

Long-time Dynamics of Spontaneous Parametric Down-conversion and Quantum Limitations of Conversion Efficiency*

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We analyze the long-time quantum dynamics of degenerate parametric down-conversion from an initial sub-harmonic vacuum (spontaneous down-conversion). Standard linearization of the Heisenberg equations of motion fails in this case, since it is based on an expansion around an unstable classical solution and neglects pump depletion. Introducing a mean-field approximation we find a periodic exchange of energy between the pump and subharmonic mode governed by an anharmonic pendulum equation. From this equation the optimum interaction time or crystal length for maximum conversion can be determined. A numerical integration of the 2-mode Schrödinger equation using a dynamically optimized basis of displaced and squeezed number states verifies the characteristic times predicted by the mean-field approximation. In contrast to semiclassical and mean-field predictions it is found that quantum fluctuations of the pump mode lead to a substantial limitation of the efficiency of parametric down-conversion.

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