Investigation of a Blue Luminescence Power in Raman Crystals

Jonas Jakutis Neto[1,2], Niklaus Ursus Wetter[2] and Helen Pask[1]
[1]*MQ Photonics Research Centre, Department of Physics, Macquarie University, Sydney, NSW 2109, Australia*
[2]*Instituto de Pesquisas Energéticas e Nucleares, CNEN/SP, Universidade de São Paulo, CEP 05508-000, São Paulo/SP, Brazil*
jonas.jakutis-neto@mqu.edu.au

Abstract: Crystalline Raman lasers have been pushed to their limits during the last decade. One of its characteristics is the very low gain, which requires a very low loss resonator to achieve better performances. Given that, this work presents the characterization of the power extracted by a blue luminescence present in some of the Raman crystals, which is a source of loss.

OCIS codes: (140.3550) Lasers, Raman; (140.3580) Lasers, solid-state; (140.7300)

1. Introduction

With the rise of the solid state Raman lasers, one special side effect has been observed, a blue luminescence. This blue emission around 475 nm comes out of the Raman active crystal when reached the threshold for the Stokes oscillation. There were some groups reporting the effect in their Raman lasers, showing the presence of the phenomenon in many different crystals, KGW [1,2], $BaWO_4$ [3,4], $SrWO_4$ [5,6], YVO_4 [7], $GdVO_4$ [8] and $SrMoO_4$ [9]. Some of them tried to explain the origin of the emission, either by an upconversion in Nd^{3+} ions or by an upconversion in Tm^{3+} ions present in the crystals as impurities. However, the scope of those works were the laser performance, thus they presented a very brief discussion on the blue emission topic.

Nowadays, Raman lasers reached a level of development that makes the reduction of losses and thermal effects relevant to improve their performance. Given that, there is the need of a better understanding of the phenomenon in order to comprehend not only the origin of the emission, but also its influence on the Raman laser performance, either as an extra loss, or as an extra heating source, which may be originated from non-radiative decays derived from the upconversion process.

Recently, two works were published discussing specifically the blue emission [10,11]. Zhu et al. [10], characterized the emission in three crystals, YVO_4, $GdVO_4$ and $SrWO_4$, with fundamental oscillations of 1063 nm, 1064 nm, 1079 nm and 1342 nm. The strongest emissions were found for the $SrWO_4$ crystals, when pumped by in the 1 μm range, but no luminescence was observed for the 1342 nm pump. The conclusion found by them is that the luminescence is produced with only fundamental oscillation around 1 μm, and no Stokes is needed for the process. However, they could not explain how the emission is build up. In [11], Kodasevich et al. made a deeper analyses of the phenomenon, comparing the experimental emission from a KGW crystal with the expected shape obtained by calculation for a Nd:KGW crystal and a Tm:YLF crystal. As a result, they found more similarities with the Neodymium emission band around 475 nm than with Thulium, although not enough to state that Nd^{3+} is the responsible for such emission. Both works discarded the Nd and Tm impurities hypothesis and suggested at the end that usual theories do not apply to this phenomenon and a new one might be needed.

In all the cases reported, the groups were looking for the origin of the phenomenon, but no considerations of its influence in the lasers were deep characterized, such as the power extracted or the thermal load added to the crystals. We present here the characterization of the blue luminescence power in a Nd:YLF/KGW Raman laser using an intracavity integrated sphere.

2. Experimental setup

To obtain accurately the blue emission power, we used an integrating sphere (Labsphere) through the setup displayed in Figure 1. For that, we built a high-Q Raman resonator using a Nd:YLF crystal as the active medium and a KGW as the Raman active medium. This combination of crystals was chosen because the KGW was the crystal presenting the strongest blue emission amongst all we observed, and the Nd:YLF because it has a weak thermal lens, so then we could make a long cavity and place the integrating sphere (diameter of 9.5 cm) into the resonator. Another precaution taken is to not use a self-Raman configuration, such as $Nd:GdVO_4$ or even a Nd:KGW, in order to avoid pump light and Nd^{3+} fluorescence to get integrated in the sphere and disturb the measurement.

