

Ring-Down Spectroscopy for Characterizing a CW Raman Laser

Parameters of operation can be obtained from a single ring-down scan.

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A relatively simple technique for characterizing an all-resonant intracavity continuous-wave (CW) solid-state Raman laser involves the use of ring-down spectroscopy. As used here, “characterizing” signifies determining such parameters as threshold pump power, Raman gain, conversion efficiency, and quality factors (Q values) of the pump and Stokes cavity modes.

Heretofore, in order to characterize resonant-cavity-based Raman lasers, it has usually been necessary to manipulate the frequencies and power levels of pump lasers and, in each case, to take several sets of measurements. In cases involving ultra-high-Q resonators, it also has been desirable to lock pump lasers to resonator modes to ensure the quality of measurement data. Simpler techniques could be useful.

In the present ring-down spectroscopic technique, one infers the parameters of interest from the decay of the laser out of its steady state. This technique does not require changing the power or frequency of the pump laser or locking the pump laser to the resonator mode.

The technique is based on a theoretical analysis of what happens when the pump laser is abruptly switched off after the Raman generation reaches the steady state. The analysis starts with differential equations for the evolution of the amplitudes of the pump and Stokes electric fields, leading to solutions for the power levels of the pump and Stokes fields as functions of time and of the aforementioned parameters. Among other things, these solutions show how the ring-down time depends, to some extent, on the electromagnetic energy accumulated in the cavity.

The solutions are readily converted to relatively simple equations for the parameters as functions of quantities that can be determined from measurements of the time-dependent power levels. For example, the steady-state intracavity conversion efficiency is given by \( \Gamma_1/\Gamma_2 = 1 \) and the threshold power is given by \( P_{th}(\Gamma_2/\Gamma_1)^2 \), where \( P_{th} \) is the steady-state input pump power immediately prior to abrupt switch-off, \( \Gamma_1 \) is the initial rate of decay of the pump field, and \( \Gamma_2 \) is the final rate of decay of the pump field. Hence, it is possible to determine all the parameters from a single ring-down scan, provided that the measurements taken in that scan are sufficiently accurate and complete.

This work was done by Andrey Matsko, Anatoly Sauvchenkov, and Lute Maleki of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30551