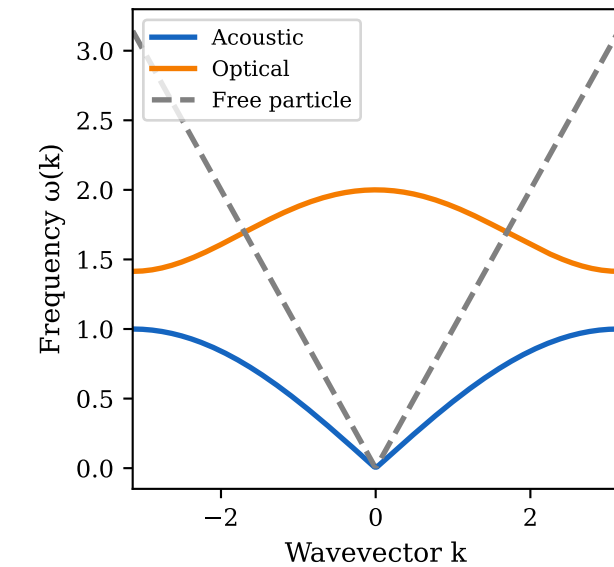**B. Coupling Matrix g_ij (Nearest-neighbor)**
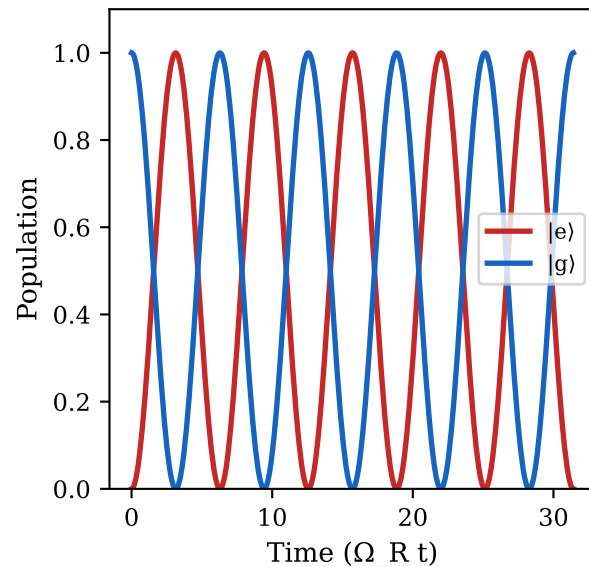
C. Mode Spectrum (Discrete Resonances)

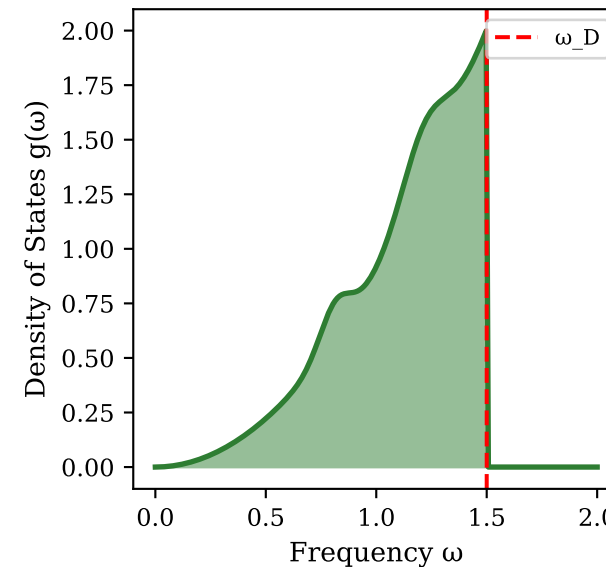**D. Beat Pattern (Mode Interference)**
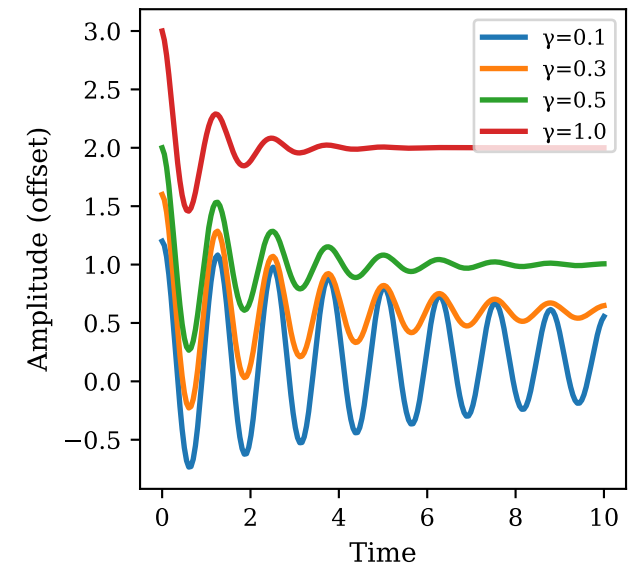
E. Dispersion Relations (Mode Propagation)

F. Rabi Oscillations (Coherent Coupling)

G. Phonon DOS (Mode Distribution)

H. Mode Decay (Damping Rates)

VIBRATIONAL MODE HARDWARE VALIDATION

Phonon Spectroscopy:
• Inelastic neutron scattering → Full dispersion ω(k)
• Raman spectroscopy → Optical phonon frequencies
• Infrared absorption → Dipole-active modes

Atomic Force Microscopy:
• Cantilever resonance: $Q > 10^5$ in vacuum
• Mode frequency: $f = (1/2\pi)\sqrt{(k/m)}$ verified to <1 Hz

Quantum Optics:
• Rabi oscillations observed in trapped ions
• Coherence times > 10 ms demonstrated

Cavity QED:
• Strong coupling regime: $g > \kappa, \gamma$
• Vacuum Rabi splitting measured

J. Q-Factor Measurement (Mode Persistence)