LightMachinery Inc.
80, Colonnade Road
Ottawa, Ontario, K2E 7L2.   Canada
Tel: (613) 749-4895   Fax (613) 749-8179

Spectrometer Application Report

Brillouin Spectroscopy of Nb_2O_5 Thin Films

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For questions, contact hyperfine@lightmachinery.com

A. Thin Film of Niobium Pentoxide on Glass or Germanium Substrate

The Brillouin frequency shift of a thin film of niobium pentoxide (Nb_2O_5) deposited on both a glass or a germanium substrate was measured using a 20X microscope objective. The thickness of the film in both cases is 5 μm, which corresponds to ~ 20 % of the excitation/collection focal volume depth of the objective (~ 25 μm along the z-axis). The spectra in Figures 1 and 2 were obtained using 25 mW of laser power at the sample.

The measured frequency shift of Nb_2O_5 is 49.84 ± 0.05 GHz on glass substrate and 49.21 ± 0.03 GHz on germanium, representing a difference of 0.63 GHz. This ΔGHz suggests the influence of substrate on the Brillouin frequency shifts of thin films. More work is required to understand and characterize this potential influence. The substrate also appears to impact the Brillouin signal intensity of the Nb_2O_5 layer. Interestingly, its amplitude is about 5 times larger on germanium than on glass substrate. Future exploratory research might thus include testing the effect of substrate reflectivity on the Brillouin signal intensities of thin films. Since the germanium substrate is more reflective than the glass substrate, a small pump laser signal can be observed in Figure 2. Also interesting in Figure 2 is the presence of unknown Brillouin peaks at low frequency shift (~ 4.9 GHz). Impurities associated with the deposition method of Nb_2O_5 on germanium might explain the presence of these peaks. Further investigation is required.

