Stimulated Raman scattering of picosecond laser pulses at 532 nm in light and heavy water

A.I. Vodchits, V.A. Orlovich
B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus
Minsk, Belarus
a.vodchits@dragon.bas-net.by

V.S. Gorelik, Y.P. Voinov
P.N. Lebedev Physical Institute of the Russian Academy of Sciences
Moscow, Russia
gorelik@sci.lebedev.ru

Abstract – Stimulated Raman scattering (SRS) of picosecond laser radiation at 532 nm in light and heavy water was studied. Raman thresholds have been determined and SRS spectra have been obtained. Several Stokes and anti-Stokes components were observed. In addition, librational modes were excited resulting in some additional Raman bands in low frequency region and also as combining tones.

Keywords – stimulated Raman scattering, picosecond laser pulses, light water, heavy water, spectrum, Raman threshold, Stokes component, anti-Stokes component.

For the first time, stimulated Raman scattering (SRS) in light water (H₂O) was studied in [1]. The strongest Raman active mode corresponds to 3424 cm⁻¹. SRS in heavy water (D₂O) has been recently investigated in [2]. In this case, the most intensive Raman line is 2448 cm⁻¹. Here we present the new results of our studies on picosecond SRS in light and heavy water.

We have used a picosecond Nd:YAG laser at 532 nm. 60 ps laser pulses with a pulse repetition rate of 20 Hz had the energy from less than 0.1 to about 30 mJ. Laser beam was focused into the fused silica cell with water using a lens of about 21 cm focal length. Experimental optical scheme allowed us to observe SRS in the forward and backward directions. The different schemes were used for registration of the scattered radiation: with a Pellen-Brock prism, with a diffraction grating, and also using only color filters. The scattered radiation from the sample was directed into the fiber tip. SRS spectra were registered using FSD-8 minispectrometer with a CCD-detector (spectral range of 240 – 1000 nm).

In light water, besides Stokes and anti-Stokes components, some shoulder appeared near anti-Stokes component spectral position, νl(A₁) = 3424 cm⁻¹. Raman threshold in light water was equal to about 0.2 mJ of pumping pulse energy. The maximum SRS efficiency reached up to about 7 - 10 %. At small exciting energy (~ 1 mJ), the observed Stokes component had the shape of a wide band with several peaks corresponding to the fundamental mode. After increasing of the exciting energy (to about 10 mJ) Raman intensity of this band was increased and its width was essentially decreased. With increasing the exciting power, the spectral position of SRS component was shifted from 3186 up to 3424 cm⁻¹. In the backward scattering geometry, we observed two wide satellites (Stokes and anti-Stokes) in low frequency region (780 cm⁻¹). Such satellites may be attributed to the librational mode, νl_ab. Also, a weak maximum at 1650 cm⁻¹ was observed corresponding to other fundamental mode, νl(A₁).

In SRS spectrum of heavy water, the most intensive line with a frequency of νl(A₁) = 2448 cm⁻¹ was observed. Raman threshold in heavy water was about 0.1 mJ of pump pulse energy. It is substantially lower in comparison with light water. The maximum SRS efficiency was about 10 - 15 %. Fig. 1a shows SRS spectra in heavy water for the backward scattering geometry. One can see two Stokes and two anti-Stokes components. The shape of the first and second Stokes lines under higher intensity of exciting radiation is shown in Fig. 1b. Two distinct Raman lines in the Stokes components, one of which corresponds to the fundamental mode, νl(A₁) and another is a combination of the fundamental one with the libration mode, νl(A₁) + νl_ab are revealed.

In conclusions, we have studied picosecond SRS in light and heavy water. Raman thresholds and Raman spectra have been determined. Several intensive Stokes and anti-Stokes components were observed. Also, additional structure in Stokes components has been revealed due to a combination of the fundamental vibrational modes with librational ones.