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Increasing Brain-Computer Interface sensitivity through Exceptional Points localisation in non-Hermitian systems

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Exceptional points (EPs) in non-Hermitian systems offer square-root-enhanced response to perturbations, promising order-of-magnitude sensitivity gains in OPM-based MEG sensors. We formulate the two-mode alkali-vapor Hamiltonian with balanced gain and loss, and locate its second-order EP by solving for the coalescence of eigenvalues and eigenvectors. To circumvent the ill-conditioned eigenvalue derivatives and noise amplification inherent to EP calculations, we introduce StaR, an algorithmic transform of problem representation, that re-expresses the non-Hermitian eigenproblem more suitably for complex-valued Neural Quantum State optimization. StaR-NQS enables automatic differentiation through the EP degeneracy and Monte Carlo–regularized evaluation of the noise-amplified frequency splitting. This methodology paves the way for compact, low-power, EP-enhanced OPM arrays in clinical BCIs.

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