Cavity Ring-Down Spectroscopy in the Quantum-Noise Limit

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We report two cavity ring-down spectrometers capable of recording cavity losses with sensitivity limited by quantum (shot) noise. The first instrument based on emerging mid-infrared quantum-cascade laser (QCL) technology operated at a center wavelength of 4.53 μm by observing passive cavity decays at DC on a low-noise liquid-nitrogen cooled InSb photodetector. The passive decays exhibited significantly more noise at early times when more light was present on the photodetector, thus revealing a characteristic funnel shape to the exponential fit residuals. In addition to achieving a low noise-equivalent absorption coefficient (NEA) of 2.6×10^{-11} cm^{-1} $Hz^{-1/2}$ in the quantum-noise limit, we also observed direct evidence of interference (i.e., mode beating) in the mid-infrared cavity decays due to a small intrinsic supermirror birefringence. The second instrument to perform in the quantum-noise limit was a heterodyne-detected cavity ring-down spectrometer [1] which utilized high-bandwidth frequency-agile rapid scanning components to reach an ultimate sensitivity of NEA = 6×10^{-14} cm^{-1} $Hz^{-1/2}$ with 1 mW of detected near-infrared (1.55-1.6 μm) laser power [2].

References
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