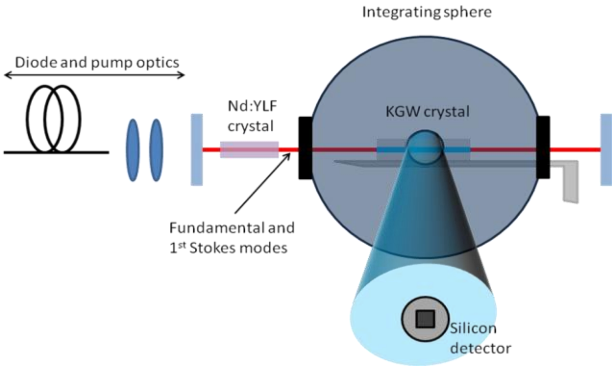

Fig. 1. Laser cavity with the integrating sphere used to measure the blue emission power.

Looking in another angle it is possible to see the solid angle that effectively reaches the detector, Figure 2. In front of the detector a photopic filter was placed in order to not get infrared photons in the detector.

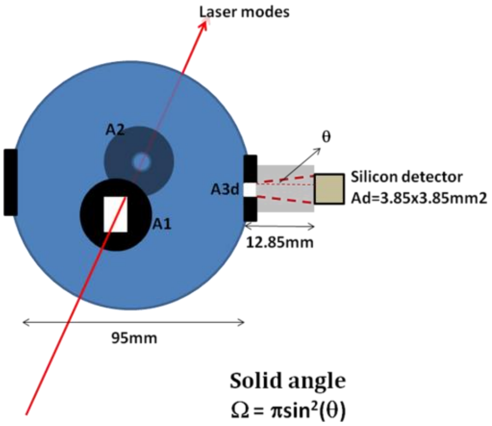

Fig. 2. Another perspective of the sphere showing the detector field of view.

Using a well known laser source, an alignment green laser (532 nm; 3.5 mW), we performed the calibration of the sphere. It is also known all the port areas in where the light escapes from the sphere and the internal reflectivity of its internal surface (spectraflect- 99.8% at 475 nm). Then the flux of light into the detector can be calculated and compared to the value measured. If the numbers are different, it means that the real system has extra losses that the calculation did not consider, like the crystal holder we introduced to place the KGW crystal in the center of the sphere. However, it should be minimized as we wrapped the holder with white Teflon tape. From the power measured in the detector for the green laser and the blue luminescence corrected by detector sensitivity and the photopic filter transmissions (a factor of 0.8 at 532 nm and of 0.1 at 475 nm), it is possible to linearly extrapolate the total blue power generated in the crystal.

3. Results

As a result, it was measured a total blue power of 25 mW for 15 W of absorbed pump power in the Nd:YLF crystal. As it was a high-Q cavity, the intracavity Stokes field was of the order of hundreds of Watts. Also, considering the most probable origin of this luminescence as an upconversion in Tm^{3+} impurities, it is possible to estimate the Stokes power extracted from the cavity. The energy scheme in Figure 3 shows the possible paths and number of Stokes photons used to reach the $^1G_4$ blue emitting level.

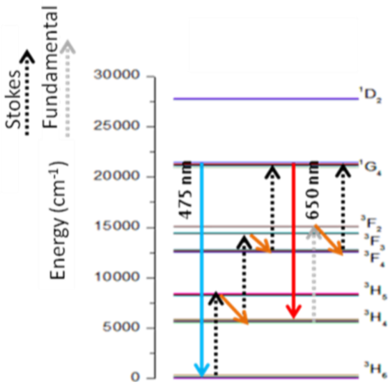

Fig. 3. Tm^{3+} energy levels scheme with the possible upconversion pathways.

Therefore, it represents a loss of less than 0.03% per pass for the Stokes field, since it has a maximum of three photons involved in the upconversion process as we have suggested. The coatings in the crystals have a reflectivity of around 0.05% for the Stokes wavelength which is already two times higher than the upconversion loss, showing the low influence of the phenomenon to the laser performance. However, it may have some thermal influence that deserves further investigation, adding to the thermal lensing of the crystal which would also influence the laser performance.

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