Beyond the Squeezing Spectrum: Output-Field Quantum Fisher Information in Parametric Optical Sensors

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Squeezed light is a central resource for quantum-enhanced sensing, but the squeezing spectrum alone does not determine how much information is available about a physical parameter. We analyze parameter sensing in an optical parametric oscillator where the input field is vacuum. Using quantum Fisher information, we evaluate how the full frequency-dependent output covariance matrix changes under an infinitesimal intra-cavity parameter perturbation and identify how information is distributed across correlated frequency pairs. This framework separates three notions that are often implicitly connected but are not generally equivalent: maximum squeezing, enhanced spectral response, and optimal parameter sensitivity. We show that the operating point with the strongest squeezing is not necessarily the most informative one, and that enhanced response features such as operating at the exceptional point do not by themselves determine the achievable sensing performance. We further discuss the implications for practical homodyne readout. Our results provide design principles for parametric squeezed-light sensors beyond optimizing the squeezing spectrum alone.