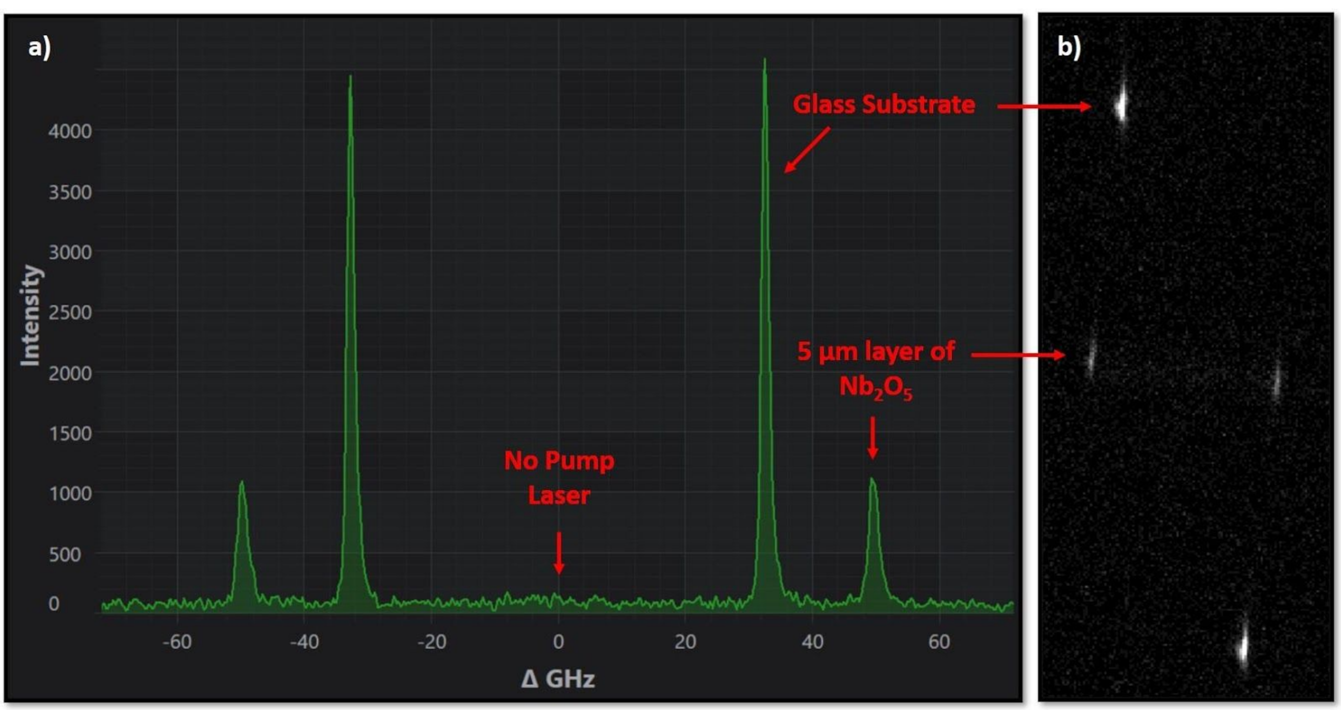

Figure 1: a) Brillouin frequency shift spectrum of a thin film of Nb_2O_5 deposited on a glass substrate. b) Raw sensor image. The time exposure was set to 20 seconds and the number of averages to 5.

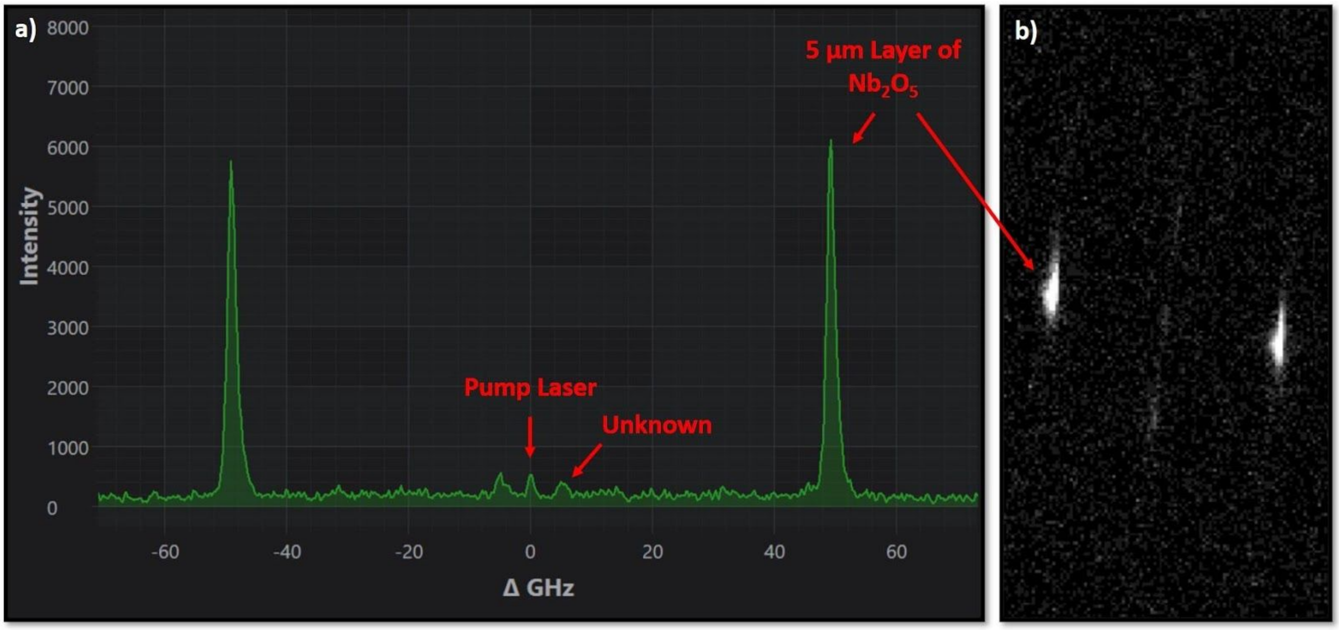

Figure 2: a) Brillouin frequency shift spectrum of a thin film of Nb2O5 deposited on a germanium substrate. b) Raw sensor image. The time exposure was set to 20 seconds and the number of averages to 5.

