We formulate a semiconductor laser rate equation based approach to carrier recovery in a Bayesian filtering framework. Filter stability and the effect of model inaccuracies (unknown or un-useable rate equation coefficients) are discussed. Two potential application areas are explored: laser characterization and carrier recovery in coherent communication. Two rate equation based Bayesian filters, the particle filter and extended Kalman filter, are used in conjunction with a coherent receiver to measure frequency noise spectrum of a photonic crystal cavity laser with less than 20 nW of fiber-coupled output power. The extended Kalman filter is also used to recover a 28 Gbd DP-16 QAM signal where a decision-directed phase-locked loop fails.