Broadband spectrum generation using continuous-wave molecular modulation

Joshua J. Weber and Deniz D. Yavuz

Department of Physics, 1150 University Avenue, University of Wisconsin, Madison, WI, 53706

Since the invention of the laser in 1960, optical scientists have sought to develop light sources capable of generating coherent optical spectra covering the infrared, visible, and ultraviolet spectral regions. Broadband sources are of particular interest because they have applications in a wide range of research areas including ultrafast physics, precision spectroscopy, and quantum control. In this work, we report an experiment that we see as the first step in extending the molecular modulation technique into the CW domain [1]. By using low-pressure molecular deuterium inside a high-finesse cavity, we produce a broad CW ro-vibrational spectrum that is two octaves wide, ranging from 0.8 \( \mu m \) to 3.2 \( \mu m \) in wavelength [2].

We perform our experiments inside a cavity with a high finesse near the pump (1.06 \( \mu m \)) and vibrational-Stokes (1.55 \( \mu m \)) wavelengths. Figure 1 shows the ro-vibrational spectrum generated at a deuterium pressure of 0.1 atm. The 0.8-1.65 \( \mu m \) region is observed on an optical spectrum analyzer in a single scan, and the two-mid-infrared sidebands (2.9 \( \mu m \) and 3.2 \( \mu m \)) are measured using a PbSe photo-diode. The insets show optical heterodyne linewidth measurements for the 1.06 \( \mu m \) and 1.6 \( \mu m \) beams, which demonstrate absolute linewidths of 11 kHz and 28 kHz, respectively. When the pump laser at 1.06 \( \mu m \) is locked to the cavity, the vibrational Stokes sideband at 1.55 \( \mu m \) on the \(| \nu = 0, J = 0 \rangle \rightarrow | \nu = 1, J = 0 \rangle \) transition is generated through Raman lasing. The pump and the generated Stokes beams drive the coherence and produce the vibrational anti-Stokes (0.8 \( \mu m \)) and second Stokes (2.9 \( \mu m \)) sidebands through four-wave mixing. The mirrors do not have high reflectivity near 0.8 \( \mu m \) nor in the mid-infrared. As a result, the vibrational anti-Stokes and second Stokes sidebands are generated in a single pass through the cavity. In addition to vibrational Raman generation, we observe rotational Raman lasing on the \(| \nu = 0, J = 0 \rangle \rightarrow | \nu = 0, J = 2 \rangle \) transition, producing the broad ro-vibrational spectrum of Fig. 1.

![Figure 1: The ro-vibrational spectrum generated in molecular D$_2$ using a cavity with a high finesse near wavelengths 1.06 \( \mu m \) and 1.55 \( \mu m \). The 0.8-1.65 \( \mu m \) region is observed on an optical spectrum analyzer in a single scan, and the two-mid-infrared sidebands (2.9 \( \mu m \) and 3.2 \( \mu m \)) are measured using a PbSe photo-diode.](image)

References