<u>Specifications</u>

Sample	System
• Material: Nb_2O_5 layer on germanium substrate (not a single crystal) • Thickness of Nb_2O_5: 5 µm • The estimated Brillouin frequency shift for bulk Nb_2O_5 is around 47.3 GHz (using a speed of sound of 5311 m/s, a refractive index of 2.37, and a pump wavelength of 532 nm).	• Pump wavelength: 532 nm • Power at sample: 25 mW • Excitation/collection with 20X objective • FWHM of the instrument response: nominal 0.9 GHz • Repeatability of Brillouin shift: highly sample and exposure dependent; < 10 MHz is possible

B. Thin Film of Niobium Pentoxide on Germanium Substrate using a lower noise detector

The same experience was performed with a lower noise camera in order to acquire the Brillouin signal of the germanium substrate. Figure 3b) shows the raw sensor image, where the strong peaks are attributed to the Nb2O5 layer, while the faint diagonal lines correspond to the Brillouin signal of the germanium substrate. This signal is difficult to distinguish in the unwrapped spectrum because it is shaped as a weak uniform pedestal. There are no well-defined Brillouin peaks from the germanium presumably because it is not single crystalline and also because of the strong absorption at that wavelength (532 nm). We also notice the presence of the unknown peaks at ~ 4.9 GHz, as discussed in section A).

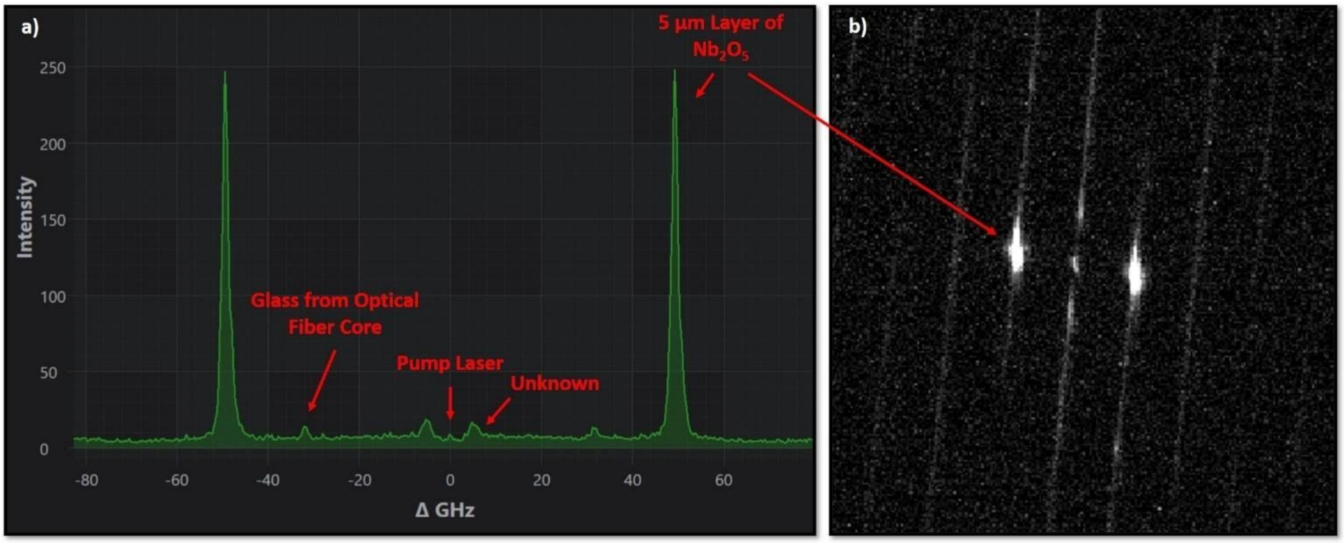

Figure 3: a) Brillouin frequency shift spectrum of a thin film of Nb2O5 deposited on a germanium substrate, acquired with the lower noise camera. b) Raw sensor image. The time exposure was set to 10 seconds and the number of averages to 20.

Specifications

Sample	System
• Material: Nb_2O_5 layer on germanium substrate (not a single crystal) • Thickness of Nb_2O_5: 5 µm • The estimated Brillouin frequency shift for bulk Nb_2O_5 is around 47.3 GHz (using a speed of sound of 5311 m/s, a refractive index of 2.37, and a pump wavelength of 532 nm).	• Camera: 0.7 e- rms read out noise sCMOS cooled to -5°C • Pump wavelength: 532 nm • Power at sample: 25 mW • Excitation/collection with 20X objective • FWHM of the instrument response: nominal 0.9 GHz • Repeatability of Brillouin shift: highly sample and exposure dependent; < 10 MHz is possible